Management of dilated ascending aorta during aortic valve replacement: Valve replacement alone versus aorta wrapping versus aorta replacement

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Objectives: The optimal management of dilated ascending aorta during aortic valve replacement (AVR) remains controversial. This study compared the outcomes among 3 different managements (AVR alone, aorta wrapping, and aorta replacement) for the dilated ascending aorta.

Methods: The study enrolled 499 consecutive non-Marfan patients undergoing AVR in the presence of the ascending aorta dilatation (40 to 55 mm). We evaluated rates of death and aortic events; in addition, we evaluated the aortic expansion rate by serial echocardiography.

Results: The surgery involved AVR alone (n = 362), aorta wrapping (n = 67), or aorta replacement (n = 70). Early mortality occurred in 1.2% (n = 6, $P = .61$). Throughout 1590.0 patient-years of follow-up, 47 deaths occurred. The 5-year survival rates were 90.1% ± 2.0%, 91.8% ± 3.5%, and 82.2% ± 7.5% in the AVR alone, aorta wrapping, and aorta replacement groups, respectively ($P = .64$). One aortic event (acute type A dissection) occurred in the AVR alone group. For the AVR alone group, the median aortic expansion rate was −0.6 mm/y (interquartile range, −3.2 to 0.6 mm/y). The aortic expansion rates were affected neither by the morphology of aortic valves (bicuspid vs tricuspid; $P = .10$) nor by the initial aorta diameter ($\gamma = -0.31$, $P = .61$). Clinically relevant aortic expansion (≥5 mm/y) was observed only in 5 patients; of these patients, 2 showed the aortic diameter of 60 mm or greater at the end of follow-up.

Conclusions: Compared with concomitant aortic wrapping or replacement, AVR alone achieved similar clinical outcomes, showing considerably low risks of adverse aortic events or relevant aortic expansion in dilated ascending aorta. These findings argue against routine aortic replacement at the time of AVR. (J Thorac Cardiovasc Surg 2013;146:802-9)

ACD

A significant proportion of patients undergoing aortic valve replacement (AVR) are reported to have a dilated ascending aorta.[1] Several observational studies have shown that an untreated ascending aorta aneurysm may predispose to fatal aortic dissection or rupture[2,3]; consequently, practice guidelines recommend performing aortic replacement at the time of AVR if the aortic diameter is greater than 45 mm, especially in patients with a bicuspid aortic valve (BAV).[4,5] These guidelines are further supported by evidences that aortic dilatation is not solely related with hemodynamic turbulences caused by aortic valve diseases but is also attributable to the intrinsic pathology of the aortic wall.[6-9] Because AVR treats only the hemodynamic abnormalities, and not the intrinsic aortopathy, aorta replacement during AVR has been regarded as a reasonable option in patients with a dilated ascending aorta.

More recent studies, however, have shown that patients undergoing isolated AVR in the presence of the ascending aorta dilation are at a considerably low risk of adverse aortic events throughout long-term follow-up, raising arguments against routine replacement of the aorta at the time of AVR, even in BAV.[10-13] Furthermore, a recent large-scale clinical study using echocardiographic evaluations revealed that a long-term hemodynamic burden is the most important contributing factor of aortic dilatation in BAV and that isolated AVR is an effective method to prevent pathologic progression.[14] These findings suggest that recommendations in current guidelines should be reevaluated through further clinical investigations and better data analysis.

In this study, we sought to compare clinical outcomes of patients undergoing AVR in the presence of a dilated ascending aorta, according to the different methods of managing the ascending aorta (AVR alone, aorta wrapping, and aorta replacement) in a reasonably sized cohort. Furthermore, we

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Abbreviations and Acronyms
AVR = aortic valve replacement
BAV = bicuspid aortic valve
CT = computed tomographic
IQR = interquartile range
LV = left ventricular
TAV = tricuspid aortic valve

evaluated the changes in sizes of the native ascending aorta through data from serial echocardiographic assessments.

METHODS

Patients

From January 2001 through December 2011, a total of 2076 patients underwent AVR at the Asan Medical Center (Seoul, Korea). Of these patients, those with Marfan/Ehlers-Danlos syndrome or those who had aortic root aneurysm requiring concomitant aortic root replacement were excluded. Finally, we retrieved 499 patients who had a *dilated ascending aorta* (defined as 40-55 mm in its maximal diameter, based on preoperative echocardiographic assessments), and these patients formed the subject population of this study. Regarding the surgical management of the dilated ascending aorta, 362 patients (72.5%) underwent AVR alone, 67 (13.4%) underwent ascending aorta wrapping using prosthetic vascular grafts, and 70 (14.0%) underwent concomitant ascending aorta replacement. The decision to perform concomitant aortic procedures was affected by the aortic size, the morphology of the AV (bicuspid [BAV] vs tricuspid [TAV]), and expected surgical risks manifested by left ventricular (LV) functions, but was finally at the discretion of the attending surgeon.

This study was approved by the Ethics Committee/Review Board of the Asan Medical Center, and the committee waived the requirement for informed consent from the individual patient because of the retrospective nature of the study.

Surgical Technique

Median sternotomy (n = 475), upper hemisternotomy (n = 18), or transverse sternotomy (n = 6) approaches were used according to the surgeon's preferences. The distal ascending aorta (n = 466) was the most common site for the arterial cannulation, whereas femoral artery cannulation was used in some patients (n = 10) undergoing minimally invasive approaches. In patients who were judged to replace the aorta beyond the distal ascending aorta (n = 23), the right axillary artery was used for the cannulation.

For patients undergoing concomitant aorta replacement, 24- to 34-mm (median, 28-mm) commercially available vascular grafts were used for aorta replacement. In patients requiring open distal aorta anastomosis, antegrade selective cerebral perfusion was used during circulatory arrest under moderate systemic hypothermia.

For patients receiving the aorta wrapping technique, 26- to 34-mm (median, 32-mm) vascular grafts were used to surround the native ascending aorta. The aorta wrapping procedure was done after the completion of hemostasis and protamine reversal after the AVR. The length of the vascular graft was determined according to the distance between the sinotubular junction and the origin of the innominate artery. After the longitudinal incision of the graft, the native ascending aorta was surrounded by the graft, and the incised portion of the graft was reattached at the anterior side of the aorta using 4-0 or 3-0 polypropylene (Prolene) sutures (Ethicon, Inc, Somerville, NJ). To prevent graft migration, several fixation stitches were made on the aortic adventitia at most proximal and distal parts of the graft.

Follow-up

The primary outcomes of interest were all-cause death and adverse aortic events, the latter including aortic dissection/rupture, reoperation of the proximal aorta, and sudden death. Data were obtained through June 2012, during regular visits to the outpatient clinic. For validation of complete follow-up information regarding mortality, data on vital status, and dates of death were obtained through June 2012 from the Korean National Registry of Vital Statistics. *Early mortality* was defined as death within 30 days of surgery. All deaths were considered of cardiovascular origin unless a noncardiovascular origin was established clinically.

To assess the changes in maximal diameter of the ascending aorta in patients who underwent AVR alone or aorta wrapping, serial postoperative echocardiographic data were reviewed. Postoperative echocardiographic assessments were routinely performed before discharge. Generally, follow-up echocardiographic evaluations were done at 6 months, 1 year, and then biennially thereafter. During the echocardiographic assessments, the size of the ascending aorta was routinely measured through parasternal long axis view. The difference in aortic diameters between "before surgery" and "at last follow-up" was calculated, and this difference was divided by follow-up duration to yield the aortic expansion rate.

Statistical Analysis

Categorical variables, presented as frequencies and percentages, were compared using the χ^2 test. Continuous variables, expressed as mean $\pm$ SD or median with range, were compared using the analysis of variance or Kruskal-Wallis test, as appropriate. The Kaplan-Meier method was used to delineate the survival rate, and a log-rank test was used to compare the differences in the rates among patient groups.

A Pearson correlation coefficient analysis was used to determine the relationship between preoperative aortic diameter and postoperative aortic expansion rate. All reported P values were 2 sided, and $P < .05$ was considered statistically significant. SPSS, version 18.0 (IBM Corp, Armonk, NY), was used for the statistical analysis.

RESULTS

Baseline Characteristics and In-Hospital Outcomes

Baseline demographic, clinical, and echocardiographic parameters are detailed in Table 1. In summary, patients who underwent concomitant aorta replacement were biased toward female sex, were more likely to have aortic stenosis and bicuspid aortic valves, and had a larger ascending aorta, a higher LV ejection fraction, and smaller LV dimensions compared with those who underwent AVR alone or aorta wrapping. Aorta clamping and cardiopulmonary bypass times were significantly longer in patients undergoing AVR plus aorta replacement than in those undergoing aorta wrapping and AVR alone. Of the patients who were planned to undergo AVR alone, 2 (0.5%) required aorta replacement because of aortic injuries at the cannulation sites. (These patients were categorized in the aortic replacement group.) Early mortality occurred in 6 patients (1.2%; 5 in the AVR alone group and 1 in the aortic wrapping group). Table 2 shows early postoperative outcomes of patients.

Clinical Events: Adverse Aortic Outcomes

Clinical follow-up was complete in 469 patients (94.0%), with a median follow-up duration of 43.6 months (interquartile range [IQR], 24.5-68.8 months), which

TABLE 1. Baseline characteristics of patients

Characteristics	AVR alone (n = 362)	Aorta wrapping (n = 67)	Aorta replacement (n = 70)	*P* value
Age, y	59.7 ± 12.6	62.3 ± 11.3	60.1 ± 12.0	.25
Female sex	102 (28.2)	24 (35.8)	32 (45.7)	.011
Diabetes mellitus	29 (8.0)	5 (7.5)	3 (4.3)	.55
Hypertension	81 (22.4)	16 (23.9)	11 (15.7)	.41
Chronic renal failure	9 (2.5)	1 (1.5)	1 (1.4)	.78
Previous cardiac surgery	16 (4.4)	1 (1.5)	5 (7.1)	.27
Urgent or emergent surgery	6 (1.7)	0	0	.68
Infective endocarditis	24 (6.6)	1 (1.5)	2 (2.9)	.14
Aortic valve disease				.034
AS	142 (39.2)	32 (47.8)	38 (54.3)	
AR	141 (39.0)	14 (20.9)	19 (27.1)	
Mixed ASR	78 (21.5)	21 (31.3)	13 (18.6)	
No AS or AR	1 (0.3)	0	0	
Bicuspid aortic valve	139 (38.4)	34 (50.7)	48 (68.6)	<.001
Atrial fibrillation	34 (10.2)	9 (13.4)	7 (10.0)	.72
Maze procedure	16 (4.4)	5 (7.5)	2 (2.9)	.42
Maximal aorta diameter, mm	43.1 ± 2.9	46.0 ± 3.4	47.5 ± 4.1	<.001
≥40, <45	260 (71.8)	25 (37.3)	21 (30.0)	
≥45, <50	88 (24.3)	30 (44.8)	24 (34.3)	
50-55	14 (3.9)	12 (17.9)	25 (35.7)	
Echocardiographic data				
LV EF, %	54.0 ± 12.5	54.7 ± 12.5	59.3 ± 9.7	.007
LVDs, mm	40.2 ± 11.9	38.3 ± 11.5	35.7 ± 9.7	.014
LVDd, mm	58.4 ± 11.5	55.0 ± 10.0	55.1 ± 9.3	.020
LV mass, g	301.7 ± 100.2	292.7 ± 78.6	276.6 ± 82.3	.15
Peak TR PG, mmHg	27.5 ± 14.0	26.6 ± 12.2	23.4 ± 11.1	.094
Concomitant CABG	45 (12.4)	7 (10.4)	10 (14.3)	.79
Cardiac ischemic time, min	71.9 ± 27.9	74.0 ± 27.7	118.2 ± 47.1	<.001
Total pump time, min	116.3 ± 46.9	128.4 ± 49.0	182.2 ± 71.0	<.001

Values are given as number (%) unless otherwise indicated. *AVR*, Aortic valve replacement; *AS*, aortic stenosis; *AR*, aortic regurgitation; *ASR*, aortic stenoregurgitation; *LV*, left ventricle; *EF*, ejection fraction; *LVDs*, left ventricular systolic dimension; *LVDd*, left ventricular diastolic dimension; *TR PG*, tricuspid regurgitation pressure gradient; *CABG*, coronary artery bypass grafting.

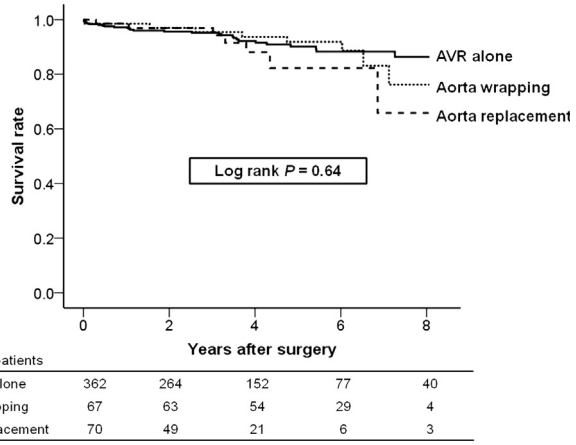
comprised 1590.0 patient-years of follow-up. During the late period, 40 patients died (27 in the AVR alone group, 6 in the wrapping group, and 7 in the replacement group). Cardiovascular causes of death (n = 26) were as follows: congestive heart failure (n = 4), infective endocarditis (n = 4), acute aortic dissection (n = 1) (previously mentioned), descending aortic aneurysm (n = 2, 1 rupture case and 1 surgical mortality), stroke (n = 1), ventricular arrhythmia (n = 1), and unknown cause (n = 13). Causes of noncardiovascular deaths (n = 14) were malignancy (n = 8), complications related to chronic renal insufficiency (n = 3), pneumonia (n = 2), and suicide (n = 1). Overall 5-year survival rates were 90.1% ± 2.0%, 91.8% ± 3.5%, and 82.2% ± 7.5% in the AVR alone, the wrapping, and the replacement groups, respectively, without significant differences among the groups ($P = .64$, Figure 1). Furthermore, among patients who underwent AVR alone (n = 362), the overall survival rates did not significantly differ between 2 patients groups, according to a cutoff of 45 mm for baseline ascending aorta diameter (Figure 2).

One aortic dissection occurred in a patient who underwent AVR alone for severe AR (tricuspid aortic valve).

TABLE 2. Early postoperative complications

Variables	AVR alone (n = 362)	Aorta wrapping (n = 67)	Aorta replacement (n = 70)	*P* value
Re-exploration for bleeding	12 (3.3)	1 (1.5)	4 (5.7)	.39
Requirement for dialysis	3 (0.8)	1 (1.5)	0	.62
LCOS*	4 (1.1)	1 (1.5)	0	.64
Neurologic deficit†	2 (0.6)	1 (1.5)	0	.52
Complete AV block	2 (0.6)	1 (1.5)	0	.52

Values are given as number (%) unless otherwise indicated. *AVR*, Aortic valve replacement; *LCOS*, low cardiac output syndrome; *AV*, aortic valve. *Requiring mechanical supports, such as intra-aortic balloon pumping or extracorporeal life support. †Includes 1 permanent (AVR-alone group) and 2 transient deficits.



N. of patients					
AVR alone	362	264	152	77	40
+ wrapping	67	63	54	29	4
+ replacement	70	49	21	6	3

FIGURE 1. Kaplan-Meier survival curves according to the management for the ascending aorta. *AVR*, Aortic valve replacement.

The maximal diameter of the ascending aorta was 43 mm at the time of AVR, and he underwent emergent surgery for acute type I aortic dissection that occurred 1731 days after initial surgery. He eventually died of neurologic damages after the emergent aortic surgery. There was no case of proximal aorta reoperation, except for the patient who had acute aortic dissection. Including 5 patients who died suddenly or of unknown causes, overall 6 cases of adverse aortic events occurred in the AVR alone group. The linearized rate of the adverse aortic events for AVR alone was 0.5% per patient-year.

Changes in Aortic Diameter

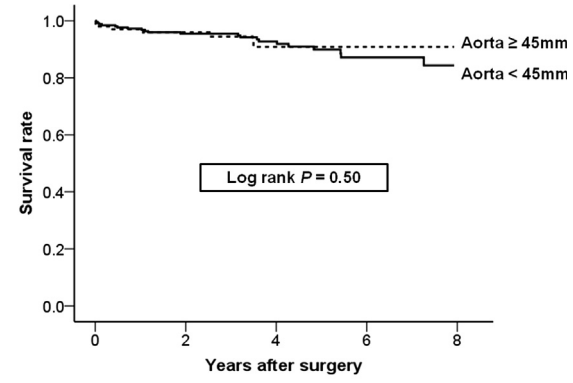
Echocardiographic evaluations in the late period (>6 months) were available in 404 patients of 488 late (>6 months) survivors (82.8%). Median echocardiographic follow-up duration was 24.9 months (IQR, 12.6-47.9 months), and the duration was significantly longer with the AVR alone (34.1 ± 28.0 months) or the wrapping (37.5 ± 21.7 months) groups compared with the replacement group (25.9 ± 21.0 months; $P = .017$).

In the AVR alone group (echocardiographic follow-up: n = 290), the aortic expansion rate was −0.6 mm/y (IQR, −3.2 to 0.6 mm/y) and the maximal diameter of the ascending aorta at last follow-up was 40.9 ± 7.3 mm. The frequency distribution of the aortic expansion rate is illustrated in Figure 3. The aortic expansion rates were not significantly different between BAV and TAV ($P = .10$, Table 3), or among stenosis, regurgitation, and mixed stenoregurgitation of the aortic valves ($P = .084$). Furthermore, there was no significant correlation between initial maximal aortic diameter and aortic expansion rate ($\gamma = -0.31$, $P = .61$, Figure 4). Five patients (1.7%) showed an aortic expansion rate of more than 5 mm/y, and all of these patients had TAV, with a maximal aortic diameter of 40 to 43 mm at baseline. At the end of follow-up, 2 patients (0.7%, 1 with BAV and 1 with TAV, whose condition was complicated with aortic dissection) showed an aorta diameter of more than 60 mm. The patient with BAV (a 72-year-old man) was recommended to undergo aorta replacement at 6 years after initial surgery, but he refused the surgery and is receiving conservative management.

In the wrapping group (echocardiographic follow-up: n = 54), the aortic expansion rate was −2.1 mm/y (IQR, −3.9 to −0.9 mm/y) and the maximal diameter of the ascending aorta at last follow-up was 39.8 ± 5.8 mm. None of the patients in the wrapping group showed rapid aortic expansion (>5 mm/y) or definite aneurysm formation of the ascending aorta (>55-60 mm).

DISCUSSION

In the present study, we found that adverse aortic events were rare after AVR alone (0.5% per patient-year)



No. of patients					
Aorta ≥ 45mm	102	74	41	26	13
Aorta < 45mm	260	190	111	51	27

FIGURE 2. Kaplan-Meier survival curves of patients who underwent isolated aortic valve replacement (n = 362) according to the ascending aortic diameter at baseline.

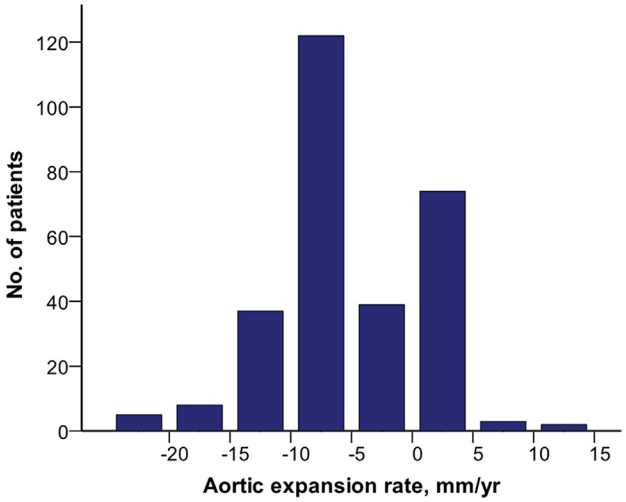


FIGURE 3. Frequency distribution of aortic expansion rate during follow-up.

TABLE 3. Preoperative and postoperative data of patients who underwent aortic valve replacement alone according to the baseline aortic valve morphology

Variables	BAV (n = 139)	TAV (n = 223)	*P* value
Preoperative profiles			
Aortic valve disease, no. (%)			<.001
AS	84 (60.4)	58 (26.0)	
AR	24 (17.3)	117 (52.5)	
Mixed ASR	31 (22.3)	47 (21.1)	
No AS or AR	0	1 (0.4)	
Maximal aorta diameter, mm	43.1 ± 2.6	43.1 ± 3.0	.90
≥40, <45	100 (71.9)	160 (72.1)	
≥45, <50	35 (25.2)	53 (23.9)	
50-55	4 (2.9)	9 (4.1)	
Postoperative profiles			
Maximal aorta diameter at last visit, mm	40.0 ± 6.0	41.4 ± 7.9	.10
Aortic expansion rate, mm/y	−1.3 (−3.0 to 2.1)	−0.6 (−1.7 to 1.9)	.10

BAV, Bicuspid aortic valve; *TAV*, tricuspid aortic valve; *AS*, aortic stenosis; *AR*, aortic regurgitation; *ASR*, aortic stenoregurgitation.

in patients with a dilated ascending aorta (40-55 mm), and the overall survival was not affected by the aortic diameter at baseline. When patients were assessed by serial echocardiography, clinically relevant aneurysm formation or rapid expansion of the aorta was also rare, and the aortic expansion rates did not significantly correlate with any of the following: morphology (TAV vs BAV) or valvulopathy (stenosis vs regurgitation) of the aortic valves and the aortic diameter at baseline. Furthermore, the aortic wrapping technique was also helpful in stabilization of the aorta, with excellent long-term durability. Nevertheless, safety profiles of ascending aorta replacement during AVR were also acceptable, supporting more liberal choices of aorta management based on the individual patient's conditions (ie, expected surgical risks and life expectancy).

According to practice guidelines pertaining to the management of ascending aorta during AVR, patients with ascending aorta of greater than 45 mm should be considered for concomitant replacement of the ascending aorta.[4,5] Reviewing the reference supporting this recommendation, only a single observational study exists.[3] In the cited study, the authors retrospectively reviewed 201 patients who underwent AVR for BAV without aortic replacement. Of the 201 patients, 64 had mild dilatation (40-44 mm) and 22 had moderate dilatation (45-49 mm) of the ascending aorta. Because the authors learned that the 15-year freedom from ascending aorta–related complications was 86%, 81%, and 43% in patients with an aortic diameter of less than 40 mm, 40 to 44 mm, and 45 to 49 mm, respectively ($P < .001$), they concluded that patients undergoing surgery for BAV disease should be considered for concomitant replacement of the ascending aorta if the diameter is 45 mm or greater. This cutoff value of "45 mm" has been firmly accepted as touchstone in the management of ascending aorta during AVR, and this suggestion was

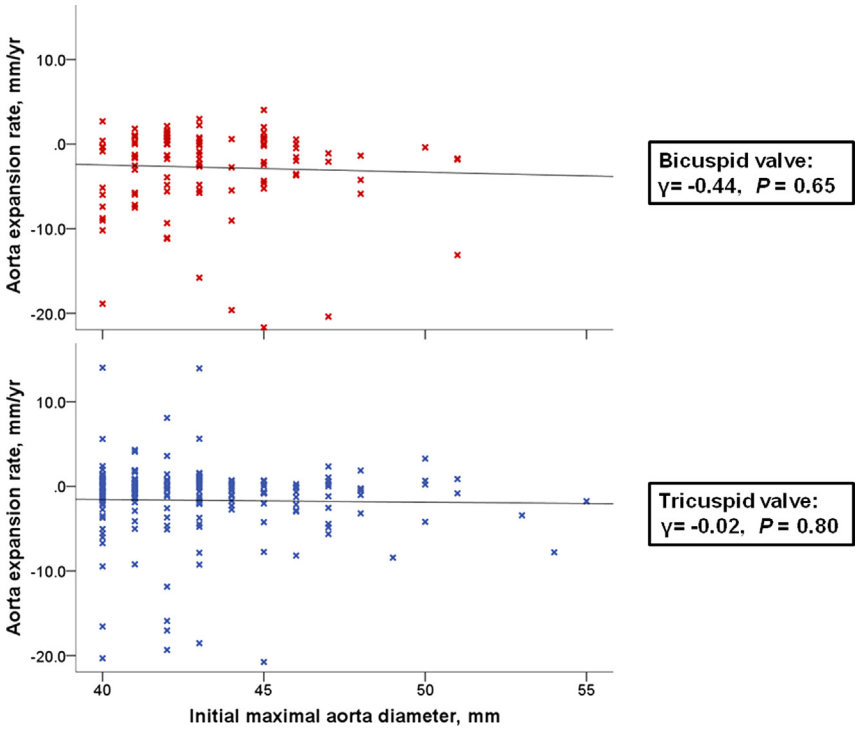


FIGURE 4. Aortic expansion rate according to the initial maximal diameter of the ascending aorta.

reinforced by several studies on intrinsic aortopathy in AV diseases.[6-9] In those studies, aortic dilatation is attributable to hemodynamic turbulence caused by AV disease and intrinsic abnormality of the aortic wall; thus, the aorta is likely to further expand, even after correction of AV diseases. The size-derived guidelines extended to AVR in TAV, but no pertinent data available to date are in support of this recommendation in TAV.

These size-derived current guidelines, however, are limited by weaknesses of the key citing research, in that despite the strength of long-term follow-up data, the results are derived from retrospective observational data including only a few patients in a single center.[3] In particular, the number of patients with a moderately dilated ascending aorta (>45 mm) was only 22; the data are too small to form a robust conclusion. In this regard, there have been arguments on current practice guidelines that they should be reevaluated through better data analysis, considering the risk and benefit of concomitant replacement of the aorta.[10,12-14]

More recent studies raised contradictions on routine replacement of dilated ascending aorta during AVR.[10-13] Gaudino and colleagues[13] evaluated 93 patients with dilation of the ascending aorta (50-59 mm) submitted to AVR alone for TAV stenosis. Patients were observed for a mean of 14.7 ± 4.8 years, and no patients experienced adverse aortic events or had to have the aorta reoperated on. Furthermore, there was no significant increase in aortic diameter, with a mean ascending aorta expansion rate of 0.3 ± 0.2 mm/y. The authors concluded that AVR alone is sufficient in patients with poststenotic dilation of the ascending aorta if connective tissue disorders are not present. Nevertheless, leaving the aorta of nearly 60 mm in diameter during AVR may be regarded as neither reasonable nor safe by most practicing surgeons because the aortic size of 55 mm or greater is regarded as a surgical indication by itself, even in asymptomatic subjects with an isolated ascending aorta aneurysm.

McKellar and colleagues[10] retrospectively reviewed 1286 patients who underwent AVR for BAV without aortic replacement or repair. During a median follow-up of 12 years, there were aortic dissections in 1%, ascending aortic replacements in 0.9%, and documented cases of progressive aortic enlargement in 9.9%, resulting in 15-year freedom from adverse aortic events of 89%. Of the patients, quantitative data on preoperative ascending aorta size were available in 323, of whom 248 had a normal aorta (<40 mm), whereas 75 had a dilated ascending aorta (>40 mm). When compared with those with a normal aorta, the patients with a dilated aorta showed similar risks of adverse aortic events ($P = .13$), overall mortality ($P = .67$), and cardiovascular mortality ($P = .32$). The authors concluded that, although there was a true risk for adverse aortic events after AVR for BAV, its incidence was low, and additional surgical risk imposed by concomitant aortic replacement should, therefore, be at least equally low.

In support of their study, Girdauskas and colleagues[12] conducted an analysis on 153 patients with BAV stenosis and concomitant ascending aortic dilation (40-50 mm) undergoing AVR alone. During a mean follow-up of 11.5 ± 3.2 years, surgery on the ascending aorta was required in 5 patients (3%) for progressive ascending aortic aneurysm, but no documented aortic dissection or rupture occurred. Freedom from adverse aortic events was 93% at 15 years postoperatively. The authors concluded that patients with BAV stenosis and concomitant mild-to-moderate ascending aortic dilation are at a considerably low risk of adverse aortic events during long-term follow-up after an isolated AVR. Andrus and colleagues[11] evaluated aortic expansion rates after isolated AVR in 185 patients, including both types of AV morphology (BAV and TAV). Dilatation of the ascending aorta (>35 mm; range, 35-53 mm) was present in 107 patients (58%) at baseline, and there was no significant increase in mean ascending aortic diameter (40 ± 4 vs 39 ± 6 mm) or development of aortic aneurysm (>55 mm) during follow-up in this subset of patients.

Recent studies previously cited are in support of a conservative approach in the management of a mild to moderately dilated ascending aorta during AVR, which are in agreement with the findings of the present study.[10-13] Moreover, the overall survival was not affected by the baseline aortic diameter (≥45 vs <45 mm) in patients undergoing isolated AVR in the present study, the result being discordant with the key citing reference in the current guidelines.[3] This needs to be verified by accumulation of further clinical data. Finally, agreeing with McKellar and colleagues,[10] the feasibility of concomitant replacement of the aorta should be evaluated through studies on a larger population, considering the early surgical risks and the long-term prophylactic benefits added by the aorta replacement.

Aortic dilatation associated with BAV diseases has been regarded as a result of a genetic disorder or inherited fragility, and this knowledge has led to recommendations that the proximal aorta in patients with BAV be replaced more aggressively.[6,8,9] In contrast, in a recent study, a cross-sectional analysis of echocardiographic data was undertaken in many patients (n = 595) with aortic valvulopathy, with longitudinal follow-up to evaluate the aortic expansion rates.[14] In the cited study, the annual dilatation rates of the ascending aorta were significantly higher in the patients with BAV not undergoing AVR compared with those undergoing AVR for BAV or TAV diseases. Furthermore, the aortic expansion rates did not differ between the BAV and TAV groups when treated with AVR. These findings of the protective effects of AVR in

patients with BAV indicate that valvular dysfunction is the major determinant of the development of aortopathy and, thus, the reevaluation of recommendations in current practice guidelines through better clinical investigations and better data analysis was claimed by the authors.

Although computed tomographic (CT) scanning is the gold standard method in the evaluation of the aorta, it inevitably accompanies radiation hazards and, therefore, its use as a tool for lifelong follow-up in patients with reasonable life expectancy has been limited.[15] Meanwhile, echocardiography is a well-proven modality in accurately measuring the size of the ascending aorta without such risks, which is highly correlated with values obtained by CT scans.[16] Reflecting this general consensus, echocardiographic data were available in most patients (82.8%) during the late period, whereas the data from CT assessments were limited to yield aortic expansion rate (<60% of follow-up) in the present study. Echocardiography measures internal diameters, whereas CT measures external diameters; therefore, some allowance should be made for echocardiographic measurements being smaller than CT measurements.[17]

Study Limitations

This study is subject to the limitations inherent to a retrospective analysis of observational data. The decision to perform procedures on the aorta was affected by patients' preoperative conditions, in which patients undergoing AVR alone tended to have TAV more frequently and to have a smaller aortic diameter than those undergoing concomitant aortic procedures. Moreover, only 14 patients who had an aortic diameter of more than 50 mm underwent AVR alone; therefore, statistical power regarding the evaluation of safety profile of AVR alone in this patient subset might have been limited to generalize the conclusion to those having a relatively larger aorta.

Aortic size measurements were made with transthoracic echocardiographic assessment, which is not the gold standard method in aortic evaluations. In particular, measurement variations may occur when the distal ascending aorta is evaluated. Limited durations of clinical and echocardiographic follow-up are also important limitations of this study. Not all patients could be assessed with echocardiography in the late period. Longitudinal echocardiographic assessments in these populations, however, are inevitably limited because a significant proportion of patients no longer need imaging assessments during follow-up. These are the cases with stabilization or regression in the aortic sizes in the AVR alone group (65.9%).

The number of early mortalities was too small to evaluate surgical risks added by the concomitant replacement of ascending aorta with adequate statistical power. The safety issue of concomitant aorta replacement should, therefore, be addressed in further studies involving larger populations.

CONCLUSIONS

Compared with concomitant aortic wrapping or replacement, AVR alone achieved similar clinical outcomes, showing considerably low risks of adverse aortic events or relevant aortic expansion in dilated ascending aorta. These findings argue against routine aortic replacement at the time of AVR. Further large-scale studies are mandatory to define proper indications of concomitant aorta replacement during AVR, considering the surgical risks and long-term benefits.

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Discussion

Dr Thoralf M. Sundt *(Boston, Mass)*. Congratulations on conducting what I think is an important study with profound clinical implications.

Aortic dissection is a highly lethal condition without doubt, and the results of aortic replacement have improved so much over the course of the last decade or so that we, as cardiac surgeons, and cardiac surgeons all around the world have become much more aggressive about replacing even the moderately dilated aorta. However, as you have pointed out, the data actually supporting that practice are pretty thin.

You have chosen to study a population of all patients undergoing aortic valve replacement who have moderate aortic dilatation, although this is most often discussed in the setting of bicuspid aortic valve. As you have noted, because BAV is so common, the recommendations we make concerning the management of patients with this condition turn out to impact a huge number of patients.

Your results suggest that we should be more circumspect, that the moderately dilated aorta need not be routinely replaced. This is an important and useful counterpoint to the current trend. I hope there will be a lot of discussion from the floor on this topic because I do think it is an important one.

There are some challenges in interpreting your study, however, and I would like to draw attention to several issues and ask several questions. First, it is challenging any time intellectually, mentally, when we are comparing 3, rather than just 2, treatment groups. You have compared the results of AVR alone, AVR with aortic replacement, and AVR with wrapping. In fact, in the West, aortic wrapping is seldom, if ever, practiced. In the view of most surgeons given modern graft material, aortic wrapping offers little advantage over the more definitive procedure of aortic replacement.

So with your permission, I would want to focus only on 2 groups, the groups that we would most commonly deal with in this country, AVR alone versus AVR with aortic replacement. That leaves us with 70 patients with aortic replacement and 362 who had AVR alone.

If you focus on these 2 groups, they are of similar age and similar functional valve pathology, but with female gender much more common among those with replacement, and BAV almost twice as common among those with aortic intervention.

Furthermore, the distribution of aortic diameter was actually much different between these 2 groups, with over 70% of the patients in the AVR-only group having aortas less than 45 mm compared with less than a third of those in the aortic intervention group having these small-sized aortas.

In fact, over one-third of the aortic replacement group had an aorta over 5 cm compared with 4% in the no-aortic intervention group.

So, my first question really is how do you see these 2 groups as comparable? Are you not really comparing the outcome of AVR alone with minimally enlarged aortas in the presence of a trileaflet valve versus AVR plus aortic replacement in BAV disease?

Dr Kim. Thank you, Dr Sundt, for your important question. I absolutely agree with you that maybe 3, and 2, groups are not fairly comparable because there were significant differences in baseline profiles in terms of aortic valve morphology and the size of the aorta.

However, the number of patients in the aorta replacement group was too small, 70 patients only. Therefore, an adequate statistical status method, including propensity score matching, was nearly impossible. We could only obtain less than 50 pairs of patients if you had a matching technique.

And furthermore, there was only 1 aortic event; therefore, multivariate analysis was also impossible. Therefore, our study may be better viewed as a study evaluating the later course of AVR alone in the moderately dilated ascending aorta, mostly in 40 to 50 mm in our data set, and the second aim may be the assessment of a safety profile of an additional aortic procedure.

Dr Sundt. I agree with you. I think that the most interesting group is actually the control group, the AVR-alone group.

Second, there were 13 patients with unknown cause of death. What happens to your analysis if you assume that all of these deaths were due to aortic complications? Do you come to the same conclusion?

Dr Kim. Thank you. Thirteen patients with unknown causes of death were regarded as cardiac deaths, and when we broke down the analysis according to the all-cause death and cardiac death, there were no significant differences among the 3 groups. So I believe the management strategy did not affect the survival.

Dr Sundt. And, third, there is significant controversy as to whether the dilated aorta associated with a bicuspid valve is size for size, diameter for diameter, fundamentally more prone to complications than the aorta associated with a trileaflet valve.

In your control group, you have 139 patients with BAV. You have shown what appears to be no difference in rate of growth, but just to emphasize the point, do you see in the control group any evidence for a difference in behavior at any given diameter between the aorta associated with a trileaflet valve or a bicuspid valve?

Dr Kim. That is an important point. We try to compare in terms of aortic events, aortic expansion rate, but we could not find any significant difference between tricuspid valves and bicuspid. Even when the analysis was broken down according to the aortic diameter, we did not find any significant difference between the 2 valve morphology types.

Dr Sundt. Thank you much because I think, regardless of what the histology shows and the theory may be, the bottom line always is the clinical behavior. And so we need these kinds of clinical data to really know whether we are doing the right thing for our patients. Thank you.

Dr Kim. Thank you very much.