Minimally Invasive Aortic Valve Surgery in the Elderly: A Case-Control Study

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Introduction—Although minimally invasive aortic valve surgery (MIAVR) is performed in many centers, few studies have compared its results to a standard sternotomy (SS) approach. We assessed the hypothesis that, when compared with SS in the elderly population, MIAVR has similar morbidity and mortality and allows faster hospital recovery.

Methods and Results—From January 1995 through February 2002, 515 patients over age 65 underwent isolated aortic valve replacement. Using data gathered prospectively, 189 MIAVR patients were matched with 189 SS patients by age, ventricular function, valvular pathology, urgency of operation, diabetes, previous cardiac surgery, renal disease, and history of stroke. In each group, 56.1% of patients underwent non-elective procedures, and 28% were ≥80 years old. Hospital mortality (6.9%) and freedom from postoperative morbidity (82.5% versus 81.5%, P=0.79) were similar. Multivariate analysis revealed that urgent procedures [Odds Ratio (OR)=3.97; P=0.03], congestive heart failure (OR=3.94; P=0.03), and ejection fraction <30% (OR=4.16; P=0.03) were significant predictors of hospital mortality. Prolonged length of stay was associated with age (P=0.05), preoperative stroke (OR=3.5, P=0.001), CHF (OR=2.2, P=0.004), and sternotomy approach (OR=2.3, P=0.002) by multivariate analysis. More MIAVR patients were discharged home (52.6% versus 38.6%, P=0.002) rather than to rehabilitation facilities. Three year actuarial survival revealed no difference between groups.

Conclusions—Minimally invasive aortic valve surgery is safe in elderly patients, with morbidity and mortality comparable to sternotomy approach. The shorter hospital stay and greater percentage of patients discharged home after MIAVR reflect enhanced recovery with this technique. (Circulation. 2003;108[suppl II]:II-43-II-47.)

Key Words: survival • valves • morbidity • mortality

Experimental studies beginning in 19941-2 have led to the introduction of a minimally invasive surgical technique using peripheral perfusion and a balloon catheter for aortic occlusion. Early results of minimally invasive aortic valve surgery were promising in selected centers, with mortality rates of 0.8% to 4%, leading to increasing utilization of less invasive approaches for valve surgery throughout the world.3-9 However, many surgeons remain skeptical about the advantages of this approach and require more data before adopting a less invasive technique.10 Comparative studies of minimally invasive and conventional median sternotomy approaches for AVR demonstrated comparable early mortality.11,12 Although most studies have shown less need for transfusion and better postoperative pulmonary function after minimally invasive approaches,13-15 there have been contradictory reports regarding earlier hospital discharge.6,11,16 Increased operative risk has been reported for elderly patients undergoing aortic valve surgery, with operative mortality between 7.4 to 16.7%.17-19

In the present study we assessed the hypothesis that in the elderly population, MIAVR is comparable to a standard sternotomy (SS) approach in terms of morbidity and mortality but results in a shorter and more facile hospital recovery.

Materials and Methods

Patients

Between December 1996 and January 2002, 482 patients underwent minimally invasive aortic valve surgery (MIAVR) at the New York University Medical Center. Isolated MIAVR was performed in 233 patients older than 65 years. This study focuses on 189 of these patients who were fully case-matched with an equal number of patients operated on via median sternotomy in the same institution during the same period. The choice of procedure depended on the preference of the surgeon. The matching variables were age, ventricular function, valvular pathology, operation urgency, diabetes, previous cardiac surgery, renal disease, and history of stroke. Preoperative characteristics and baseline co-morbid conditions of the patients undergoing isolated MIAVR and standard sternotomy AVR are presented in Table 1. Patient age ranged from 65 to 95 years with a mean age of 75.3±6.6. Most of the patients (77.7%) had predominantly aortic stenosis (AS).

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Supported in part by The Foundation for Research in Cardiac Surgery and Cardiovascular Biology.
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Circulation is available at http://www.circulationaha.org

DOI: 10.1161/01.cir.0000087446.53440.a3
TABLE 1. Patient Clinical Characteristics and Comparison Between the Minimally Invasive and Standard Sternotomy Approaches for Isolated Aortic Valve Replacement

<table>
<thead>
<tr>
<th></th>
<th>MIAVR N=189</th>
<th>Sternotomy n=189</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs.) (mean±SD)</td>
<td>75.3±6.4</td>
<td>75.3±6.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Octo-nonagenarian</td>
<td>53 (28.0%)</td>
<td>53 (28.0%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Male gender (%)</td>
<td>96 (50.8%)</td>
<td>99 (52.4%)</td>
<td>0.76</td>
</tr>
<tr>
<td>Predominant AI</td>
<td>41 (22.2%)</td>
<td>41 (22.2%)</td>
<td>1.0</td>
</tr>
<tr>
<td>CHF</td>
<td>57 (30.2%)</td>
<td>64 (33.9%)</td>
<td>0.44</td>
</tr>
<tr>
<td>COPD</td>
<td>25 (13.2%)</td>
<td>24 (12.7%)</td>
<td>0.89</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>10 (5.3%)</td>
<td>15 (7.9%)</td>
<td>0.30</td>
</tr>
<tr>
<td>Previous MI</td>
<td>69 (36.5%)</td>
<td>37 (19.6%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetic</td>
<td>14 (7.4%)</td>
<td>14 (7.4%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Previous stroke, TIA or carotid disease</td>
<td>20 (10.6%)</td>
<td>20 (10.6%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Renal disease</td>
<td>4 (2.1%)</td>
<td>5 (2.6%)</td>
<td>0.74</td>
</tr>
<tr>
<td>LVEF ≤40%</td>
<td>30 (15.9%)</td>
<td>35 (18.5%)</td>
<td>0.85</td>
</tr>
<tr>
<td>Previous cardiac operation</td>
<td>32 (16.9%)</td>
<td>32 (16.9%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Urgent/emergent operation</td>
<td>106 (56.1%)</td>
<td>106 (56.1%)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

MIAVR, Minimally invasive aortic valve replacement; AI, aortic insufficiency; LVEF, left ventricular ejection fraction; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction; CHF, congestive heart failure; TIA, transient ischemic attack; Urgent, nonelective operation.

Operative Procedure

Minimally invasive AVR was performed through a small right anterior thoracotomy through the second or third intercostal space in 169 patients (89.4%) and through minirsternotomy in the remainder of the patients. Ascending aortic (“central”) cannulation was performed in 128 patients (68.8%), or via the femoral artery as has been described. Venous drainage was established via the femoral vein or through small venous cannulas directly placed into the right atrium (29.1% of the cases). The femoral venous cannula was inserted over a guide wire, with its tip advanced into the superior vena cava under TEE guidance. Cardiopulmonary bypass with vacuum assisted drainage was initiated using a membrane oxygenator equipped with an arterial filter. A vent was typically inserted through the right superior pulmonary vein. Carbon dioxide was routinely infused into the thoracic cavity through a small catheter in the latter half of our experience. An external cross-clamp was applied directly to the aorta. The majority of aortic procedures were performed with moderate hypothermia (28 to 30°C) and cold blood cardioplegia. The cardioplegia was administered antegrade, via direct coronary cannulation (23.6%) or direct trans-atrial cannulation (18.0%), or retrograde through a percutaneous (jugular) coronary sinus catheter (57.3% of patients). Standard aortic valve replacement techniques were used with a pledgeted, interrupted suture technique. Intracardiac air was aspirated through a catheter in the aortic root, guided by TEE.

Full median sternotomy approach was performed according to standard technique, applying double stage venous cannulas with the same methods of myocardial protection. As in the minimally invasive cases, intraoperative TEE was used routinely for assessment of cardiac function, proper positioning of the coronary sinus catheter, evaluation of surgical results and confirmation of the de-airing process.

Patient data were collected according to the definitions used by the New York State Cardiac Surgery Reporting Form, which is an audited data collection instrument used to record and analyze all cardiac surgery performed in New York State. The definitions used to determine the presence of preoperative risk factors, perioperative complications and data collection were those delineated by the New York State Cardiac Surgery Reporting System in January 1998. Using this nomenclature, stroke is defined as a permanent new focal neurological deficit that occurs anytime during the postoperative hospitalization and/or new findings on computed tomography (CT) or magnetic resonance imaging (MRI). Left ventricular function was evaluated by echocardiography. Follow-up survival was ascertained from the Social Security Death Index.

Statistical analysis was performed using the statistical software SPSS (version.11.0; SPSS Inc., Chicago, IL). Patient demographic and operative data were summarized as mean ± standard deviation, median, or prevalence, as appropriate. Continuous variables were analyzed by the Student’s t-test and categorical variables by the chi-square test. Survival analysis was performed by using life table methodology, and differences were tested with a Wilcoxon statistic. Predictors of late mortality were calculated by Cox regression analysis. A probability value <0.05 was considered to be significant.

Results

Overall hospital mortality was identical in the MIAVR and SS groups (13/189, 6.9%). Morbidity analysis (Table 2), however, revealed that the MIAVR group was associated with shorter mean length of stay compared with the SS group (10.9±1.07 [SE] versus 14±1.35 [SE] days, P=0.001). There were no statistically significant differences between the MIAVR and SS groups in the prevalence of postoperative complications. No aortic dissection was observed in the minimally invasive group.

Univariate risk factor analysis (Table 3) demonstrated that age ≥80 years, urgent or emergent operation, congestive heart failure, chronic obstructive pulmonary disease, previous myocardial infarction, and left ventricular ejection fraction ≤30% were associated with increased risk for hospital mortality. Peripheral vascular disease was a borderline risk factor for hospital mortality. Multivariate analysis (Table 4) revealed that congestive heart failure, urgent or emergent operation, and left ventricular ejection fraction ≤30% were independent predictors of hospital mortality.

Perioperative stroke occurred in 2.9% of all patients, without any difference because of operative approach. Stroke analysis over the study period revealed that although the incidence was unchanged in the SS group, most strokes in the MIAVR group occurred before 1999 with only one patient (0.9%) suffering a stroke after 1999 (P=0.016). Univariate analysis in those MIAVR patients showed that previous MI was the only associated risk factor for stroke (8/106 [7.5%] versus 7/272 [2.6%]; P=0.026). Multivariate analysis of the risks for stroke did not reveal any significant associated factors in this study group of elderly patients.

A greater percentage of patients in the MIAVR group were discharged directly home (52.6% versus 38.6%, P=0.03) rather than to a rehabilitation facility or nursing home. Multivariate analysis revealed that age (P=0.05), history of stroke or cerebrovascular disease (Expβ=3.5, P=0.001), CHF (Expβ=2.2, P=0.004), and sternotomy approach (Expβ=2.3, P=0.002) were associated with a prolonged length of stay.

Follow-up analysis (95.8% complete) revealed a 36 month cumulative survival rate of 87.2% for the MIAVR group and 82.8% for the SS (P=0.35; Figure 1). Cox multivariate regression analysis revealed age (P<0.001) as the only significant risk for mortality, while congestive heart failure was weakly associated with mortality (P=0.11).
Discussion
The current study has demonstrated that MIAVR is associated with comparable hospital morbidity and mortality and similar mid-term survival compared with the SS approach. Minimally invasive aortic valve surgery, however, results in a significantly shorter hospital stay and higher percentage of patients discharged directly home.

During the first 6 years of minimally invasive aortic valve surgery, several different methods of operative access have been reported and different techniques of great vessel cannulation, aortic occlusion, and de-airing have been proposed.3–5,16,20,21 The parasternal approach generally involves resection of the third and fourth costal cartilages, and occasionally leads to instability of a portion of the anterior chest wall.3,22 Upper sternotomy allows operation on the ascending aorta, 23,24 but has the potential for sternal morbidity, especially in elderly patients.

Because aortic atherosclerosis is independently associated with aortic valve sclerosis, 25 groin cannulation for MIAVR with its use of a long arterial cannula carries the potential for direct aortic injury, aortic dissection, atheroembolism and limb ischemia.26 Despite the safety of femoral cannulation and the port access technique in patients undergoing mitral operation,13 we prefer direct cannulation of the ascending aorta with direct cross clamping in this subset of elderly patients. Our data show that this strategy of cannulation can be accomplished using a right anterior thoracotomy in most cases. The absence of peripheral vascular complications in the current study may be attributed to this approach. Additionally, it was suspected that more reliance on central arterial cannulation, which occurred during the study period, might explain the observed reduction in stroke rate; however this was not statistically borne out.

Previous studies have identified advanced age, 27 re-operation, 28 reduced left ventricular function, 29 and implantation of a stentless bioprosthesis 30 as independent risk factors for mortality in patients undergoing AVR. The current data

TABLE 3. Risk Factor Analysis for Hospital Mortality for All Patients (chi-square test)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Hospital Mortality With</th>
<th>Hospital Mortality Without</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous cardiac surgery</td>
<td>4/64 (6.3%)</td>
<td>22/314 (7.0%)</td>
<td>0.8</td>
</tr>
<tr>
<td>Age 70 or older</td>
<td>23/295 (7.8%)</td>
<td>3/83 (3.6%)</td>
<td>0.18</td>
</tr>
<tr>
<td>Age 80 or older</td>
<td>13/107 (12.1%)</td>
<td>13/271 (4.8%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Urgent/emergent operation</td>
<td>23/212 (10.8%)</td>
<td>3/166 (1.8%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2/28 (7.1%)</td>
<td>24/350 (6.9%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>4/25 (16.0%)</td>
<td>22/353 (6.2%)</td>
<td>0.08</td>
</tr>
<tr>
<td>Female gender</td>
<td>13/183 (7.1%)</td>
<td>13/195 (6.7%)</td>
<td>0.87</td>
</tr>
<tr>
<td>Previous MI</td>
<td>12/106 (11.3%)</td>
<td>14/272 (5.1%)</td>
<td>0.03</td>
</tr>
<tr>
<td>Renal failure</td>
<td>1/9 (11.1%)</td>
<td>25/369 (6.8%)</td>
<td>0.48</td>
</tr>
<tr>
<td>CHF</td>
<td>19/121 (15.7%)</td>
<td>7/257 (2.7%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>COPD</td>
<td>8/49 (16.3%)</td>
<td>18/329 (5.5%)</td>
<td>0.005</td>
</tr>
<tr>
<td>LVEF ≤30%</td>
<td>4/16 (25%)</td>
<td>22/362 (6.1%)</td>
<td>0.02</td>
</tr>
<tr>
<td>Previous stroke, TIA or carotid disease</td>
<td>4/40 (10.0%)</td>
<td>22/338 (6.5%)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Exp β</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF</td>
<td>3.94</td>
<td>1.1–13.8</td>
<td>0.03</td>
</tr>
<tr>
<td>Urgent/emergent operation</td>
<td>3.97</td>
<td>1.1–14.0</td>
<td>0.03</td>
</tr>
<tr>
<td>LVEF ≤30%</td>
<td>4.16</td>
<td>1.1–15.4</td>
<td>0.03</td>
</tr>
<tr>
<td>Age</td>
<td>1.062</td>
<td>—</td>
<td>0.07</td>
</tr>
</tbody>
</table>

CHF, congestive heart failure; LVEF, left ventricular ejection fraction.
clearly show the detrimental effect of congestive heart failure and urgent operation on hospital mortality. These factors, when added to the increased risk associated with advanced age, may explain the high mortality rate that was observed in the elderly patient undergoing urgent AVR or presenting with congestive heart failure.

The stroke rate in the current study was comparable in the MIAVR and sternotomy groups, although there has been a significant reduction in the stroke rate within the MIAVR group since 1999. This study and other reports show no increase in the peri-operative stroke rate associated with the minimally invasive approach. Intraoperative TEE allows for accurate detection of residual air in the left ventricle before the release of the aortic cross-clamp and weaning from cardiopulmonary bypass. Additionally, flooding the thoracic cavity with CO2 reduces the danger of gas bubbles by increasing their solubility. The application of all these modalities, coupled with a transvalvular vent and a vent in the ascending aorta, minimize the risk of neurologic complications and may responsible for the stroke reduction seen in the latter half of the current study.

In accordance with other reports, we could not demonstrate any hospital or mid-term survival benefit for MIAVR compared with the full sternotomy technique, but we did observe a significantly shorter hospital length of stay. Both the shorter length of stay and the higher frequency of home discharge reflect the enhanced recovery of these patients after a minimally invasive approach. Although this study did not analyze cost data, length of stay may be considered a surrogate for resource use, and prolonged length of stay increases hospital costs at all levels. Therefore, the reduction in hospital stay and decreased use of inpatient rehabilitation services has an important impact on resource utilization.

**Limitations of the Study**

This is a comparative retrospective study. However, by using case-match analysis based on prospectively collected data we minimized bias between the minimally invasive and the median sternotomy groups. Our case match model created two cohorts with similar distribution of those factors that significantly contributed to overall patient mortality and morbidity. The series also encompasses our ‘learning curve’, as it includes our initial experiences with MIAVR. Additionally, the rate of postoperative new onset atrial fibrillation and pain score are not available as they are not included in the New York State database.

**Conclusions**

Our data show that the minimally invasive approach is a safe procedure in the elderly patient population. Our current minimally invasive approach for aortic valve surgery takes advantage of direct vision of the aortic root and uses central cannulation of the ascending aorta, while avoiding both partial sternotomy and excision of cartilage. Comparison of MIAVR with a traditional median sternotomy technique demonstrates similar hospital mortality and morbidity, with comparable actuarial survival at 3 years. MIAVR results in a shorter length of stay, with a greater proportion of patients able to be discharged directly home, rather than requiring further inpatient rehabilitation services.

**References**


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_Circulation_. 2003;108:II-43-II-47
doi: 10.1161/01.cir.0000087446.53440.a3
_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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http://circ.ahajournals.org/content/108/10_suppl_1/II-43

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