Correlation Between Aortic Angulation and Outcomes of Transcatheter Aortic Valve Replacement With New-Generation Valves

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Abstract: The aim of this study was to assess the correlation of aortic angulation (AA) on immediate postprocedural and long-term outcomes following transcatheter aortic valve replacement (TAVR) with new-generation valves. There is limited and conflicting data on the impact of AA on short- and long-term outcomes in patients undergoing TAVR. Available studies to date were done with first-generation valves. We assessed 179 patients who underwent TAVR with either a balloon-expandable or self-expandable valve at our institute from May 2014 to June 2017 and had multislice computed tomography scans available for AA evaluation. All included patients received a second- or third-generation valve. TAVR endpoints, device success, and adverse events were defined according to the Valve Academic Research Consortium-2 criteria. The mean AA of the study population was 49.05 ± 10.07. Patients were divided into 2 groups: AA <49 and AA ≥49, and then further subdivided by valve type. There were no difference in mean age, The Society for Thoracic Surgery (STS) score, or race distribution between the AA <49 and AA ≥49

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groups. The preimplantation balloon valvuloplasty rate was higher in patients with AA $\geq$ 49 compared to patients with AA $<$49, (70% vs 55.1%, *P* = 0.04). There was no difference in re-hospitalization, pacemaker implantation, post-procedural aortic regurgitation or mortality between patients with AA $<$49 and AA $\geq$49 irrespective of valve type (*P* $<$ 0.05). AA does not significantly affect short- or long-term outcomes in patients who undergo TAVR with new-generation balloon-expandable or self-expandable valves. (Curr Probl Cardiol 2021;46:100415.)

Introduction

Transcatheter aortic valve replacement (TAVR) is an approved therapy for intermediate to high-risk surgical patients with severe aortic valve stenosis.[1-3] The use of multislice computed tomography (MSCT) is a mainstay of preprocedural planning in TAVR; providing accurate quantification of aortic valve calcification, precise reconstruction of the aortic annulus and proper bioprosthesis selection.[4-6]

Aortic angulation (AA), defined as the angle between the horizontal plane and the plane of the aortic annulus (Fig), has been of procedural consideration during TAVR. Prior studies acknowledge the difficulties of proper positioning of the self-expanding (SE) valve in patients with a "horizontal aorta" and high angulation,[7,8] leading to exclusion of most patients with aortic angulation (AA) >70% from TAVR clinical trials.[9] Furthermore, there is limited and conflicting data regarding the impact of increasing AA and device success following TAVR. Prior studies using first-generation valves suggest increased postprocedural paravalvular regurgitation and reduced procedural success among patients who underwent TAVR with SE valve.[10,11] The more recent study also concluded that the degree of AA does not affect early clinical outcomes in patients undergoing TAVR with a SE valve.[10] These studies suggested that newer generations of TAVR prostheses might improve our ability to treat patients with a higher angulation.[10-12]

The purpose of the present study was to evaluate the impact of AA on short- and long-term outcomes following TAVR with new generation SE and balloon-expanding (BE) valves.

Methods

We retrospectively analyzed AA in the 179 patients with severe symptomatic aortic stenosis who underwent TAVR at our institute and had

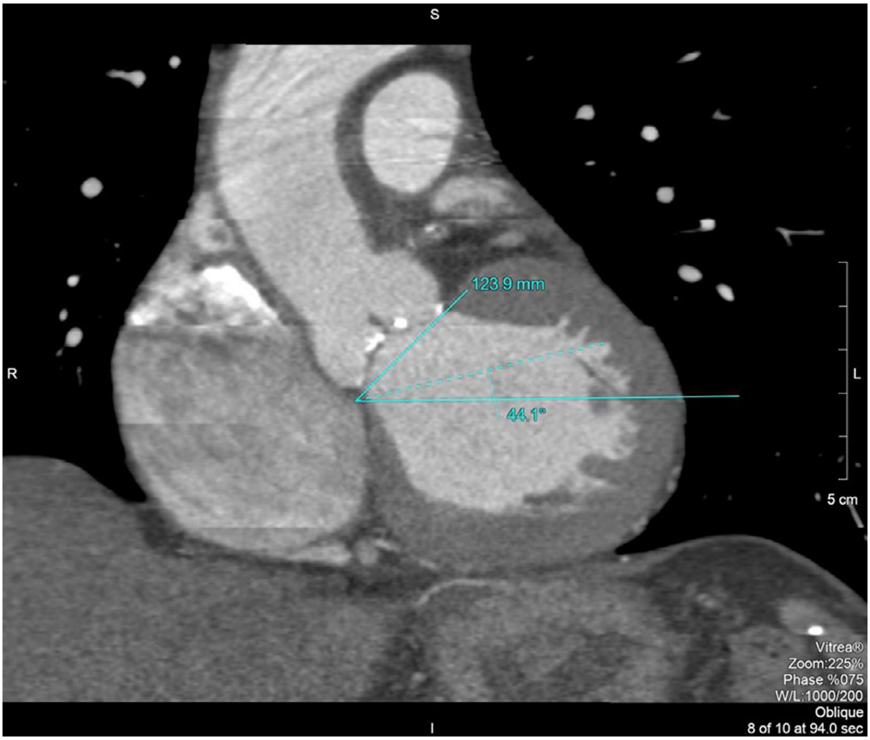

FIG. CT assessment of aortic angulation.

electrocardiographically gated MSCT angiography study with a Siemens Somatom Cardiac 64 scanner (Siemens Medical Solutions USA Inc, Malvern, Pennsylvania). Angulation of the aorta was calculated from a coronal projection at the level of the aortic annulus by radiologists who were specialized in cardiac CT (Fig). AA was defined as the angle between the horizontal plane and the plane of the aortic annulus. The mean AA was 49.05 $\pm$ 10.07 and the median AA was 48, interquartile range of 13 [42-55]. We divided patients into 2 numerically equal groups: AA $<$49 (n = 92) and AA $\geq$49 (n = 87). Baseline clinical, echocardiographic, and procedural details for TAVR were recorded for all patients, including 1-month, 6-month, and 1-year clinical and echocardiographic assessments during a follow-up "valve-clinic" visit. TAVR endpoints and adverse events were defined according to the Valve Academic Research Consortium-2 criteria.[13] The institutional review board at our center approved the study, and individual informed consent was waived from all subjects, as this was a purely retrospective chart-review study.

All data were summarized and displayed as mean ± SD for continuous variables and as number (percentage) of patients in each group for categorical variables. The Student *t* test and the Pearson chi-square test or Fisher's exact test were used to evaluate statistical significance between continuous and categorical variables, respectively. All of the analyses were considered significant at a 2-tailed *P* value of <0.05. SPSS statistical version 20.0 (IBM, Armonk, New York) was used to perform all statistical evaluations.

Results

A total of 524 patients underwent SE Corevalve/Evolut-R (Medtronic, Minneapolis, Minnesota) or BE Sapien XT/Sapien 3 (Edwards Lifesciences, Irvine, California) TAVR at our institution from 2012 to 2017. We excluded 339 patients between 2012 and early 2014 due to either the absence of MSCT images for pre-TAVR planning or using obsolete method of measuring AA from the method used in our study. A further 7 patients were excluded as they received first-generation valves. The remaining 179 patients were analyzed for this study. Baseline characteristics, procedural details, and clinical outcomes are outlined for balloon-expandable valves (Table 1), self-expandable valves (Table 2) and according to AA (Table 3). The preimplantation balloon valvuloplasty rate was higher in patients with AA ≥49 compared to patients with AA <49, (70% vs 55.1%; $P = 0.04$).

Ninety-two (51%) of patients had AA <49 on MSCT while 87 (49%) had AA ≥49. More patients received BE valves in our study cohort (72%). Out of 128 BE valves used, 118 were Edwards Sapien 3 valves while 10 were Sapien XT. All 52 SE valves were CoreValve Evolut-R. There was no significant difference in cardiac re-hospitalization, pacemaker implantation rates, postprocedural aortic regurgitation ≥grade 2, and 30-day and 1-year mortality between patients who had an AA <49 and AA ≥49 (Table 3). All other baseline characteristics, procedural details, and outcomes were similar between patients who received BE and SE valves and patients with AA <49 and AA ≥49.

Discussion

To our knowledge, this is the first study to assess the correlation of increased AA on immediate postprocedural and long-term outcomes following TAVR with new-generation valves. In our analysis, we did not find any statistically significant correlation between increasing AA and short- or long-term outcomes in our cohort regardless of valve type used.

TABLE 1. Baseline characteristics, procedural details, and clinical outcomes – balloon-expandable valve.

	<**49 (64)**	>**49 (63)**	***P* value**
Age (y)	79.5 ± 8.25	78.6 ± 9.1	0.56
STS score	6.99 ± 5.6	7.15 ± 4.04	0.85
Race (*n*)			
Caucasian	54	57	1.0
African American	6	5	1.0
Other	4	1	
Male sex	36	38	1.0
PAD	25%	22.5%	0.83
BMI	29.97 ± 7.70	29.68 ± 7.76	0.83
LOS			
Previous CVA	11%	19%	0.32
Mean EF (pre-TAVR)	56.0 ± 12.1	55.68 ± 11.85	0.88
Valve size (mm)			
20	2	0	
23	18	20	
26	27	27	
29	16	17	
34	1	0	
Valve type			
	Sapien 3 - 62 Sapien XT 3	Sapien 3 -56 Sapien XT -7	
TAVR access			
Trans apical	2	1	
Subclavian	0	1	
Trans femoral	61	61	
Trans AORTIC	1	0	
TTE postprocedure AVA cm^2 after 1 mo	1.9 ± 0.3 (54)	1.98 ± 0.49 (62)	0.29
Contrast used (mL)	161.55 ± 51.55 (59)	168.2 ± 50.77 (58)	0.48
Cardiac Re-Hosp	13%	19.6%	0.44
PPM	7.8%	14.2%	0.27
Device success	88.9%	93.6%	0.53
30-d mortality	1.7%	4.9%	0.61
6-mo mortality	3.5%	6.9%	0.67
1-y mortality	5.7%	7.2%	1.0
Preballoon	80%	88%	0.31
Postballoon	20%	18.3%	0.82
Valve-in-valve	1.5%	0%	1.0
Vent Perf	0%	1.5%	1.0
Postprocedure AR grade			
0	38	43	
1	14	10	
2	6	4	0.74
3	1	2	0.61
4	0	0	

TABLE 2. Baseline characteristics, procedural details, and clinical outcomes – self expandable valves.

	<49 (28)	>49 (24)	*P* value
Age (y)	80.3 ± 7.0	77.8 ± 9.5	0.28
STS score	6.02 ± 3.3	6.0 ± 3.4	0.98
Race			
Caucasian	24	21	1.0
African American	4	3	
Other	0	0	
Male sex	12	11	1.0
PAD	37%	**9.5%**	**0.04**
BMI	29.3 ± 6.5	30.4 ± 8.29	0.59
Previous CVA	11%	16.7%	0.69
Mean EF (pre-TAVR)	58.25 ± 11.4	48.75 ± 15.2	**0.01**
Valve size (mm)			
20	0	0	
23	1	6	
26	12	3	
29	15	13	
31	0	0	
34	0	2	
Valve type			
	CV Evolut R – 28	CV Evolut R – 24	
TAVR access			
Trans apical	1	0	
Subclavian	2	0	
Trans femoral	25	24	
Trans aortic	0	0	
TTE Pre-TAVR AVA	0.73 ± 0.14	0.75 ± 0.18	
TTE postprocedure AVA cm^2 after 1 mo	1.94 ± 0.52 ($n = 25$)	1.88 ± 0.46 ($n = 21$)	0.68
Contrast used (mL)	156.2 ± 52.9 ($n = 25$)	156.8 ± 51.2	
Cardiac Re-Hosp	18%	25%	0.73
PPM	11%	13%	1.0
Device success	96%	96%	1.00
30-d mortality	0%	4.1%	0.47
6-mo mortality	0%	4.3%	0.46
1-y mortality	0%	4.5%	0.44
Preballoon	3.6%	19%	0.15
Postballoon	10.7%	25%	0.27
Valve-in-valve	0%	8.3%	0.2
Vent Perf	3.6%	0%	1.0
Postprocedure AR grade			
0	20	13	
1	5	6	
2	3	5	
3	0	0	
4	0	0	

Bold value show Aortic angulation.

TABLE 3. Baseline characteristics, procedural details, and clinical outcomes – by Aortic angulation

	<49 (92)	>49 (87)	*P* value
Age (y)	79.7 ± 7.8	78.4 ± 9.2	0.30
STS score	6.69 ± 5.01	6.8 ± 3.8	0.87
Race			
Caucasian	78	78	1.0
African American	10	8	0.9
Other	4	1	
Male sex	48	49	1.0
PAD	28.5%	18.6%	0.15
BMI	29.7 ± 7.33 (82)	29.9 ± 7.8 (78)	0.86
Previous CVA	11.2%	18.3%	0.2
Mean EF (pre-TAVR)	56.6 ± 11.8	53.77 ± 13.1	0.13
Valve size (mm)			
20	2	0	
23	19	26	
26	39	30	
29	31	29	
31	0	0	
34	1	2	
TAVR access			
Trans apical	3	1	
Subclavian	2	1	
Trans femoral	86	85	
Trans aortic	1	0	
Contrast used (mL)	159.97 ± 54.4 (78)	164.83 ± 50.8 (80)	0.56
Cardiac Re-Hosp	14.4%	21.9%	0.56
PPM	8.7%	13.8%	0.35
PPM dependency	20%	40%	0.6
Device success	91.2%	94.2%	0.56
30-d mortality	1.1%	4.7%	0.36
6-mo mortality	2.4%	6%	0.27
1-y mortality	3.6%	6.4%	0.48
Preballoon dilatation	55.1%	70%	**0.04**
Postballoon dilatation	17.4%	19.5%	0.84
Valve-in-valve	1%	2.3%	0.9
Vent Perf	1%	1.1%	1.0
Postprocedure AR grade			
0	58	56	
1	19	16	
2	9	9	
3	1	2	
4	0	0	

Bold value show Aortic angulation.

Accurate imaging of the aortic annulus is a crucial component of preprocedural TAVR planning by estimating annular shape, calcification, and diameter for proper valve selection.[14] Previously, only 2D-transthoracic echocardiogram was used for procedural planning leading to inappropriate

TABLE 4. Valve type and generation by study.

Valve type	Sherif et al, 2010 (*n* = 50)	Abramowitz et al, 2016 (*n* = 582)	Popma et al, 2016 (*n* = 3587)	Our study, 2019 (*n* = 179)
SE valve type				
Sapien	-	17%	-	0%
Sapien XT	-	48%	-	8%
Sapien 3	-	35%	-	92%
BE valve type				
CoreValve	100%	100%	100%	0%
Evolut-R	0%	0%	0%	100%

device sizing and complications such as paravalvular leak, coronary artery occlusion, device embolization, and dysfunction leading to poor outcomes.[14,15] MSCT is now the preferred imaging modality in aortic assessment prior to TAVR,[15,16] and is superior to other imaging modalities for calculation of the AA.[17-19]

During pre-TAVR planning, assessment of AA plays an important role in predicting procedural difficulty.[19-21] Higher AA would require the valve, whether BE or SE, to be subjected to a higher degree of bending which could make accurate positioning of the valve more difficult and in theory, increase the likelihood of complications postimplantation such as paravalvular leak, valve-embolization, and valve-in-valve placement.[20,22] A prior study by Abramowitz et al[12] found that a higher AA reduces procedural success following SE but not in BE TAVR and proposed the use of BE valves in patients who have higher AA. A subsequent study by Popma et al.[10] reported no correlation between AA and procedural success or clinical outcomes in SE valves and attributed their findings to the use of the most up-to-date techniques in valve deployment.[10] The majority of patients in both studies received first-generation valves. Both studies hypothesized an improvement of procedural outcomes in patients with increased AA with newer generation TAVR valves.[10,12] Our study exclusively analyzed patients who received newer generation valves—The Medtronic Evolut-R or Edwards Sapien XT/Sapien 3 valves. We have displayed the historical and current studies comparing the percentages of valve types arranged by generation (Table 4). Several improvements were made to the self-expandable Evolut-R valve, including a shorter prosthesis height, a new more responsive delivery catheter that has increased ease of prosthesis deployment, and accuracy. The in-line sheath system of the device also reduces the delivery profile to the equivalent of a 14-Fr sheath.[23] Sapien S3 SE valve system also has several improvements including improved frame geometry, lower delivery profile, a new outer skirt to minimize paravalvular leak. It is equipped with a lower profile 14-16 Fr expandable sheath system for transfemoral delivery to reduce vascular complications. Both new-generation valves have been shown in clinical trials to reduce the rate of paravalvular leak, major vascular complications, bleeding, stroke, and 30-day mortality.[24-29] Hence it is no surprise that our cohort with a higher angulation (AA $\geq$ 49) who received these improved devices did not have reduced procedural success and did not show worse short- or long-term outcomes.

Although current TAVR practice is moving away from preimplantation balloon valvuloplasty,[30] we performed it more frequently in patients with AA $\geq$49 due to more challenging anatomy that our operators encountered. The use of balloon valvuloplasty during TAVR continues to be supported in cases of critical aortic valve stenosis, severe valve calcification and also aids in the sizing of the annulus.[31] Higher site volume for TAVR procedures is associated with lower in-hospital risk-adjusted outcomes, including mortality, vascular complications, and bleeding.[32] Our center has a 6-year experience in TAVR, and most procedures in our study (>75%) were done 3 years or more after establishing our TAVR program. Increased operator expertise may have played a role in better procedural outcomes in patients with higher AA. Our study thus confirms our hypothesis that AA does not affect procedural outcomes or short- and long-term mortality in TAVR patients with the use of newer generation valves and delivery systems.

Limitations

The main limitations of this study are its retrospective nature and being a single-center experience. The higher volume of BE valve implantations compared to SE valve implantation may also have influenced the results. Future prospective, randomized studies with a larger number of patients will be useful.

Due to the small number of patients in our study (n = 179) and an even smaller number who received SE valves, (n = 52) we were unable to perform a multivariate regression analysis on statistically significant (P = 0.05) univariate factors to adjust for confounders in our study, a recognized limitation.

Conclusions

Increasing AA does not significantly affect short- or long-term outcomes in patients who undergo TAVR with new-generation balloon-expandable or self-expandable valves. Larger studies are needed but this small, single centered study suggests safe use of newer generation valves in patients with highly angulated aortas.

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