The Role of Percutaneous Aortic Balloon Valvuloplasty in Patients With Cardiogenic Shock and Critical Aortic Stenosis

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Objectives. The goal of this study was to evaluate the role of percutaneous aortic valvuloplasty in patients with cardiogenic shock due to severe aortic stenosis and associated major comorbid conditions and to establish predictors of survival.

Background. The prognosis for patients in cardiogenic shock with severe aortic stenosis is poor. Aortic valve replacement can be lifesaving, but the presence of multiorgan failure precludes these patients from operation. Percutaneous aortic balloon valvuloplasty has been used in these patients with short-term improvement and could be an alternative therapeutic option.

Methods. Of 310 patients undergoing percutaneous aortic balloon valvuloplasty, 21 were in cardiogenic shock and were included in this study. All 21 patients had associated major comorbid conditions at the time of presentation.

Results. After percutaneous aortic balloon valvuloplasty, systolic aortic pressure increased from 77 ± 3 (mean ± SEM) to 116 ± 5 mm Hg (p = 0.0001); aortic valve area increased from 0.48 ± 0.04 to 0.54 ± 0.06 cm² (p = 0.0001); and cardiac index increased from 1.84 ± 0.13 to 2.24 ± 0.15 liters/min per m² (p = 0.06). Nine patients died in the hospital, two during the procedure and seven after successful percutaneous aortic balloon valvuloplasty (five from multiorgan failure). Five patients had vascular complications. Stroke, cholesterol emboli and aortic regurgitation requiring aortic valve replacement occurred in one patient each. Twelve patients (57%) survived and were followed up for 15 ± 6 months; five patients subsequently died. The Kaplan-Meier survival curve showed a 36 ± 11% survival rate at 27 months. The only predictor for longer survival rate was the postprocedure cardiac index.

Conclusions. 1) Emergency percutaneous aortic balloon valvuloplasty can be performed successfully as a lifesaving procedure. 2) Morbidity and mortality remain high despite successful percutaneous aortic balloon valvuloplasty. 3) For nonsurgical candidates, percutaneous aortic balloon valvuloplasty may be the only therapeutic alternative.

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However, those studies involved a small, relatively youthful number of patients and did not analyze predictors for long-term survival. Therefore, the present study was undertaken to evaluate the role of percutaneous aortic balloon valvuloplasty in cardiogenic shock secondary to severe aortic stenosis in a consecutive group of elderly patients who were nonsurgical or very high risk surgical candidates at the time of presentation and to determine predictors for long-term survival.

Methods

Patient group (Table 1). From 310 patients who underwent 394 percutaneous aortic balloon valvuloplasty procedures at the Massachusetts General Hospital between February 1986 and February 1993, we identified 21 (10 men, 11 women, mean ± SEM age 74 ± 3 years, range 35 to 90 years; mean left ventricular ejection fraction was 29 ± 39%, range 15 to 61) patients who presented in cardiogenic shock due to aortic stenosis. All patients had at least one major medical comorbid condition that made them either nonsurgical or high risk surgical candidates at the time of presentation. All patients met the following criteria of cardiogenic shock: 1) sustained arterial hypotension with sys-
Table 1. Clinical Characteristics of 21 Study Patients

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Age (y)</td>
<td>74 ± 3</td>
</tr>
<tr>
<td>LV EF (%)</td>
<td>29 ± 3</td>
</tr>
</tbody>
</table>

Concomitant conditions:
- Chronic renal failure: 9 (42.9%)
- Severe CAD: 8 (38.1%)
- Previous stroke: 3 (14.3%)
- Cancer: 3 (14.3%)
- Severe COPD: 3 (14.3%)
- Liver failure: 1
- AIDS: 1
- Pneumonia: 1
- Pulmonary embolism: 1
- Pulmonary hemorrhage: 1

*Selected from 310 patients who underwent 294 percutaneous aortic valvuloplasty procedures at the Massachusetts General Hospital. Values presented are mean value ± SEM or number (%) of patients. AIDs = acquired immuno deficiency syndrome; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; P = female; LV EF = left ventricular ejection fraction; M = male.

Echocardiography. Successful percutaneous aortic balloon valvuloplasty was defined as ≥50% reduction in aortic gradient or ≥50% increase in aortic valve area, or both.

Follow-up. Follow-up data were obtained by telephone contact with the patient, primary physician, nursing home staff, or next of kin or closest relative. When clinical events occurred at follow-up, the relevant medical records were reviewed after consent from the hospital, patient or next of kin. Follow-up was obtained in all patients.

Statistical analysis. Comparisons between hemodynamic variables before and after percutaneous aortic balloon valvuloplasty were performed using the Student paired t test. A total of 34 demographic and hemodynamic variables were used for the analysis of predictors for early and late survival. Because of the small number of patients, these variables were run in groups of nine at a time. All variables are expressed as mean value ± SEM.

Patients were followed up for 15 ± 6 months after percutaneous aortic balloon valvuloplasty. End points of follow-up were death, aortic valve replacement, repeat percutaneous aortic balloon valvuloplasty and clinical evaluation according to New York Heart Association functional classification.

Actuarial survival curves were performed. Predictors for survival were determined using the Cox regression analysis. Variables included in the analysis were gender, age, before and after percutaneous aortic balloon valvuloplasty functional class, balloon size as determined by the effective balloon dilating area, effective balloon dilating area normalized by body surface area (EBDA/BSA) and the following hemodynamic variables before and after percutaneous aortic balloon valvuloplasty: aortic gradient, cardiac output, cardiac index, aortic valve area, aortic valve area index, aortic valve resistance, aortic valve resistance index, delta aortic gradient, delta aortic valve area left ventricular ejection fraction, and pulmonary artery systolic, left ventricular systolic and end-diastolic, right atrial and mean pulmonary capillary wedge pressures.

A similar test was conducted for event-free survival. Data for the patients who underwent valvuloplasty were prepared with the RS'1 data management and analysis software (18).
running on a Digital Equipment Corp. microcomputer VAX 3600. Actuarial survival analysis was carried out with the BMDP statistical survival analysis program (19) with the use of the RS/1 interface to BMDP provided in RS/1. Cox proportional hazards models of the covariates of survival and of survival free of events were constructed with the BMDP2L program and were used to identify significant predictors of survival (20). These covariates of survival were selected in a stepwise fashion: only significant ($p < 0.05$, chi-square analysis) covariates were retained in each model.

Results

Associated comorbid conditions. All patients had more than one medical comorbid condition (average 1.9) that made them either nonsurgical or high risk surgical candidates at the time of presentation (Table 1). Chronic renal failure defined as serum creatinine >1.5 mg% was present in nine patients (blood urea nitrogen 90 ± 8 mg%; creatinine 4.25 ± 1.83 mg%, range 1.7 to 15.2). Significant multivessel coronary artery disease, defined as a $>70\%$ decrease in arterial lumen diameter in two angiographic orthogonal views was present in eight patients. Five patients had a history of previous myocardial infarction, and three patients had previously undergone coronary artery bypass graft surgery. Furthermore, 11 patients had elevation of creatine kinase (CK) consistent with non-Q wave myocardial infarction at the time of presentation. Previous stroke was present in three patients, cancer in three and severe chronic obstructive pulmonary disease (forced expiratory volume in 1 s \[FEV_1\] <1 liter) in three. Liver failure, pneumonia, pulmonary hemorrhage, pulmonary embolism and acquired immunodeficiency syndrome (AIDS) were the associated medical problems. All patients required inotropic and pressor support at the time of the procedure, and two patients required an intraaortic balloon pump after percutaneous aortic balloon valvuloplasty.

Hemodynamic variables. The immediate hemodynamic changes produced by percutaneous aortic balloon valvuloplasty are shown in Table 2. Systolic arterial pressure increased significantly after percutaneous aortic balloon valvuloplasty from 77 ± 3 to 116 ± 8 mm Hg ($p = 0.0001$). Sixteen patients were successfully weaned from inotropic support within the first 24 h after the procedure. Mean aortic gradient decreased from 49 ± 4 to 21 ± 3 mm Hg ($p = 0.0001$); cardiac index increased from 1.84 ± 0.13 to 2.24 ± 0.15 liters/min per m$^2$ ($p = 0.06$); and aortic valve area increased from 0.48 ± 0.04 to 0.84 ± 0.06 cm$^2$ ($p = 0.0001$). Because the Gorlin formula is flow dependent, with valve area increasing as flow increases despite a fixed orifice valve area, we also used aortic valve resistance. With percutaneous aortic balloon valvuloplasty, aortic valve resistance decreased from 1,413 ± 230 to 524 ± 76 dynes-s-cm$^{-5}$ ($p = 0.001$). Left ventricular systolic and end-diastolic, systolic pulmonary artery and right atrial pressures did not change significantly after percutaneous aortic balloon valvuloplasty.

| Table 3. Complications of Percutaneous Aortic Balloon Valvuloplasty |
|--------------------------|-----------------|
| In-hospital mortality    | 9 (43%)         |
| Procedural              | 2 (9.5%)        |
| After procedure         | 7 (33.3%)       |
| Vascular (non-ischemic) | 5 (24%)         |
| Secondary to PAV         | 3 (14%)         |
| Secondary to IABP        | 2 (10%)         |
| Vascular surgery         | 3 (14%)         |
| Severe AV regurgitation  | 1               |
| Stroke                   | 1               |
| Cholesterol emboli       | 1               |

IABP = intraaortic balloon pump; other abbreviations as in Table 2.

Procedure-related morbidity and mortality (Table 3). Total hospital mortality rate was 43% (9 of 21 patients). Two patients died during the procedure. Both patients had non-Q wave myocardial infarction before percutaneous aortic balloon valvuloplasty. At autopsy, one patient had an extensive circumferential subendocardial necrosis with normal coronary arteries. The other patient had severe three-vessel coronary artery disease with occluded coronary artery bypass grafts, severe mitral stenosis, mitral and tricuspid regurgitation, a remote transmural anteroseptal infarct and a recent intercoronary and right ventricular transmural infarct. The myocardium was infected with Listeria monocytogenes, with cavitation and abscess formation. Seven additional patients died subsequently despite successful percutaneous aortic balloon valvuloplasty (two from congestive heart failure due to a myopathic left ventricle, five from multiorgan failure). Local vascular complications occurred in five patients (24%), two of them related to the use of intraaortic balloon pump. Three patients (14%) required vascular surgery. One patient developed severe aortic regurgitation and underwent successful aortic valve replacement 24 h after percutaneous aortic balloon valvuloplasty. The anatomic findings at operation included severe aortic valve tear with dissection of the aortic annulus and the interventricular septum. The patient was discharged from hospital 19 days after percutaneous aortic balloon valvuloplasty. One patient had an embolic stroke. Cholesterol emboli occurred in one patient. There was elevation of CK, MB fraction, consistent with the presence of myocardial necrosis in 11 patients (53%). Coronary arteriography or autopsy demonstrated significant coronary artery disease in seven patients (58%) and normal coronary arteries in three. In the other patient, the coronary arteries were not evaluated.

Follow-up (Fig. 1). Twelve patients (57%) survived (including one patient with aortic valve replacement 24 h after percutaneous aortic balloon valvuloplasty) and were discharged from the hospital with marked improvement at 21 ± 2 days after percutaneous aortic balloon valvuloplasty.

Three additional patients underwent elective aortic valve replacement after discharge. Aortic valve replacement was not performed in the other eight patients. There were five cardiac deaths during a 15 ± 6-month follow-up period.
Patients with aortic valve replacement (Table 4). As described earlier, one patient underwent aortic valve replacement 24 h after percutaneous aortic balloon valvuloplasty because of severe aortic regurgitation. Three additional patients (mean age 76 ± 3 years, mean left ventricular ejection fraction 42 ± 12%) underwent aortic valve replacement at 60 ± 14 days after percutaneous aortic balloon valvuloplasty. No patient died during the operation. However, there were two cardiac deaths during follow-up. One patient died of congestive heart failure and multiple organ failure 1 month after aortic valve replacement. One asymptomatic patient with left ventricular ejection fraction of 20% after surgery died suddenly 5 months later. The other two patients were in functional class I at 21 ± 3 months after aortic valve replacement.

Patients without aortic valve replacement (Table 4). Eight patients (mean age 71 ± 6 years, mean left ventricular ejection fraction 25 ± 4%) did not undergo aortic valve replacement after percutaneous aortic balloon valvuloplasty. Aortic valve replacement was not performed in five patients because of associated major comorbid conditions limiting their life span (AIDS [one patient], cancer [one patient], severe coronary occlusive pulmonary disease [FEV1 < 1 liter] and cancer [one patient], stroke [two patients], and in three patients who refused operation. In this group there were three cardiac deaths: congestive heart failure at 9 months after percutaneous aortic balloon valvuloplasty (3 months after a second percutaneous aortic balloon valvuloplasty) (one patient), aortic valve endocarditis 45 days after percutaneous aortic balloon valvuloplasty (one patient) and poor left ventricular function that led to sudden death 2 months after percutaneous aortic balloon valvuloplasty (one patient). A total of five patients were in functional classes I and II at 6 ± 2 months (range 1 to 12) after percutaneous aortic balloon valvuloplasty.

Predictors for survival, Kaplan-Meier survival curve showed a 38 ± 11% survival rate at 27 months (Fig. 1). Cox regression analysis demonstrated that the only predictor for a longer survival time was cardiac index after percutaneous aortic balloon valvuloplasty (p = 0.02).

**Table 4. Follow-Up After Percutaneous Aortic Balloon Valvuloplasty**

<table>
<thead>
<tr>
<th></th>
<th>AVR (n = 5)</th>
<th>No AVR (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>76 ± 3</td>
<td>71 ± 4*</td>
</tr>
<tr>
<td>M/F</td>
<td>2/2</td>
<td>5/3</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>42 ± 12</td>
<td>23 ± 4</td>
</tr>
<tr>
<td>S/I</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Survivor</td>
<td>21 ± 3</td>
<td>6 ± 2</td>
</tr>
<tr>
<td>NYHA functional class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>II</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

*Includes a 35-year-old man with acquired immuno deficiency syndrome (AIDS). Values presented are mean ± SEM or number of patients. NYHA = New York Heart Association; other abbreviations as in Tables 1 and 2.

**Discussion**

This study demonstrates that percutaneous aortic balloon valvuloplasty can be performed successfully in patients in cardiogenic shock due to severe aortic stenosis. In these patients percutaneous aortic balloon valvuloplasty resulted in a significant decrease in aortic gradient and aortic valve resistance and in a significant increase in cardiac output, aortic valve area and systolic arterial pressure in 19 (90%) of these 21 moribund patients. However, the in-hospital mortality rate was high (43%). Two patients died in the catheterization laboratory during percutaneous aortic balloon valvuloplasty, and seven additional patients died subsequently despite a successful percutaneous aortic balloon valvuloplasty. Of note, five of these seven patients died of associated comorbid medical conditions. The main cause of in-hospital death was multiorgan failure rather than aortic stenosis itself. The in-hospital survival rate of 57% in this group of patients after percutaneous aortic balloon valvuloplasty compared favorably with the extremely high mortality rate reported in previous surgical studies in patients with cardiogenic shock and severe aortic stenosis (21, 22). In these surgical studies, high hospital death occurred in the absence of associated major comorbid conditions.

Our results seem to disagree with those of previous studies of percutaneous aortic balloon valvuloplasty in the treatment of cardiogenic shock due to severe aortic stenosis (9-11). Cribier et al. (12) reported successful percutaneous aortic balloon valvuloplasty in 10 patients with cardiogenic shock due to aortic stenosis and significant comorbid conditions. Early mortality rate was 20%. Six patients had aortic valve replacement with excellent outcome, and two patients who refused operation were asymptomatic at 24- and 48-month follow-up, respectively. This apparent difference in survival rate between our results and those of Cribier et al. could be explained by the younger patient group, fewer asso-
associated comorbid conditions and higher cardiac index after percutaneous aortic balloon valvuloplasty in the latter study.

Aortic valve replacement in patients with cardiogenic shock and severe aortic stenosis is associated with high mortality. Hutter et al. (21) reported the results of aortic valve replacement in patients with severe congestive heart failure or low cardiac output due to aortic valve disease, or both, requiring pressor support at the time of surgery. In the subgroup of patients with isolated aortic stenosis, the in-hospital mortality rate was 77%. In patients with cardiogenic shock, the in-hospital mortality rate increased to 52%. Kirtik et al. (22) reported a 29% in-hospital mortality rate after aortic valve replacement in patients with cardiogenic shock due to severe aortic stenosis, associated comorbid conditions were not addressed in this study.

Important variables affecting early mortality after aortic valve replacement include older age, reduced left ventricular ejection fraction, renal dysfunction and high functional class (3). Most patients in our study had at the time of presentation at least one of these risk factors, including nine patients with multigorgan failure, making them high risk surgical candidates. Nevertheless, with percutaneous aortic balloon valvuloplasty, 57% of these patients survived and were discharged from the hospital despite associated major comorbid conditions. Thus, under most adverse circumstances, percutaneous aortic balloon valvuloplasty can be performed with a high initial success rate, allowing stabilization of selected patients for eventual aortic valve replacement.

Study limitations. Despite limitations, such as a retrospective design, small number of patients, short-term follow-up and the absence of a control group at the time of admission, percutaneous aortic balloon valvuloplasty was considered the only possible approach for these very sick, moribund patients.

Conclusions. 1) Emergency percutaneous aortic balloon valvuloplasty can be performed with a high success rate in patients with cardiogenic shock due to severe aortic stenosis who are not candidates for aortic valve replacement at the time of presentation (owing to the presence of associated major comorbid conditions). Percutaneous aortic balloon valvuloplasty can be used to stabilize appropriately selected patients (those without terminal comorbid conditions) for eventual aortic valve replacement. 2) In this subset of patients with cardiogenic shock and severe aortic stenosis, in-hospital morbidity and mortality remain high, despite successful percutaneous aortic balloon valvuloplasty. 3) A subgroup of patients with a significant increase in cardiac index after percutaneous aortic balloon valvuloplasty may obtain greater benefit from the procedure. 4) For those patients who are nonsurgical or very high risk surgical candidates at the time of presentation, percutaneous aortic balloon valvuloplasty may be the only alternative. It is therefore recommended that: 1) percutaneous aortic balloon valvuloplasty should be performed in patients with cardiogenic shock due to severe aortic stenosis who are nonsurgical or very high risk surgical candidates at the time of presentation; and 2) because of the high incidence of restenosis after percutaneous aortic balloon valvuloplasty, aortic valve replacement should always be considered if the patient's condition improves after percutaneous aortic balloon valvuloplasty.

References