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Aorta: Short Report

Trends and Outcomes of Aortic Root Enlargement During Bioprosthetic Aortic Valve Replacement

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ABSTRACT

BACKGROUND Aortic root enlargement (ARE) during aortic valve replacement (AVR) mitigates prosthesis–patient mismatch, but its use has been low. Transcatheter aortic valve-in-valve (VIV) as a treatment for failing bioprosthetic valves is limited by small surgical valves, renewing interest in ARE during the index AVR. This study demonstrates trends and outcomes of ARE after commercial approval of VIV in 2015.

METHODS This retrospective cohort study analyzed 2182 patients undergoing nonemergent AVR between August 2007 and December 2022. Endocarditis, aortic dissection, and concomitant root replacement or ventricular assist device placement were excluded. Trends in ARE use, valve size, and types were compared. Outcome measures included 30-day mortality and gradients and were compared between patients with and without ARE.

RESULTS Overall, 74 patients (3.4%) underwent ARE, 14 (1.0%) before 2015 and 60 (7.6%, $P < .0001$) after 2015. Use of smaller valves (19–21 mm) decreased from 372 (26.8%) before 2015 to 85 (10.7%, $P < .0001$) after 2015. ARE group was younger than the AVR-alone group (64 vs 68 years, $P = .001$) but had similar predicted risk of mortality (median, 1.7%). Both groups had comparable postoperative mean gradients (ARE: 11 vs AVR-alone: 10 mm Hg, $P = .42$). ARE had higher 30-day mortality (5 [7%] vs 48 [2%], $P = .014$); however, no difference was found in elective patients (2 of 65 [3%] vs 39 of 1898 [2%], $P = .57$).

CONCLUSIONS ARE use has increased since commercial approval of VIV. The addition of ARE to AVR did not affect early safety in elective cases, and postoperative gradients were similar to those in patients not requiring ARE. Further studies are required to determine long-term outcomes after ARE, including VIV candidacy.

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Aortic root enlargement (ARE) can be performed at the time of aortic valve replacement (AVR) to accommodate larger valve sizes. ARE requires the surgeon to dissect the aortic root and reconstruct the annulus with varying levels of complexity. Traditionally, ARE was reserved for patients with small aortic roots at risk of prosthesis-patient mismatch (PPM), which

IN SHORT

- Surgical aortic valve replacement with root enlargement is safe, and its utility is increasing.
- Surgical aortic valve replacement with root enlargement allows for placement of larger valves and lower gradients to reduce risk for prosthesis–patient mismatch.

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is associated with poorer short-term and long-term survival and increased risk of early structural valve deterioration requiring reintervention.[1,2] Despite accumulating data that ARE effectively decreases the risk of both moderate and severe PPM,[3] the procedure continues to be underused.[4]

The landscape of transcatheter aortic valve interventions (TAVIs) continues to evolve with more populations gaining approval for the use of TAVI. After transcatheter aortic valve-in-valve (VIV) was approved for high-risk patients in 2015, registry data have demonstrated safety and good outcomes from all risk stratifications, comparable even to the index TAVI.[5-7] Moreover, VIV could be safer and less morbid compared with redo surgical AVR.[8] Valve gradients after VIV are an obstacle to patients with small aortic bioprosthetic valves; therefore, ARE is now being considered more at the index AVR to allow for future VIV. The purpose of this study is to demonstrate our institutional trends and outcomes of ARE after approval of VIV.

PATIENTS AND METHODS

PATIENT POPULATION AND DATA COLLECTION. This is a single-institution review of adult patients undergoing elective and urgent AVR. Preoperative, intraoperative, and postoperative data were obtained from our institutional Cardiovascular Research Database in the Clinical Trial Unit (Institutional Review Board: STU00012288 approved through February 2024) and medical record review. Patients who refused participation in the registry were excluded.

Patients undergoing elective or urgent AVR between August 2007 and December 2022 were analyzed. Endocarditis, root replacement with ARE, aortic dissection, or ventricular assist device patients were excluded. Patients were divided into 2 cohorts: patients with AVR without ARE (AVR-only) and patients undergoing AVR with ARE. Trends in ARE use, valve size, and types were compared over the study period. Outcome measures included 30-day mortality, valve size, and gradients and were compared between patients with AVR-only and with ARE.

STATISTICAL ANALYSIS. Continuous variables are expressed as mean ± SD or median and interquartile range (IQR) and discrete variables as count (percentage). Preoperative, intraoperative, and postoperative variables were compared between AVR-only and ARE based on 2-sample t tests, the rank sum, the χ test, or the Fisher exact test. Statistical analyses were performed using SAS 9.4 software (SAS Institute Inc., Cary, NC), and statistical significance was declared at a 2-sided α level of 5%. No adjustments for multiplicity were made.

RESULTS

BASELINE CHARACTERISTICS AND INTRAOPERATIVE DETAILS. We identified 2182 AVR patients; of those, 74 (3.4%) underwent ARE. The ARE group was younger (64 ± 10 years vs 69 ± 12 years, $P = .001$), had more women (59 [80%] vs 743 [35%], $P < .0001$), and had a smaller body surface area (1.9 ± 0.3 m^2 vs 2.0 ± 0.3 m^2, $P = .02$). The Society of Thoracic Surgeons median predicted risk of mortality was similar (1.7% [IQR, 1.0%-3.6%] for ARE vs 1.7% [IQR, 0.9%-3.2%] for AVR-only, $P = .53$). The ARE group required more cardiac reoperations (27 [36%] vs 312 [15%], $P < .0001$). Table 1 summarizes the remainder of the preoperative characteristics.

The ARE group had longer bypass times (140 minutes [IQR, 112-173 minutes] vs 102 minutes [IQR, 77-140 minutes], $P < .0001$) and longer cross-clamp times (114 minutes [IQR, 99-140 minutes] vs 85 minutes [IQR, 64-113 minutes], $P < .0001$). The ARE group had smaller implanted valve sizes (23 mm vs 25 mm, $P < .001$). Table 2 summarizes the remainder of the intraoperative details. More patients underwent ARE (7.6% vs 1.0%, $P < .0001$), and fewer 19- to 21-mm valves were implanted (10.7% vs 26.8%, $P < .0001$) after approval of VIV in 2015 (Supplemental Table). Annual trends in ARE use and 19- to 21-mm valve implantation also reflect these changes (Figures 1, 2). Almost all valves in recent years have been stented bovine pericardial valves with expandable frames (Supplemental Figure).

POSTOPERATIVE CHARACTERISTICS. The ARE group had similar intensive care unit (46 hours [IQR, 35-97 hours] vs 45 hours [IQR, 26-82 hours], $P = .57$) and hospital lengths of stay (4 days [IQR, 4-6 days] vs 5 [IQR, 4-8 days], $P = .22$), and postoperative complications (27 [36%] vs 925 [44%], $P = .21$). Groups had similar predischarge aortic valve mean gradients (ARE: 11 mm Hg [IQR, 9-14 mm Hg] vs AVR: 10 mm Hg [IQR, 8-14 mm Hg], $P = .42$). The ARE group had higher 30-day mortality rates (5 [7%] vs 48 [2%], $P = .014$); however, elective ARE had similar 30-day mortality compared with elective AVR (2 of 65 [3%] vs 39 of 1898 [2%], $P = .57$). Table 2 summarizes the remainder of the postoperative characteristics.

TABLE 1 Preoperative Characteristics

Characteristic	All AVR (N = 2182)	AVR-Only (n = 2108)	ARE (n = 74)	*P* Value
Age, y	68.5 ± 11.7	68.7 ± 11.7	64.0 ± 10.8	.0007
Female sex	802 (37)	743 (35)	59 (80)	<.0001
Body surface area, m^2	2.0 ± 0.3	2.0 ± 0.3	1.9 ± 0.3	.017
Creatinine, mg/dL	1.0 (0.8-1.2)	1.0 (0.8-1.2)	0.9 (0.8-1.0)	.0005
STS predicted risk of mortality, %	1.7 (0.9-3.2)	1.7 (0.9-3.2)	1.7 (1.0-3.6)	.53
Echocardiogram				
Ejection fraction	0.60 (0.55-0.65)	0.60 (0.55-0.65)	0.63 (0.60-0.70)	.0003
NYHA class III-IV	715 (37)	689 (37)	26 (46)	.15
Left atrial size, cm	4.0 (3.6-4.5)	4.0 (3.6-4.5)	4.0 (3.5-4.4)	.40
Aortic valve area, cm^2	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.8 (0.6-0.9)	.085
Aortic valve mean gradient, mm Hg	41 (30-52)	41 (30-52)	41 (36-51)	.53
Aortic valve peak velocity	4.1 (3.8-4.8)	4.1 (3.8-4.8)	4.1 (4.0-4.8)	.66
Disease history				
Diabetes	513 (23)	488 (23)	25 (34)	.034
Pulmonary hypertension	830 (38)	804 (39)	26 (36)	.67
Dyslipidemia	1585 (73)	1527 (73)	58 (78)	.28
Hypertension	1692 (78)	1633 (77)	59 (80)	.65
Chronic lung disease	329 (15)	318 (15)	11 (15)	.95
Peripheral vascular disease	171 (8)	169 (8)	2 (3)	.09
Cerebrovascular disease	325 (15)	313 (15)	12 (16)	.75
Stroke	123 (6)	119 (6)	4 (5)	.95
Myocardial infarction	220 (10)	213 (10)	7 (9)	.85
Congestive heart failure	698 (32)	679 (32)	19 (26)	.23
Coronary artery disease	981 (47)	956 (47)	25 (35)	.043
Atrial fibrillation history	537 (27)	522 (27)	15 (21)	.22
Prior cardiac surgery	339 (16)	312 (15)	27 (36)	<.0001

Data are presented as n (%), mean ± SD, or as median (25th-75th percentile). AVR, aortic valve replacement; ARE, aortic root enlargement; NYHA, New York Heart Association; STS, The Society of Thoracic Surgeons.

COMMENT

Our report shows an increase in ARE use, a decrease in use of small valves (19 mm-21 mm), and an increase in the use of bioprosthetic valves with expandable frames since VIV approval. Although short-term mortality rates were higher after ARE, they were similar when only elective cases were compared.

Our short-term mortality rate was slightly higher than other reports, but we also had a higher rate of reoperative surgery in the ARE group, with more than one-third being reoperative cases. Despite the high rate of reoperations, when elective AREs were selected, the 30-day mortality rate was similar to other groups that reported 30-day mortality ranging from 2% to 5%.[9,10]

Use of small valves (19-21 mm) decreased significantly over the study period, a reassuring finding because 19- to 21-mm valves have been associated with double the risk of death.[5] In parallel, our data show comparable postoperative mean gradients between the groups, suggesting that PPM was potentially avoided by doing an ARE. PPM is a well-described complication after VIV. Registry data

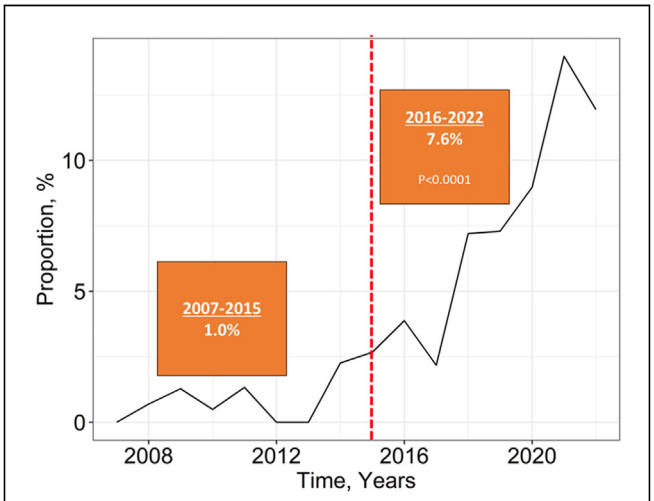

FIGURE 1 The proportion of aortic valve replacements with aortic root enlargements has increased over time. The vertical red dashed line marks valve-in-valve approval year, 2015.

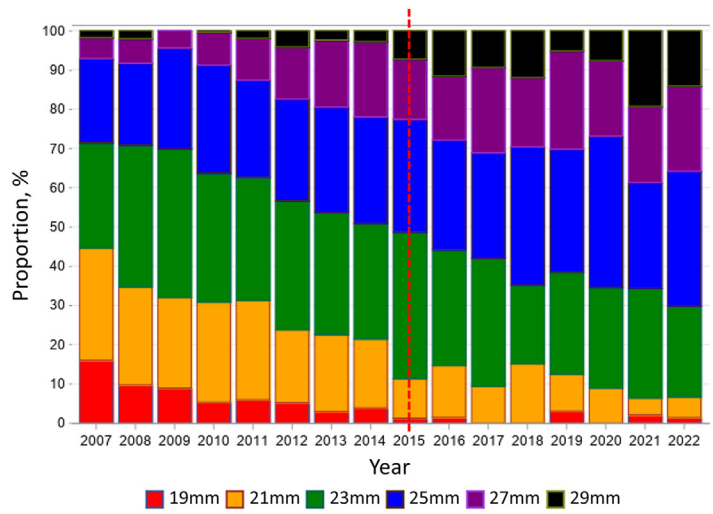

FIGURE 2 The proportion of 19- to 21-mm implanted valves has decreased over time. The vertical red dashed line marks valve-in-valve approval year, 2015.

have demonstrated elevated mean gradients often >20 mm Hg at 30 days and beyond, which were again associated with higher mortality.[5,6] Implanting a bioprosthetic valve with an expandable frame at the index AVR allows providers a way to implant a larger valve if VIV is needed. Our data show an almost exclusive transition to such valves in case there is a need for a future VIV.

Our study is a single-institution, retrospective review, so conclusions may not be generalizable. However, our hope is that with enough institutional data demonstrating safety and utility of ARE, more programs will feel comfortable performing ARE. Moreover, the increase in ARE rates allows for more trainees to graduate with experience to perform the procedure in their practice. Another limitation is that we are a high-volume TAVI program, so we may have a bias to perform more ARE in anticipation of VIV.

TABLE 2 Intraoperative and Postoperative Characteristics

Characteristic	All AVR (N = 2182)	AVR-Only (n = 2108)	ARE (n = 74)	*P* Value
Cardiopulmonary bypass time, min	104 (78-142)	102 (77-140)	140 (112-173)	<.0001
Cross-clamp time, min	86 (65-114)	85 (64-113)	114 (99-140)	<.0001
Type of bioprosthetic valve				<.0001
Stented bovine pericardium with expandable ring	356 (16)	312 (15)	44 (59)	
Stented bovine pericardium	1812 (83)	1783 (85)	29 (39)	
Size of bioprosthetic valve				.0002
19 mm	90 (4)	88 (4)	2 (3)	
21 mm	367 (17)	347 (16)	20 (27)	
23 mm	671 (31)	636 (30)	35 (47)	
25 mm	607 (28)	594 (28)	13 (18)	
27 mm	321 (15)	317 (15)	4 (5)	
29 mm	126 (6)	126 (6)	0 (0)	
Other cardiac operations performed				
Coronary artery bypass grafting	657 (30)	643 (31)	14 (19)	.033
Mitral valve surgery	332 (15)	322 (15)	10 (14)	.68
Tricuspid valve surgery	120 (5)	117 (6)	3 (4)	.58
Aortic aneurysm	165 (8)	161 (8)	4 (5)	.48
Length of stay				
Intensive care unit, h	45 (26-82)	45 (26-82)	46 (35-97)	.57
Hospital, d	5 (4-8)	5 (4-8)	4 (4-6)	.22
Postoperative stroke > 24 hours	56 (3)	54 (3)	2 (3)	.94
Prolonged ventilation >24 hours	199 (9)	192 (9)	7 (9)	.92
Postoperative atrial fibrillation	615 (28)	599 (28)	16 (22)	.20
Predischarge permanent pacemaker	101 (5)	98 (5)	3 (4)	.81
30-day mortality	53 (2)	48 (2)	5 (7)	.014
Predischarge valve mean gradient, mm Hg	10 (8-14)	10 (8-14)	11 (8-14)	.42
Readmission within 30 days	241 (11)	236 (12)	5 (7)	.24

Data are presented as n (%) or as median (25th-75th percentile). AVR, aortic valve replacement; ARE, aortic root enlargement.

The use of ARE may not have increased at the national level yet, but regional and institutional analyses suggest the national trend will soon catch up. The lifetime approach to aortic valve disease should not be isolated to TAVI programs, and surgeons should consider optimizing patients for potential future interventions by performing ARE or root replacements in appropriate patients to best prepare them for potential VIV.

The Supplemental Material can be viewed in the online version of this article [https://doi.org/10.1016/j.atssr.2024.09.007] on https://www.annalsthoracicsurgery.org.

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