Valvular Heart Disease

Valvular Replacement for Patients with Aortic Stenosis and Severe Left Ventricular Dysfunction

Chung-Pin Liu, Ron-Bin Hsu, Shi-Zhe Hua and Yi-Lwun Ho

Background and Purpose: The 2-year survival of patients with aortic stenosis (AS) and congestive heart failure is less than 10% under medical treatment. On the other hand, the surgical risk of aortic valve replacement (AVR) also increases for patients with AS and severe left ventricular (LV) dysfunction. The aim of this study was to evaluate the risk and benefit of AVR for such patients.

Methods: From May 1999 to April 2003, 8 consecutive patients with AS and severe LV dysfunction (ejection fraction [EF] ≤ 30%) underwent aortic valve replacement in National Taiwan University Hospital. The myocardial protection was initially achieved with antegrade perfusion and maintained with continuous retrograde cold blood or crystalloid cardioplegia. The indication for aortic valve replacement was severe AS, which was defined as an aortic valve area of ≤ 1.0 cm² or a maximum pressure gradient of ≥ 50 mmHg assessed by Doppler echocardiography. The mean age was 67 ± 9 years; and 7 of 8 patients suffered from severe exertional dyspnea (functional class III-IV of New York Heart Association). Respiratory failure developed in 5 patients prior to surgery.

Results: The perioperative (30-day) mortality was 0%. During a mean follow-up period of 32 ± 18 months (range 16-61 months), the survival rate was 75%. The clinical symptoms of heart failure improved at least one functional class in all patients. The mean change of LVEF was an increase of 26 ± 18 EF units (p = 0.005), and the mean reductions of LV end-systolic dimension and LV end-diastolic dimension were 16 ± 8 mm (p = 0.005), respectively.

Conclusions: The surgical risk was acceptable for AVR in patients with AS and severe LV dysfunction. Improvements in symptoms, heart size and LV systolic function were observed in most patients.

Key Words: Aortic stenosis • Valvular replacement • Left ventricular dysfunction • Left ventricular remodeling

INTRODUCTION

In patients with aortic stenosis (AS), increases in left ventricular (LV) pressure lead to decreases in stroke volume and ejection fraction (EF) that contribute to LV dysfunction.1-2 Furthermore, irreversible systolic dysfunction may be caused by myocardial fibrosis due to LV hypertrophy or superimposed myocardial infarction.3 Severe AS with congestive heart failure carries a poor prognosis, with a 2-year survival less than 10% under medical treatment.4 The surgical risk of aortic valve replacement (AVR) also increases for patients with AS and severe LV dysfunction.5-7 Many patients are often denied surgical treatment, especially the elderly.8 AS with severe LV dysfunction was also an indication for heart transplantation in the past.9 However, with recent improvements in myocardial protection and design of
valve prosthesis, the outcome of AVR for such patients is of great interest. There have been only a few papers about this issue. Therefore, we conducted the present study to (1) evaluate the surgical risk and survival of such patients after AVR; (2) assess the effects of AVR on the regression of heart size, improvement of heart failure symptoms and LV function in such patients.

MATERIAL AND METHODS

Patients

We identified all the patients with AS and severe LV dysfunction (LVEF ≤ 30%) who underwent AVR in National Taiwan University Hospital between 1999 and 2003. The indication for aortic valve replacement was severe AS, which was defined as an aortic valve area (AVA) of ≤ 1.0 cm² or a maximum pressure gradient of ≥ 50 mmHg assessed by Doppler echocardiography. Preoperative LVEF was determined by echocardiography and radionuclide angiography. All patients received coronary angiography prior to surgery. The medical records were reviewed, including preoperative clinical data, echocardiographic results, coronary artery anatomy and operative data. The functional classes of the patients were evaluated preoperatively and one month later after surgery.

Echocardiography

Standard echocardiographic assessment was performed within 30 days before AVR and at a mean interval of 6 months after surgery without knowledge of this study. The LVEF was determined by area length method. Measurements of posterior wall thickness, interventricular septal thickness, left ventricular end-diastolic and end-systolic dimensions were made according to the criteria of the American Society of Echocardiography. The LV outflow tract area was calculated from the diameter of the outflow tract (area = diameter² × 0.785), assuming a circular geometry. The velocity of the LV outflow tract was obtained by pulsed-wave Doppler echocardiography from the apical four-chamber view, and the maximum pressure gradient across aortic valve was calculated from the peak Doppler velocity by the modified Bernoulli equation (pressure gradient = 4 × velocity²). The AVA was calculated by the continuity equation using time-velocity integral (TVI) of the aorta and left ventricular outflow tract (LVOT) as follows: AVA = (AreaLVOT × TVI LVOT)/TVIAorta.

Surgical procedure

All of the operations were conducted by a single surgeon (RB Hsu). Aortic valve replacement was performed in a standard manner with median sternotomy, cardiopulmonary bypass and aortic cross-clamp. Interrupted mattress sutures of 2-0 Ticron were used with Teflon felts. Myocardial protection was initially achieved with antegrade perfusion of the coronary artery and maintained with continuous retrograde cold blood or crystalloid cardioplegia of the coronary sinus. The temperature of the cardioplegia was maintained at 4 °C. After excision of the aortic valve, careful debridement of the annular calcium was performed if necessary. Bioprosthesis was used in patients with old age (> 65 years-old) or high risk of bleeding tendency. One patient received simultaneous mitral valve replacement due to severe mitral stenosis in addition to aortic stenosis. The largest prosthesis that could be fitted was implanted. Lifelong anticoagulant treatment was administered to the patients with a mechanical prosthesis.

Statistical analysis

The clinical data collected from the patients were listed individually, including preoperative and postoperative findings. All results were expressed as mean ± standard deviation. Continuous variables between groups before and after AVR were compared by paired- t test. p < 0.05 was considered as significant.

RESULTS

Clinical characteristics (Tables 1 and 2)

Eight consecutive patients fulfilled the entrance criteria and were included in the analysis. There were 5 of 8 patients with LV hypertrophy on electrocardiography. Five patients (62.5%) were ventilator-dependent due to respiratory failure, and six patients (75%) received intravenous infusion of inotropic agents prior to AVR. Seven patients suffered from severe exertional dyspnea (functional class III-IV of New York Heart As-
LV dilatation was noted in all patients; the mean LV end-diastolic dimension (LVEDD) was 66 ± 12 mm and the LV end-systolic dimension (LVESD) was 60 ± 10 mm. The maximum pressure gradients across aortic valve ranged from 46 to 132 mmHg, with a mean of 78 ± 29 mmHg. The mean LVEF was 20 ± 6% and the mean AVA was 0.7 ± 0.2 cm². Four patients had atrial fibrillation and two patients had coronary artery disease. Because there were no critical coronary lesions, we did not perform any simultaneous coronary artery bypass grafting during operation of AVR.

### Outcome

No patient died within the perioperative period (30 days). Mean intubation period after AVR was 5 ± 4 days except for one patient (pt No. 1), for whom ventilator weaning was hindered by chronic obstructive pulmonary disease. It took 75 days for that patient to be weaned from ventilator.

The mean follow-up period was 32 ± 18 months (ranged from 15 to 61 months). Two patients died during the follow-up period. One of the patients (pt No. 1) suffered from prolonged weaning (75 days) mentioned previously and had received tracheostomy. However, infective endocarditis with septic lung occurred 15 months after AVR and she expired due to profound shock. The other patient (pt No. 4) recovered well after surgery. Unfortunately, tracheostenosis with upper airway obstruction occurred 3 months after surgery.

### Table 1. Preoperative clinical data

| Pt No. | Age (yr) | Gender | Significant comorbidity | Ventilator use | NYHA class | AR grading | AVA (cm²) | MPG (mmHg) | LVEF (%) | LVIVS (mm) | LVPW (mm) | LVESD (mm) | LVEDD (mm) |
|--------|----------|--------|--------------------------|----------------|------------|------------|------------|------------|----------|------------|------------|------------|------------|------------|
| 1      | 57/F     | COPD, DM| AF                      | Yes            | IV         | 2          | 0.9        | 53         | 18       | 14         | 14         | 49         | 55         |
| 2      | 78/F     | Nil    | AF                      | Yes            | IV         | 3          | 0.7        | 85         | 11       | 12         | 12         | 57         | 61         |
| 3      | 51/M     | MS     | AF                      | Yes            | IV         | 2          | 0.6        | 132        | 20       | 12         | 14         | 56         | 62         |
| 4      | 65/M     | HTN    | AF                      | Yes            | IV         | 1          | 0.6        | 83         | 16       | 10         | 10         | 63         | 68         |
| 5      | 75/M     | HTN    | NSR                     | No             | III        | 1          | 0.5        | 102        | 27       | 15         | 12         | 48         | 54         |
| 6      | 75/M     | CAD, PTB | NSR                    | Yes            | IV         | 0          | 0.9        | 50         | 25       | 11         | 11         | 57         | 64         |
| 7      | 65/M     | Nil    | NSR                     | No             | II         | 2          | 0.8        | 46         | 26       | 9          | 10         | 75         | 91         |
| 8      | 67/M     | Nil    | NSR                     | No             | III        | 0          | 0.6        | 76         | 14       | 14         | 14         | 71         | 76         |

AR = aortic regurgitation, (0: nil, 1: mild, 2: moderate, 3: moderate-to-severe, 4: severe); AF = atrial fibrillation; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; F = female; HTN = hypertension, LVEDD = left ventricular end-diastolic dimension; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic dimension; LVIVS = left ventricular interventricular septal thickness; LVPW = left ventricular posterior wall thickness; M = male; MPG = maximum pressure gradient; MS = mitral stenosis; NSR = normal sinus rhythm; NYHA = New York Heart Association; Pt = patient; Pul TB = pulmonary tuberculosis.

### Table 2. Surgical and postoperative data

<table>
<thead>
<tr>
<th>Pt No.</th>
<th>Aortic prosthesis type (trademark), size (mm)</th>
<th>CPB time (min)</th>
<th>ACC time (min)</th>
<th>Cardioplegia type</th>
<th>Weaning days</th>
<th>NYHA class</th>
<th>PPG (mmHg) (%)</th>
<th>LVEF (LVEDD)</th>
<th>LVIVS (LVESD)</th>
<th>LVPW (LVESD)</th>
<th>Follow-up (month)</th>
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<tr>
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<td>119</td>
<td>73</td>
<td>blood</td>
<td>75</td>
<td>III</td>
<td>30</td>
<td>57</td>
<td>14</td>
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<td>109</td>
<td>crystalloid</td>
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CPB = cardiopulmonary bypass; CPE = Carpentier-Edwards; ACC = aortic cross-clamp, LVEDD = left ventricular end-diastolic dimension; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic dimension; LVIVS = left ventricular interventricular septal thickness; LVPW = left ventricular posterior wall thickness; NYHA = New York Heart Association; PPG = prosthetic valve pressure gradient.
months postoperatively. He received tracheostomy and died of pneumonia 33 months after AVR.

Most patients showed a significant increase in LVEF and a decrease of LVEDD. The mean change of LVEF was an increase of 26 ± 18 EF units (p = 0.005) (Figure. 1), and the mean reductions of LVESD and LVEDD were 16 ± 8 (p = 0.001) and 11 ± 8 mm (p = 0.005). The symptoms improved at least one functional class in all patients (Figure. 2). The maximal pressure gradient of the prosthetic valve was 23.5 ± 8.2 mmHg, with a significant decline from the baseline (p = 0.001). However, there was no significant change of wall thickness.

**DISCUSSION**

Under medical treatment, the average survival of AS with congestive heart failure is only 1.5 years. 20 Unfortunately, the surgical risk of AVR increases significantly in the presence of LV dysfunction. 21,22 The decision of AVR for patients with severe AS and LV dysfunction has been a medical dilemma. The high proportion of severe heart failure symptoms and ventilator use in such patients often shifted the surgical decision from AVR to heart transplantation in the past. In 1997, Connolly et al. reported a series of AVR for patients with AS and an LVEF ≤ 35%. The operative mortality was 9% and 5-year survival was 58%. 23 Thereafter, clinical studies of AVR for patients with severe AS and LV dysfunction have increased. 24,25

Very old age (> 80-year-old), renal impairment and coronary artery disease have been related to worsen prognosis of AVR for such patients. 26 Our patients were relatively younger (mean age 67 ± 9 years) and their renal functions were not severely impaired. The prevalence of coronary artery disease was also low in our patients. In addition, we used continuous retrograde cardioplegia during operation. Improved surgical outcomes in aortic valve surgery using this cardiac protection method were reported increasingly. 27,28 Compared with previous reports, these factors contributed to the lower peri-operative mortality in the present study.

Long-term mortality occurred in 2 patients during follow-up period, and both patients died of non-cardiac causes. About 31% of late deaths have been reported to result from non-cardiac causes. 23 Our data was compatible with the previous study. Similar to the result of Powell et al., 10 no relationship was found between LVEF and patient survival. In our study, both the 2 mortality cases had successful LV remodeling (LVEDD decreased from 55 mm to 50 mm in pt No. 1 and 68 mm to 47 mm in pt No. 4) and systolic function improvement (LVEF increased from 18% to 57% in pt No. 1 and 16% to 48% in the pt No. 4). On the other hand, underlying pulmonary conditions (such as chronic obstructive pulmonary disease and tracheostenosis) of the patients should be considered as distinctive risk factors for AVR in such patients.

In severe AS, the chronic pressure overload was compensated by hypertrophy of the LV. The cardiac output

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Figure 1. Left ventricular ejection fraction (LVEF) before (preop) and after (postop) aortic valve replacement. Solid horizontal line indicates mean EF; hatched box indicates one standard deviation; vertical line indicates highest and lowest values.

Figure 2. Changes of preoperative (preop) and postoperative (postop) New York Heart Association (NYHA) functional class.
and LVEF were maintained initially. However, when the wall stress exceeds the compensating mechanism, the LV function declines and the chamber size becomes enlarged.\textsuperscript{29,30} There was once a suspicion of the reversibility of myocardial contractility in patients with AS and severe systolic dysfunction. In our study, not only the symptoms and LVEF improved, but also the LV size decreased in most patients after AVR. There was one patient (pt No. 7) who had improved clinical symptoms without improvement of LVEF. The possible explanation is the significant decrease of LV size (LVESD from 91 to 71 mm and LVESD from 75 to 59 mm), implying improved LV stretch and LV end-diastolic pressure. The successful LV remodeling encourages further surgical intervention for such patient group.\textsuperscript{31,32}

Our study had several limitations. First, the patient number in this study was small. Second, the follow-up period was not long enough. Third, a lack of control group was also a drawback.

CONCLUSIONS

The surgical mortality was acceptable in patients with AS and severe LV dysfunction. Heart failure symptoms, heart size, and LV contractility improved postoperatively. Given the substantial potential clinical benefit, patients with AS and severe LV dysfunction might be considered as candidates for AVR.

REFERENCES


主動脈瓣狹窄併發嚴重左心室功能不良患者之主动脈瓣膜置換手術

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背景 主動脈瓣狹窄患者併發心衰竭後的兩年存活率不及百分之十；此外，進行外科手術的風險也會增加。本研究的目的是要評估主動脈瓣膜置換手術在這樣的病患的風險與效益。

方法 從 1999 年 5 月至 2003 年 4 月，共有連續 8 名主動脈瓣狹窄併發嚴重左心室功能不良 (心脈射出分率小於 30%) 的患者在台大醫院接受主動脈瓣膜置換手術。心肌保護的方式是初始順流灌注，繼之以連續的逆流冷血液或電解質溶液灌注。手術的適應症為嚴重主動脈瓣狹窄，定義是主動脈瓣面積 \( \leq 1 \text{ cm}^2 \) 或是以都卜勒氏超音波量測的最大壓力差 \( \geq 50 \text{ mmHg} \)。平均病患年齡為 67 ± 9 歲，其中有兩位病患已於手術前已有重度運動性呼吸困難 (New York Heart Association functional class III-IV)，有五位在手術前已有急性呼吸衰竭。

結果 手術後短期內 (30 天) 的死亡率為 0%。在追蹤期間內 (平均 32 ± 18 月) 的存活率為 75%，所有病患心衰竭的症狀都獲得改善。平均心脈射出分率進步 26 ± 18 單位 \((p \text{ 值} = 0.005)\)，左心室收縮和舒張末期直徑分別縮小 16 ± 8 \((p \text{ 值} = 0.001)\) 和 11 ± 8 mm \((p \text{ 值} = 0.005)\)。

結論 主動脈瓣狹窄併發嚴重左心室功能不良患者進行主動脈瓣膜置換手術之風險是可以接受的。本研究大部分的病患獲得了症狀、心臟大小及左心室收縮功能之改善。

關鍵詞：主動脈瓣狹窄，瓣膜置換手術，左心室功能不良，左心室改擴。