

Minimally Invasive Cardiac Valve Surgery Improves Patient Satisfaction While Reducing Costs of Cardiac Valve Replacement and Repair

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Objective

This study compares the quality of valve replacement and repair performed through minimally invasive incisions as compared to the standard operation for aortic and mitral valve replacement.

Summary Background Data

With the advent of minimally invasive laparoscopic approaches to orthopedic surgery, urology, general surgery, and thoracic surgery, it now is apparent that standard cardiac valve operations can be performed through very small incisions with similar approaches.

Methods

Eighty-four patients underwent minimally invasive aortic ($n = 41$) and minimally invasive mitral valve repair and replacement ($n = 43$) between July 1996 and April 1997. Demographics, procedures, operative techniques, and postoperative morbidity and mortality were calculated, and a subset of the first 50 patients was compared to a 50-patient cohort who underwent the same operation through a conventional median sternotomy. Demographics, postoperative morbidity and mortality, patient satisfaction, and charges were compared.

Results

Of the 84 patients, there were 2 operative mortalities both in class IV aortic patients from multisystem organ failure. There was no operative mortality in the patients undergoing mitral valve replacement or repair. The operations were carried out with the same accuracy and attention to detail as with the conventional operation. There was minimal postoperative bleeding, cerebral vascular accidents, or other major morbidity. Groin cannulation complications primarily were related to atherosclerotic femoral arteries. A comparison of the minimally invasive to the conventional group, although operative time and ischemia time was higher in minimally invasive group, the requirement for erythrocytes was significantly

less, patient satisfaction was significantly greater, and charges were approximately 20% less than those in the conventional group.

Conclusions

Minimally invasive aortic and mitral valve surgery in patients without coronary disease can be done safely and accurately through small incisions. Patient satisfaction is up, return to normality is higher, and requirement for postrehabilitation services is less. In addition, the charges are approximately 20% less. These results serve as a paradigm for the future in terms of valve surgery in the managed care environment.

Corrective cardiac valve surgery, either replacement or repair, is one of the most significant advances in medical science of the 20th century, beginning in 1923 with Cutler's epic closed mitral commissurotomy¹ and extending to the current era of cardiac valve prosthesis, bioprosthesis, and biologic valves.² These operations have alleviated the suffering and have prolonged life for patients with aortic, mitral, and tricuspid valve disease. The operation for valve replacement and repair over the past 30 years has evolved to using a median sternotomy incision, cardiopulmonary bypass, varying degrees of systemic hypothermia, and antegrade and retrograde cardioplegic myocardial protection. With the establishment of minimally invasive major surgery in orthopedics, gynecologic surgery, general surgery, and thoracic surgery over the past 15 years, cardiac surgeons recently have begun to explore the use of minimally invasive approaches for patients undergoing standard cardiac valve operations, both replacement and repair. In 1996, the rather routine use of "key hole" valvular surgery was begun^{3,4} to minimize surgical trauma, improve cosmesis, and, in turn, shorten the length of intensive care unit stay and the total hospital, thus reducing costs and increasing productivity and decreasing the reliance on post-hospital rehabilitation services.

This article will summarize the initial experience with minimally invasive cardiac valve replacement and repair in both aortic and mitral positions at the Brigham and Women's Hospital from July 1996 to April 1997.

MATERIAL AND METHODS

From July 1, 1996, through April 1, 1997, 84 operations using a minimally invasive approach were performed at the Brigham and Women's Hospital: 41 underwent aortic valve replacement–repair and 43 underwent mitral valve

replacement–repair. All patients were entered into the Brigham cardiac valve surgery database to prospectively document preoperative indications, in-hospital operative morbidity and mortality operation, and post-hospital morbidity and mortality. In addition, the first 50 patients, in terms of cost data, length of stay, and requirement for post-hospital rehabilitation services, were compared to 50 patients who had undergone standard valve replacement for similar indications by sternotomy over the exact period. Patient satisfaction also was analyzed and compared in both groups, which included reliance on pain medicine, ease of rehabilitation, return to productivity, and return to full activity, by a very detailed questionnaire provided to these patients by a cardiac nurse practitioner. These data were loaded on the Brigham cardiac surgical database computer, analyzed, collated, and compared statistically.

Any patient with concomitant major coronary artery disease was excluded from the analysis, although two patients did undergo single-vessel bypass to the right coronary artery (RCA) in conjunction with a minimally invasive aortic and mitral valve replacement due to proximity of the right internal mammary artery to the right coronary artery.

Operative Techniques

The operations performed, including valve types and operative times, are summarized in Table 1. The patients undergoing aortic valve replacement were treated by 2 different incisions: 1) the right parasternal using femoral–femoral bypass in 21 and the "mini-sternotomy" using intrathoracic cannulations in 20. In the parasternal incision (Figs. 1A–C), the incision is made approximately 6 to 10 cm in the right parasternal area overlying the second and third costal cartilage. These costal cartilages are excised completely and the pericardium is opened. The aorta is identified. Simultaneously, a 5-cm diagonal incision that parallels the ingranil crease identifies the femoral artery and femoral vein. After heparinization, the femoral artery and femoral vein are cannulated with standard cannula and the cardiopulmonary bypass is begun with lowering of the systemic temperature to 28 C. The heart

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Table 1. MINIMALLY INVASIVE CARDIAC VALVE SURGERY

	Operative Procedure	
	Aortic Valve Replacement	Mitral Valve Replacement
Valve type		
St. Jude	16	5
Carpentier-Edwards	15	—
Pericardial		
Homograft	6	—
Hancock Porcine	3	1
Repair	1	37
Total	41	43
Reoperations (n)	4	0
Ischemia time (min)	105	105
CBP time (min)	137	159

CPB = cardiopulmonary bypass.

is fibrillated electrically, and the aorta is cross-clamped through the parasternal incision. An oblique hockey stick incision is made in the aorta and then is carried down to the noncoronary cusp. The cardiac valve replacement or repair then is carried out in the standard techniques (Table 1).

In the mini-sternotomy incision (Fig. 2), a midline incision is made beginning at the sternal notch and the sternotomy is incised with the oscillating saw down to the third intercostal space. An angled incision is made into the third intercostal space, thus disarticulating the third costal cartilage using a standard finicceto retractor. The aorta and the proximal portion of the right atrium are exposed. After heparinization, cannula are placed in the distal aorta in either the right atrium or the innominate vein, threading the cannula down into the right atrium. Similar myocardial protection and systemic temperature are used.

Intracardiac air in all procedures is monitored by the transesophageal echo. In the mini-sternotomy, the wound is closed with two sternal wires, which, for the right parasternal incision, the pericardium is closed loosely after chest tubes are inserted and the fascia and subcutaneous tissue and skin are closed. The femoral artery and femoral vein are repaired after decannulation. The femoral vein is not incised, but a purse string is placed in the sapheno-femoral junction or body of the common femoral vein (CFV). A catheter is introduced here, and the purse string is merely tied when the cannula is removed. Primary repair of the transverse femoral arteriotomy is accomplished with 5-0 Prolene (Ethicon, Somerville, NJ).

For mitral valve replacement or repair, all incisions are performed through a right parasternal incision, excising the third and fourth costal cartilage. The right atrium is

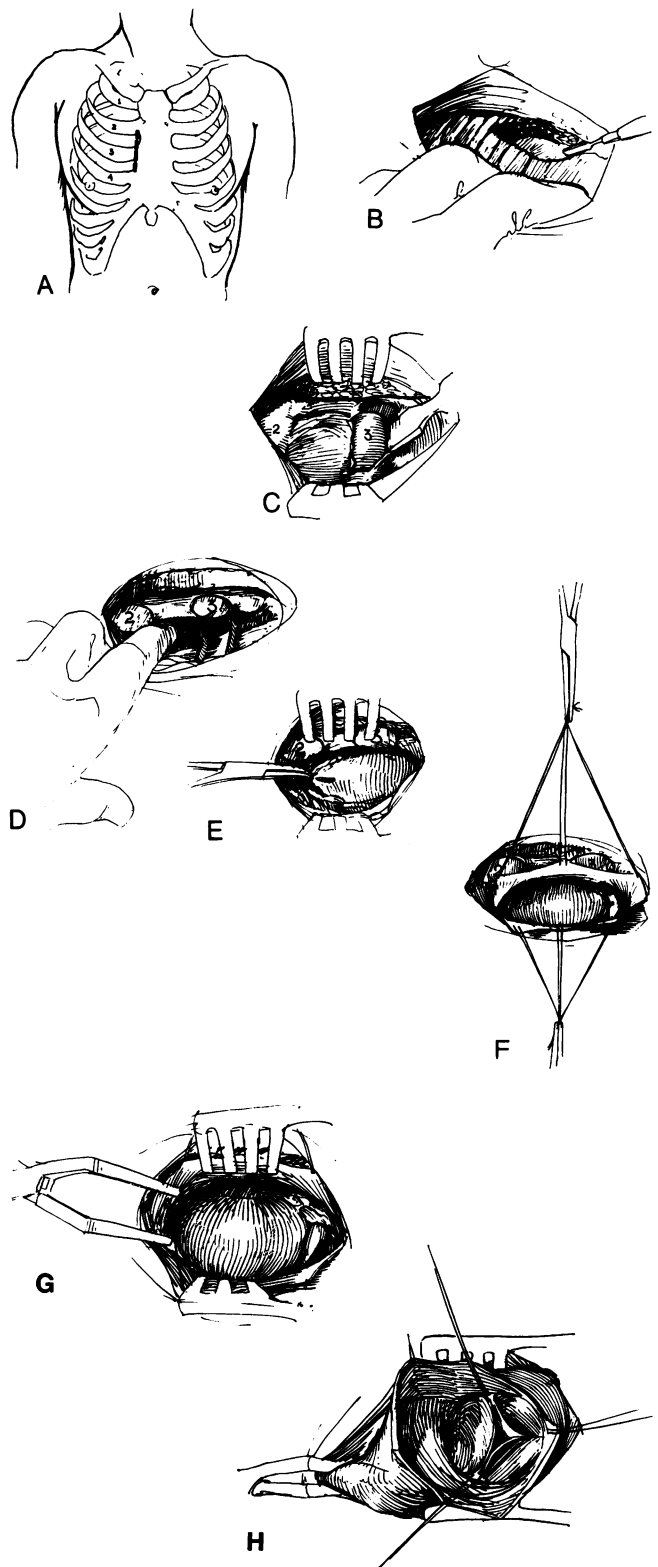


Figure 1. Minimally invasive aortic valve replacement. (A) Right parasternal incision. (B) Pectoralis divided. (C) Second and third costal cartilages exposed. (D) 2 + 3 costal cartilages excised. (E) Pericardium opened. (F) The aorta is exposed. (G) The aorta exposed for operation. (H) The valve exposed for operation.

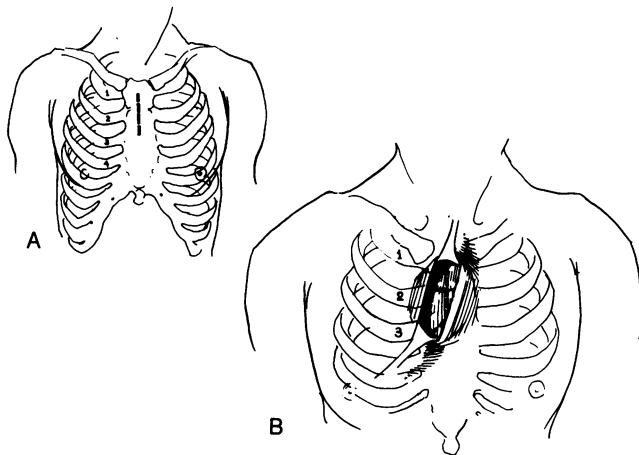


Figure 2. (A) Minimally invasive aortic valve replacement. (B) Ministernotomy, "T" off in three interspace.

exposed and opened after caval tapes were put down, isolating the right atrium. The aortic cross-clamp is applied before incising the right atrium. A transeptal incision then is made into the left atrium. Antegrade blood cardioplegia through the aortic root is administered. Similarly, systemic temperature is lowered to 28 C. Once the atrial septum is incised, the mitral valve is repaired or replaced by standard techniques reported previously.^{5,6} The atrial septum then is closed with a running 4-0 Prolene (Ethicon), as is the right atrium. In a few instances, left atrium was opened directly with reflection of the right atrium and incision in Sondergaard's plane.

RESULTS

Table 2 lists demographics for both aortic and mitral patients undergoing minimally invasive valve surgery, including age, gender, class, and valve etiology. In four patients (Table 1), reoperative aortic valve replacement was carried out through a ministernotomy, three with previous aortic valve replacements alone and one with a previous coronary artery bypass graft in whom new aortic stenosis developed. Table 3 outlines operative mortality and postoperative morbidity. The operative mortality for the aortic valve replacement or repair was 2 (5%) of 41. The operative mortality for mitral valve surgery was 0 (0%) of 43. The two operative deaths were in Class IV patients, one from liver failure and one from an arrhythmia in one of the reoperative patients. In the mitral valve group, 6 (14%) of 43 had replacement and 37 (86%) had reparative procedures. All repairs, which included a Cosgrove ring annuloplasty, showed minimal-to-trace mitral regurgitation by intraoperative and immediate postoperative transesophageal echo. Two aortic patients were reoperated on for bleeding and one patient had an intraoperative aortic dissection at the site of the ascending aortic needle vent after

Table 2. DEMOGRAPHIC DATA AND VALVE ETIOLOGY

	Aortic Valve Replacement	Mitral Valve Replacement
Demographic data		
n	41	43
Sex (M/F)	20/21	23/20
Age (yr) (range)	64 (35-84)	64 (34-83)
Mean Functional Class	2.6	2.4
Valve etiology		
Degenerative	25	—
Myxomatous	4	32
Congenital	6	1
Rheumatic	2	6
SBE	3	2
SVD	1	—
Ischemic	—	2

SBE = endocarditis; SVD = structured valve degeneration.

mitral valve repair, repaired by excising an additional costal cartilage and repairing the dissection under deep hypothermic circulatory arrest. The patient made a completely uneventful recovery. There were several episodes of atrial fibrillation requiring more than 24 hours of pharmacologic treatment or cardioversion or both. There were zero wound infections of the thoracic incision. Three patients had a nonhealing groin wound, which responded to conservative therapy, and three patients had arterial complications requiring an operative repair of the femoral artery in the operating room. There were no cases of femoral vein thrombus or phlebitis. One aortic valve patient receiving warfarin, in whom the INR rose to 6 from the ordinarily prescribed INR of 2, had a pericardial effusion shortly after leaving, which was relieved by needle

Table 3. MINIMALLY INVASIVE VALVE SURGERY OPERATIVE MORBIDITY AND MORTALITY

	Aortic Valve Surgery (n = 41)	Mitral Valve Surgery (n = 43)
Operative mortality	2/41 (5%)	0
Postoperative new AF	11 (27%)	5/25 (12%)
Bleeding	2/41 (5%)	—
Groin complications*	4	3
Intraoperative dissection†	—	1
Number transfused	25 (66%)	16 (37%)
Mean RBCs used	2.2	1.2

AF = atrial fibrillation; RBCs = red blood cells.

* Three superficial infections, four intraoperative arterial reconstructions.

† Antegrade dissection of air vent not associated with retrograde perfusion.

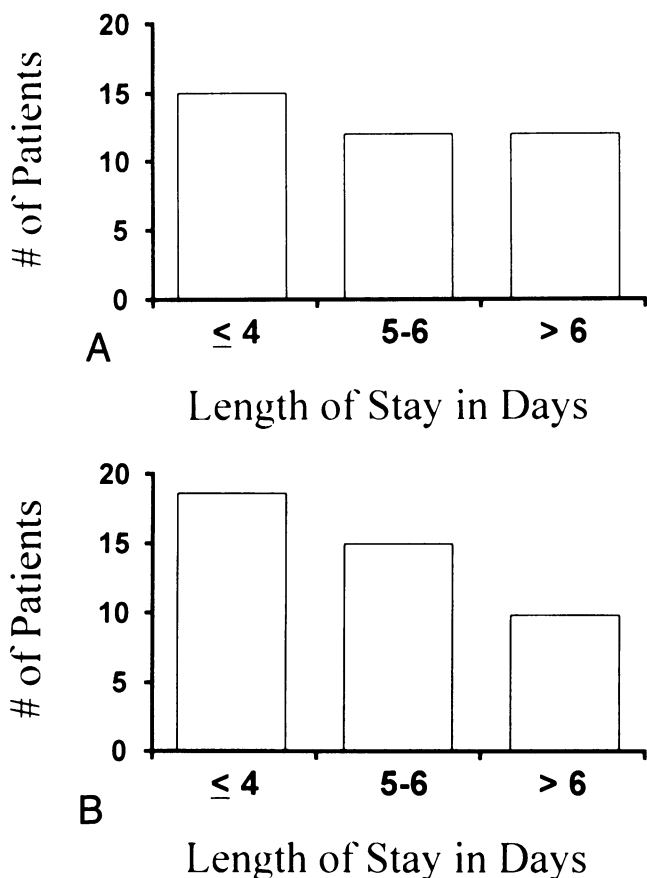


Figure 3. (A) Length of stay after minimally invasive aortic valve replacement. (B) Length of stay after minimally invasive mitral valve replacement.

aspiration. One patient had conversion to sternotomy after aortic valve replacement because the patient sustained a coronary sinus injury due to a coronary sinus retrograde cardioplegia catheter. No other patients had necessity of conversion through a full sternotomy from either the parasternal or the ministernotomy incision. In the medium-term follow-up extending to April 1, 1997, all patients improved, and there was one postoperative death. Significant morbidity in this period included one transient ischemic attack and one cerebrovascular accident. All patients improved at least two functional classifications in the New York Heart Association. Figures 3A and 3B show length of stay in days for patients who underwent aortic valve replacement (A) and those who underwent mitral valve replacement (B).

Table 4 summarizes a cohort of the first 50 minimally invasive valve patients *versus* 50 standard valve operations via standard sternotomy who were operated on in the same period. Demographics, operative details, patient satisfaction, and charges are shown. Although operative times were longer in the minimal incision group, erythrocytes were used less and overall charges were approximately 20% less. A functional and productivity classification in comparison including

pain management in the hospital and after discharge showed less pain, less pain medication usage, and a significantly faster return to normal activity.

DISCUSSION

Cardiac valve replacement and repair for the adult patient has become an exceedingly effective operative therapy for congenital, infectious, degenerative, and myxomatous lesions of both the aortic and mitral valve. Aortic valve surgery, for example, has transformed the elderly patient with severe symptoms into a productive member of society, including patients well into their 80s.⁷ Mitral valve reparative surgery has had a renaissance in the past 10 years, and many patients with mitral regurgitation now have their own valve repaired successfully to effect normal valve function yet preserving the papillary muscle chordal interaction, important for normal cardiac function.⁸ Until this past year, these operations have been performed through the standard complete median sternotomy and cardiopulmonary bypass with intrathoracic cannulations. With the advent of minimally invasive cardiac valve surgery, several new observations have arisen regarding the treatment of patients with isolated valve dis-

Table 4. COMPARISON OF MINIMALLY INVASIVE VALVE WITH CONVENTIONAL VALVE VIA STERNOTOMY

	MIVS (n = 50)	Conventional (n = 50)
Operative data		
Ischemic time (min)	103	82
CPB time (min)	143	104
Number of RBCs		
MVR	0.8	2.6
AVR	1.6	2.8
Length of stay (days)(range)	5 (3–12)	6 (3–48)
Pain control		
Pain in hospital (0–10)	4.1	4.4
Pain >2 wk (0–10)	1.7	2.4
Finished pain medication (%)	7	23
Took no pain medication (%)	14	8
Patient satisfaction (wk)		
Return to work	6.3	8.2
Return to normal activity	4.6	9.4 (p = 0.0002)
“Feel like myself”	6.4	10.3 (p = 0.009)
Charges (dollars)		
Mitral	38	46
Aortic	44	51
Overall	41	48

MIVS = minimally invasive valve sternotomy; CPB = cardiopulmonary bypass; RBCs = red blood cells; MVR = mitral valve replacement; AVR = aortic valve replacement.

ease. Certainly, trauma is considerably less with the minimally invasive incisions. Sternal infections are avoided, and for the most part, there is less blood loss from the incision and the operative site. In fact, in this series of 84 patients, only 2 patients had to go back for postoperative bleeding from a suture line bleeder, whereas erythrocyte usage was much lower in the minimally invasive valve surgery group.

In addition, there is improved cosmesis with these incisions. In many patients, this is of considerable concern. The incisions are relatively small, particularly in the mitral area. Mitral valve repair can be performed through a 6- to 9-cm incision in the lower right parasternal area. Other techniques of minimally invasive surgery under development currently include a Port Access system,⁹ which actually does mitral valve surgery through an even smaller transverse incision under the right breast fold and is more superior cosmetically.

The pain in these incisions is considerably less than in patients with the median sternotomy. Median sternotomy, however, compared to other thoracic incisions is a relatively painless incision, but still many report considerable problems, especially late after surgery. With these minimal incisions, incisional pain is even less. In our survey of standard *versus* the minimally invasive incisions, there appeared to be significantly less incisional pain, less requirement for pain medication both in the hospital and after surgery, and a faster return to normal activity.

A disadvantage has been, of course, use of the femoral area for cannulation and perfusion in many patients. Retrograde dissection may occur, so the thoracic aorta is monitored for severe atherosclerotic changes by transesophageal echo before using the technique. In fact, groin complications amounted to only 8% and were, in fact, a source of minor morbidity to the patient cohort. There were three groin infections, four arteries requiring reconstruction in the operating room, and no venous complications.

The major question to be asked is this: can one achieve the same quality of operation that one can do through the complete median sternotomy without complete exposure of the heart? The answer, based on our experience, thus far, is an emphatic "yes." The quality of the valve repair and replacement in both the aortic and mitral has been exactly equal to the standard operation. There have been no perivalvular leaks in any of the valves implanted, and there has been excellent visualization of the mitral valves as to perform complicated repairs, including leaflet resection, chordoplasty, and commissuroplasty documented by intraoperative and postoperative by transesophageal echo. Thus, we believe that the quality of the valve operations has not been mitigated in any way. The ischemia time and bypass times are somewhat longer than the standard operation and do balance out a certain amount of cost reduction realized from

the reduced length of stay, but overall changes were down much less than the standard operation. Conversely, we have learned that in extremely sick patients with a high degree of risk and potential morbidity, these minimal procedures at present may not be as useful because of the necessity for speed and efficiency in patients who functionally are quite ill to minimize ischemia and bypass time. Indeed, some of the outliers in this series were, in fact, the older, sicker patients who, it was thought, might benefit from limited incisional trauma but, in fact, may have lingered longer in the hospital because of slightly increased perfusion and ischemia time.

Finally, these techniques are a paradigm for the future in terms of cost-effective treatment of patients with valvular heart disease.¹⁰ If the same quality of operation can be performed through a less traumatic and better cosmetic incision resulting in less hospital stay and a lower overall cost, this approach would coincide with many of the good goals of managed care. Moreover, these patients have less requirement for post-hospital rehabilitation, a major bonus of this technique. It is estimated that post-hospital care now exceeds tens of billions of dollars in the United States this past year and this cost is rising. If operations can be performed as effectively as the open operation and significantly reduce the need for post-hospital care, this again is an advantage in the cost-effective medical world we live in.

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