Featured Article

Changes in aortic root dimensions post aortic root enlargement with Y-incision and modified aortotomy

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Background: Lifetime management in aortic stenosis (AS) can be facilitated by aortic root enlargement (ARE) to improve anatomy for future valve-in-valve (ViV) procedures. A mitral valve-sparing ARE technique ("Y-incision") and sinotubular junction (STJ) enlargement ("roof" patch aortotomy) allow upsizing by 3–4 valve sizes, but quantitative analysis of changes in root anatomy is lacking.

Methods: Among 78 patients who underwent ARE by Y-incision technique (± roof aortotomy closure) we identified 45 patients with high-quality pre- and post-operative computed tomography angiography (CTA) scans to allow analysis of change in aortic root dimensions. Detailed measurements of the annulus/basilar ring and sinuses were performed by an expert imager on both pre- and post-operative CTAs. The basal ring was defined as the functional annulus when a bioprosthetic valve was present.

Results: Average age was 65±11 years, the majority were female (29, 64%), and 9 (20%) had undergone prior aortic valve replacement (AVR). Valve upsizing was ≥3 sizes in 41 (91%). Post-operative mean basal ring diameter was larger compared to the native annular diameter (26.3 *vs.* 25.3 mm, P<0.01) and substantially larger than prior prosthetic valve in redo AVR (25.6 *vs.* 19.3 mm, P<0.001). Diameters of the sinuses at pre-operative computed tomography (CT) increased by +7.7±2.8 [right sinuses of Valsalva (R SVS)], +6.7±3.0 [left sinuses of Valsalva (L SVS)], and +6.6±2.9 mm [non-coronary sinuses of Valsalva (N SVS)]. Mean diameter of the STJ increased to 38.3±3.7 post-operative (+8.1±3.2 mm). Left main (LM) and right coronary artery (RCA) heights decreased by −6.3±3.3 and −3.7±3.4 mm respectively due to the supra-annular position of the valve, however, the post-operative valve-to-coronary (VTC) artery distances were 6.6±2.3 and 4.9±2.0 mm, respectively.

Conclusion: The Y-incision root enlargement technique significantly enlarges the sinus and STJ diameters by 6–7 mm while preserving VTC distances despite upsizing by 3–4 valve sizes, resulting in post-operative anatomy that is favorable for future transcatheter aortic valve-in-surgical aortic valve (TAV-in-SAV).

Keywords: Aortic root enlargement (ARE); Y-incision; roof procedure; valve-in-valve (ViV); aortic valve replacement (AVR)

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Introduction

The mainstay treatment for severe aortic stenosis (AS) is surgical aortic valve replacement (SAVR), often performed via placement of a stented bioprosthetic aortic valve replacement (bioAVR). Given that bioprosthetic valves have a reported median half-life of approximately 15 years (1), many patients undergoing bioAVR outlive their index valve replacement and will require redo aortic valve replacement (AVR). Given recent advancements in valve-in-valve transcatheter aortic valve replacement (ViV

TAVR), transcatheter valve replacement has become an attractive alternative for failed bioAVR due to its minimally invasive nature (2). However, unlike redo open AVR, there are several important anatomic limitations for ViV TAVR within a bioAVR. Specifically, due to the leaflets of the bioAVR becoming pinned in an open position by the stent frame of the TAVR valve, this anatomy raises risk of direct coronary occlusion and/or sinus sequestration (3,4). While the risk of coronary occlusion is low (2–6%), the consequences of this complication are dire with mortality rates approaching 40%, and concern for this dreaded complication limits the availability of ViV TAVR among the subgroup of patients with small root dimensions (5,6). An additional anatomic consideration for ViV TAVR is the potential to create or worsen patient prosthesis mismatch (PPM) as a result of the additional space occupied within bioAVR by the TAVR frame and leaflets. This downsizing of the geometric orifice area is particularly relevant given data from large trials has shown that the most commonly implanted bioprosthetic sizes (21 and 23) (7-9), have been shown to increase the risk of PPM, even prior to ViV TAVR (10-12). Thus, optimal lifetime management of patients with bioAVR would be promoted by surgical techniques to enlarge the aortic annulus and sinuses of Valsalva (SVS) at the time of index SAVR, lessen the chances of coronary complications and PPM and promote anatomic candidacy for future ViV TAVR.

Aortic root enlargement (ARE) at the time of index AVR can be an important factor in the lifetime management of patients with small native aortic roots by improving valve hemodynamics and optimizing anatomy for future ViV TAVR. Existing techniques for ARE include the Nicks (13) and Manouguian (14) procedures, however, these techniques typically only allow valve upsizing by one or two sizes and the Manouguian procedure comes with additional risk of post-operative mitral regurgitation (15). In response to these limitations, our group recently described a novel ARE technique termed the "Yang procedure" after its inventor Dr. Yang (16-19). This technique involves a Y-incision through the left non-coronary commissure, terminating underneath the aortic annulus, with a rectangular patch to yield significant annular enlargement and valve upsizing by up to five sizes, while avoiding any manipulation of the mitral valve, left atrium, or coronary arteries. The Yang procedure ARE can be further augmented by the "roof technique", which involves patch enlargement of the sinotubular junction (STJ) and proximal ascending aorta to further promote anatomy for ViV TAVR while maintaining good hemostasis of the aortotomy (17,20). A recently published series of 50 patients undergoing Yang procedure demonstrated a median valve upsizing of three sizes, mean postoperative gradient 7 mmHg, mean valve area of 1.9 cm^2, and low rates of surgical complications, supporting the role of this technique in the lifetime management of patients with AS (21).

Considering the growing interest in ARE techniques there is a significant need for studies that specifically quantify changes in aortic root anatomy that accompanies such ARE procedures. Specifically, given surgical enlargement of the annulus, sinuses, and STJ are performed as part of the Yang procedure, a comprehensive analysis of changes in aortic root anatomy as they relate to candidacy for future ViV TAVR is critical, but yet such data is currently lacking. Thus, in this study we aim to perform detailed anatomic analyses of paired pre- and post-operative computed tomography angiography (CTA) exams among patients who underwent Yang procedure ARE to more precisely define changes in root anatomy. We specifically sought to investigate imaging parameters that have been shown to relate to risk of coronary complications at subsequent ViV TAVR, including valve-to-coronary (VTC) distance and valve-to-aorta (VTA) distance, in addition to investigating the relationship between the size of the patient's native left ventricular outflow tract and the geometric orifice of the implanted upsized bioAVR.

Methods

Study design and population characteristics

We conducted a single-center retrospective cohort study on patients with CTA performed before and after Yang procedure AVR between December 2020 and March 2023. This retrospective analysis was performed as part of an Institutional Review Board approved study (HUM00211344), and informed consent was waived. Patients were identified with the use of an internal research database.

Among 78 consecutive patients who underwent ARE by Y-incision technique at our center (± proximal ascending enlargement using roof technique), we retrospectively identified 45 patients with high-quality pre-operative and post-operative CTA scans to allow quantitative analysis of aortic root dimensions. The surgical technique for the Yang procedure (Y-incision ARE) and roof procedure have been described elsewhere (19,20).

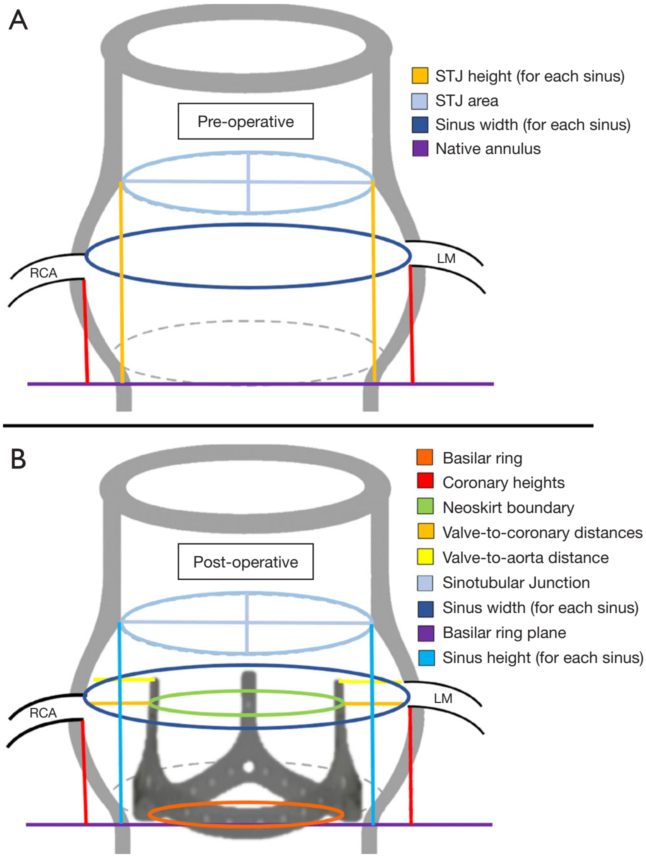

Figure 1 Detailed aortic root measurement schematic. Standard root measurements for transcatheter valve replacement planning were performed on pre-operative CT scans including annular sizes, sinus of Valsalva dimensions, heights of the sinuses and coronary ostia, and STJ size (A). On post-operative CT scans after bioAVR with upsizing and ARE, the pre-operative measurements were repeated, with the addition of measurements of the VTC and VTA distances (B). STJ, sinotubular junction; RCA, right coronary artery; LM, left main; CT, computed tomography; bioAVR, bioprosthetic aortic valve replacement; ARE, aortic root enlargement; VTC, valve-to-coronary; VTA, valve-to-aorta.

Measurement technique

Detailed measurements were performed on paired pre- and post-operative computed tomography (CT) angiograms for all patients as depicted in *Figure 1*. Measurements were performed by an experienced cardiovascular imager using specialized three-dimensional (3D) analysis software (Vitrea, Vital Images Inc., Product Version 7.14, Minnetonka, MN, USA). In patients with native roots pre-operatively, the root dimensions were measured as per standard TAVR planning protocols (22): (I) annulus—measured in systole at the virtual basilar ring formed by the hinge points of the aortic leaflets with measurements including maximal and minimal diameters, area and perimeter; (II) sinus width—diameter at the widest point of each sinus of Valsalva measured from cusp-to-commissure; (III) sinus heights—linear distance from the annular plane to the STJ for all sinuses; (IV) coronary heights—linear distance from the annular plane to the inferior edge of the coronary ostia for both right coronary artery (RCA) and left main (LM); and (V) STJ diameter and area—the area of the STJ and area-derived average diameter. In redo AVR patients with pre-existing bioAVR, the internal diameter of the valve was used in place of the native annulus measurement. In the post-operative state, the internal dimensions of the metallic bioprosthetic valve stented frame were used to define the functional annulus and the inferior margin of the stented valve frame was used to define basilar ring from which coronary and sinus heights were re-measured post-operatively. The STJ area and area-derived diameter was measured similarly to the pre-operative scan, however, if the STJ was effaced on the post-operative CTA, then the STJ was measured at the same level as the average sinus height on the pre-operative scan. VTC distance was measured by placing a circular region of interest (ROI) just outside of the metallic valve posts at the level of any coronary ostia arising below the valve posts and measuring the linear distance between the ROI (simulating the estimated neoskirt post-ViV TAVR) and the center of the coronary ostia; a VTC distance of ≤4 mm was considered low (5). Lastly, the VTA distance was measured as the smallest linear distance between the bioAVR valve post and the adjacent aortic wall; a VTA distance ≤2 mm was considered low (23,24).

Statistical analysis

Patient characteristics were reported as mean ± standard deviation (SD) and frequencies for categorical variables. Normality was assessed by Shapiro-Wilk test. Paired *t*-tests were used to examine significant changes in root anatomy metrics between pre- and post-operative measurements. Change in STJ dimensions were analyzed in a stratified manner by the presence or absence of concomitant "roof technique" STJ enlargement at the time of ARE. A P value of <0.05 was considered significant for all statistical tests. Statistical analyses were performed using Stata 14.0 (StataCorp LP, College Station, TX, USA).

Table 1 Patient and surgical characteristics

Characteristics	Values (n=45)
Demographics	
Age (years)	64.6±10.7
Male sex	16 [36]
Bicuspid aortic valve	21 [47]
Prior AVR	9 [20]
Surgical characteristics	
Native annulus size (intra-operative sizer)	
17	1 [2]
19	10 [22]
21	15 [33]
23	15 [33]
25	4 [9]
Implanted prosthesis size	
25	5 [11]
27	11 [24]
29	29 [64]
Upsizing (number of valve sizes)	
2	4 [9]
3	26 [58]
4	13 [29]
5	2 [4]
Roof procedure	28 [62]
Concomitant ascending aortic repair	7 [16]
Concomitant CABG	3 [7]
Concomitant mitral valve repair	1 [2]

Values are presented as mean ± SD or n [%]. AVR, aortic valve replacement; CABG, coronary artery bypass grafting; SD, standard deviation.

Results

Patient and operative characteristics

Among 78 patients who underwent AAE by Y-incision technique at our center (± proximal ascending enlargement using roof technique) we identified 45 with high-quality pre- and post-operative CT scans for analysis. The average age was 65±11 years, the majority were female (n=29, 64%), and 9 (20%) had undergone prior AVR. The native annulus sized for a 23 valve or smaller in 41 (91%) patients. Average patient body size index and body surface area were 31.1±6.8 kg/m^2 and 2.0±0.3 m^2, respectively. Approximately half of patients had a history of bicuspid aortic valve (n=21, 47%). The primary indication for AVR was severe AS in 40 (89%) and severe aortic insufficiency in 5 (11%); two cases were urgent in patients with aortic inefficiency, but otherwise all cases were elective.

The majority of patients (n=28, 62%) underwent roof technique STJ enlargement. The implanted bioprosthetic valves were Magna Ease (Edwards Lifesciences, Irvine, CA, USA) in 44 (98%) and Avalus (Medtronic, Minneapolis, MN, USA) in 1 (n=2%). The implanted valve was upsized by either three sizes (n=26, 58%) or four sizes (n=13, 29%) in most cases, resulting in the most commonly implanted valve sizes of 27 (n=11, 24%) and 29 (n=29, 64%). Of note, a minority of patients underwent concomitant procedures at the time of AVR and ARE including: ascending aortic repair (n=7, 16%), coronary artery bypass (n=3, 7%), and mitral valve repair (n=1, 2%). Demographic and surgical characteristics are shown in *Table 1*.

Change in aortic root dimensions with ARE

Complete results depicting changed in root measurements between pre-operative and post-operative anatomy are shown in *Table 2*. The post-operative mean basal ring diameter was slightly larger in comparison to the mean diameter of the annulus in patients with native roots (26.3 *vs.* 25.3 mm, P<0.01) and substantially larger than the basilar ring among patients with existing bioprosthetic valves undergoing redo AVR (25.6 *vs.* 19.3 mm, P<0.001). The pre-operative sinus widths were 30.2±3.5 at the right SVS (R SVS), 31.2±3.8 mm at the left SVS (L SVS), and 31.6±4.1 mm at the non-coronary SVS (N SVS), and these dimensions increased significantly at all sinuses on post-operative imaging after Yang procedure ARE; +7.7 mm at the R SVS, +6.7 mm at the L SVS and +6.6 mm at the N SVS (P<0.001 for all). Regarding SVS heights, the pre-operative height of the R SVS and L SVS were 20.2±4.4 and 18.7±4.4 mm respectively, and both the R SVS and L SVS heights significantly decreased a small amount post-operatively (−1.8 mm for R SVS and −3.7 mm for L SVS). Conversely, the N SVS height significantly increased by +3.4 mm post-operatively. Both the STJ mean diameter and area increased substantially from pre-operative dimensions

Table 2 Detailed aortic root measurements taken from gated CTA, before and after Y-incision ARE with modified aortotomy closure technique (roof procedure)

Aortic root measurement	Pre-operative	Post-operative	Change
Native annulus mean diameter (n=36) (mm)	25.3±2.3	26.3±1.4†	+1.1±2.0**‡
Prior prosthesis basal ring size (n=9) (mm)	19.3±1.8	25.6±1.6	+6.2±1.0***
LM height (mm)	11.9±3.5	5.6±2.9	−6.3±3.3***
RCA height (mm)	13.7±4.7	10.0±3.4	−3.7±3.4***
R SVS width (mm)	30.2±3.5	37.9±3.7	+7.7±2.8***
L SVS width (mm)	31.2±3.8	37.8±3.5	+6.7±3.0***
N SVS width (mm)	31.6±4.1	38.2±3.8	+ 6.6±2.9***
R SVS height (mm)	20.2±4.4	18.3±5.2	−1.8±5.1*
L SVS height (mm)	18.7±4.4	15.0±5.2	−3.7±5.1***
N SVS height (mm)	20.0±5.1	23.7±6.1	+3.4±8.0**
STJ mean diameter (mm)	30.2±4.2	38.3±3.7	+8.1±3.2***
Roof technique (n=28)	30.5±3.9	39.5±3.1	+9.0±2.7***
No roof technique (n=17)	29.6±4.8	36.1±3.7	+6.5±3.4***
STJ area (mm^2)	710.7±195.6	1,152.9±211.0	+442.2±153.2***
Roof technique (n=28)	726.6±181.9	1,225.4±185.1	+498.8±125.1***
No roof technique (n=17)	684.4±219.4	1,033.5±200.6	+349.1±152.8***
VTC distance RCA (mm)	4.7±1.2§	4.9±2.0	+0.2
VTC distance LM (mm)	4.4±2.6§	6.6±2.3	+2.2
VTA distance R SVS (mm)	4.5±2.3§	4.4±2.3	−0.1
VTA distance L SVS (mm)	4.5±1.8§	5.7±2.5	+1.2
VTA distance N SVS (mm)	4.2±2.1§	8.1±2.3	+3.9**

Paired *t*-test with *, P<0.05; **, P<0.01; ***, P<0.001. Values are presented as mean ± SD unless otherwise specified. †, basal ring used to define annular plane and measurements in post-AVR state; ‡, difference in mean diameter between native annulus and post-AVR basal ring; §, only calculated in subgroup of patients with pre-existing bioAVR (n=9). CTA, computed tomography angiography; ARE, aortic root enlargement; LM, left main; RCA, right coronary artery; R SVS, right SVS; SVS, sinuses of Valsalva; L SVS, left SVS; N SVS, non-coronary SVS; STJ, sinotubular junction; VTC, valve-to-coronary; VTA, valve-to-aorta; AVR, aortic valve replacement; bioAVR, bioprosthetic aortic valve replacement.

(30.2±4.2 mm and 710.7±195.6 mm^2 respectively), with an average increase in the STJ diameter by +8.1 mm overall (+9.0 mm with roof procedure *vs.* +6.5 mm without roof procedure) and STJ area by +442 mm^2 overall (+499 mm^2 with roof procedure *vs.* +349 mm^2 without roof procedure, P<0.001).

Post-operative VTC distances were 4.9±2.0 and 6.6±2.3 mm for the LM and RCA respectively. There were four of 45 (9%) patients that had a LM VTC distance of <4 mm post-operatively, although the average VTA at the L SVS was 3.9±1.0 mm and none of these had left VTA ≤2 mm. There were 16 of 45 (36%) of patients with RCA VTC distance of ≤4 mm post-operatively, although the average VTA of the R SVS was 2.9±1.6 mm and four of these 16 patients had a VTA distance at the R SVS of ≤2 mm. However, among cases with either VTC distance of ≤4 mm at the LM or RCA, the VTA at the N SVS was 8.2±2.7 mm with a minimal non-coronary VTA distance of 5.7 mm. Among cases with a post-operative VTC distance of ≤4 mm at either the LM or RCA, the pre-operative average sinus

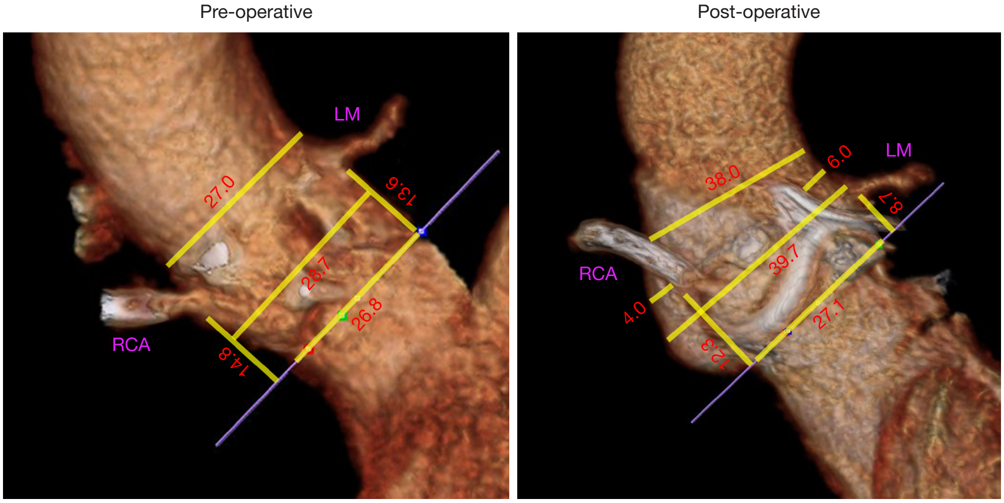

Figure 2 Representative example with 3D renderings of the aortic root from pre-operative (left) and post-operative (right) CT scans, demonstrating typical changes in the anatomy observed with Y-incision ARE, including significant enlargement of the sinus widths (+11 mm in this case) and STJ with upsizing by three valve sizes (implanted 29 mm Maga Ease). RCA, right coronary artery; LM, left main; 3D, three-dimensional; CT, computed tomography; ARE, aortic root enlargement; STJ, sinotubular junction.

diameter was smaller (29.1±3.1 *vs.* 31.9±3.1 mm, P=0.007), and there was a non-significant trend towards a smaller basilar ring size of the implanted bioAVR (25.7±1.7 *vs.* 26.5±1.2 mm, P=0.078). A representative case of pre- and post-operative root anatomy and measurements by CTA are shown in *Figure 2*.

Discussion

This study is the first detailed examination of changes in aortic root anatomy accompanying the Yang procedure (Y-incision) ARE with roof procedure for aortotomy closure using high-quality, pre- and post-operative CTAs. The main findings of this study are that the Yang procedure ARE results a comparable—even slightly larger—basilar ring internal diameter post-AVR compared to the dimension of the patient's native annulus, confirming that this anatomy should effectively eliminate the possibility of PPM and contribute to greatly reduce risk of PPM related to implant of a TAVR valve frame within the bioAVR if the need for future ViV TAVR arises. Second, we observed that the sinus widths and STJ dimensions significantly increase post-ARE, although owing to the supra-annular positioning of the implanted bioAVR, the SVS and coronary heights decrease; however, this change is not unique to the Yang procedure and would also be expected with any supra-annular bioAVR even without ARE. Lastly, we observed that despite significant valve upsizing by three sizes or more in >90% of patients, the vast majority maintained favorable VTC and VTA distances. In the small minority that had low post-operative VTCs at the right or left coronary ostia, this subgroup had smaller average sinus widths (mean of 29 mm) and all had large VTA distances at the N SVS—due to the rectangular patch in this location—suggesting a low risk for sinus sequestration at future ViV TAVR. Overall, the findings of this study provide further anatomic evidence to support the proposed advantages of the Yang procedure ARE which include a significant upsizing of the aortic annulus to match of the prosthetic valve's effective orifice with the patient's native outflow tract to minimize any PPM, as well as significant SVS and STJ enlargement to maximize anatomic candidacy for future ViV TAVR.

The results of our study provide quantitative data to support the anatomic benefits of the Yang procedure ARE that can facilitate future ViV TAVR (19,21). Specifically, a key advantage of the Yang procedure is the a dramatic increase in post-operative widths of the sinus of Valsalva as well as the STJ size, contributing to sinus anatomy that should be strongly protective against the risk of coronary obstruction and/or sinus sequestration with ViV TAVR (4). The degree of STJ enlargement was significantly higher in patients that underwent the roof procedure, suggesting the added value of this aortotomy closure technique. In contrast to the SVS widths, the R SVS and L SVS and coronary heights decreased post-operatively. However, this change is expected given that the Yang procedure ARE does not explicitly enlarge the R SVS or L SVS or manipulate the coronary ostia, and thus the sinus and coronary heights would be expected to decrease due to the supra-annular position of the implanted bioAVR ring from which these heights are measured. Despite implantation of a significantly larger bioAVR and decreases in SVS and coronary heights, the compensatory enlargement of the SVS and STJ resulted in the vast majority of cases with VTC and VTA distances above approximate risk thresholds of (≤4 and ≤2 mm respectively) (5,23,24), and no cases showed an at-risk VTA measurements (≤2 mm) at all sinuses. Regardless, among the small number of patients with low VTC measurements post-operative, smaller native SVS widths were noted, suggesting that it may be pertinent to carefully consider the degree to which the bioAVR is upsized during the Yang procedure ARE in patients with average native sinus dimensions <30 mm. Future work will examine the potential value of a pre-operative CT-based ARE planning approach to determine the required upsizing degree required to match the patients outflow tract while at the same time minimizing any risk of oversizing leading to low VTC/VTA dimensions.

Beyond catastrophic ViV TAVR procedural complications such as sinuses sequestration and coronary obstruction, an additional anatomic consideration is the potential future need for coronary re-access related to either valve-related complications or progression of native coronary artery disease requiring either urgent or elective percutaneous coronary intervention. Coronary re-access after TAVR is known to be challenging in some cases due to interactions between the TAVR frame, neoskirt and the patients' native sinuses and coronary ostial locations (4,25). Specifically, coronary re-access requires sufficient space to deliver a catheter past the valve into the sinuses as well as sufficient space within the sinuses to allow catheter manipulation to engage the coronary ostia. Overall, despite decreased coronary heights owing to the supra-annular bioprosthetic valve, we observed good preservation of the VTC and VTA distances post-Yang procedure ARE, with no patients demonstrating both low VTC and VTA measurements at the LM and only 4 (9%) demonstrating low VTC and VTA at the RCA, although three of these four patients occurred in the subgroup who did not undergo the roof procedure for STJ and proximal aortic enlargement. Regardless, considering that the R SVS was the most likely anatomic location to demonstrate a borderline VTC or VTA measurement post-ARE, specific attention should be paid intra-operatively to the position of the bioAVR as it relates to the right sinus wall and RCA. Another factor seen as relevant to the feasibility of coronary re-access after ViV and future BASILICA (bioprosthetic or native aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction during TAVR) is commissural alignment (26-29). Thus, an additional advantage of an index open AVR, is the ability to ensure commissural alignment in addition to enlargement of the aortic root and proximal aorta.

Our results confirm that ARE can also be of significant benefit to prevent issues related to PPM, both at the time of index surgical AVR and with subsequent ViV TAVR. PPM occurs when an implanted valve effective orifice area is too small for the patient's body habitus resulting in higher post-operative gradients, which can in turn lead to worse long-term outcomes such as premature valve degeneration and increased morbidity and mortality, especially in those with reduced left ventricular function (11,30). PPM has been associated with the use of smaller valves (sizes 19–23), which comprise the majority of implanted valves in the absence of ARE (7-9). Our study demonstrated that the Yang procedure ARE permits upsizing by at least two valve sizes and upsizing by at least three sizes in 91% of patients, allowing the effective orifice area of the bioAVR to match, and even slightly exceed that of the patient's native outflow tract (e.g., mean basilar ring post-ARE was 1.1 mm larger than native annulus). Placing the largest bioAVR initially, allows for larger transcatheter valve sizes to be implanted at future ViV TAVR than otherwise would have been possible, while also maintaining the highest possible EOA for the longest duration of time.

Our study has several limitations. Firstly, this was a single-center study, with ARE procedures performed by Dr. Yang, the architect of the Yang procedure, and thus the results of this study may not be generalizable; however, the Yang procedure is considered less technically demanding compared to other ARE techniques. Secondly, given that CT analysis was retrospective, some patients had to be excluded for the lack of high-quality pre-operative or post-operative CTs. Lastly, given that the Yang procedure was described within the last 5 years, there has not yet been sufficient follow-up time to allow evaluation for how the anatomic changes introduced by the Yang procedure affect outcomes of AVR and or technical success of future ViV TAVR, although given the recently described excellent hemodynamic results of the Yang procedure (21) and the favorable anatomic changes in annular and root anatomy detailed in this paper, we believe that this approach is well-positioned to advance life-time management of patients with severe aortic valve dysfunction.

In conclusion, the Yang procedure (Y-incision) ARE technique with roof procedure for modified aortotomy closure significantly enlarges the sinus of Valsalva and STJ diameters by 6–9 mm on average while preserving favorable VTC and VTA distances despite upsizing the implanted bioprosthetic valve by 3–4 valve sizes. The combination of the larger bioprosthetic valve, matching the patients native outflow tract size, in addition to the capacious sinuses that results from the Yang procedure ARE, result in post-operative anatomy that reduces the risk of PPM and improves anatomic favorability for future ViV TAVR to advance lifetime management of this patient population.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

References

1. Jamieson WR, Ling H, Burr LH, et al. Carpentier-Edwards supraannular porcine bioprosthesis evaluation over 15 years. Ann Thorac Surg 1998;66:S49-52.
2. Sá MPBO, Van den Eynde J, Simonato M, et al. Valve-in-Valve Transcatheter Aortic Valve Replacement Versus Redo Surgical Aortic Valve Replacement: An Updated Meta-Analysis. JACC Cardiovasc Interv 2021;14:211-20.
3. Dvir D, Leipsic J, Blanke P, et al. Coronary obstruction in transcatheter aortic valve-in-valve implantation: preprocedural evaluation, device selection, protection, and treatment. Circ Cardiovasc Interv 2015;8:e002079.
4. Ochiai T, Oakley L, Sekhon N, et al. Risk of Coronary Obstruction Due to Sinus Sequestration in Redo Transcatheter Aortic Valve Replacement. JACC Cardiovasc Interv 2020;13:2617-27.
5. Ribeiro HB, Rodés-Cabau J, Blanke P, et al. Incidence, predictors, and clinical outcomes of coronary obstruction following transcatheter aortic valve replacement for degenerative bioprosthetic surgical valves: insights from the VIVID registry. Eur Heart J 2018;39:687-95.
6. Ojeda S, González-Manzanares R, Jiménez-Quevedo P, et al. Coronary Obstruction After Transcatheter Aortic Valve Replacement: Insights From the Spanish TAVI Registry. JACC Cardiovasc Interv 2023;16:1208-17.
7. Thyregod HG, Steinbrüchel DA, Ihlemann N, et al. Transcatheter Versus Surgical Aortic Valve Replacement in Patients With Severe Aortic Valve Stenosis: 1-Year Results From the All-Comers NOTION Randomized Clinical Trial. J Am Coll Cardiol 2015;65:2184-94.
8. Rodés-Cabau J, Pibarot P, Suri RM, et al. Impact of aortic annulus size on valve hemodynamics and clinical outcomes after transcatheter and surgical aortic valve replacement: insights from the PARTNER Trial. Circ Cardiovasc Interv 2014;7:701-11.
9. Johnston DR, Soltesz EG, Vakil N, et al. Long-term durability of bioprosthetic aortic valves: implications from 12,569 implants. Ann Thorac Surg 2015;99:1239-47.
10. Zorn GL 3rd, Little SH, Tadros P, et al. Prosthesis-patient mismatch in high-risk patients with severe aortic stenosis: A randomized trial of a self-expanding prosthesis. J Thorac Cardiovasc Surg 2016;151:1014-22, 1023.e1-3.
11. Pibarot P, Weissman NJ, Stewart WJ, et al. Incidence and sequelae of prosthesis-patient mismatch in transcatheter versus surgical valve replacement in high-risk patients with severe aortic stenosis: a PARTNER trial cohort--a analysis. J Am Coll Cardiol 2014;64:1323-34.
12. Ternacle J, Pibarot P, Herrmann HC, et al. Prosthesis-Patient Mismatch After Aortic Valve Replacement in the PARTNER 2 Trial and Registry. JACC Cardiovasc Interv 2021;14:1466-77.
13. Nicks R, Cartmill T, Bernstein L. Hypoplasia of the aortic root. The problem of aortic valve replacement. Thorax 1970;25:339-46.
14. Manouguian S, Seybold-Epting W. Patch enlargement of the aortic valve ring by extending the aortic incision into the anterior mitral leaflet. New operative technique. J Thorac Cardiovasc Surg 1979;78:402-12.
15. Imanaka K, Takamoto S, Furuse A. Mitral regurgitation late after Manouguian's anulus enlargement and

aortic valve replacement. J Thorac Cardiovasc Surg 1998;115:727-9.
16. Nyamande D, Ramoroko PS. The Yang procedure: Renaming the recently described "Y" incision/rectangular patch aortic annulus enlargement technique. JTCVS Tech 2023;18:43.
17. Yang B, Ghita C, Palmer S. Y-incision Aortic Root Enlargement With Modified Aortotomy Upsizing the Annulus by 5 Valve Sizes. Ann Thorac Surg 2022;114:e479-81.
18. Yang B. A novel simple technique to enlarge the aortic annulus by two valve sizes. JTCVS Tech 2021;5:13-6.
19. Yang B, Naeem A. A Y Incision and Rectangular Patch to Enlarge the Aortic Annulus by Three Valve Sizes. Ann Thorac Surg 2021;112:e139-41.
20. Yang B, Naeem A, Palmer S. "Roof" technique-a modified aortotomy closure in Y-incision aortic root enlargement upsizing 3-4 valve sizes. JTCVS Tech 2022;12:33-6.
21. Yang B, Ghita C, Makkinejad A, et al. Early outcomes of the Y-incision technique to enlarge the aortic annulus 3 to 4 valve sizes. J Thorac Cardiovasc Surg 2024;167:1196-1205.e2.
22. Blanke P, Weir-McCall JR, Achenbach S, et al. Computed tomography imaging in the context of transcatheter aortic valve implantation (TAVI) / transcatheter aortic valve replacement (TAVR): An expert consensus document of the Society of Cardiovascular Computed Tomography. J Cardiovasc Comput Tomogr 2019;13:1-20.
23. Akodad M, Sellers S, Gulsin GS, et al. Leaflet and Neoskirt Height in Transcatheter Heart Valves: Implications for Repeat Procedures and Coronary Access. JACC Cardiovasc Interv 2021;14:2298-300.
24. Jabbour RJ, Tanaka A, Finkelstein A, et al. Delayed Coronary Obstruction After Transcatheter Aortic Valve Replacement. J Am Coll Cardiol 2018;71:1513-24.
25. Barbanti M, Webb JG, Tamburino C, et al. Outcomes of Redo Transcatheter Aortic Valve Replacement for the Treatment of Postprocedural and Late Occurrence of Paravalvular Regurgitation and Transcatheter Valve Failure. Circ Cardiovasc Interv 2016;9:e003930.
26. Nai Fovino L, Scotti A, Massussi M, et al. Coronary Angiography After Transcatheter Aortic Valve Replacement (TAVR) to Evaluate the Risk of Coronary Access Impairment After TAVR-in-TAVR. J Am Heart Assoc 2020;9:e016446.
27. Abdelghani M, Landt M, Traboulsi H, et al. Coronary Access After TAVR With a Self-Expanding Bioprosthesis: Insights From Computed Tomography. JACC Cardiovasc Interv 2020;13:709-22.
28. Kawamura A, Maeda K, Shimamura K, et al. Coronary access after repeat transcatheter aortic valve replacement in patients of small body size: A simulation study. J Thorac Cardiovasc Surg 2022. [Epub ahead of print]. doi: 10.1016/j.jtcvs.2022.11.023.
29. Khalid AM, O'Sullivan CJ. Commissural alignment in transcatheter aortic valve replacement: A literature review. Front Cardiovasc Med 2022;9:938653.
30. Morita S. Aortic valve replacement and prosthesis-patient mismatch in the era of trans-catheter aortic valve implantation. Gen Thorac Cardiovasc Surg 2016;64:435-40.

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