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ORIGINAL ARTICLE
Valvular Heart Disease

Conventional Aortic Valve Replacement for Elderly Patients in the Current Era

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Background: Because of the rising expectation of prolonged life in the general population and the recent recognition of undertreated aortic valve disease in the elderly, updating the available results of aortic valve surgery is imperative, especially considering the rapid evolution of the transcatheter valve implantation procedure.

Methods and Results: Between 1997 and 2010, 308 patients aged 70 years or older underwent aortic valve replacement (AVR) for aortic stenosis (AS). Short- and long-term results were analyzed and risk factors for long-term mortality were determined. Mean age was 78.5 years and 124 patients were aged 80 or older. Concomitant coronary artery bypass grafting (CABG) was performed in 46% of the cases. Mean left ventricular ejection fraction (LVEF) was 52%. Overall observed and expected operative mortality using the Society of Thoracic Surgeons-Predicted Risk of Mortality score was 3.9% and 4.8%, respectively. Overall survival rates at 1, 5, and 10 years were 88.6%, 71.6%, and 31.8%, respectively. Predictors of long-term mortality included diabetes; preoperative shock; LVEF ≤40%; New York Heart Association functional class III or IV; and age.

Conclusions: Short- and long-term results of conventional AVR in the elderly prove it to be durable and, especially in relatively low-risk patients and patients who require concomitant CABG, operative mortality is reasonably low. Conventional AVR±CABG remains the gold standard for elderly patients with AS. (*Circ J* 2011; **75:** 2692–2698)

Key Words: Aortic stenosis; Aortic valve replacement; Elderly patients

Aortic stenosis (AS) is the most frequent valvular lesion in the elderly.[1] The prevalence rates of aortic valve sclerosis (leaflet thickening, stiffness, and/or calcification without stenosis) in those aged 75–85 years and in those older than 85 are 35% and 48%, respectively; furthermore, in these age groups, 2.4% and 4%, respectively, have AS.[2] The elderly population in the United States is projected to grow and the 80 and older population will reach 18.9 million by 2030 from 11.5 million in 2010.[3] With the rapidly increasing geriatric population, it is common in current practice to have aged patients referred for surgical treatment of AS. In 2006, in the United States, approximately 40% of patients undergoing aortic valve replacement (AVR) were 75 years old or older.[4]

AVR is the gold standard for the treatment of severe AS. Previous studies have shown acceptable short- and long-term outcomes, as well as improved quality of life in elderly patients.[5–10] Ongoing studies of transcatheter aortic valve implantation (TAVI) have demonstrated its feasible short- and mid-term results in patients who were not considered suitable candidates for conventional AVR.[12–14] Because of both the increasing number of elderly patients with multiple comorbidities and recent awareness of the underdiagnosed or undertreated patient population with aortic valve disease, it is imperative to analyze the operative outcome of conventional AVR in current practice within the context of rapidly evolving transcatheter valve implantation procedures. The aim of this study was to evaluate operative mortality and morbidity in elderly patients aged 70 or older who underwent conventional AVR and to investigate the long-term outcomes of these patients.

Methods

Patient Population

From December 1997 to September 2010, a total of 308 patients aged 70 or older underwent AVR for AS at Thomas Jefferson University Hospital. We excluded those patients with dominant aortic regurgitation, aortic valve endocarditis, and concomitant non-cardiac or cardiac procedures other than coronary artery bypass grafting (CABG). Information was collected retrospectively by reviewing the medical chart and included: preoperative patient demographics; preoperative hemodynamic parameters and echocardiographic data; pre-

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Table 1. Preoperative Patient Demographics

	All patients (n=308)	Age 70–79 years (n=184)	Age 80–92 years (n=124)	P value
Age	78.5±5.0	75.1±2.8	83.5±2.7	<0.001
Sex, n (%)				
Male	169 (55)	104 (57)	65 (52)	0.478
Female	139 (45)	80 (44)	59 (48)	
Caucasian, n (%)	287 (93)	169 (92)	118 (95)	0.258
History of smoking, n (%)	70 (23)	45 (25)	25 (20)	0.378
Chronic lung disease, n (%)	67 (22)	43 (23)	24 (19)	0.042
Diabetes mellitus, n (%)	81 (26)	55 (30)	26 (21)	0.081
Renal dysfunction (S-Cr ≥2.0 mg/dl), n (%)	18 (5.8)	11 (6.0)	7 (5.6)	0.903
Chronic hemodialysis, n (%)	7 (2.3)	4 (2.2)	3 (2.4)	0.999
Peripheral vascular disease, n (%)	29 (9.4)	15 (8.2)	14 (11)	0.355
Carotid disease, n (%)	21 (6.8)	8 (4.3)	13 (11)	0.036
Previous stroke, n (%)	29 (9.4)	11 (6.0)	18 (15)	0.012
Hypertension, n (%)	234 (77)	147 (80)	87 (70)	0.050
Previous cardiac surgery, n (%)	40 (13)	24 (13)	16 (13)	0.971
Body mass index (kg/m²)	28.3±5.8	29.0±6.2	27.2±5.0	0.007
Body surface area (m²)	1.87±0.23	1.90±0.23	1.81±0.22	0.001

Data are presented as mean ± standard deviation or number (percentage).
S-Cr, serum creatinine.

Table 2. Preoperative Hemodynamics and Cardiac Profiles

	All patients (n=308)	Age 70–79 years (n=184)	Age 80–92 years (n=124)	P value
LVEF (%)	52.2±14.2	53.0±13.6	50.9±15.2	0.209
LVEF ≤40%, n (%)	73 (24)	38 (21)	35 (29)	0.125
Coronary artery disease, n (%)	202 (66)	115 (63)	87 (70)	0.165
Previous myocardial infarction, n (%)	57 (19)	26 (14)	31 (25)	0.016
Unstable angina, n (%)	39 (13)	19 (10)	20 (16)	0.133
NYHA functional class, n (%)				
I	38 (12)	33 (18)	5 (4.0)	<0.001
II	91 (30)	64 (35)	27 (22)	
III	137 (45)	70 (38)	67 (54)	
IV	42 (14)	17 (9)	25 (20)	
Cardiogenic shock, n (%)	11 (3.6)	5 (2.7)	6 (4.8)	0.360
Congestive heart failure, n (%)	61 (20)	29 (16)	32 (26)	0.032
Aortic valve lesion, n (%)				
AS	267 (87)	149 (81)	118 (95)	<0.001
AS + AI (moderate or more)	41 (13)	35 (19)	6 (4.8)	
Peak pressure gradient (mmHg)	68±23	67±22	68±245	0.714
Mean pressure gradient (mmHg)	44±15	44±15	45±16	0.372
Aortic valve area (cm²)	0.74±0.20	0.76±0.20	0.71±0.20	0.070
STS-PROM (%)	4.8±5.4	3.8±3.1	6.3±7.3	0.001
<7.5%, n (%)	274 (89)	169 (92)	105 (85)	0.105
≥7.5–<15%, n (%)	27 (8.8)	11 (6.0)	16 (13)	
≥15%, n (%)	7 (2.3)	4 (2.2)	3 (2.4)	

Data are presented as mean ± standard deviation or number (percentage).
LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; AS, aortic stenosis; AI, aortic insufficiency; STS-PROM, Society of Thoracic Surgeons Predicted Risk of Mortality.

operative comorbidities; details of operative procedure; and postoperative comorbidities. The Society of Thoracic Surgeons Predicted Risk of Mortality (STS-PROM) score was calculated in all patients, including isolated AVR (n=166) and AVR with concomitant CABG (n=142), using the online calculator, available at the STS website (http://209.220.160.181/STSWebRiskCalc261/). Operative mortality was defined as death during hospitalization or within 30 days after surgery. Patients' survival status was followed and confirmed by Social Security Death Index search until October 2010. This study was reviewed and approved by the Thomas Jefferson University institutional review board.

Table 3. Operative Data

	All patients (n=308)	Age 70–79 years (n=184)	Age 80–92 years (n=124)	P value
Timing of surgery, n (%)				0.233
Elective	217 (70.5)	136 (73.9)	81 (65.3)	
Urgent	82 (26.6)	44 (23.9)	38 (30.6)	
Emergency	9 (2.9)	4 (2.2)	5 (4.0)	
Prosthesis type, n (%)				0.761
Bioprosthesis	297 (96.4)	178 (96.7)	119 (96.0)	
Mechanical	11 (3.6)	6 (3.3)	5 (4.0)	
Prosthesis size (mm), n (%)				0.167
17	6 (1.9)	2 (1.1)	4 (3.2)	
19	92 (29.9)	50 (27.2)	42 (33.9)	
21	124 (40.3)	79 (42.9)	45 (36.3)	
23	71 (23.1)	47 (25.5)	24 (19.4)	
25	12 (3.9)	4 (2.2)	8 (6.5)	
27–29	3 (1.0)	2 (1.1)	1 (0.8)	
Concomitant CABG, n (%)	142 (46.1)	86 (46.7)	56 (45.2)	0.785
Cross-clamp time	91±28	94±29	88±26	0.069
Bypass time	119±36	120±36	117±36	0.538

Data are presented as mean ± standard deviation or number (percentage).
CABG, coronary artery bypass grafting.

Table 4. Postoperative Complications and Course

	All patients (n=307)	Age 70–79 years (n=183)	Age 80–92 years (n=124)	P value
Perioperative IABP use, n (%)	20 (6.5)	12 (6.5)	8 (6.5)	0.980
Reexploration for bleeding, n (%)	16 (5.2)	11 (6.0)	5 (4.0)	0.444
Myocardial infarction, n (%)	1 (0.3)	1 (0.5)	0 (0.0)	0.999
Atrial fibrillation, n (%)	116 (38)	68 (37)	48 (39)	0.783
Permanent pacemaker placement, n (%)	24 (7.8)	15 (8.2)	9 (7.3)	0.764
Deep sternal infection, n (%)	1 (0.3)	0 (0.0)	1 (0.8)	0.404
Cerebrovascular accident, n (%)	8 (2.6)	5 (2.7)	3 (2.4)	0.999
Renal dysfunction, n (%)	11 (3.6)	5 (2.7)	6 (4.8)	0.361
Newly required hemodialysis, n (%)	5 (1.6)	2 (1.1)	3 (2.4)	0.397
Prolonged ventilation >24 h, n (%)	47 (15)	24 (13)	23 (19)	0.195
GI bleeding/other GI complication, n (%)	14 (4.6)	6 (3.3)	8 (6.5)	0.191
Tracheotomy, n (%)	13 (4.2)	8 (4.3)	5 (4.0)	0.888
Percutaneous/open gastrostomy, n (%)	13 (4.2)	6 (3.3)	7 (5.6)	0.337
Hospital stay after surgery (days)	10.8±8.3	10.1±7.9	11.7±8.7	0.096
Discharged home, n (%)	177 (60.0)	124 (70.5)	53 (44.5)	<0.001
Readmission, n (%)	48 (16.2)	21 (11.9)	27 (22.7)	0.013

Data are presented as mean ± standard deviation or number (percentage).
IABP, intra-aortic balloon pump; GI, gastrointestinal.

Operative Technique

Operation was performed via either full median sternotomy or partial right upper hemi-sternotomy, under standard cardiopulmonary bypass and antegrade and retrograde cardioplegic arrest. Through a transverse aortotomy, the aortic prosthesis was implanted in a supra-annular position with pledgetted mattress sutures. In patients requiring coronary revascularization to the left anterior descending artery, the left internal mammary artery was used as an in-situ graft unless patient-specific factors precluded the use of this conduit.

Statistical Analysis

Statistical analysis was performed with SPSS 11.0 software (SPSS 11.0, Chicago, IL, USA). Difference in continuous variables was analyzed using independent sample Student's t-tests. Categorical variables were compared by chi-square analysis, or the Fisher exact test when appropriate. Mortality data were analyzed by the Kaplan-Meier survival analysis, with comparisons between groups performed using the log-rank test. Independent long-term risk factors for mortality were identified using the Cox proportional hazards regression model; hazard ratio (HR) as well as its 95% confidence interval (CI) was obtained. All P values were 2-sided and P<0.05 was considered to be statistically significant.

Table 5. Operative Mortality

	All patients (n=308)		Age 70–79 years (n=184)		Age 80–92 years (n=124)	
	Observed	Expected	Observed	Expected	Observed	Expected
Operative mortality	12/308 (3.9%)	4.8%	7/184 (3.8%)	3.8%	5/124 (4.0%)	6.3%
Isolated AVR	8/166 (4.8%)	4.0%	5/98 (5.1%)	3.1%	3/68 (4.4%)	5.3%
AVR+CABG	4/142 (2.8%)	5.8%	2/68 (2.3%)	4.7%	2/56 (3.6%)	7.5%
STS-PROM						
<7.5%	5/274 (1.8%)	3.7%	4/169 (2.4%)	3.1%	1/105 (1.0%)	4.6%
≥7.5–<15%	5/27 (18.5%)	10.1%	3/11 (27.3%)	9.8%	2/16 (12.5%)	10.4%
≥15%	2/7 (28.6%)	29.1%	0/4 (0%)	18.8%	2/3 (66.7%)	42.7%

AVR, aortic valve replacement; CABG, coronary artery bypass grafting; STS-PROM, Society of Thoracic Surgeons Predicted Risk of Mortality.

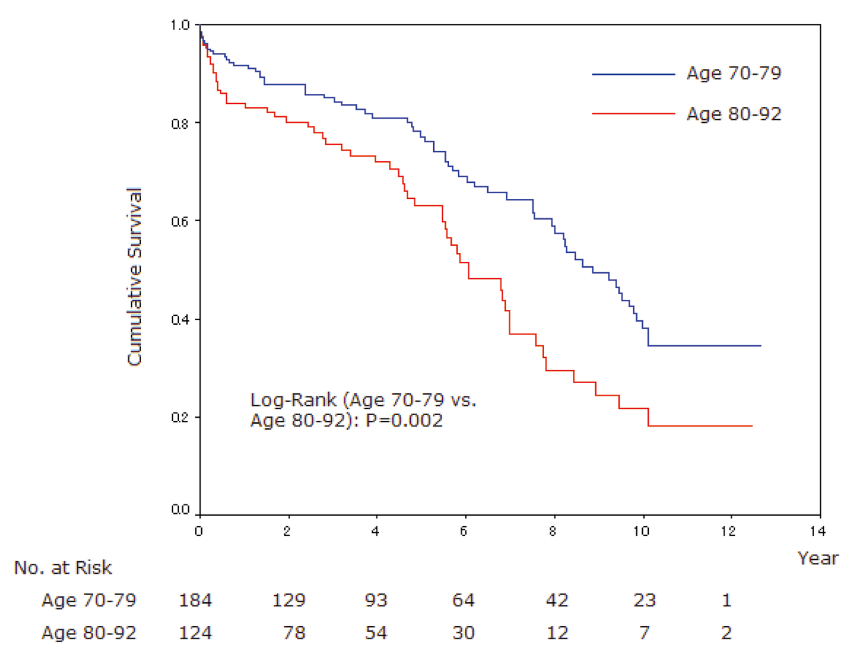

Figure 1. Kaplan-Meier curve of survival for age 70–79 vs. age 80–92 years.

Results

Demographics

The preoperative demographics of this patient cohort are shown in Table 1. The mean age was 78.5±5.0 years; 184 patients were aged 70–79 and 124 patients were aged 80–92 years. The younger group of patients were more likely to have hypertension and a higher body mass index, as well as body surface area greater than patients aged 80–92. Other than the aforementioned data points, there was no significant difference regarding preoperative comorbidities between these age groups. Preoperative hemodynamics and cardiac profiles are shown in Table 2. The patients aged 80–92 were more likely to have had a previous myocardial infarction (31/124 vs. 26/184, P=0.016) and to have symptoms of congestive heart failure compared with patients aged 70–79 (32/124 vs. 29/184, P=0.032). Overall New York Heart Association (NYHA) class was 2.6±0.9 and 74.2% of patients aged 80-92 were either in class III or IV compared with 47.3% of patients aged 70–79 (P<0.001). As expected, the STS-PROM was significantly higher in the patients aged 80–92 (6.3±7.3%, vs. 3.8±3.1% in the patients aged 70–79, P=0.001). Operative data are shown in Table 3, and there was no significant difference between the 2 groups.

Postoperative Outcomes

Postoperative comorbidities are listed in Table 4. The most common postoperative complication was atrial fibrillation (116/308, 37.8%), followed by a need for ventilation for a duration of greater than 24 h (47/308, 15.3%), and then a requirement of permanent pacemaker (24/308, 7.8%). Despite the difference in average age between the 2 groups, there was no significant difference regarding postoperative complications between them.

The average length of hospital stay after the surgery was 10.1±7.9 days and 11.7±8.7 days for patients aged 70–79 and 80–92, respectively (P=0.096). The older group was less likely to be discharged home (53/124, 44.5% vs. 124/184, 70.5%, P<0.001) and more likely to be readmitted within 30 days after surgery than patients aged 70–79 (27/124, 22.7% vs. 21/184, 11.9%, P=0.013). The overall operative mortality rate was 3.9% and there was no significant difference between the 2 age groups (Table 5).

Long-Term Follow-up

Actuarial survival of the 2 age groups is shown in Figure 1. Survival at 1, 3, 5, and 10 years in patients aged 70–79 was 91.6%, 85.1%, 77.2%, and 38.0%, respectively, as compared

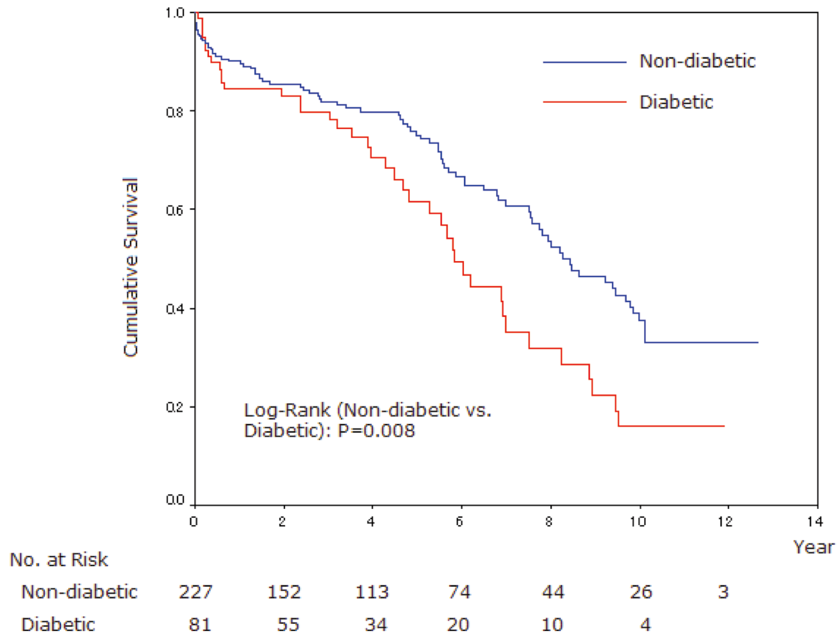

Figure 2. Kaplan-Meier curve of survival for non-diabetic patients vs. diabetic patients.

with 84.1%, 75.7%, 63.0%, and 21.7% in patients aged 80–92 (P=0.002). The Cox regression model revealed that independent predictors for worse long-term survival included: diabetes (HR 2.12; 95%CI 1.41–3.20; P<0.001, Figure 2); preoperative shock (HR 2.65; 95%CI 1.41–6.67; P=0.039); left ventricular ejection fraction (LVEF) ≤40% (HR 1.59; 95%CI 1.04–2.41; P=0.032); NYHA class III or IV (HR 1.59; 95%CI 1.02–2.47; P=0.040); and age (per 1-year increment, HR 1.09; 95%CI 1.04–1.13; P<0.001).

Discussion

Mortality

Our study showed reasonable and durable results following AVR for AS in elderly patients. Although the proportion of elderly patients with multiple comorbidities is expanding, operative outcomes following AVR were still improving in the past decade.[4] Brown et al published the outcomes of isolated AVR in North America by analyzing the STS National Database, comprising 108,687 patients, and compared the mortality rates in 1997 with those in 2006. In their analysis, patients aged 70–75 had a mortality rate of 3.2% in 1997 and 2.9% in 2006; for patients aged 80–85, the mortality rate was 6.3% in 1997 and 4.9% in 2006.[4] In single-center-based studies published between 2004 and 2010, the mortality rate of AVR in octogenarians ranged from 3.0% to 10.6% for isolated AVR and from 8.4% to 13.0 % for AVR with concomitant CABG.[4–10,15,16]

In our study, patients aged 80–92 who underwent isolated AVR or AVR with CABG showed an acceptable mortality rate of 4.0%, comparable to the 3.8% mortality rate in patients aged 70–79. Moreover, if the STS-PROM is less than 7.5%, the observed operative mortality rates in both age groups surpassed expected mortality rates with an observed to expected (O/E) ratio of 0.49. This trend was also seen in patients who required the concomitant CABG (O/E ratio of 0.48, Table 5). These improvements in operative outcome in the past decade could be related to multiple factors, including patient selection and perioperative management. Stamou et al suggested that goal-directed, multidisciplinary protocols and quality improvement program were associated with improved operative outcome in cardiac surgery.[17] We believe that, with the elderly, especially those aged 80 years or older, goal-oriented strategies such as early extubation, judicious sedation management, medication dosing based on renal or liver function, early involvement of physical or occupational therapists, and speech/swallow specialists are all indispensable.

Risk Factors for Long-Term Survival

As expected, age was identified as an independent risk factor for poor long-term survival. Other risk factors such as diabetes mellitus, existence of preoperative shock, LVEF ≤40%, and preoperative NYHA class III or IV also significantly affected long-term results in our patient cohort. In previous studies, other risk factors such as urgency of the operation and preoperative renal dysfunction or stroke have been reported;[6,7,11] however, these did not affect our patients' outcomes. Although identifying the high-risk population for AVR has been attempted,[16] an ideal model is not currently established to precisely identify the high-risk patients. STS-PROM score and the European System for Cardiac Operative Risk Evaluation (EuroSCORE) have been used as part of the inclusion/exclusion criteria for the TAVI trial and to quantify the operative risk of conventional AVR in that trial.[12] However, the possibility of overestimating the operative mortality rates by using these risk-prediction models and the inescapable discrepancy between the estimated and observed mortality rate has been acknowledged.[9]

Concomitant CABG

Our data showed that concomitant CABG did not alter short- or long-term mortality in the elderly patients. Similar to that associated with isolated AVR, the operative mortality of AVR with concomitant CABG has shown constant improvement, from 6.3% in 2001 to 4.4% in 2010 in the STS database.[18] Patients who required coronary revascularization were not included in the recent TAVI trial.[12] Thus, a patient with severe

AS and coronary artery disease should undergo conventional AVR with concomitant CABG as the standard procedure of choice. The importance of appropriate revascularization in this cohort is further emphasized by the evidence of left ventricular diastolic dysfunction and impaired subendocardial function as an age-associated alteration of the ventricle in the elderly population.[19] The prevalence of using an internal mammary artery graft in elderly patients has contributed to the improvement in operative outcomes.[20]

Complications

Interestingly, there was no difference in the postoperative complication rate between the patients aged 70–79 and those aged 80–92, even though the patients aged 80–92 had worse preoperative NYHA functional class, advanced chronological age, and of course, higher STS-PROM scores. However, our study revealed that patients aged 80–92 were more likely to be discharged to rehabilitation facilities or other medical facilities and more likely to be readmitted after surgery than patients aged 70–79. The relatively high incidence of discharge to rehabilitation facilities and of postoperative readmission could suggest a prolonged physical or functional recovery from surgery in elderly patients and could become an obstacle to the patients' regaining normal lives within their limited life expectancy. Additionally, we found that approximately 4% of patients required postoperative tracheotomy and/or gastrostomy tube placement. Although these procedures were unavoidable during postoperative care, the modality to decrease these complications remains an unsolved issue in current practice. The less-invasive transcatheter valve implantation procedure may offer the benefit of decreasing such complications. Accumulating results regarding postoperative comorbidities in the elderly population undergoing the TAVI procedure will be followed with continued attention. Although not shown in our study, the reoperation rate, especially in patients who received a bioprosthetic valve, is a vital factor in the quality measure of AVR; however, the beneficial effect of advanced age on the development of structural valvular deterioration following AVR has been acknowledged.[21]

Study Limitations

Because this study was a retrospective review at a single institution, there are several inherent limitations. First, survival status was drawn only from the Social Security Death Index; information such as cause of death (cardiac or non-cardiac) and comorbidities after discharge from the institution were not investigated in this study. Although we demonstrated a significant difference in the ratio of discharge to home between age groups, the disposition placement decisions were made by different physical therapists and physicians, so the reason for placement might vary. Second, after referral from the cardiologist, the decision to bring the patients to the operating room is determined by each surgeon; there might be patients who looked too ill or frail and were not included in the study, thus causing selection bias. In addition to the factors listed in STS-PROM or EuroSCORE, each surgeon's decision was also based on objective data or even the surgeon's "impression" to some extent, such as the patient's physical and emotional activity, intellectual function, and family support structure. Frailty is another important element that affects the operative outcome,[22] although it was not evaluated in this study. Although quantifying these factors cannot be easily done, this field is definitely in need of further investigation. Even considering the existence of patient selection bias, we believe that our operative results are based on and directed by the updated guidelines for surgical indication and postoperative management; therefore, our results can be seen as a benchmark of operative results of AVR in current practice.

Conclusion

In conclusion, we confirmed durable results after conventional AVR with or without concomitant CABG in elderly patients in a single-center retrospective review. Risk of mortality was reasonably low and even surpassed predicted mortality in relatively low-risk patients as well as patients requiring concomitant CABG. Postoperative factors such as readmission, transferral to rehabilitation facilities, and gastrostomy and/or tracheotomy placement might significantly affect elderly patients.

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