Long-Term Survival of the Very Elderly Undergoing Aortic Valve Surgery

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Background—Increasing numbers of the very elderly are undergoing aortic valve procedures. We describe the short- and long-term survivorship for this cohort.

Methods and Results—We conducted a cohort study of 7584 consecutive patients undergoing open aortic valve surgery without (51.1%; AVR) or with (48.9%; AVR + CABG) concomitant coronary artery bypass graft surgery between November 10, 1987 through June 30, 2006. Patient records were linked to the Social Security Administration’s Death Master File. Survivorship was stratified by age and concomitant CABG surgery. During 39 835 person-years of follow-up, there were 2877 deaths. Among AVR, there were 3304 patients <80 years of age, 419 patients 80 to 84 years, and 156 patients ≥85 years (24 patients >90 years). Among AVR+CABG patients, there were 2890 patients <80 years of age, 577 patients 80 to 84 years, and 238 patients ≥85 years (22 patients >90 years). Median survivorship for patients undergoing isolated AVR was 11.5 years (<80 years), 6.8 years (80 to 84 years), 6.2 years (≥85 years); for patients undergoing AVR+CABG, median survivorship was 9.4 years (<80 years), 6.8 years (80 to 84 years), and 7.1 years (≥85 years). Among both procedures, adjusted survivorship was significantly different across strata of age (P<0.001).

Conclusions—Survivorship among octogenarians is favorable, with more than half the patients surviving more than 6 years after their surgery. Concomitant CABG surgery does not diminish median survivorship among patients >80 years of age. (Circulation. 2009;120[suppl I]:S127–S133.)

Key Words: valves ■ coronary disease ■ survival ■ aging

According to the 2008 national projections by the US Census Bureau, there will be 23.8 million people between the ages of 80 to 89 by 2050—more than double the number of octogenarians recorded in the 2000 census. More than one third (36.5%) of octogenarians have some form of cardiac disease, and 8.1% have aortic stenosis. Although the prevalence of aortic stenosis increases with age, it may only be definitively treated surgically. Octogenarians who have had cardiac surgery have repeatedly shown to have favorable survivorship. However, most of the previously published data on aortic valve surgery in octogenarians has focused primarily on short-term outcomes. Reported 30-day mortality in octogenarians ranges from 4.8% to 10.1%, compared with 4% to 5% 30-day mortality in patients younger than 80 years, an increase small enough for most clinicians and patients to accept. Although the data are convincing that aortic valve replacement (AVR) carries a satisfactory rate of in-hospital or 30-day mortality in the elderly, there are limited data on long-term outcomes. In the largest study to date, published in 1997, Asimakopoulos et al reported on 1100 octogenarians who underwent AVR. They found actuarial survival to be 68.7% at 5 years and 45.8% at 8 years. Most of the other data on long-term outcomes have been based on small, mostly single-center,
retrospective studies, with wide variation reported in terms of the duration of follow-up as well as survival.9–13 A number of studies have also examined outcomes of AVR conducted with concomitant CABG surgery.14–16 With few exceptions, concomitant CABG surgery does not increase a patient’s operative risk. Again, there has been very little reported about the effect that AVR + CABG has on long-term survival. Considering the mounting evidence for the acceptable perioperative outcomes after AVR with or without concomitant CABG in the elderly, perhaps the fact that as many as one third of patients >80 years of age with severe aortic stenosis are still denied surgery because of their age17 is due at least in part to the lack of evidence for long-term outcomes.

We examined the short- and long-term survival for a cohort of 7584 consecutive patients undergoing open AVR with and without concomitant CABG from 1987 through 2006 in northern New England.

Methods

Patient Population
We conducted a prospective cohort study of short- and long-term survival associated with consecutive patients undergoing open AVR with or without concomitant CABG surgery at all Northern New England Cardiovascular Disease Study Group centers. For this analysis, we did not include patients having any other concomitant procedures. All patients enrolled in the registry were ≥30 years of age.

Data Collection
Data were obtained from the registries of the Northern New England Cardiovascular Disease Study Group, a voluntary research consortium composed of clinicians, research scientists, and hospital administrators. The goal of the group is to foster the continuous improvement in the quality of care, safety, and effectiveness of cardiovascular interventions through the analysis of process and outcomes data and the timely feedback of these data to the clinicians involved in providing these services.18–20 Data are collected on all cardiac surgery procedures in the northern New England region and are periodically validated using administrative data sources. The data collected included patient demographics, comorbid conditions, cardiac history, cardiac anatomy, cardiac function, procedural indication, priority, and end-diastolic pressure. We adopted a similar approach for creating adjusted Kaplan–Meier curves as described by Ghali et al21 and subsequently by Zhang et al.22 Adjusted Kaplan–Meier curves were created using the statistical program R (version 2.6.0, Foundation for Statistical Computing). All statistical analyses outside of generating our adjusted Kaplan–Meier curves were performed using Stata release 10.0 software (Stata Corp).23

Results
From November 10, 1987, through June 30, 2006, we studied 7584 consecutive patients who underwent aortic valve surgery. Of these, 51.1% underwent aortic valve surgery alone (AVR) and 48.9% had concomitant coronary artery bypass graft surgery (AVR+CABG). During 39 835 person-years of total follow-up, there were 2877 deaths.

Isolated Aortic Valve Surgery
In the AVR group, there were 3304 patients <80 years of age, 419 patients ages 80 to 84 years, and 156 patients ≥85 years of age (24 patients were 90 years or older). Increasing age was associated with female sex, more vascular disease and congestive heart failure, and procedural urgency (Table 1). Patients in this group were less likely to have diabetes.

Patients undergoing AVR were more likely to have tissue valves rather than mechanical valves (Table 2). The use of tissue valves increased with age (58.3% among patients <80, 88.9% in the 80 to 84 age group, and 89.3% among patients ≥85, P<0.001). Nearly 100% of patients had their aortic valve replaced.

Perioperatively, older age was associated with increased risk of stroke, atrial fibrillation, and longer length of stay (Table 3). The 30-day mortality among this cohort was 3.7% for patients <80, 6.7% in the 80 to 84 age group, and 11.7% in those ages ≥85 (P<0.001). Crude survivorship through 12 years beyond the index admission is detailed in Table 4. For patients <80 years, median survivorship was 11.5 years (Figure 1). Median survivorship decreased to 6.8 years among patients 80 to 84 years and 6.2 years among those ≥85 years. Survivorship was significantly different across strata of age (P<0.001).

AVR+CABG
Among AVR+CABG patients, there were 2890 patients <80 years of age, 577 patients ages 80 to 84 years, and 238 patients >85 years of age (22 patients were older than 90). Increasing age in this group was significantly associated with female sex, left main stenosis, procedural urgency, congestive heart failure, number of diseased vessels, and lower ejection fraction (Table 5). Crude mortality was 3.7% for patients <80 years, 6.6% in the age group 80 to 84 years, and 11% among patients ≥85 years (P<0.001). Crude survivorship through 12 years beyond the index admission is detailed in Table 6. Median survivorship decreased to 6.3 years among patients 80 to 84 years and 6.1 years among those ≥85 years. Survivorship was significantly different across strata of age (P<0.001) among AVR+CABG patients.
fraction (Table 1). Patients over age 80 in this group were less likely to have diabetes and chronic obstructive pulmonary disease.

Most patients undergoing AVR+CABG had an internal mammary artery (Table 2), followed by a saphenous vein. Patients were more likely to have tissue rather than mechanical valves. The use of tissue valves increased with age (73.9% among patients <80, 92.6% in the 80 to 84 age group, and 97.4% among patients ≥85, P<0.001). Nearly 100% of patients had their aortic valve replaced.

<table>
<thead>
<tr>
<th>Variable</th>
<th>AVR</th>
<th>AVR+CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of procedures</td>
<td>3,304</td>
<td>419</td>
</tr>
<tr>
<td>Female sex, %</td>
<td>38.5</td>
<td>53.2</td>
</tr>
<tr>
<td>Comorbid disease, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular disease, yes</td>
<td>5.2</td>
<td>9.1</td>
</tr>
<tr>
<td>Diabetes, yes</td>
<td>16.9</td>
<td>14.8</td>
</tr>
<tr>
<td>COPD, yes</td>
<td>5.2</td>
<td>6.4</td>
</tr>
<tr>
<td>CHF, yes</td>
<td>39.7</td>
<td>52.7</td>
</tr>
<tr>
<td>Dialysis or creatinine ≥2, yes</td>
<td>2.8</td>
<td>4.1</td>
</tr>
<tr>
<td>Cancer</td>
<td>1.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥40</td>
<td>68.5</td>
<td>70.6</td>
</tr>
<tr>
<td>&lt;40</td>
<td>9.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Missing</td>
<td>21.6</td>
<td>20.5</td>
</tr>
<tr>
<td>Left main stenosis, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;50</td>
<td>99.1</td>
<td>98.3</td>
</tr>
<tr>
<td>50–89</td>
<td>0.8</td>
<td>1.4</td>
</tr>
<tr>
<td>≥90</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Diseased vessels (No.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>92.6</td>
<td>88.4</td>
</tr>
<tr>
<td>2</td>
<td>2.8</td>
<td>8.2</td>
</tr>
<tr>
<td>3</td>
<td>4.7</td>
<td>3.4</td>
</tr>
<tr>
<td>Priority</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elective</td>
<td>67.3</td>
<td>53.5</td>
</tr>
<tr>
<td>Urgent</td>
<td>30.4</td>
<td>45.8</td>
</tr>
<tr>
<td>Emergency</td>
<td>2.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Prior myocardial infarction, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>96.7</td>
<td>93.6</td>
</tr>
<tr>
<td>&lt;7 d before procedure</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>≥7 d before procedure</td>
<td>2.9</td>
<td>5.7</td>
</tr>
</tbody>
</table>

COPD indicates chronic obstructive pulmonary disease; CHF, congestive heart failure.
Perioperatively, older age was associated with increased risk of atrial fibrillation and longer length of stay (Table 3).

Among patients undergoing AVR+ CABG, 6.2% of patients <80 years died within 30 days, 9.4% among those 80 to 84, and 8.5% of patients ≥85 years (P = 0.01). Survival over the entire follow-up period favored the younger patients (Table 4). For AVR+ CABG patients, median survivorship followed a similar trend, with patients <80 surviving 9.4 years, patients 80 to 84, 6.8 years, and patients older than 85, 7.1 years (Figure 2). Survivorship was significantly different across strata of age (P trend <0.001).

**Discussion**

In our study of 7584 patients, including 815 over the age of 80, we found that short- and long-term survival was favorable across all age groups. Specifically, more than half of the patients undergoing aortic valve procedures were alive 6 years after surgery. Among patients <80 years, survivorship favored those undergoing isolated AVR procedures, but among octogenarians, concomitant CABG surgery did not result in reduced survivorship. These findings mirror the life expectancy among the general population, which show an additional 7 years of life among those ages 80 to 84 years and 5 years among those ages ≥85 years.26

The natural history of untreated severe aortic stenosis strongly suggests the need for surgical intervention. In 1968, Ross and Braunwald reported that the average survival in aortic stenosis patients is 3 years after the onset of angina or syncope and only 1½ years after onset of heart failure.27 Thirty years after Ross and Braunwald’s publication, the American College of Cardiology/American Heart Association guidelines estimate a patient’s survival from initial aortic stenosis symptoms to be less than 2 to 3 years.2 Varadarajan et al22 examined survival among 277 patients >80 years of age presenting with severe aortic stenosis; 80 underwent AVR. Survival was significantly improved in the surgical patients. After AVR, 1-year, 2-year, and 5-year survival was 87%, 78%, and 68%, compared with 52%, 40%, and 22%, respectively, in the patients who were managed medically, demonstrating that surgery is the best alternative for survival in octogenarians with severe symptoms. In their study of 103 octogenarians with severe, symptomatic aortic stenosis, Kojodjojo et al28 showed that patients who refused AVR had a greater than 12-fold in-hospital mortality rate relative to the cohort of patients who underwent surgery.

Our findings agree with previous reports concerning octogenarians undergoing aortic valve surgery. In 1997, Asimakopoulous et al22 reviewed United Kingdom Heart Valve Registry data from 1100 patients >80 years of age who underwent AVR from January 1986 to December 1995. They reported 30-day mortality as 6.6% with actuarial survival of 89%, 79.3%, 68.7%, and 45.8% at 1, 3, 5, and 8 years, respectively. Lanagan et al24 reviewed in-hospital data for 771 octogenarians undergoing AVR between 1978 to 2003. The authors reported a 10.1% operative mortality, yet did not follow patients beyond their index admission. Our index admission mortality findings among patients undergoing isolated AVR are in agreement with Lanagan (7.6% among 80 to 84 years, 10.3% among ≥85 years). Among studies reporting survivorship beyond the index admission, five-year survival ranged from 56% to 64%.13,29,30 Our series is consistent with these reports, with 6-year survival of 54.7% in

### Table 4. Percentage of Patients Surviving Isolated AVR or AVR+ CABG by Age Group and Time Interval

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>AVR</th>
<th>AVR+ CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;80 y</td>
<td>80–84 y</td>
</tr>
<tr>
<td>At discharge</td>
<td>96.2 (95.5, 96.8)</td>
<td>93.1 (90.2, 95.3)</td>
</tr>
<tr>
<td>3 y</td>
<td>87.7 (86.5, 88.9)</td>
<td>75.1 (70.4, 79.1)</td>
</tr>
<tr>
<td>6 y</td>
<td>77.2 (75.6, 78.8)</td>
<td>54.7 (48.8, 60.2)</td>
</tr>
<tr>
<td>9 y</td>
<td>63.1 (61.0, 65.2)</td>
<td>27.1 (20.5, 34.1)</td>
</tr>
<tr>
<td>12 y</td>
<td>48.7 (46.0, 51.4)</td>
<td>17.9 (10.9, 26.2)</td>
</tr>
</tbody>
</table>

Data reflect crude survivorship across age strata.
patients 80 to 84 following AVR and 53.3% in patients 80 to 84 following AVR+CABG.

The effect of concomitant CABG surgery on short and long-term survivorship appears mixed. After studying 245 octogenarians from 1993 to 2005, Melby et al\(^{13}\) reported that concomitant CABG improved both 30-day (odds ratio, 0.3; 95% confidence interval [CI], 0.08 to 0.083; \(P = 0.017\)) and long-term survival (hazards ratio, 0.7; 95% CI, 0.47 to 0.96; \(P = 0.020\)). In contrast, Roberts et al\(^{16}\) in their series of 196 octogenarians found that simultaneous CABG had no effect on 60-day mortality (relative risk, 0.96; 95% CI, 0.54 to 1.70) and a statistically insignificant increased median late survival: 7.4 years (95% CI, 6.4 to 13.3) for patients after AVR+CABG versus 6 years (95% CI, 5.4 to 8.9) for patients after AVR. Our present findings are similar to those of Gulbins et al\(^{31}\) who showed that in-hospital mortality rates were higher among patients having AVR+CABG versus those undergoing AVR (10% versus 4%, \(P < 0.05\)). Gulbins et al\(^{31}\) suggested that the additional risk of mortality was acceptable, given a lower observed mortality rate relative to that predicted through the use of Euroscore.

Recent publications have highlighted survivorship among patients undergoing percutaneous aortic valve replacement.\(^{32}\) Grossi et al\(^{32}\) reported the inability for a commonly used risk prediction model, the Euroscore, to predict accurately the risk of mortality among patients undergoing these procedures. The authors focused their study among high-risk patients, that is, those with a Euroscore of \(\geq 7\). Interestingly, 44% of their patients were \(\geq 80\) years. Our regional collaborative does not have any experience in performing aortic valve surgery percutaneously. As such, we cannot comment on the generalizability of our findings to patients undergoing percutaneous procedures.

We acknowledge several limitations to the current study. First, from a patient’s perspective, functionality after the surgery may be more important than survivorship alone. Using the Seattle Angina Questionnaire, Huber et al\(^{13}\) interviewed 136 patients who were \(\geq 80\) years of age at the time of cardiac surgery (isolated CABG, AVR, or AVR+CABG). They found that 95% lived in their own homes, and 93% reported that they had experienced no reduction to their quality of life. Kolh et al\(^{12}\) interviewed 61 long-term survivors of AVR and found that 92% of patients believed that having heart surgery at age \(\geq 80\) was a “good choice,” with 88% of patients feeling “as good or better” than they had before surgery. Additionally, Maillet et al\(^{34}\) reported results...
from 84 octogenarians undergoing either AVR or AVR+CABG between 1998 to 2001. The majority (91.1%) lived in their own homes (compared with 75% of the general French population ages >80 years), whereas 26.7% of patients required help with activities of daily living (compared with 35% to 40% of the general population). Sundt et al\textsuperscript{9} reported functional status and survivorship up to 5 years among 133 patients undergoing AVR with or without CABG. Patient-reported functional status was comparable to the general population.

Second, although we do not report the cause of death in our series, other authors have examined whether octogenarians who have undergone AVR are more likely to die of a cardiac cause. The Asimakopoulos et al\textsuperscript{8} analysis of the UK Heart Valve Registry found that 42 of the 73 early deaths (within the first 30 postoperative days) were attributable to cardiac origins. However, late deaths tended to be for noncardiac reasons (only 61 of 205 deaths were due to a cardiac cause), with malignancy, stroke, and pneumonia the most common. Similarly, Chiappini et al\textsuperscript{10} found that 84.4% (27 of 32) of early deaths were related to cardiac causes. In their series, 427 patients survived the 30-day postoperative period. Eighty-five patients died during the follow-up period, only 38.8% of them for cardiac reasons. Again, malignancy and stroke were the most common causes of late death after AVR.

Third, we report findings from our prospective cohort experience, and as such are unable to account for any unknown confounding factors or selection of patients referred for surgery. The decision for the type of procedures was at the discretion of the patient and his or her provider. We do not have information on patients who were turned down for AVR, CABG, or both. Because of the known extremely poor prognosis for patients with severe aortic stenosis who do not undergo AVR, it would be impossible to design an ethical randomized trial.

In conclusion, this study presents the largest experience to date of octogenarians undergoing surgical treatment of aortic stenosis. As the number of octogenarians continues to increase in the United States, so too does the number of elderly patients with severe aortic stenosis. We have demonstrated that aortic valve replacement with or without concomitant CABG is a safe and effective option for elderly patients with severe aortic stenosis. Survivorship in this cohort is favorable, with more than half the patients surviving more than 6 years after their surgery, a finding mirroring the general population life tables. Although concomitant CABG adds a slight mortality risk in the immediate postoperative period, it does not appreciably affect long-term survival among patients older than 80 years.

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Disclosures
None.

References


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