Implications of Bicuspid Aortic Valves for Transcatheter Aortic Valve Implantation

Crochan J. O’Sullivan, MB BCh; Stephan Windecker, MD

Bicuspid aortic valve (BAV) occurs in 0.5% to 2% of the general population, with strong male predilection. Valvular complications include aortic stenosis, aortic regurgitation (AR), and infective endocarditis. Vascular complications comprise aortic dilatation, aneurysm formation, and aortic dissection. Coarctation of the aorta and left coronary artery dominance are also associated with BAV. BAV consists of 2 cusps, usually of unequal size. The larger cusp may contain 1 or 2 raphes—fibrous ridges extending from the malformed commissure to the free edge of the 2 conjoint cusps. An anatomic classification distinguishes BAV types principally by the number of raphes (Figure). Because a raphe can be missed on echocardiography, Schaefer et al proposed 3 types based instead on the pattern of leaflet fusion. Clinical presentation of BAV is variable. Some patients present with severe disease in infancy, whereas others present with asymptomatic disease in old age. In a recent series of 642 asymptomatic adults with BAV referred to a tertiary center, 25% had a primary cardiac event at mean follow-up of 9 years. Aortic valve or ascending aorta intervention comprised most (22%) events. In another series of 212 asymptomatic adults with BAV recruited from the community, primary cardiac outcomes occurred in 42% at 20-year follow-up. Overall survival rates were similar to the general population.

BAV and Surgical Aortic Valve Replacement
Surgical aortic valve replacement (SAVR) is generally performed at a younger age among BAV patients compared with patients with tricuspid aortic valve disease. In a recent study, the average age for SAVR was 49±20 versus 67±16 years for BAV and tricuspid aortic valve patients, respectively. Surgical options for BAV include isolated valve replacement, Ross and Bentall procedures, or, less commonly, valve repair. Valve-sparing aortic root replacements can be performed for isolated aortopathy. Thirty percent of patients undergoing aortic valve replacement require aortic root surgery. Importantly, aortic root dilatation can continue to progress even after isolated aortic valve replacement.

BAV and Transcatheter Aortic Valve Replacement
Transcatheter aortic valve implantation (TAVI) is an alternative therapeutic modality to SAVR to treat high-risk or inoperable patients presenting with symptomatic severe aortic stenosis. To date, there has only been limited experience of TAVI in treating BAV patients, and BAV is considered a relative contraindication for TAVI according to current guidelines. In addition, BAV patients were excluded from the recent Placement of Aortic Transcatheter Valves (PARTNER) trials. Roberts et al reported that 22% of patients aged ≥80 years undergoing SAVR for aortic stenosis had BAV. Extrapolating these figures to the TAVI population suggests that more than one fifth of otherwise eligible high-risk/inoperable octogenarian patients may be precluded from TAVI on the basis of BAV disease. Because the prognosis associated with conservative management of symptomatic severe aortic stenosis is dismal, it is important to understand barriers precluding TAVI among BAV patients and determine whether they may be overcome.

Why is BAV considered a relative contraindication to TAVI? The principal reason relates to the asymmetrical anatomy of the BAV annulus, which increases the risk of uneven expansion of the (circular) bioprosthesis. This can theoretically cause leaflet deformity and valve dysfunction. An anatomic study by Zegdi et al highlighted this issue. The investigators deployed noncommercial valved stents intraoperatively into the aortic annulus of patients with severe tricuspid (n=19) and bicuspid (n=16) aortic stenosis before SAVR. They observed stent misdeployment, with a noncircular stent shape (ie, elliptical or triangular), in almost one third of tricuspid aortic valves and in all BAVs. The noncircular stent shapes were reported to distort leaflet geometry.

Wijesinghe et al were the first to report a series of BAV patients (n=11) undergoing TAVI with the Edwards-SAPIEN device (ESV; Edwards Lifesciences, Inc, Irvine, CA). Moderate paravalvular leaks occurred in 2 (18%) patients, and another patient experienced device migration as a result of valve undersizing requiring late conversion to surgery. Noteworthy, valve expansion appeared relatively circular in all patients after deployment on transesophageal echocardiography. Himbert et al described a series of BAV patients (n=15) undergoing TAVI with the Medtronic CoreValve system (MCS; Medtronic, Inc, Minneapolis, MN). One in-hospital death after emergency conversion to surgery for severe symptomatic AR occurred after the device was inserted too low. Despite asymmetrical expansion of the MCS at the level of the native annulus in all remaining 14 patients, moderate AR was observed in 1 patient only; all others had mild AR, and mean gradients ranged between 5 and 18 mm Hg. One BAV patient died 8 months post-TAVI after aortic dissection.

In this issue of Circulation: Cardiovascular Interventions, Hayashida et al compared procedural and 30-day clinical...
outcomes between patients with (n=21) and without (n=208) BAV undergoing TAVI at their institution. This is the first study to compare clinical outcomes between BAV and non-BAV patients undergoing TAVI. All patients had preprocedural multidetector computed tomography (MDCT) and transthoracic echocardiography and transesophageal echocardiography. Patients who did not undergo preprocedural MDCT were excluded (n=241). Baseline characteristics were similar between groups except for diabetes mellitus. Ascending aortic diameters were significantly larger among BAV patients, but annular sizes were similar. BAV patients received either an ESV (n=11) or an MCS (n=10) device via the transfemoral (n=13), transapical (n=3), or transaortic (n=5) route. No significant differences in procedural and 30-day end points were observed between the BAV and non-BAV groups. Specifically, no incidences of annular rupture, valve migration, or conversion to open heart surgery occurred among BAV patients, although there was one instance of coronary occlusion. Device success was 100%. One BAV patient died at 30 days. Postprocedural AR ≥ 2+ was observed in 4 of 21 (19%) BAV patients (3 MCS and 1 ESV), which was not significantly different from the non-BAV group (14.9%). Among patients having postprocedural MDCT, both ESV and MCS exhibited an oval shape. Of the 11 BAV patients with 1-year follow-up, 2 had died. One-year echocardiography follow-up, available in 6 patients, showed an overall mean gradient of 9.0±3.6 mm Hg, although AR was not reported.

What are the clinical implications of this study? First, it demonstrates that TAVI is technically feasible and short-term clinical outcomes seem promising. Procedural and 30-day outcomes were similar to non-BAV patients. Second, despite an oval shape postdeployment, both ESV and MCS prostheses appeared to function adequately ≤ 30 days (and ≤ 1 year in 6 patients with 1-year follow-up).

**Figure.** Anatomic classification of bicuspid aortic valves (BAV) based on a study of 304 surgical specimens. Prominent black lines denote the raphe(s). Type 0=no raphe, type 1=1 raphe, and type 2=2 raphes. Each type is subcategorized according to the spatial position of the cusps (type 0) or raphes (types 1 and 2). Percentages represent the approximate prevalence of each BAV type observed in the Sievers study. ap indicates anterior-posterior; L, left coronary sinus; lat, lateral; N, noncoronary sinus; and R, right coronary sinus. Figure adapted from Sievers et al with the permission of Elsevier.

**Table.** Transcatheter Aortic Valve Implantation and Bicuspid Aortic Valves: Published Case Reports and Series To Date

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>Edwards SAPIEN or XT Valve</th>
<th>Medtronic CoreValve System</th>
<th>Balloon Predilation</th>
<th>Route</th>
<th>Postdeployment Prosthetic Shape</th>
<th>Postdeployment Imaging</th>
<th>Postdeployment Mean Gradient</th>
<th>Postdeployment AR</th>
<th>Follow-up</th>
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<tr>
<td>Delgado et al</td>
<td>2009</td>
<td>1</td>
<td>26 mm</td>
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<td>NR</td>
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<td>Circular</td>
<td>CT</td>
<td>10 mm Hg</td>
<td>NR</td>
<td>1 mo</td>
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<td>...</td>
<td>Yes</td>
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<td>Circular</td>
<td>CT</td>
<td>20 mm Hg</td>
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<td>6 mo</td>
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<tr>
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<td>1</td>
<td>26 mm</td>
<td>...</td>
<td>NR</td>
<td>TA</td>
<td>NR</td>
<td>Echo</td>
<td>6 mm Hg</td>
<td>Absent</td>
<td>In-hospital</td>
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<td>11</td>
<td>26 mm (n=10) 23 mm (n=1)</td>
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<td>See text</td>
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<tr>
<td>Jilaihawi et al</td>
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<td>1</td>
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<td>TF</td>
<td>Elliptical</td>
<td>Echo</td>
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<td>2-y</td>
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<td>Raja et al</td>
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<td>26 mm</td>
<td>...</td>
<td>Yes</td>
<td>TF</td>
<td>Circular</td>
<td>CT</td>
<td>NR</td>
<td>Mild</td>
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<tr>
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<td>...</td>
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<td>CT</td>
<td>16 mm Hg</td>
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<td>NR</td>
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<td>Baralis et al</td>
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<td>29 mm XT</td>
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<td>NR</td>
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<td>15</td>
<td>...</td>
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<td>CT</td>
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<tr>
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<td>n=11 23 mm (n=5) 29 mm (n=5) 26 mm (n=2) 29 mm (n=4)</td>
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<td>TF=13</td>
<td>TA=3</td>
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<td>CT†</td>
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<td>See text</td>
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</tbody>
</table>

CT indicates computed tomography; NR, not reported; TA, transapical; TAo, transaortic; TF, transfemoral; and TS, transsubclavian.

*Two-year values.
†Postprocedural CT not systematically performed on all patients (number not specified).
echo follow-up). Adequate valvular function, despite asymmetrical expansion of the MCS at the annular level, is thought to relate to the supra-annular position of the prosthetic leaflets.24 Although undersizing and nonuniform expansion is almost invariably present on computed tomography after MCS implantation, only minimal deformation and underexpansion occur at the supra-annular level where the leaflets coapt.25 This constrained segment of the MCS prosthesis has high hoop strength, making it resistant to compression, helping to preserve leaflet geometry and coaptation.24 Several case reports seem to suggest that the ESV device maintains a more circular shape after deployment in BAV annuli,9,10,14,16 albeit not in every case (Table).18

Several limitations deserve mention. First, follow-up was short (30 days). One-year clinical and echocardiographic follow-up were available in only 11 and 6 patients, respectively. Further studies assessing longer-term clinical outcomes and valve durability in larger numbers of BAV patients undergoing TAVI are needed. Second, a 19% rate of paraprosthetic AR ≥2+ may be excessive and requires further technical improvement with newer generation TAVI devices. Third, BAV patients included in this study may not be representative of BAV patients as a whole, and further studies are needed to define the role of MDCT in diagnosing BAV. Finally, MDCT was not systematically performed post-TAVI in BAV patients, therefore precluding an opportunity to assess and learn from the postdeployment configuration of the bioprosthetic devices.

In summary, observational studies to date suggest that TAVI is technically feasible in BAV patients and is safe and effective at least in the short-term. Further studies are required to assess longer-term valve durability. The role of newer generation valve devices in treating BAV is yet to be defined. Because nonvalvular findings occur in ≤50% of BAV patients,1 it is essential to look beyond the valve. Unique safety concerns not applicable to tricuspid aortic valve patients (eg, aortic dissection and progressive aortic root dilatation even after valve implantation) need to be considered in the BAV population.

Disclosures
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References

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