Does the 45 mm Size Cutoff for Ascending Aortic Replacement Predict Better Early Outcomes in Bicuspid Aortic Valve?

Yi-Jia Li[1]   Wei-Guo Ma[2]   Yue Qi[3]   Jun-Ming Zhu[2]   Ya Yang[1]   Li-Zhong Sun[2]

[1] Department of Echocardiography, Beijing Anzhen Hospital, Capital Medical University, and Beijing Institute of Heart Lung and Blood Vessel Diseases, Beijing, China
[2] Department of Cardiovascular Surgery, Beijing Anzhen Hospital, Capital Medical University, and Beijing Institute of Heart Lung and Blood Vessel Diseases, Beijing, China
[3] Department of Epidemiology, Beijing Anzhen Hospital, Capital Medical University, and Beijing Institute of Heart Lung and Blood Vessel Diseases, Beijing, China

Address for correspondence Ya Yang, MD, Beijing Anzhen Hospital, Capital Medical University, Beijing, China
(e-mail: yangyaecho@gmail.com).

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Abstract

Background The aim of this study is to test if the newly proposed 45 mm size criterion for ascending aortic replacement (AAR) in bicuspid aortic valve (BAV) patients undergoing aortic valve replacement (AVR) is predictive of improved early outcomes.

Methods Data of 306 BAV patients with an aortic diameter of $\geq$45 mm undergoing AVR alone or with AAR were retrospectively analyzed. Patients were divided into groups of AVR + AAR ($n = 220$) and AVR only ($n = 86$) based on if surgery was performed according to the 45 mm criterion. End point was early adverse events, including 30-day and in-hospital mortality, cardiac events, acute renal failure, stroke, and reoperation for bleeding. Cox regression was used to assess if conformance to 45 mm criterion could predict fewer early adverse events.

Results AVR + AAR group had significantly higher postoperative left ventricular ejection fraction (LVEF) (0.59 ± 0.09 vs. 0.55 ± 0.11, $p = 0.006$) and longer cardiopulmonary bypass (CPB) time (128 vs. 111 minutes, $p = 0.002$). Early adverse events occurred in 45 patients (14.7%), which was more prevalent in the AVR-only group (22.1% vs. 11.8%, $p = 0.020$). Conformance to the 45 mm criterion predicted lower rate of early adverse events (hazard ratio [HR]: 0.53, 95% confidence interval [CI]: 0.28–0.98, $p = 0.042$). After adjustment for gender, age, AAo diameter, sinuses of Valsalva diameter, preoperative LVEF, Sievers subtypes, BAV valvulopathy, and CPB and cross-clamp times, conformance to the 45 mm size criterion still predicted lower incidence of early adverse events (HR: 0.37, 95% CI: 0.15–0.90, $p = 0.028$).

Conclusions This study shows that conformance to 45 mm size cutoff for preemptive AAR during aortic valve replacement in patients with BAV was not associated with increased risk for adverse events and may improve early surgical outcomes.

Keywords
► bicuspid aortic valve
► ascending aorta
► surgery
► aortic valve replacement
► surgical outcomes

Introduction

In patients with bicuspid aortic valve (BAV) undergoing aortic valve replacement (AVR), there is continued debate regarding the aortic diameter at which prophylactic ascending aortic replacement (AAR) should be performed.[1,2] Proponents of the 50 mm cutoff for AAR maintain that aortas in BAV patients with aortic diameter of 40 to 50 mm undergoing AVR do not dilate, with a low risk of aortic adverse events and mortality.[3–8] In addition, AVR + AAR is associated with increased risk of mortality, neurologic, and cardiac events,[9,10] which should be balanced against the benefits of AAR to prevent late complications. A recent American Association for Thoracic Surgery (AATS) Consensus Guidelines on BAV-Related Aortopathy proposed that concomitant AAR be performed when aortic diameter was ≥45 mm in BAV patients undergoing AVR (Class IIa, Level of Evidence B).[11] In this study, we seek to evaluate whether the 45 mm size criterion for ascending aortic replacement in BAV patients undergoing AVR was associated with lower surgical risks and improved early outcomes.

Methods

Ethical Statement

The Ethics Committees of Beijing Anzhen Hospital of Capital Medical University approved submission and publication of this work and waived the need for informed patient consent (No. 2017015A; October 2017).

Patients

From January 2008 to December 2017, 658 patients with BAV underwent surgical treatment in our institution. Of these, 306 patients with a diameter of the sinuses of Valsalva [SOV] and/or ascending aorta (AAo) of ≥45 mm underwent AVR alone or with AAR. BAV patients with aortic dissection, congenital heart disease, Behçet and other autoimmune diseases, and connective tissue disorders were excluded. Patients were divided into two groups: AVR + AAR (n = 220) and isolated AVR (n = 86), based on if surgery was performed in consistence with the 45 mm criterion. In some patients with fusiform AAo aneurysms, a reduction aortoplasty with or without external wrapping of the AAo was performed as described by Robicsek previously.[12]

Data Collection

BAV morphology was evaluated by transthoracic echocardiography preoperatively and confirmed by surgical findings. BAV was diagnosed by parasternal long- and short-axis views, showing the existence of only two commissures in systole. Measurement was based on the American Society of Echocardiography guidelines.[13,14] The Sievers classification scheme was used to categorize BAV morphologies and to distinguish BAV from degenerative fusion of tricuspid aortic valve cusps.[15]

BAV valvulopathy was classified as moderate-to-severe stenosis (m-s-AS), regurgitation (AR) ≥ 2$^+$, or both (m-s-AS + AR ≥ 2$^+$). The degrees of AS and AR were evaluated according to the European Society of Cardiology and European Association for Cardio-Thoracic Surgery Guidelines for the management of valvular heart disease.[16] The diameters of the SOV and AAo were measured using the leading edge-to-leading edge technique in parasternal long-axis view perpendicular to the centerline of aorta. Dilatation of SOV and AAo was defined as a diameter of ≥40 mm. BAV aortopathy was classified as isolated root dilatation (including SOV, aortic valve, and coronary ostia), isolated AAo dilatation, and diffuse dilatation involving root and AAo.[17]

Statistical Analysis

Continuous variables are expressed as mean ± standard deviation or median (interquartile range). Categorical variables are expressed as number (percentage). Comparison was made using unpaired Student's t test or Mann–Whitney U test or one-way analysis of variance for continuous variables and chi-squared test or Fisher's exact test for categorical variables.

The study end point was early adverse events (EAE), including in-hospital and 30-day mortality, cardiovascular events (myocardial infarction, ventricular tachycardia or fibrillation, acute heart failure, use of circulatory support devices), acute kidney injury, stroke, and reoperation for bleeding. The impact of conformance to the 45 mm size criterion on EAE was assessed using proportional Cox hazard models. Adjusted candidate variables are confounding factors that either have been reported more than once with an effect on postoperative EAE[18,19] or exhibited significance in univariate analysis, including gender, age, diameters of SOV and AAo, preoperative left ventricular ejection fraction (LVEF), times of cardiopulmonary bypass (CPB) and aortic cross-clamp, Sievers types, and types of BAV valvulopathy.

Propensity score matching was performed to confirm the impact of conformance to the 45 mm criterion on EAE. A propensity score was first calculated by a logistic regression model based on gender, age, diameters of the SOV and AAo, preoperative LVEF, CPB and cross-clamp times, Sievers types, and types of BAV valvulopathy. Patients with AVR + AAR and isolated AVR were then matched at a 1 to 1 ratio by propensity score using nearest-neighbor matching without replacement, with a caliper of 0.02. Baseline characteristics and in-hospital management between the two propensity-matched subsets were recompared. As some characteristics did not exactly match between two groups even after propensity matching, multivariable logistic regression was performed to compare the risk by adjusting factors eventually included in the whole study population by stepwise selection. Specifically, a cutoff value at 45 mm for AAR was adopted to determine whether this size criterion was associated with decreased surgical risks and predicted improved early outcomes.

Statistical analysis was performed using SAS 9.4 (SAS Inc., Cary, North Carolina, United States) and Stata 15.1 for Mac (Stata, College Station, Texas, United States). All tests were two-sided and a p-value of < 0.05 was considered statistically significant.

Results

Baseline Characteristics

Mean age was 52.2 ± 11.3 years and 243 were men (73.3%). The SOV diameter averaged 38.2 ± 7.5 mm preoperatively. Preoperative AAo diameter was 49.7 ± 6.0 mm and ≥ 50mm in 47.1% (144/306). The mean preoperative LVEF was 0.61 ± 0.09. AR $\geq 2^+$ was seen in 128 (41.8%), m–s-AS in 110 (35.9%), and m-s-AS $+$ AR $\geq 2^+$ in 68 (22.2%). Aortopathy included isolated AAo dilatation in 188 (61.4%), diffuse dilatation in 110 (35.9%), and isolated root dilatation in 8 (2.6%) (►**Table 1**).

Age, gender, SOV diameter, LVEF, the Sievers types, BAV valvulopathy, and aortopathy did not differ significantly between two groups ($p > 0.05$). Compared with those undergoing AVR $+$ AAR, patients with isolated AVR had significantly smaller AAo diameter (46.5 ± 2.7 vs. 51.0 ± 6.5 mm, $p < 0.001$) and were less likely to have an AAo of ≥ 50 mm (7.6 vs. 92.4%, $p < 0.001$) (►**Table 1**).

Clinical Characteristics, Valvulopathy, and Aortopathy by Sievers Types

Sievers type 1 L–R was most common, seen in 62.4%, followed by type 0 (20.3%), type 1 R-N (14.7%), and type 1 L–N (2.7%)

Table 1 Baseline characteristics

Variables	Total ($n = 306$, %)	AAR $+$ AVR ($n = 220$, %)	AVR only ($n = 86$, %)	*p*-Value
Age, y	52.2 ± 11.3	52.0 ± 11.1	52.4 ± 11.9	0.785
Male, *n* (%)	243 (73.3)	180 (81.8)	63 (73.3)	0.096
Body surface area, m^2	1.8 ± 0.2	1.8 ± 0.2	1.8 ± 0.2	0.175
Systolic blood pressure, mm Hg	124.9 ± 16.3	124.8 ± 17.2	125.2 ± 14.0	0.850
Diastolic blood pressure, mm Hg	72.1 ± 12.7	72.5 ± 12.6	71.1 ± 12.7	0.381
Coronary artery disease, *n* (%)	33 (10.8)	23 (10.5)	10 (11.6)	0.766
Blood lipid, mmol/L				
Triglyceride	1.3 (0.9, 1.8)	1.3 (0.9, 1.9)	1.2 (0.9, 1.7)	0.722
Total cholesterol	4.3 (3.8, 5.0)	4.3 (3.8, 4.9)	4.4 (3.8, 5.1)	0.470
High-density lipoprotein	1.1 (0.9, 1.3)	1.1 (0.9, 1.3)	1.1 (0.9, 1.4)	0.506
Low-density lipoprotein	2.7 (2.1, 3.1)	2.7 (2.1, 3.1)	2.7 (2.1, 3.2)	0.739
Echocardiography				
SOV diameter, mm	38.2 ± 7.5	38.6 ± 8.1	37.1 ± 5.9	0.063
AAo diameter, mm	49.7 ± 6.0	51.0 ± 6.5	46.5 ± 2.7	<0.001
AAo diameter ≥ 50 mm, *n* (%)	144 (47.1%)	133 (92.4)	11 (7.6)	<0.001
LVEDD, mm	57.5 ± 11.5	57.2 ± 11.2	58.4 ± 12.4	0.408
LVESD, mm	38.6 ± 10.0	38.2 ± 9.6	39.7 ± 11.0	0.250
LVEF	0.61 ± 0.09	0.61 ± 0.08	0.61 ± 0.09	0.772
BAV Sievers subtypes, *n* (%)				0.772
Type 0	62 (20.3)	42 (19.1)	20 (23.3)	
Type 1 L-R	191 (62.4)	141 (64.1)	50 (58.1)	
Type 1 R-N	45 (14.7)	31 (14.1)	14 (16.3)	
Type 1 L-N	8 (2.6)	6 (2.7)	2 (2.3)	
BAV valvulopathy, *n* (%)				0.699
Moderate-to-severe stenosis (AS)	110 (35.9)	80 (36.4)	30 (34.9)	
Aortic regurgitation (AR) $\geq 2^+$	128 (41.8)	89 (40.5)	39 (45.3)	
AS $+$ AR $\geq 2^+$	68 (22.2)	51 (23.2)	17 (19.8)	
BAV aortopathy, *n* (%)				0.271
Root dilation only	8 (2.6)	6 (2.7)	2 (2.3)	
AAo dilation only	188 (61.4)	129 (58.6)	59 (68.6)	
Diffuse dilatation	110 (35.9)	85 (38.6)	25 (29.1)	

Abbreviations: AAR, ascending aortic replacement; AVR, aortic valve replacement; BAV, bicuspid aortic valve; SOV, sinuses of Valsalva; AAo, ascending aorta; LVEDD, left ventricular end-diastolic dimension; LVESD, left ventricular end-systolic dimension; LVEF, left ventricular ejection fraction.
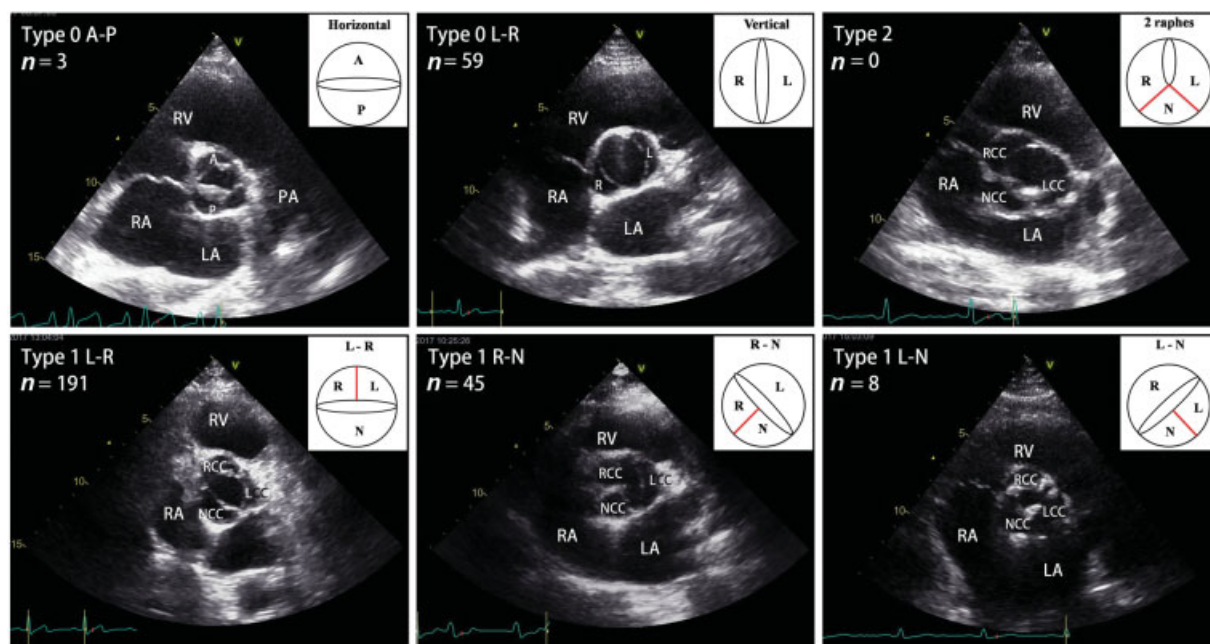
Fig. 1 Sievers types of bicuspid aortic valvulopathy in 306 patients. LA, left atrium; LCC, left coronary cusp; NCC, noncoronary cusp; PA, pulmonary artery; RA, right atrium; RCC, right coronary cusp; RV, right ventricle.

(►Table 1; ►Fig. 1). Age, gender, coronary artery disease, and AAo diameter and LVEF did not differ significantly among Sievers subtypes ($p > 0.05$). Patients with type 0 had higher systolic and diastolic blood pressures (127.1 ± 18.1 and 76.6 ± 12.2 mm Hg) compared with other types ($p < 0.05$). The SOV size was largest in type 1 L–R (39.4 ± 7.8 mm), followed by type 0 (36.6 ± 6.5 mm), type 1 L–N (36.3 ± 7.5 mm), and type 1 R–N (35.6 ± 6.7 mm) ($p = 0.009$) (►Table 2).

The incidences of valvulopathy ($p = 0.019$) and aortopathy ($p = 0.019$) differed significantly among Sievers subtypes. m-s-AS was most common in patients with type 0 (51.6%). Compared with other types, patients with type 1 L–R were more likely to have AR $\geq 2^+$ (48.2%), isolated root dilatation (3.7%), and diffuse dilatation (42.9%), but less likely to have moderate-to-severe AS + AR $\geq 2^+$ (19.4%) and isolated AAo dilatation (53.4%). Type 1 R–N patients had the highest rate of isolated AAo dilatation (77.8%) and no isolated root dilatation. Moderate-to-severe + AR $\geq 2^+$ was most prevalent in type 1 L–N (37.5%). In patients with type 1 L–N, the proportions of m–s-AS (25%) and AR $\geq 2^+$ (25%) were lowest and none had isolated root dilatation (►Table 2).

Operative Data
The size of the aortic valve prostheses averaged 23.2 ± 1.8 mm and did not differ significantly between two groups (23.4 ± 1.9 vs. 22.9 ± 1.7 mm, $p = 0.051$). The median CPB and cross-clamp times were 122 and 84 minutes, respectively. Circulatory arrest was used in 27 patients (12.5%) of the group undergoing AAR + AVR, with a mean duration of 16 ± 7 minutes (median, 15; range: 7–33). The AVR + AAR group had significantly longer CPB time (128 vs. 111 minutes, $p = 0.002$) and higher postoperative LVEF (0.59 ± 0.09 vs. 0.55 ± 0.11, $p = 0.006$) (►Table 3).

Early Adverse Events
EAE occurred in 45 patients (14.7%), which was significantly higher in isolated AVR group (22.1 vs. 11.8%, $p = 0.020$). Operative mortality was 2.0% (6/306), which did not differ between two groups (1.4 vs. 3.5%, $p = 0.335$). Operative complications included ventricular tachycardia or fibrillation in 18 (5.9%), acute heart failure in 9 (2.9%), use of extracorporeal membrane oxygenation (ECMO) or intra-aortic balloon pump (IABP) in 5 (1.6%), acute myocardial infarction in 1 (0.3%), acute kidney injury in 2 (0.7%), stroke in 3 (1.0%), and reoperation for bleeding in 22 (7.2%) (►Table 4).

Impact of Aortic Size Criterion on Early Adverse Outcomes
Cox regression models showed that conformance to the 45 mm size criterion for preemptive AAR during AVR was associated with lower rate of early adverse events (hazard ratio [HR] 0.53, 95% confidence interval [CI]: 0.28–0.98, $p = 0.042$). Age (in years) was identified as a risk factor for EAE (HR: 1.04, 95% CI: 1.01–1.07, $p = 0.011$; adjusted HR 1.05, 95% CI: 1.01–1.09, $p = 0.048$). After gender, age, SOV and AAo diameter, preoperative LVEF, Sievers types, BAV valvulopathy, and CPB and cross-clamp times were adjusted, conformance to the 45 mm size criterion for AAR was still predictive of lower EAE rates in the 71 matched pairs (HR: 0.37, 95% CI: 0.15–0.90, $p = 0.028$) (►Table 5).

Discussion
Whether prophylactic AAR would reduce the risk of subsequent aortic dissection or reoperation and the timing of AAR in patients with BAV continues to be debated. Main arguments against preemptive AAR during AVR for BAV patients with moderately dilatated aorta include the increased

Table 2 Clinical characteristics, valvulopathy, and aortopathy stratified by Sievers subtypes

Variables	Type 0 (n = 62, %)	Type I L–R (n = 191, %)	Type I R–N (n = 45, %)	Type I L–N (n = 8, %)	p-Value
Age, y	52.6 ± 11.6	55.2 ± 11.4	51.4 ± 11.3	51.6 ± 9.5	0.938
Male, n (%)	49 (79.0)	154 (80.6)	34 (75.6)	6 (75.0)	0.877
Body surface area, m^2	1.8 ± 0.2	1.8 ± 0.2	1.8 ± 1.2	1.7 ± 0.2	0.293
Systolic blood pressure, mm Hg	127.1 ± 18.1	124.8 ± 15.5	125.3 ± 16.5	107.4 ± 11.3	0.016
Diastolic blood pressure, mm Hg	76.6 ± 12.2	70.6 ± 12.6	72.2 ± 12.7	71.5 ± 9.7	0.010
Coronary artery disease, n (%)	9 (14.5)	18 (9.4)	6 (13.3)	0 (0)	0.525
Echocardiography					
SOV diameter, mm	36.6 ± 6.5	39.4 ± 7.8	35.6 ± 6.7	36.3 ± 7.5	0.009
AAo diameter, mm	50.3 ± 5.1	50.0 ± 4.9	50.0 ± 4.9	49.1 ± 3.2	0.453
AAo diameter ≥ 5 cm, n (%)	34 (54.8)	83 (43.5)	22 (48.9)	5 (62.5)	0.344
LVEDD, mm	55.4 ± 11.8	57.8 ± 10.6	57.8 ± 10.6	54.1 ± 12.9	0.168
LVESD, mm	36.8 ± 9.9	38.0 ± 8.8	38.0 ± 8.8	37.9 ± 12.0	0.267
LVEF	0.62 ± 0.09	0.62 ± 0.07	0.62 ± 0.07	0.58 ± 0.09	0.228
BAV valvulopathy, n (%)					0.019
Moderate-to-severe stenosis (AS)	32 (51.6)	62 (32.5)	13 (28.9)	2 (25.0)	
Regurgitation (AR) ≥ 2$^+$	17 (27.4)	92 (48.2)	17 (37.8)	2 (25.0)	
AS + AR ≥ 2$^+$	13 (21.0)	37 (19.4)	15 (33.3)	3 (37.5)	
BAV aortopathy, n (%)					0.019
Root dilation only	1 (1.6)	7 (3.7)	0 (0.0)	0 (0.0)	
AAo dilation only	45 (72.6)	102 (53.4)	35 (77.8)	6 (75.0)	
Diffuse dilatation	16 (25.8)	82 (42.9)	10 (22.2)	2 (25.0)	

Abbreviations: AAo, ascending aorta; BAV, bicuspid aortic valve; LVEDD, left ventricular end-diastolic dimension; LVESD, left ventricular end-systolic dimension; LVEF, left ventricular ejection fraction; SOV, sinuses of Valsalva.

Table 3 Operative and postoperative data

Variables	Total (n = 306, %)	AVR + AAR (n = 220, %)	AVR only (n = 86, %)	p-Value
Operative				
Size of aortic valve prostheses, mm	23.2 ± 1.8	23.4 ± 1.9	22.9 ± 1.7	0.051
Cardiopulmonary bypass time, min	122 (100, 160)	128 (103, 166)	111 (88, 141)	0.002
Aortic cross-clamp time, min	84 (64, 108)	85 (65, 109)	78 (60, 103)	0.192
Coronary artery bypass grafting, n (%)	28 (9.2)	17 (7.7)	11 (12.8)	0.167
Hemiarch replacement, n (%)	42 (13.7)	42 (19.1)	0 (0)	<0.001
Postoperative				
Length of intensive care unit stay, hour	21 (18, 26)	21 (19, 26)	21 (17, 30)	0.456
Lengths of hospital stay, day	8 (6, 11)	8 (7, 11)	7 (6, 11)	0.036
Early adverse events, n (%)	45 (14.7)	26 (11.8)	19 (22.1)	0.020
Postoperative LVEF	0.58 ± 0.1	0.59 ± 0.09	0.55 ± 0.11	0.006
Postoperative LVEF < 0.5, n (%)	48 (15.7)	27 (12.3)	21 (24.4)	0.009

Abbreviations: AVR, aortic valve replacement; AAR, ascending aortic replacement; LVEF, left ventricular ejection fraction.

Table 4 Early adverse events

Variables	Total (n = 306, %)	AVR + AAR (n = 220, %)	AVR only (n = 86, %)	p-Value
Early adverse events, n (%)	45 (14.7)	26 (11.8)	19 (22.1)	0.020
Operative mortality, n (%)	6 (2.0)	3 (1.4)	3 (3.5)	0.355
Operative complications, n (%)				
Myocardial infarction	1 (0.3)	1 (0.5)	0 (0)	1.000
Ventricular arrhythmia	18 (5.9)	9 (4.1)	9 (10.5)	0.054
Acute heart failure	9 (2.9)	6 (2.7)	3 (3.5)	0.723
Use of ECMO or IABP	5 (1.6)	2 (0.9)	3 (3.5)	0.137
Acute kidney injury	2 (0.7)	1 (0.5)	1 (1.2)	0.484
Stroke	3 (1.0)	2 (0.9)	1 (1.2)	1.000
Reoperation for bleeding	14 (4.6)	7 (3.2)	7 (8.1)	0.073

Abbreviations: AVR, aortic valve replacement; AAR, ascending aortic replacement; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump.

Table 5 Predictors of early adverse events based on the 45 mm size cutoff

Risk factors	Hazard ratio (95% confidence interval), p-Value			
	Unadjusted analysis		Adjusted analysis	
	Univariate	Multivariate	Univariate	Multivariate
Conformance to 45 mm size cutoff	0.46 (0.23–0.93), 0.031	0.53 (0.28–0.98), 0.042	0.35 (0.14–0.89), 0.028	0.37 (0.15–0.90), 0.028
Age, y	1.03 (0.99–1.06), 0.141	1.04 (1.01–1.07), 0.011	1.03 (0.98–1.09), 0.264	1.05 (1.01–1.09), 0.048
Systolic blood pressure, mm Hg	1.00 (0.98–1.02), 0.977	0.37 (0.15–0.90), 0.028	1.00 (0.96–1.03), 0.785	
Total cholesterol, mmol/L	1.14 (0.86–1.52), 0.367	1.05 (1.01–1.09), 0.048	1.19 (0.81–1.74), 0.370	
Aortic cross-clamp time, min	1.01 (1.00–1.02), 0.007	1.01 (1.01–1.02), 0.001	1.01 (1.00–1.02), 0.221	

operative risk, the insignificant difference in long-term mortality between patients underwent AVR alone or with AAR, and the low risks of adverse aortic events or expansion in dilated AAo after AVR.[4,5,7] However, increasing data have emerged in support of a smaller size criterion for preemptive AAR during AVR in BAV patients. Reece et al reported similar 30-day mortality rates with isolated and AAR + AVR (3.8 vs. 2.7%), suggesting that AAR poses no further risk to BAV patients beyond isolated AVR.[9] In a series comparing 1,449 patients undergoing BAV surgery alone (AAo < 46 mm in 95%) to 361 patients undergoing valve surgery + AAR (AAo ≥41 mm in 80%), similar in-hospital 30-day survival (98.8 vs. 98.9%) and stroke rates (1.7 vs. 1.3%) were reported.[20] In 456 patients with BAV, Rinewalt et al found no increase in morbidity or mortality when adding AAR for patients with aortic diameter of 45–49 mm: while the 30-day mortality was 0.8% in those with isolated AVR and aortic diameter of <45 mm, the mortality rates were 0 and 1.9% with AVR +

AAR for those with aortic diameter of 45–49 and ≥50 mm, respectively.[21] The landmark research by Borger and associates proved the need for reintervention when AVR alone was performed in the setting of a moderately dilated aorta,[22] based on which an aortic diameter of 45 mm has been adopted as a criterion for concomitant AAR during AVR for BAV patients.

In the 2018 AATS guidelines, it is recommended that concomitant repair of the AAo or root should be performed when the aortic diameter is 45 mm or greater during AVR for patients with BAV.[11] In this context, the present study has validated the efficacy and appropriateness of the 45 mm size criterion of 45 mm with respect to the risk of early mortality and morbidity. In this cohort, the mean AAo sizes were 51.0 and 46.7 mm in the AVR + AAR and isolated AVR groups, respectively. The two groups showed similar rates of in-hospital 30-day survival (98.6 vs. 96.5%) and stroke (0.9 vs. 1.2%), while the AVR only group sustained more EAE (22.1 vs.

11.8%). Most importantly, propensity-adjusted analysis showed that conformance to the 45 mm criterion for AAR in BAV patients undergoing AVR was predictive of lower rates of EAE. These results show that in this cohort of BAV patients with an aortic diameter of ≥45 mm, performing an AAR during AVR based on the 45 mm cutoff was not associated with increased early mortality and morbidity, suggesting that conformance to the 45 mm size cutoff may lead to improved early surgical outcomes.

In this cohort, 86 patients who underwent an isolated AVR experienced higher rates of EAE. Although these patients were comparable to the AAR + AVR group in baseline characteristics (►**Table 1**), these patients may be more severe with respect to other preoperative factors that were not included in the propensity score matching, such as smoking, obesity, diabetes, frailty, chronic renal or hepatic insufficiency, chronic obstructive pulmonary disease, endocarditis, atrial fibrillation, mitral regurgitation, and family history of aortic dissection.[19,23,24] These risk factors for adverse outcomes may have led the surgeons to avoid the aortic procedure and choose an isolated AVR, which is one of the reasons for the worse early outcomes in patients undergoing an isolated AVR.

While current guidelines and most researches on BAV aortopathy are mainly based on evidence derived from Caucasians, only a few of studies are available on the ethic differences in morphology, valvulopathy, and aortopathy of BAV patients in China or Asia.[25–27] A recent study shows that Asians have higher prevalence of type 1 of BAV (67%), larger SOV and AAo body surface area-indexed diameter compared with Europeans (19.6 vs. 18.1 and 20.7 vs. 19.7 mm/m^2, all $p < 0.001$),[25] which may lead to the different threshold for surgical repair of bicuspid aortopathy. In this cohort, BAV patients were relatively young (mean age: 52.2 years) and type 1 L–R was prevalent (62.4%). AR ≥ 2$^+$ was most common in type 1 L–R (48.2%); AS was most prevalent in type 0 (51.6%), while type 1 L–N had the highest incidence of m-s-AS + AR ≥ 2$^+$ (37.5%). Isolated root dilatation was relatively rare, most frequent in type 1 L–R (3.7%). Isolated AAo dilatation and diffuse dilatation were most common in type 1 R–N (77.8%) and type 1 L–R (42.9%), respectively. These data show the features of valvulopathy and aortopathy among different Sievers subtypes, which may help illustrate the phenotypes of BAV in the Chinese or Asian population.

This study is limited by its retrospective nature, the small sample size, and the lack of long-term follow-up. Because different surgeons who may use different size criteria, a selection bias cannot be ruled out in which an AVR was performed on some more severe patients who should have been treated with AAR + AVR. Although the two groups were propensity matched in baseline characteristics, other important factors affecting surgical decision making and operative outcomes,[19] such as AAo growth rate ≥5 mm/year, family history,[23,24] mitral regurgitation, preoperative atrial fibrillation, diabetes, and chronic renal disease, were not included in the propensity score matching. It is questionable if the sample size is able to show a noninferiority outcome given these potential biases. Lack of long-term follow-up data

precludes the possibility of assessing if the 45 mm size criterion was associated with improved long-term outcomes concerning survival, reoperation, and adverse events. Furthermore, this study represents our single-center experience only and further validation of the 45 mm size criterion in multicenter settings is warranted.

Conclusions

This study shows that conformance to the 45 mm size cutoff for preemptive ascending aortic replacement during AVR in BAV patients was not associated with increased risk for EAE, which suggests that the size criterion for prophylactic ascending aortic replacement may need to be lowered to 45 mm in such patients to improve early surgical outcomes.

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Authors have nothing to disclose with regard to commercial support and source of funding.

Conflict of Interest
None declared.

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