Nineteen-Millimeter Bioprosthetic Aortic Valves Are Safe and Effective for Elderly Patients With Aortic Stenosis

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Background. **Replacing a stenotic aortic valve with 19-mm bioprostheses remains controversial owing to potential patient-prosthesis mismatch concerns. We report a single-center 10 year experience with 19-mm bioprosthetic valves implanted in elderly patients. We hypothesized patients would have acceptable in-hospital and long-term outcomes.**

Methods. **Between January 2002 and December 2011, 257 patients underwent aortic valve replacement with a 19-mm prosthesis, of whom 182 had available follow-up echocardiographic studies. Mean age was 77.4 ± 8.4 years, and 10 of 257 (4%) were male. Outcomes of interest included early and late mortality, peak and mean aortic valve gradients, and left ventricular mass regression.**

Results. **Operative mortality was 3.5% (9 of 257). Median postoperative echocardiographic time was 16 months. On follow-up echocardiography, mean peak aortic valve gradient decreased from 76 ± 27 mm Hg preoperatively to 32 ± 13 mm Hg and the mean gradient decreased from 46 ± 17 mm Hg to 18 ± 8 mm Hg (both $p < 0.001$) Mean left ventricular mass decreased from 191 g to 162 g ($p < 0.001$). Postoperative survival did not differ significantly between patients who met the criteria for patient-prosthesis mismatch and those who did not ($p = 0.607$).**

Conclusions. **In a series of elderly patients with aortic stenosis who were implanted with 19-mm bioprosthetic valves, long-term follow-up showed significant left ventricular mass regression and peak and mean aortic valve gradient reductions. The use of 19-mm aortic valves is safe and efficacious for elderly patients with a small aortic root.**

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Acquired aortic stenosis (aortic stenosis) is increasing along with rising mean population age [1]. The most durable and effective treatment for aortic stenosis is aortic valve replacement (AVR). Aortic valve replacement increases the effective orifice area, thereby relieving pressure overload and allowing left ventricular mass (LVM) regression, with excellent short-term and long-term results in older patients (≥70 years) [2]. Replacing a stenotic aortic valve with a small (19-mm) prosthesis remains controversial because concerns about patient-prosthesis mismatch (PPM) [3, 4]. To avoid PPM, many surgeons prefer aortic root enlargement (ARE) in patients with a small annulus—a technically demanding procedure, particularly in older patients with calcified and friable tissue and a high incidence of coronary artery disease [5]. There are concerns that ARE increases the surgical risks presented by this patient subset [6].

In this study, we sought to address whether AVR with a 19-mm bioprosthetic valve in elderly patients with critical aortic stenosis is a suitable option for obtaining hemodynamic improvement and reverse remodeling. In addition to early and late mortality, we evaluated postoperative echocardiographic findings, including peak and mean aortic valve gradients and LVM.

Patients and Methods

Patients

With permission from the Partners Institutional Review Board, we conducted a retrospective review with waived consent of all patients at Brigham and Women's Hospital who underwent AVR with a 19-mm bioprosthetic valve for isolated severe aortic stenosis between January 2002 December 2011. Patients with concomitant mitral valve procedures or severe aortic insufficiency were excluded but concomitant coronary artery bypass graft surgery (CABG) or tricuspid procedures were included. A total of 257 patients meeting our criteria were identified. Mean patient age was 77.4 ± 8.4 years and 116 of 257 (45%) were octogenarians or nonagenarians.

Patient characteristics, laboratory data, and hospital outcomes were extracted from hospital electronic medical records and coded to The Society of Thoracic Surgeons

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Abbreviations and Acronyms

ARE = aortic root enlargement
AVR = aortic valve replacement
CABG = coronary artery bypass graft surgery
CI = confidence interval
EOA = expected orifice area
HR = hazard ratio
iEOA = indexed expected orifice area
IQR = interquartile range
LVM = left ventricular mass
PPM = patient-prosthesis mismatch
STS = The Society of Thoracic Surgeons

adult cardiac database version 2.52 specifications unless otherwise noted. Survival data came from routine follow-up, our state Department of Public Health, our internal research data repository, and query of the Social Security Death Index; there was 100% survival follow-up for this study. The main echocardiographic outcomes of interest were mean and peak valve gradients, and LVM regression. Early and late mortality and aortic valve reoperations were also primary outcomes.

Echocardiograms

One preoperative echocardiogram and one echocardiogram done 60 days or more postoperatively were collected per subject. The first abnormal or most recent echocardiogram for patients with normal findings was used. Median time to the follow-up echocardiogram was 16 months. The formula of Devereux and associates [7] was used to calculate LVM. The LVM categories for men were as follows: normal, 116 g/m^2 cm or less; mildly abnormal, 116 to less than 132 g/m^2; moderately abnormal, 132 to less than 148.9 g/m^2; severely abnormal, 149 g/m^2 or more. For women, the LVM categories were as follows: normal, 96 g/m^2 or less; mildly abnormal, 96 to less than 109 g/m^2; moderately abnormal, 109 to less than 121.9 g/m^2; severely abnormal, 122 g/m^2 or more. Postoperative reverse remodeling was classified as none, mild (LVM more than 5% smaller than baseline), moderate (LVM more than 15% smaller than baseline), and substantial (postoperative LVM more than 25% smaller than at baseline).

Patient-Prosthesis Mismatch

To evaluate whether the expected orifice area (EOA) of the implant affected outcomes, we stratified patients by the presence and degree of PPM. The EOA was obtained from each device's manufacturer information. Presence and degree of PPM was determined by standard criteria [3]: the EOA specific to the implanted device was indexed to the patient's body surface area (iEOA). An iEOA of 0.85 cm^2/m^2 or greater indicated no PPM, 0.65 cm^2/m^2 to 0.85 cm^2/m^2 was moderate, and less than 0.65 cm^2/m^2 was considered severe PPM.

Statistical Analyses

Categoric data are expressed as number and percentage; continuous data are presented as mean ± SD for normally distributed data or median with 25th and 75th percentiles (interquartile range [IQR]) for nonnormally distributed data. Fisher's exact test was used to evaluate categoric data and one-way analysis of variance with Bonferoni post hoc corrections or Mann-Whitney *U* tests were used for intergroup comparisons of continuous variables, as appropriate. Kaplan-Meier analyses with Mantel-Cox log rank post hoc tests (pooled over categories) were used to evaluate survival. Forward- conditional Cox proportional hazards models were used to evaluate predictors of long-term survival. Statistics were performed using SPSS version 22.0 (IBM Corp, Armonk, NY). The criterion of significance was p less than 0.05.

Results

The mean age for all 257 patients was 77.7 years (range, 46 to 95), and The Society of Thoracic Surgeons (STS) mean risk score was 6.8 ± 3.4 (range, 1.2 to 20.4). Operative mortality was 9 of 257 (3.5%) for an observed/expected mortality ratio of 0.51. Overall, 98 of 257 (38%) had concomitant CABG, and 116 (45%) were octogenarians (aged 80 years or more). These were higher risk patients, with mean STS scores for CABG patients of 8.9 ± 3.4 and 9.1 ± 2.7 for octogenarians. Operative mortality was 2 of 98 (2%) for concomitant CABG and 6 of 116 (5%) for octogenarians. Long-term mortality data were available for all patients.

Of 248 surviving patients, 66 (26.6%) did not have postoperative echocardiographic studies for follow-up analyses. A responder-bias analysis revealed these patients to be substantially similar to our 182-patient study group in age, sex, body surface area, preoperative echocardiographic data, history of angina or arrhythmia, congestive heart failure, and renal failure status ($p \geq 0.3$ for all; data not shown).

Table 1 presents admitting characteristics for the follow-up cohort. Mean age was 77.1 ±8.5 years and 78 of 182 (43%) were octogenarians; only 6 (3%) were men. Of the 182 patients, 79 had congestive heart failure and 81 were in New York Heart Association class III/IV. Preoperative echocardiographic data showed that 142 patients (78%) had severe LVM enlargement, and 27 (15%) had moderate enlargement although ejection fraction was preserved. Total follow-up time was 1,138 patient-years, and the median follow-up time, calculated in months from date of surgery, was 6.2 years (IQR, 5 to 9).

Implanted valves included 125 Edwards Magna Pericardial (Edwards Lifesciences, Irvine, CA), 12 Medtronic Freestyle/Mosaic (Medtronic, Minneapolis, MN), 12 Sorin Mitroflow (Sorin Group, Arvada, CO), and 33 St. Jude Biocor/Epic (St. Jude Medical, St. Paul, MN; Table 2). Concomitant CABG was performed on 75 patients (41%) and tricuspid procedures on 7 (4%). Median perfusion time was 113 minutes (IQR, 87 to 131) and cross-clamp

Table 1. Preoperative Characteristics of 182 Patients Undergoing Aortic Valve Replacement With 19-mm Bioprosthetic Valves

Characteristics	Values
Age, years	77.1 ± 8.5
Age ≥80 years	42.3 (77)
Women	96.7 (176)
Body mass index, kg/m^2	26.9 ± 6.2
Body surface area, m^2	1.7 ± 0.2
Renal insufficiency	4.4 (8)
Preoperative creatinine	1.0 ± 0.4
History of atrial fibrillation	7.7 (14)
Angina	30.2 (55)
NYHA class III/IV	44.0 (80)
Congestive heart failure	43.4 (79)
Ejection fraction, %	60.0 (55–65)
Preoperative IABP	1.6 (3)
Degree LV mass enlargement	
None/mild	7.1 (13)
Moderate	14.8 (27)
Severe	78.1 (142)
STS predicted mortality	6.8 ± 3.2

Values are mean ± SD, % (n), or median (interquartile range).

IABP = intraaortic balloon pump; LV = left ventricular; NYHA = New York Heart Association; STS = The Society of Thoracic Surgeons.

Table 2. Operative Outcomes in 182 Patients Undergoing Aortic Valve Replacement With 19-mm Bioprosthetic Valves

Operative Outcomes	Values
Emergent status	1.1 (2)
Concomitant surgery	
CABG	41.2 (75)
Tricuspid valve	3.8 (7)
Valves implanted	
Edwards Magna Pericardial	68.3 (124)
Medtronic	6.6 (12)
Sorin Mitroflow	7.1 (13)
St. Jude Medical Biocor/Epic	18.0 (33)
Intraaortic balloon pump needed	1.1 (2)
Perfusion time, minutes	107 (78–148)
Cross-clamp time, minutes	78 (54–104)
EOA, cm^2	1.24 ± 0.07
iEOA, cm^2/m^2	0.76 ± 0.09
Postoperative PPM	
None, iEOA >0.85 cm^2/m^2	16.5 (30)
Moderate, iEOA 0.65–0.8 cm^2/m^2	69.8 (127)
Severe, iEOA <0.65 cm^2/m^2	13.7 (25)

Values are % (n), median (interquartile range), or mean ± SD.

CABG = coronary artery bypass graft; EOA = estimated orifice area; iEOA = estimated orifice area indexed to body surface area; PPM = patient-prosthesis mismatch.

time was 81 minutes (IQR, 57 to 107). The mean EOA for implanted valves was 1.24 ± 0.07, and mean iEOA was 0.76 cm^2/m^2.

There were 2 reoperations for bleeding (1%), 6 permanent strokes (3%) and 4 new-onset renal failures (4%). New-onset atrial fibrillation occurred in 50 patients (27%); 2 were discharged with a pacemaker. Median length of stay was 7 days (IQR, 6 to 12; Table 3).

There were no reoperations during the study. Table 4 shows follow-up echocardiographic data. Median time to postoperative echocardiogram was 16 months (range, 2 to 102). At follow-up, mean aortic valve gradient was reduced from 46 ± 16 mm Hg to 17.0 ± 7.4 mm Hg, and peak gradient from 76.9 ± 25.9 mm Hg to 32.5 ± 12.5 mm Hg (both $p \leq 0.001$). The LVM had decreased from a mean of 192 ± 62 preoperatively to 162 ± 51 ($p \leq 0.001$). That represents a relative decrease of 16.6% from preoperative LVM. All patients with normal LVM dimensions preoperatively remained so at follow-up. Of the remaining 170 patients with preoperative LVM enlargement, 36% (61) had substantial remodeling, 14% (24) had moderate remodeling, 24% (40) had mild remodeling, and 27% (45) had no remodeling on follow-up.

We evaluated whether presence of PPM affected outcomes. The iEOA was calculated for all patients; of those with follow-up, 30 (16%) had no PPM (iEOA 0.85 cm^2/m^2 or greater), 127 (70%) met the criteria for moderate (iEOA between 0.65 and 0.85 cm^2/m^2), and 25 (14%) had severe PPM (iEOA less than 0.65 cm^2/m^2). As Table 5 shows, all groups had significant ($p < 0.001$) reductions in peak and mean valve gradients, and valve gradients did not differ significantly among the three groups. All groups evidenced reverse remodeling; 34% of severe PPM and 32% of moderate PPM patients had greater than 25% reductions in LVM, compared with 44% of patients without PPM ($p = 0.15$). However, only 7% of these patients had no LVM remodeling, versus 30% of moderate and 36% of severe PPM patients ($p = 0.04$).

Table 3. Complications and Hospitalization Statistics in 182 Patients Undergoing Aortic Valve Replacement With 19-mm Valves

Complications and Hospitalization	Values
Postoperative complications	
Intraaortic balloon pump needed	1.1 (2)
Reoperation for bleeding	1.1 (2)
Permanent stroke	2.2 (4)
New-onset renal failure	3.3 (6)
New-onset atrial fibrillation	27.5 (50)
Hospitalization outcomes	
Ventilation time, hours	10.3 (6–16)
Ventilation >24 hours	9.9 (18)
Total intensive care unit stay, hours	52.0 (29–99)
Postoperative length of stay, days	7.0 (6–12)
Readmission <30 days	8.9 (16)

Values are % (n) or median (interquartile range).

Table 4. Echocardiographic Data at Follow-Up

Follow-Up Data (n = 182)	Values
Time to postoperative echocardiogram, months	16 (3–38)
Preoperative aortic root, cm	2.79 ± 0.36
Preoperative mean gradient, mm Hg	46.0 ± 16.2
Postoperative mean gradient, mm Hg[a]	17.8 ± 7.4
Preoperative peak gradient, mm Hg	76.9 ± 25.9
Postoperative peak gradient, mm Hg[a]	32.5 ± 12.5
Preoperative LVM, g/m^2	192.3 ± 61.5
Postoperative LVM, g/m^2[a]	162.2 ± 50.7
Absolute reduction in LVM, g/m^2	−32.2 ± 58.3
LVM remodeling[b]	
No change	26.5 (45)
5%–15% reverse remodeling	23.5 (40)
15%–25% reverse remodeling	14.1 (24)
>25% reverse remodeling	35.9 (61)

[a] $p \leq 0.001$ versus preoperative value. [b] In patients with preoperative left ventricular mass (LVM) enlargement (n = 170).

Values are median (interquartile range), mean ± SD, or % (n).

Figure 1 shows the survival analysis for all 257 patients, compared with the calculated expected survival for an age-matched cohort derived from the United States National Vital Statistics Report [8]. Mean survival was 8.6 years (95% confidence interval [CI]: 7.9 to 9.2). Figure 2 presents survival for all 257 patient grouped by PPM classification. Mean postoperative survival was 8.0 years (95% CI: 6.3 to 9.6) for the no PPM patients, 8.4 years (95% CI: 7.7 to 9.1) for moderate PPM, and 7.5 years (95% CI: 6.1 to 8.2) for the severe group (pooled $p = 0.607$; in pairwise comparisons, all p values were greater than 0.31). Figure 3 presents survival for the follow-up cohort of 182 patients, grouped by PPM classification. Mean survival was 7.8 years (95% CI: 5.9 to 9.7) for the no-PPM patients, 9.1 years (95% CI: 8.3 to 9.9) for moderate PPM, and 7.6 years (95% CI: 6.7 to 8.6) for the severe PPM group (pooled $p = 0.196$).

A Cox proportional hazards model was run on all patients to evaluate predictors of survival. There were 77 of 257 (30%) deaths during the study observation time. Based on preliminary univariate analyses, known contributors to survival, and clinical judgment, a forward-conditional model included the following continuous variables: age, preoperative creatinine, peak aortic valve gradient, LVM, and perfusion time. Categoric variables included sex, preoperative New York Heart Association class, diabetes mellitus, congestive heart failure, and PPM category. Independent survival predictors were creatinine (hazard ratio [HR] 1.558, 95% CI: 1.228 to 1.976, $p < 0.001$), age (HR 1.051, 95% CI: 1.018 to 1.086, $p = 0.003$), congestive heart failure (HR 2.022, 95% CI: 1.245 to 3.276, $p = 0.004$), and diabetes mellitus (HR 2.163, 95% CI: 1.240 to 3.774, $p = 0.007$). The PPM was found noncontributory ($p = 0.226$, $df = 2$; overall Cox model performance −2log likelihood = 641.900, $\chi^2 = 36.405$, $df = 4$, $p \leq 0.001$).

Table 5. Comparison of Preoperative and Postoperative Echocardiographic Measures Stratified by Patient-Prosthesis Mismatch

Echocardiographic Measures	No PPM (n = 30)	Moderate PPM (n = 127)	Severe PPM (n = 25)	*p* Value
Degree preoperative LVM enlargement				≤0.283
Normal/mild	6.7 (2)	8.7 (11)	0.0 (0)	
Moderate	20.0 (6)	15.0 (19)	8.0 (2)	
Severe	73.3 (22)	76.4 (97)	92.0 (23)	
Time to postoperative echocardiogram, months	15 (2–37)	15 (2–37)	14 (2–35)	≤0.729
Preoperative aortic root	2.91 ± 0.32	2.75 ± 0.37	2.83 ± 0.31	≤0.275
Preoperative mean gradient, mm Hg	46.5 ± 14.4	47.9 ± 17.5	46.3 ± 17.5	≤0.301
Postoperative mean gradient, mm Hg[a]	16.2 ± 6.7	17.5 ± 8.3	20.4 ± 5.7	≤0.384
Preoperative peak gradient, mm Hg	73.5 ± 26.6	78.7 ± 27.2	79.8 ± 28.1	≤0.505
Postoperative peak gradient, mm Hg[a]	31 ± 11.6	32.5 ± 13.6	34.0 ± 7.7	≤0.667
Preoperative LVM, g/m^2	178.6 ± 55.4	191.2 ± 62.8	221.4 ± 59.0	≤0.029
Postoperative LVM, g/m^2[b]	130.3 ± 38.2	162.9 ± 50.4	187.5 ± 48.6	≤0.006
Absolute reduction in LVM, g/m^2	−43.6 ± 44.1	−28.8 ± 61.1	−35.9 ± 58.3	≤0.496
Percent change LVM from baseline	−21.6 ± 24.7	−15.0 ± 36.9	−16.2 ± 24.1	≤0.190
Degree of LVM remodeling[c]	(n = 28)	(n = 116)	(n = 25)	*p* Value[d]
No change	7.1 (2)	29.3 (34)	36.0 (9)	≤0.010
5–15% reverse remodeling	32.1 (9)	22.4 (26)	20.0 (5)	≤0.329
15–25% reverse remodeling	14.3 (4)	14.7 (17)	12.0 (3)	≤1.000
>25% reverse remodeling	46.4 (13)	33.6 (39)	32.0 (8)	≤0.200

[a] Significantly different from baseline for both groups, $p \leq 0.001$. [b] Significantly different from baseline $p \leq 0.001$ for none and moderate groups, $p = 0.007$ for severe group. [c] In patients with preoperative left ventricular mass (LVM) enlargement. [d] No patient-prosthesis mismatch (PPM) versus moderate or severe; there were no significant differences between moderate and severe groups (all $p > 0.47$).

Values are % (n), median (interquartile range), or mean ± SD.

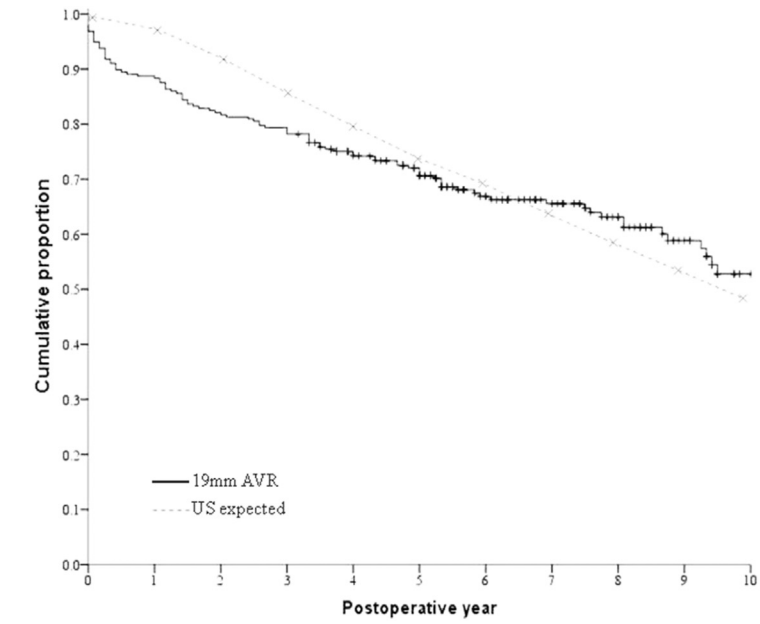


Fig 1. Survival analysis of 257 patients undergoing aortic valve replacement (AVR) with 19-mm bioprosthetic valves (solid line), compared with expected survival of the age-matched United States general population (dotted line [National Vital Statistics Reports, 2007]) [8].

Number at risk

Year starting	0	1	2	3	4	5	6	7	8	9
All AVR 19mm	257	228	211	198	171	139	103	84	60	36

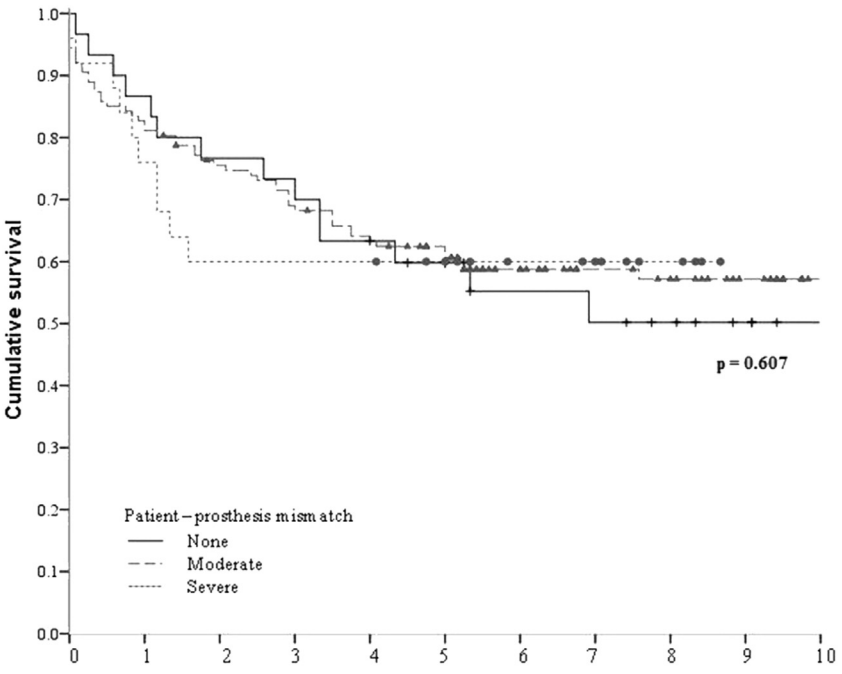
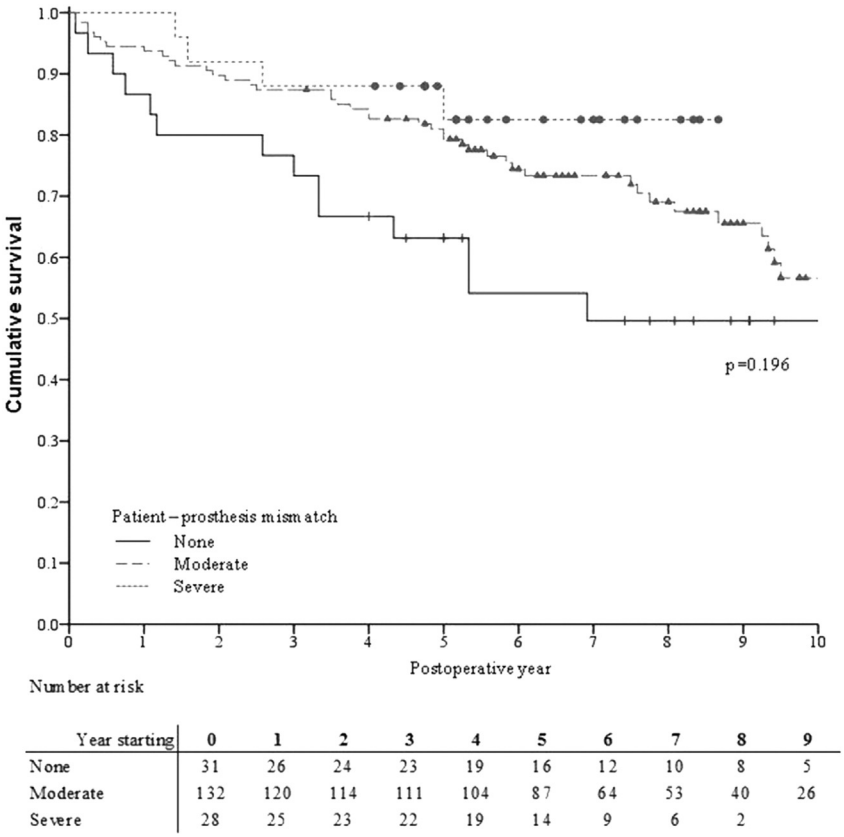


Fig 2. Survival analysis for 257 patients undergoing aortic valve replacement with 19-mm bioprosthetic valves, stratified by patient-prosthesis mismatch classification: none (solid line); moderate (dashed line); or severe (dotted line).

Number at risk

Year starting	0	1	2	3	4	5	6	7	8	9
None	41	35	33	31	24	20	16	13	11	6
Moderate	177	159	146	137	122	101	74	61	46	30
Severe	39	34	32	30	26	19	14	10	4	



Number at risk

Year starting	0	1	2	3	4	5	6	7	8	9
None	31	26	24	23	19	16	12	10	8	5
Moderate	132	120	114	111	104	87	64	53	40	26
Severe	28	25	23	22	19	14	9	6	2	

Fig 3. Survival analysis for the follow-up cohort of 182 patients undergoing aortic valve replacement with 19-mm bioprosthetic valves, stratified by patient-prosthesis mismatch classification: none (solid line); moderate (dashed line); or severe (dotted line).

We could not calculate the in vivo iEOA; we conducted a sensitivity analysis assuming a 10% overestimation of iEOA for all patients. As a result, 204 patients (79%) met moderate PPM criteria and 48 (19%) met severe PPM criteria, with 5 having no PPM. The Cox analysis results were unchanged. Likewise, the reclassified follow-up cohort results were unchanged; for example, of the 34 patients now classified with severe PPM in the follow-up cohort, 3 patients (9%) had normal before and after LVM, 19% had mild remodeling (6 of 31, compared with 5 of 25 in Table 5), 13% had moderate LVM remodeling (4 of 31, compared with 3 of 12), and 32% with substantial remodeling (10 of 31 compared with 8 of 25 in Table 5).

Comment

In 1978, Rahimtoola [9] quantified PPM as an iEOA of less than 0.85 cm^2/m^2 [10]. Controversy is ongoing regarding the clinical impact of PPM on outcomes after AVR [3, 5, 6, 10, 11]. Some suggest no risk associated with PPM [12–14], but others have demonstrated PPM is a risk factor for adverse events [12–16]. Several groups have shown that PPM is associated with reduced survival, as well as suboptimal results in reducing peak and mean valve gradient [15, 17, 18], less LVM regression, and lower functional class and exercise tolerance at follow-up after AVR [19, 20].

Various techniques exist to enlarge the aortic root. Nicks and associates [19] first described aortic annular enlargement with a posterior incision through the noncoronary sinus of Valsalva. Konno and colleagues [20] described anterior annular enlargement through the right ventricular outflow tract for congenital aortic stenosis. Manouguian and colleagues [21] reported root enlargement through the left noncoronary commissure extending into the anterior mitral valve leaflet. Several centers have demonstrated that these procedures can be done safely [22, 23], whereas others have shown ARE increased aortic cross-clamp time significantly [24] without improving long-term clinical outcomes [22]. In a recent editorial, Kulik [22] concluded that routine ARE is likely unnecessary, potentially dangerous in inexperienced hands, and therefore cannot be recommended. Moreover, most studies were limited to pediatric or relatively young patients (aged less than 60 years).

In this setting, we reviewed our 10-year results of AVR with 19-mm bioprostheses. The mean age was 77 years, 93% of patients were aged 65 years or more, and 45% of the cohort were octogenarians. The STS predicted mortality was elevated, but operative mortality was 3.5% for the entire series, with few serious postoperative complications. At follow-up, there were no aortic valve reoperations, peak and mean gradients were within normal limits, and gradient reductions were similar between groups. Overall, 73% of patients with preoperative LVM

enlargement had at least mild remodeling, with 50% having more than 15% reductions in LVM g/m^2. We noted that more moderate/severe PPM patients failed to reverse remodel; more of these patients had severe LVM enlargement, and as LV hypertrophy is associated with less reverse remodeling, we cannot assess whether a larger valve and ARE would have improved results. In a recent study of 4,264 AVR patients, Beach and colleagues [25] found that the strongest predictor of postoperative LV regression was less preoperative hypertrophy; smaller implants did not significantly affect remodeling.

Despite advanced age and elevated risk scores, postoperative survival did not differ based on PPM in our study, as others have reported [15, 17, 18]. In the follow-up cohort, marginally reduced survival was noted in the no-PPM group (Fig 3); with only 30 patients, it is difficult to draw conclusions from this. Postoperative survival was similar ($p = 0.61$) in the full cohort across PPM classes.

Our results show acceptable clinical outcomes obtained using 19-mm valves. We believe that the risks to elderly patients posed by longer operating time and pump exposure make root enlargement procedures less desirable than using smaller valves. Octogenarians particularly are likely to have calcified and friable tissues, adding to the technical demands of ARE, which is already associated with prolonged bypass times, [14] a known risk factor for increased morbidity and mortality in elderly patients. Although these factors do not pose the same risks for non-elderly patients (less than 65 years), a 19-mm valve may still be viable for patients with body surface areas less than 2.0m^2 or who are otherwise challenging. We had 7 patients with body surface area of 2.0 m^2 or greater. There was no operative mortality. Three patients were aged 75 years or more, 1 patient underwent a salvage status procedure, and 3 presented with access issues due to body habitus that rendered ARE less feasible. Of patients with follow-up data available, 4 of 5 had substantial LVM remodeling and 1 of 5 had mild remodeling.

Patients with very small aortic annulus are not TAVR candidates. The smallest available TAVR device is a 23 mm, although a 20 mm device is in clinical trials. Hence, this group is unable to be considered for percutaneous intervention, despite their elevated risks as surgical candidates.

This study is subject to the limitations of a single-center retrospective design. Follow-up echocardiographic data was missing for 66 patients; although it appears these data were missing at random, we cannot rule out that they bias our findings. Echocardiographic data were obtained from diverse sources, so interobserver variability could confound our results. Because follow-up is not routinely scheduled, it is possible our findings underestimate remodeling. We could not calculate in vivo iEOA, but sensitivity analyses indicates that potential underestimation of iEOA is unlikely to affect our conclusions. Lastly, we could not collect quality of life follow-up. Results should be interpreted with these cautions in mind.

In conclusion, we report a 10-year experience with 19-mm aortic valves in patients with critical aortic stenosis and a small aortic root. Despite AVR with a small prosthesis, aortic valve gradients were restored to normal limits, and LVM was decreased significantly at follow-up. This approach avoids the risks of complex and prolonged surgery posed by root enlargement procedures. Aortic valve replacement with a 19-mm prosthetic valve is a safe, reliable treatment option for elderly patients who are unable to be considered for TAVR.

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