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Long-Term Durability of Transcatheter Aortic Valves in Patients With Bicuspid Aortic Stenosis

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Abbreviations: AS, aortic stenosis; BVD, bioprosthetic valve dysfunction; BVF, bioprosthetic valve failure; EOA, effective orifice area; PPM, prosthesis-patient mismatch; SAVR, surgical aortic valve replacement; SVD, structural valve deterioration; TAV, transcatheter aortic valve; TAVR, transcatheter aortic valve replacement; VARC, Valve Academic Research Consortium.

ABSTRACT

Background: Data concerning the long-term durability of transcatheter aortic valves (TAVs) in patients with bicuspid aortic stenosis (AS) are lacking.

Aims: The study aims to report data on long-term valve durability following transcatheter aortic valve replacement (TAVR) in bicuspid AS.

Methods: This multicentre registry included patients who underwent TAVR for bicuspid AS with at least 2-year echocardiographic follow-up. The incidence of structural valve deterioration (SVD), bioprosthetic valve dysfunction (BVD), and bioprosthetic valve failure (BVF) was determined according to Valve Academic Research Consortium (VARC)-3 criteria.

Results: Among 894 patients (mean age: 75.6 years; 39% female), the median echocardiographic follow-up was 48.7 months with a 5-year cumulative incidence of moderate-to-severe SVD, severe SVD, severe BVD, and BVF of 8.1%, 3.2%, 11.4%, and 6.1%, respectively. Younger age (≤ 75 years) was associated with a higher likelihood of reintervention (HR 2.40, log-rank $p = 0.04$). TAV downsizing was associated with higher rates of moderate-to-severe SVD (HR 3.05, log-rank $p < 0.001$), severe BVD (HR 2.07, log-rank $p = 0.003$), and BVF (HR 3.25, log-rank $p = 0.002$). In the sub-group with small annuli (area ≤ 430 mm^2), implantation of balloon-expandable TAVs was associated with a higher rate of BVD in comparison with self-expanding TAVs (HR: 3.27, log-rank $p = 0.008$).

Conclusions: TAVs demonstrated favorable 5-year durability in patients with bicuspid AS, although younger patients were more likely to require valve reintervention. Nominal TAV sizing was associated with better durability outcomes as compared to TAV downsizing. Self-expanding valves were associated with superior hemodynamics in patients with small annuli.

1 | Introduction

Bicuspid aortic valve disease is a common congenital cardiac anatomical variant that poses unique challenges when treated with transcatheter aortic valve replacement (TAVR) [1–3]. TAVR has emerged as a transformative treatment option for patients with severe aortic stenosis (AS) across all levels of surgical risk and is progressively implemented in younger populations, in whom bicuspid aortic valve anatomy is more frequently encountered [4–15]. However, these patients with bicuspid AS have historically been underrepresented in clinical TAVR trials owing to their more complex anatomy. While US guidelines recommend surgical aortic valve replacement (SAVR) for bicuspid AS patients [16], European guidelines do not provide a formal recommendation, but suggest that SAVR is preferable in patients with bicuspid AS and associated aortopathy [17]. In reality, TAVR is already widely adopted for the treatment of bicuspid AS in daily clinical practice, and previous observational studies have shown comparable outcomes for TAVR in tricuspid and bicuspid AS patients [18–20]. However, limited data exist concerning long-term transcatheter aortic valve (TAV) durability in bicuspid AS, which is increasingly relevant as TAVR expands to younger patients, with more bicuspid AS and longer life-expectancies.

In the present study, we aim to address this knowledge gap by reporting on the main Valve Academic Research Consortium (VARC)-3 defined endpoints of bioprosthetic valve durability in a large multi-center cohort of bicuspid AS patients treated with TAVR [21]. In addition, we aim to explore the impact of different clinical, anatomical, and procedural factors on longer-term bioprosthetic valve performance.

2 | Methods

2.1 | Study Design and Patient Population

This retrospective registry addressing TAV durability in patients with bicuspid AS was established through a collaboration of 34 heart centers across 14 countries (Belgium, China, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Netherlands, Slovenia, Switzerland, the United Kingdom, and the United States). Consecutive patients with bicuspid AS who underwent TAVR and who had more than 2 years of transthoracic echocardiographic follow-up data available were included. The devices used in this study included Sapien 3 (Ultra) (Edwards Lifesciences, USA), Evolut R/PRO (+) (Medtronic, USA), Venus-A (Venus MedTech, China), ACURATE neo2 (Boston Scientific, USA), Lotus (Boston Scientific, USA), and Portico/Navitor (Abbott, USA). Decisions concerning the indication for TAVR and the chosen type of TAV were made by the local multidisciplinary Heart Team and TAVR operator. The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committees at each participating site. Written informed consent for the use of anonymized clinical data for research was obtained from patients when stipulated; although this requirement was waived by some of the ethics committees.

2.2 | Baseline Characteristics and Study Endpoints

The main endpoints of this study were structural valve deterioration (SVD), bioprosthetic valve dysfunction (BVD), and bioprosthetic valve failure (BVF), defined according to VARC-3 criteria [21]. The definition for SVD focused on hemodynamic aspects of valve deterioration: (A) moderate SVD: in case of an increase in mean transvalvular gradient ≥ 10 mmHg resulting in a mean gradient ≥ 20 mmHg, OR new occurrence or increase of ≥ 1 grade of intra-prosthetic aortic regurgitation (AR) resulting in ≥ moderate AR; (B) severe SVD: in case of an increase in mean transvalvular gradient ≥ 20 mmHg resulting in a mean gradient ≥ 30 mmHg, OR new occurrence or increase of ≥ 2 grades of intra-prosthetic AR resulting in severe AR. Severe BVD was defined as a composite endpoint of severe SVD, severe non-SVD (severe paravalvular AR and severe prosthesis-patient mismatch [PPM]), clinical valve thrombosis, and endocarditis. Severe PPM was defined as an indexed effective orifice area (EOA) ≤ 0.65 cm²/m² for patients with a body mass index (BMI) < 30 kg/m² and ≤ 0.55 cm²/m² for those with BMI ≥ 30 kg/m². BVF was defined as a composite endpoint of severe SVD, valve-related death, and aortic valve reintervention. The study also evaluated the impact of procedural techniques in terms of nominal sizing, which was defined as adherence to manufacturer-recommended valve dimensions, and down-sizing, which was defined as the selection of a TAV size smaller than the manufacturer's guidelines based on preprocedural annular measurements.

Bicuspid morphology was adjudicated at each site using pre-procedural multidetector computed tomography based on Sievers' criteria [22]. Echocardiographic measurements were performed and verified by experienced physicians, and data were collected directly from each site.

2.3 | Statistical Analysis

Categorical data were presented as numbers (%) and continuous data were presented as mean ± standard deviation (SD) or median (interquartile range). Time-to-event analyses were conducted using Kaplan–Meier estimates to calculate the cumulative incidence of each endpoint, with comparisons made using the log-rank test. The Cox proportional hazards model was used to evaluate the impact of covariates on the time-to-event outcomes, providing hazard ratios (HR) with corresponding 95% confidence intervals (CI). A conservative approach was used for the time-to-event analyses of BVD and BVF (which included both clinical and echocardiographic criteria with potentially differing follow-up times) by choosing the earliest follow-up time in cases of discrepancy. Specific latest follow-up times were applied when reporting the cumulative incidence of individual components of these composite endpoints. Two-tailed *p*-values were reported with $p < 0.05$ indicating statistical significance. Statistical analyses were performed using RStudio (V2023.06, Posit Software).

3 | Results

3.1 | Study Population

Amongst 2197 consecutive bicuspid AS patients who underwent TAVR between January 2015 and December 2022 at the participating centers, 894 patients with echocardiographic follow-up

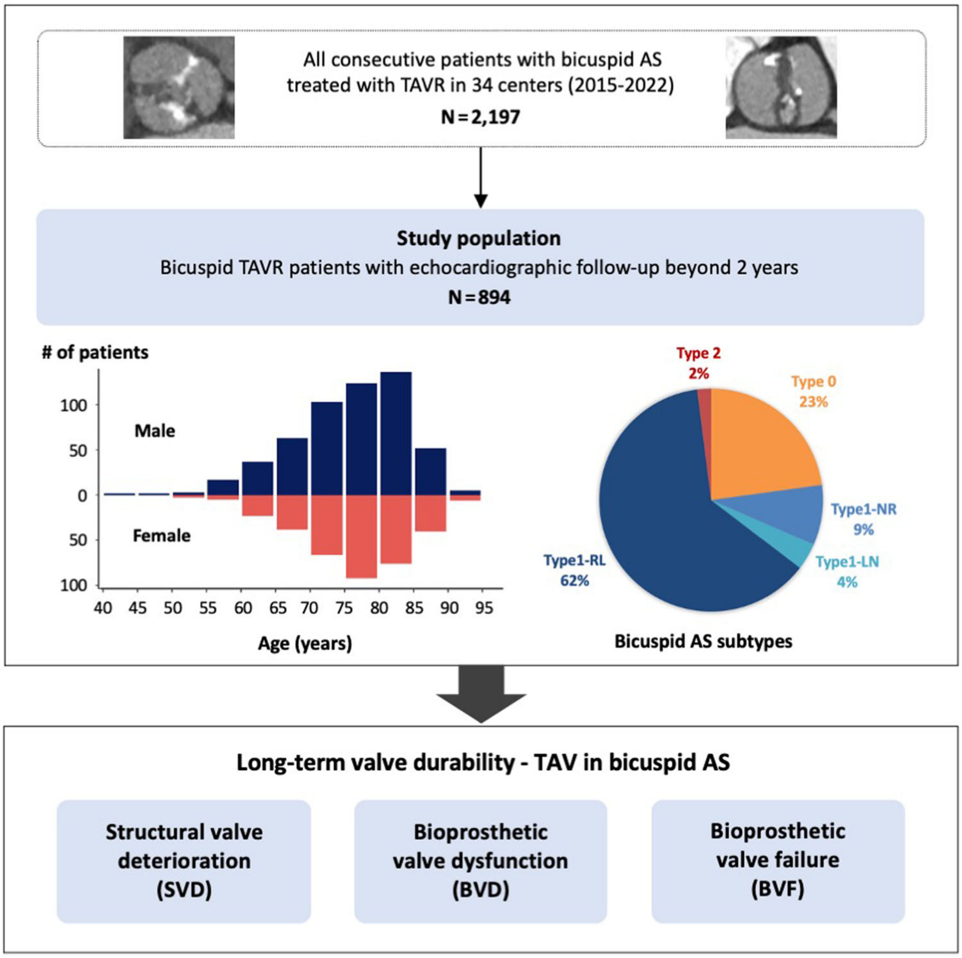


FIGURE 1 | Study design. The study population was derived from a cohort of patients with bicuspid AS who underwent TAVR with echocardiographic follow-up beyond 2 years. The key endpoints of this study were VARC-3-defined structural valve deterioration (SVD), bioprosthetic valve dysfunction (BVD), and bioprosthetic valve failure (BVF). AS, aortic stenosis; STS, Society of Thoracic Surgeons; TAVR, transcatheter aortic valve replacement; VARC, Valve Academic Research Consortium. [Color figure can be viewed at wileyonlinelibrary.com]

data beyond 2 years post-TAVR were included in this study (Figure 1). The median echocardiographic follow-up was 48.7 months (interquartile range: 37.8–60.8 months).

The mean age of the study population was 75.6 ± 8.1 years with a mean Society of Thoracic Surgeons risk score of 4.0 ± 3.2%. Baseline characteristics of the study population are summarized in Table 1. Sievers type 1 was the most common bicuspid aortic valve phenotype (75%) and right-left cusp fusion the predominant subtype (Figure 1). The distribution of TAVs implanted was as follows: self-expanding 64.8%, balloon-expandable 30.8%, and mechanically-expandable 4.4% (Supporting Information S1: Figure 1).

TABLE 1 | Study population.

	***N* = 894**
Demographics and co-morbidities	
Age, years	75.6 ± 8.1
Female	350 (39.1%)
Arterial hypertension	538 (60.3%)
Diabetes mellitus	163 (18.3%)
Coronary artery disease	282 (31.5%)
Prior PCI	144 (16.1%)
Prior CABG	38 (4.3%)
Peripheral artery disease	127 (14.2%)
Chronic renal failure	109 (12.2%)
Atrial fibrillation	184 (20.6%)
Prior stroke	107 (12.0%)
Permanent pacemaker	68 (7.6%)
Chronic lung disease	208 (23.3%)
Society of Thoracic Surgeons risk score, %	3.9 ± 3.2
EuroScore II,%	3.5 ± 3.5
Baseline echocardiographic and CT features	
Left ventricular ejection fraction, %	53.9 ± 14.2
Aortic valve mean gradient, mmHg	51.6 ± 17.7
Effective orifice area, cm^2	0.70 ± 0.19
Aortic regurgitation ≥ moderate	125 (14.2%)
Aortic annulus perimeter, mm	80.4 ± 8.6
Aortic annulus area, mm^2	500 ± 107
Bicuspid Sievers type	
Type 0	194 (22.8%)
Type 1	639 (75.2%)
Ascending aorta mean diameter, mm	37.7 ± 5.5
TAVR procedural features	
Transfemoral access	872 (97.5%)
Self-expanding valve	579 (64.8%)
Prosthesis size, mm	27.5 ± 3.1
Predilation	666 (74.9%)
Postdilation	331 (37.3%)

Abbreviations: CABG, coronary artery bypass graft surgery; CT, computed tomography; PCI, percutaneous coronary intervention; TAVR, transcatheter aortic valve replacement.

3.2 | Long-Term TAV Durability Outcomes

The cumulative incidence of moderate-to-severe and severe SVD at 5 years was 8.1% and 3.2%, respectively, and was principally driven by an increase in trans-prosthetic gradient. The 5-year cumulative incidence of severe BVD was 11.4%, with severe PPM being the primary contributor. The incidence of both clinical valve thrombosis and endocarditis was low (0.4% and 2.6%, respectively). Finally, the 5-year risk of BVF was 6.1%, with a valve reintervention rate of 2.4% (Figure 2).

3.3 | Impact of Clinical and Anatomical Characteristics

Younger age (≤ 75 years) was not associated with a higher risk of moderate-to-severe SVD (log-rank test: $p = 0.5$) or severe BVD (log-rank test: $p = 0.3$) compared to older age (> 75 years) over 5-year follow-up. However, younger patients had a higher incidence of BVF, primarily driven by aortic valve reintervention in the 3-to-5-year follow-up period (10/15 total BVF events; Figure 3A).

TAV durability outcomes were similar in patients with Sievers type 0 and type 1 bicuspid AS (moderate-to-severe SVD: log-rank test $p = 0.7$; severe BVD: log-rank test $p = 0.9$; BVF: log-rank test $p = 0.9$) (Figure 3B) and in patients with and without small annuli ≤ 430 mm^2 (moderate-to-severe SVD: log-rank test $p = 0.5$; severe BVD: log-rank test $p = 0.3$; BVF: log-rank test $p = 0.7$) (Figure 3C).

Long-term TAV durability outcomes were also similar in males and females, and were independent of oral anticoagulant treatment status (Supporting Information S1: Figures 2–3).

3.4 | Impact of TAV Device and Procedural Techniques

In the overall population, patients who received a self-expanding TAV had similar rates of moderate-to-severe SVD (log-rank test $p = 0.2$), severe BVD (log-rank test $p = 0.1$), and BVF (log-rank test $p = 0.1$) compared to those who received a balloon-expandable TAV (Figure 4A). In subgroup analyses, self-expanding and balloon-expandable TAVs also had comparable outcomes in patients with Sievers type 1 anatomy and in those with larger annuli (area > 540 mm^2) (Figure 5A,C). However, in patients with a small annulus (area ≤ 430 mm^2), the cumulative incidence of severe BVD was higher in those who received a balloon-expandable TAV when compared to those who received a self-expanding TAV (27.8% vs. 8.9%, $p = 0.005$), primarily driven by immediate postprocedural PPM (Figure 5B).

TAV downsizing was associated with significantly higher rates of moderate-to-severe SVD (HR 3.05, log-rank test $p < 0.001$),

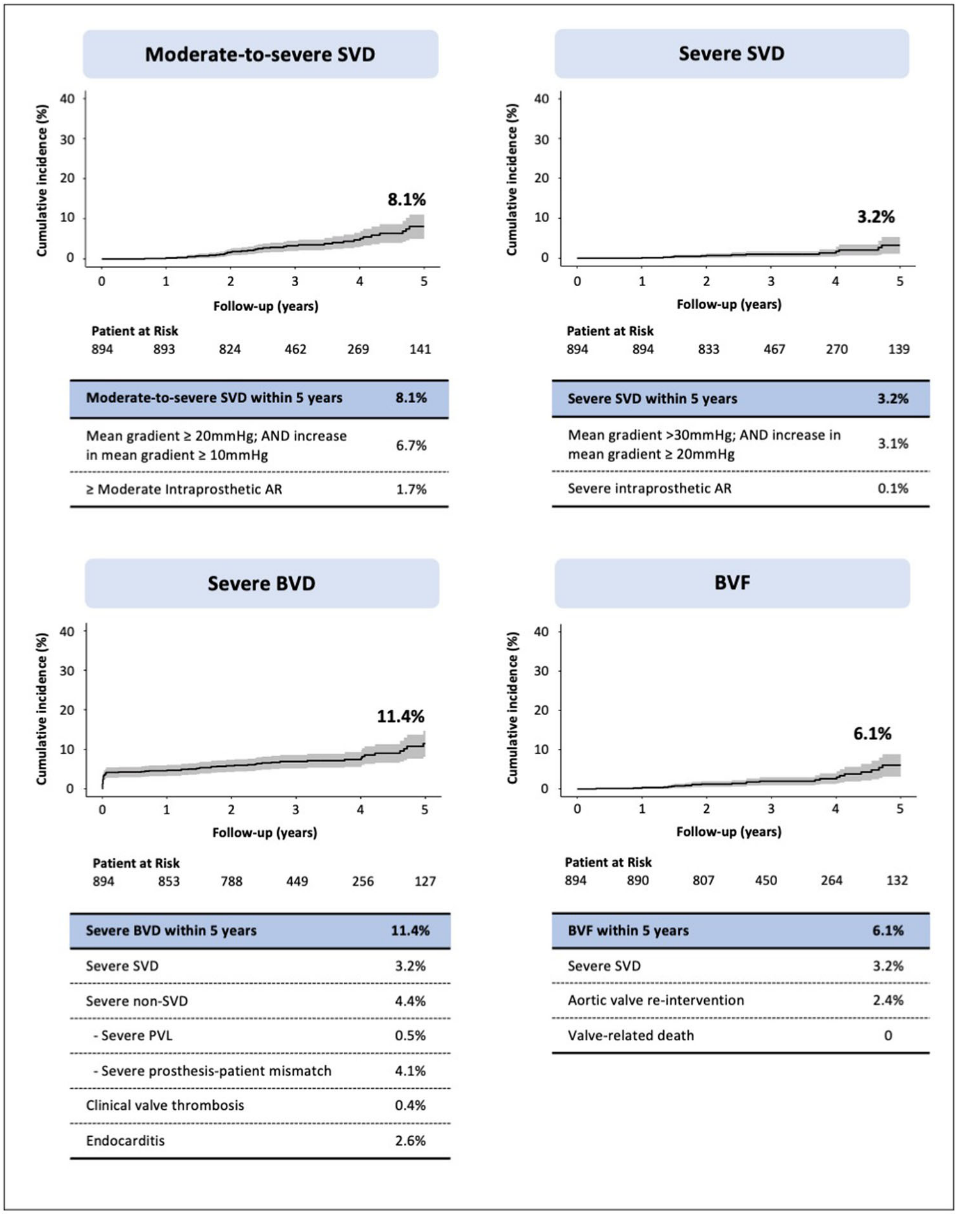


FIGURE 2 | Cumulative incidence of SVD, BVD, and BVF following TAVR in bicuspid AS. Kaplan–Meier curves illustrating the 5-year cumulative incidence rates of moderate-to-severe SVD, severe SVD, severe BVD, and BVF. The cumulative incidences for each component are listed in the accompanying tables. AR, aortic regurgitation; AS, aortic stenosis; BVD, bioprosthetic valve dysfunction; BVF, bioprosthetic valve failure; PVL, paravalvular leak; SVD, structural valve deterioration. [Color figure can be viewed at wileyonlinelibrary.com]

severe BVD (HR 2.07, log-rank test $p = 0.003$), and BVF (HR 3.25, log-rank test $p = 0.002$) as compared to nominal sizing (Figure 4B). Patients with TAV post-dilatation exhibited a numerically higher rate of moderate-to-severe SVD (HR 1.87, log rank test $p = 0.05$), but not severe BVD (log rank test $p = 0.7$) or BVF (log rank test $p = 0.3$) (Figure 4C).

3.5 | Impact of Immediate Postprocedural PPM on Long-Term TAV Durability Outcomes

We further analyzed the impact of immediate post-procedural PPM on long-term TAV durability (according to the VARC-3 endpoints, SVD and BVF). Amongst the entire study population, 20.5% demonstrated ≥ moderate PPM immediately postprocedure. Whilst the cumulative incidence of moderate-to-severe SVD (15.3% vs. 6.3%, $p = 0.1$), severe SVD (6.7% vs. 2.4%, $p = 0.08$), and BVF (10.9% vs. 5.0%, $p = 0.08$) was numerically higher at 5 years in patients with ≥ moderate PPM compared to those with no or mild PPM, none of these differences reached statistical significance (Figure 6).

4 | Discussion

In this unique, real-world bicuspid TAVR registry with median echocardiographic follow-up greater than 4 years, we found that: (1) overall rates of SVD, BVD, and BVF in patients with bicuspid AS undergoing TAVR were comparable to those observed in historical cohorts of TAVR patients with tricuspid

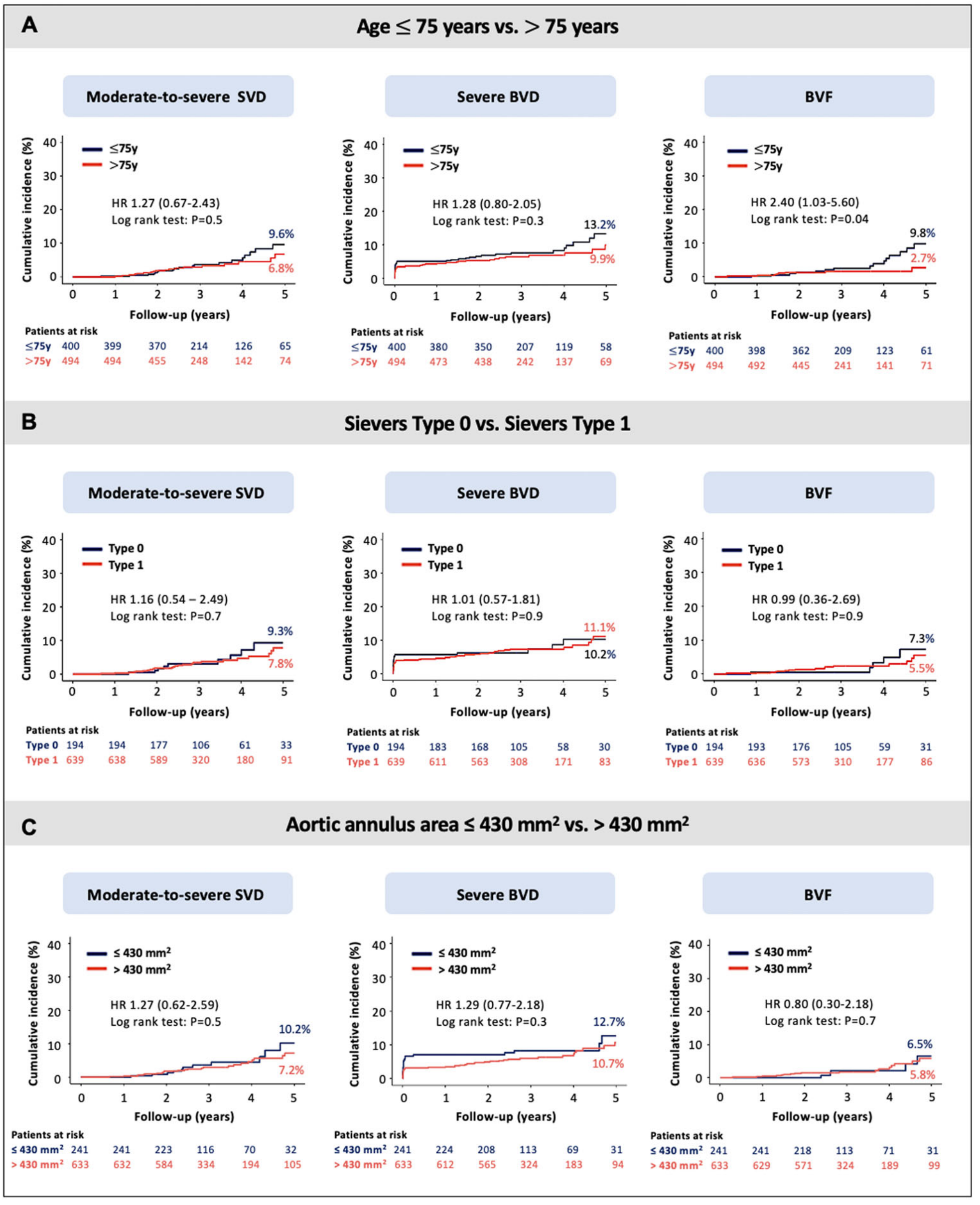


FIGURE 3 | Impact of patient characteristics on TAV durability in bicuspid AS. Kaplan–Meier curves illustrating the 5-year cumulative incidences of moderate-to-severe SVD, severe BVD, and BVF comparing (A) younger (≤ 75 years) versus older (> 75 years) patients, (B) Sievers type 0 versus type 1 bicuspid AS patients, and (C) patients with annulus area ≤ 430 and > 430 mm^2. AS, aortic stenosis; BVD, bioprosthetic valve dysfunction; BVF, bioprosthetic valve failure; SVD, structural valve deterioration; TAV, transcatheter aortic valve. [Color figure can be viewed at wileyonlinelibrary.com]

AS; (2) TAV durability outcomes were similar in younger and older patients but the former were more likely to undergo TAV reintervention; (3) TAV durability was similar in Sievers type 0 and type 1 sub-groups; (4) BVD outcomes in patients with a small aortic annulus seemed to be superior with self-expanding TAVs compared with balloon-expandable TAVs (primarily driven by a lower rate of PPM); and (5) TAV downsizing was associated with significantly higher rates of SVD, BVD, and BVF compared to nominal TAV sizing.

4.1 | Long-Term TAV Durability in Bicuspid AS Population

Pivotal trials have recently reported long-term valve durability outcomes after TAVR for tricuspid AS. In the recently reported 10-year outcomes of the NOTION (Nordic Aortic Valve Intervention) trial, rates of moderate-to-severe SVD, severe SVD, severe BVD, and BVF were 15.4%, 1.5%, 20.5%, and 9.7%, respectively, in low-risk patients with tricuspid AS treated using the CoreValve TAV [13]. Consistent with these findings, the UK-TAVI registry reported moderate-to-severe SVD in 13.6% of patients over 12 years of follow-up after TAVR for tricuspid AS, with severe SVD in 5.9% [23]. Similarly, in a post hoc analysis of pooled data from the CoreValve US High Risk Pivotal and SURTAVI (Surgical Replacement and Transcatheter Aortic Valve Implantation) randomized clinical trials, the cumulative incidence of severe SVD and BVD was 2.2% and 7.8%, respectively, through 5 years of follow-up [24]. In comparison, the 5-year incidence of severe SVD and BVD in our bicuspid TAVR cohort was 3.2% and 11.4%, respectively. Meanwhile, the PARTNER (Placement of Aortic Transcatheter Valves) 3 low-risk trial also reported rates of severe

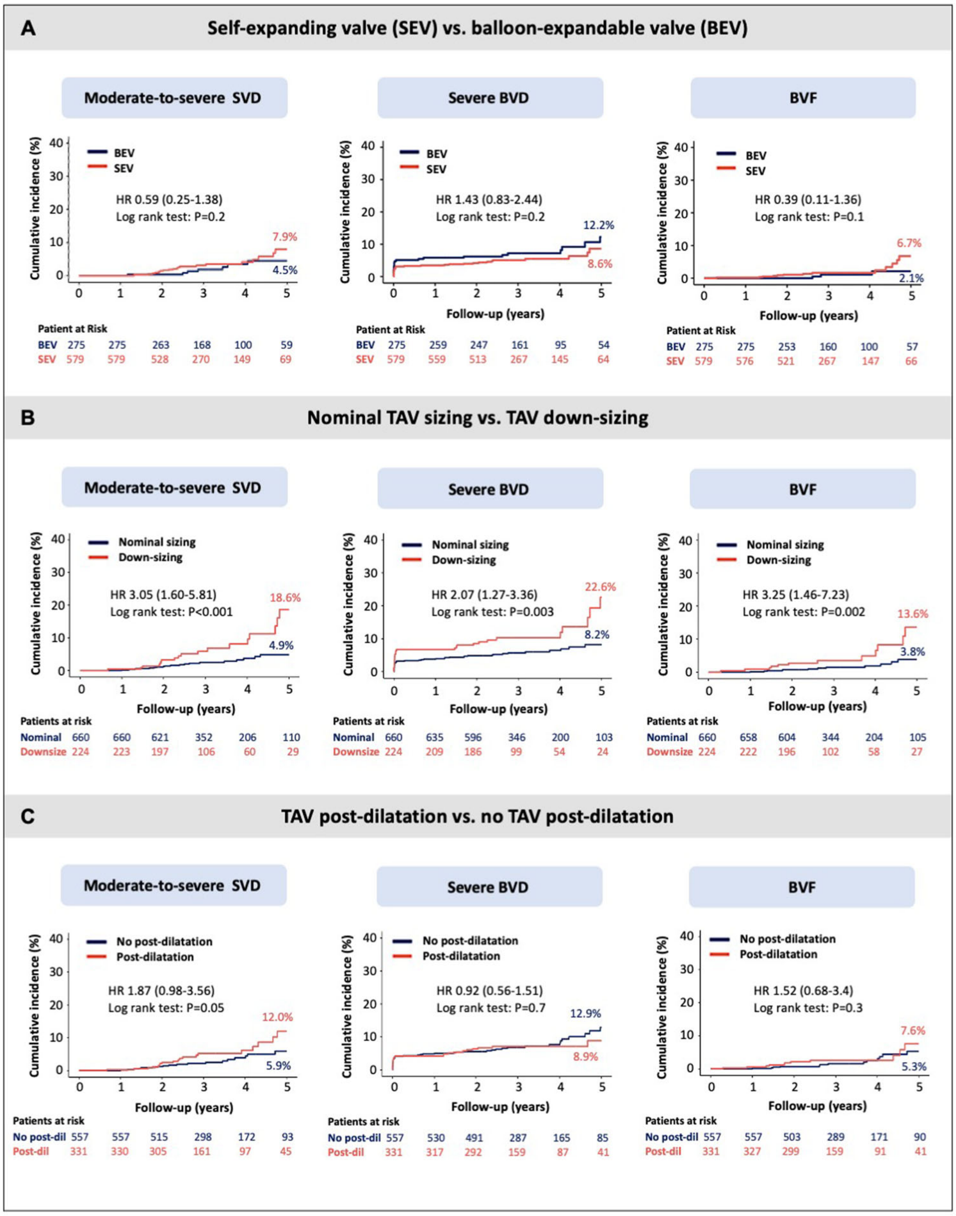


FIGURE 4 | Impact of procedural techniques on TAV durability in bicuspid AS. Kaplan–Meier curves illustrating the 5-year cumulative incidences of moderate-to-severe SVD, severe BVD, and BVF comparing (A) self-expanding valves (SEV) and balloon-expandable valves (BEV), (B) TAV nominal sizing and TAV downsizing, and (C) TAVR with and without TAV post-dilatation. AS, aortic stenosis; BVD, bioprosthetic valve dysfunction; BVF, bioprosthetic valve failure; SVD, structural valve deterioration; TAV, transcatheter aortic valve. [Color figure can be viewed at wileyonlinelibrary.com]

SVD of 1.1%, BVF of 3.3%, and aortic valve reintervention of 2.2% at 5 years [25], while the 4-year rate of reintervention in the Evolut low-risk trial was 1.3% [26].

Evidence concerning TAV durability in patients with bicuspid AS has been limited thus far, with most studies focusing on short-term outcomes. The BAVARD registry observed similar outcomes in tricuspid and bicuspid AS patients with respect to transvalvular gradient, EOA, and rates of moderate-to-severe PPM at 30 days [27]. Similarly, 26.2% of patients in the NOTION-2 trial had bicuspid AS, and the rate of severe PPM was 10.1% at 1-year, with valve reintervention in 1.1% [10]. Similar favorable 30-day outcomes have also been reported in other bicuspid TAVR studies [28, 29]. Mean trans-prosthetic gradients remained stable at 14.5 ± 9.6 mmHg over medium-term (15 month) follow-up in 79 bicuspid AS patients who underwent TAVR [30], whilst the recent Italian STABILITY (Bicuspid Transcatheter Aortic Valve Durability) registry reported sustained clinical benefits of TAVR and favorable TAV durability in 109 patients with bicuspid AS [31].

The present study, with median echo follow-up greater than 4 years, is so far the largest bicuspid AS-TAVR registry to systematically report long-term VARC-3-defined TAV durability outcomes in this previously underrepresented TAVR population. Based upon our findings, we can provide reassuring evidence that TAV durability outcomes are favorable in a large bicuspid AS cohort and comparable to the outcomes observed in historical tricuspid AS cohorts.

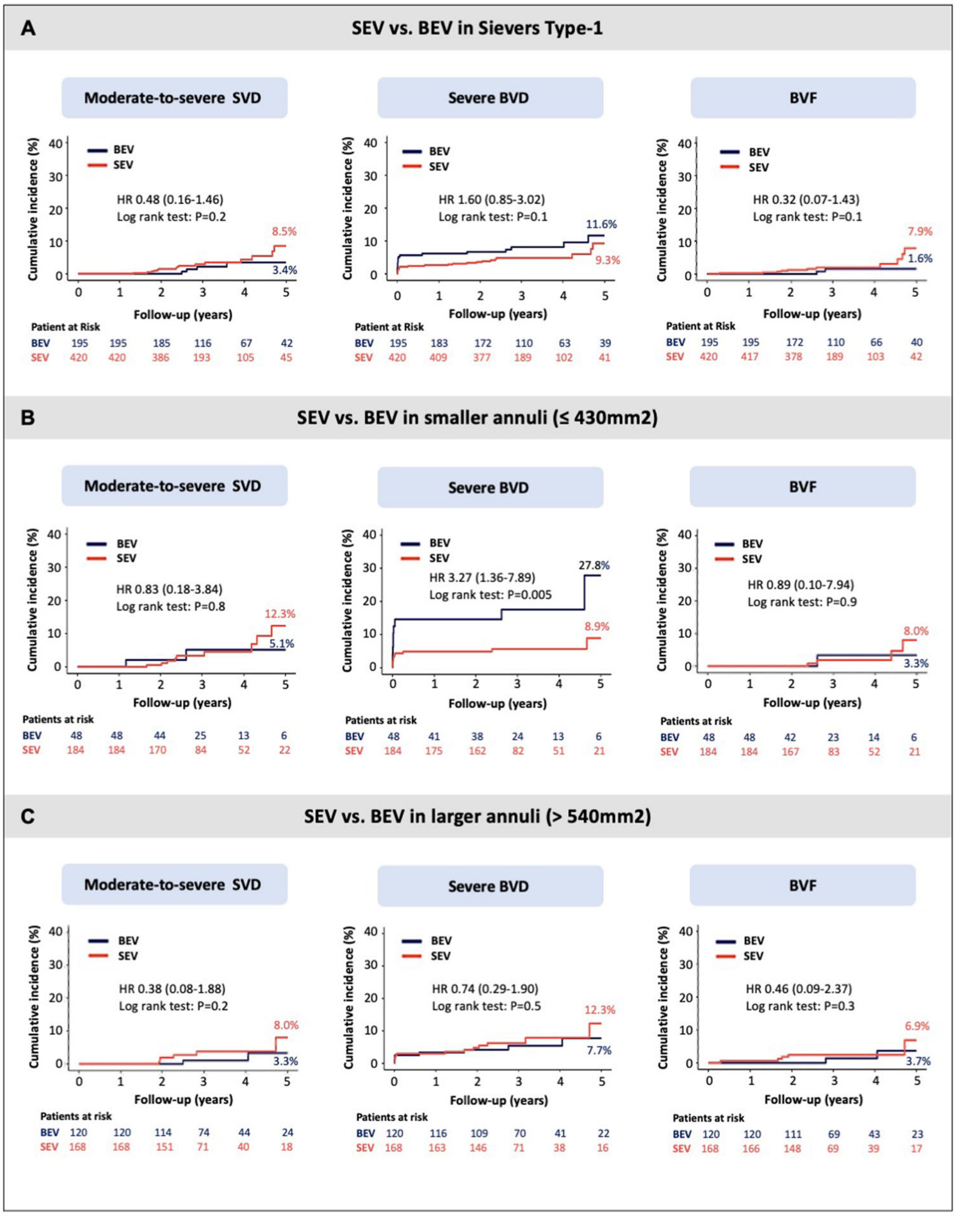


FIGURE 5 | Impact of valve design on TAV durability in bicuspid anatomical subgroups. Kaplan–Meier curves illustrating the 5-year cumulative incidences of moderate-to-severe SVD, severe BVD, and BVF following the use of SEV and BEV in (A) Sievers type 1 anatomy, (B) patients with smaller annuli (area $\leq 430\,mm^2$), and (C) larger annuli (area $> 540\,mm^2$). BEV, balloon-expandable valve; BVD, bioprosthetic valve dysfunction; BVF, bioprosthetic valve failure; SEV, self-expanding valve; SVD, structural valve deterioration; TAV, transcatheter aortic valve. [Color figure can be viewed at wileyonlinelibrary.com]

4.2 | Impact of Patient Characteristics on TAV Durability

Current European guidelines recommend TAVR as the first-line treatment for severe AS in patients ≥ 75 years of age [17]. In contrast, US guidelines suggest TAVR for patients aged > 80 years (or those with life expectancy < 10 years), and SAVR for those aged < 65 years (or with a life expectancy > 20 years), leaving a substantial "gray zone" for clinical discretion [16].

In our study, we observed comparable TAV durability for younger (≤ 75 years) and older (> 75 years) patients. Nonetheless, it is important to highlight the slightly higher incidence of BVF in younger patients, mainly driven by higher rates of reintervention. We speculate that this may relate to the anticipated longer life expectancy of young patients and a more proactive approach to reintervene in those cases with an initial suboptimal TAVR outcome. Clearly, even longer-term durability outcomes beyond 10 years are needed to justify a more routine use of TAVR in young bicuspid AS patients.

In addition, rates of SVD, BVD, and BVF were similar in patients with Sievers type 0 and type 1 bicuspid aortic valves, as well as between different annulus sizes, suggesting that these anatomical variations do not significantly influence TAV durability.

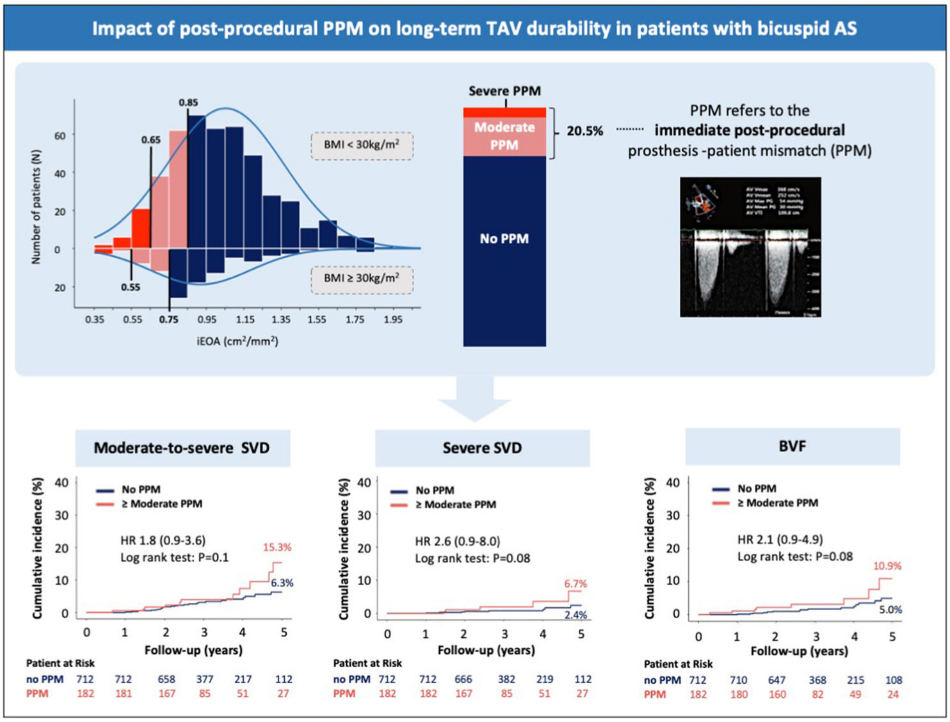


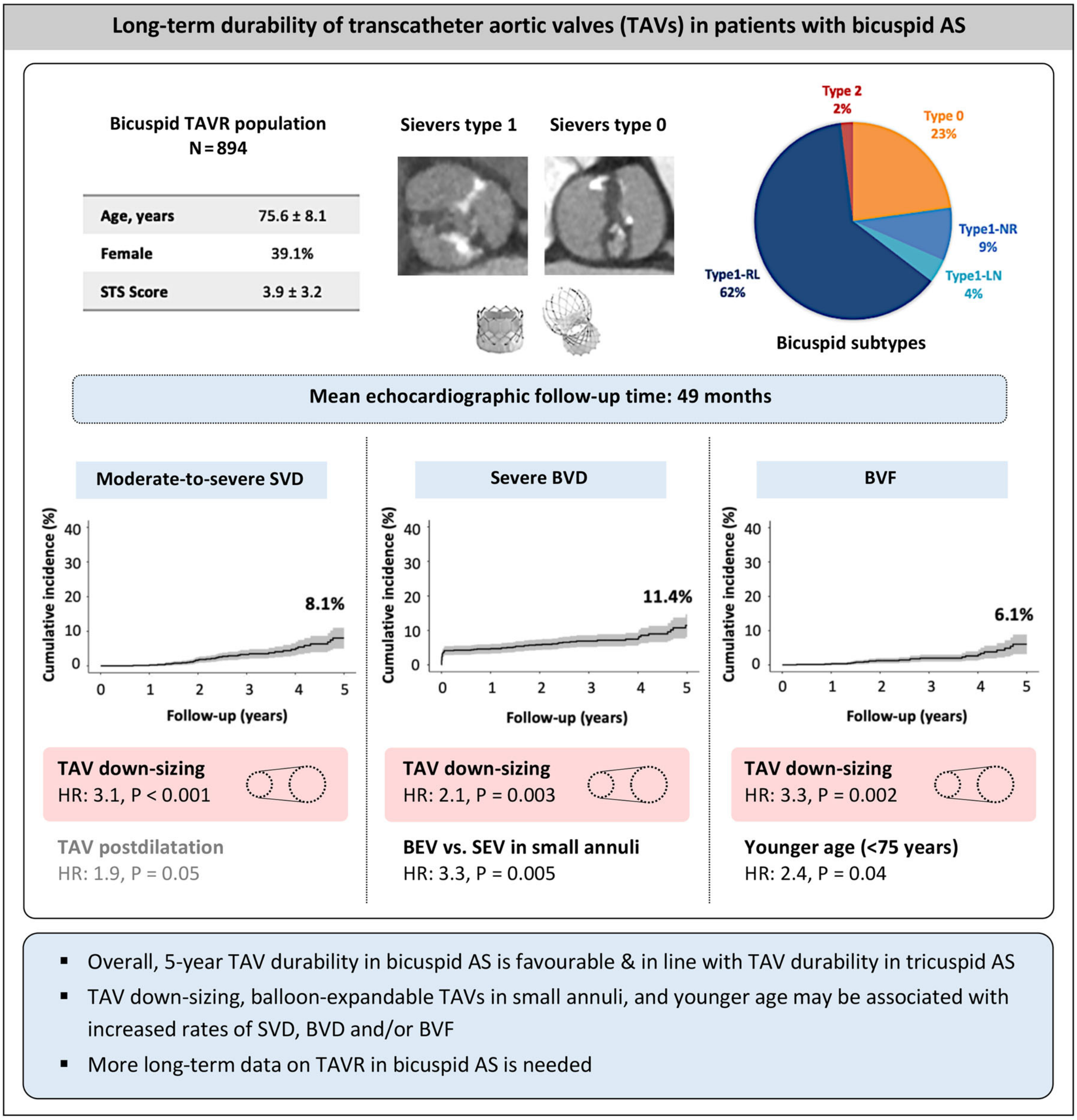
FIGURE 6 | Impact of post-procedural PPM on TAV durability. Kaplan–Meier curves illustrating the impact of immediate postprocedure PPM on 5-year cumulative incidences of moderate-to-severe SVD, severe SVD, and BVF. AS, aortic stenosis; BMI, body mass index; BVD, bioprosthetic valve dysfunction; BVF, bioprosthetic valve failure; iEOA, indexed effective orifice area; PPM, prosthesis-patient mismatch; SVD, structural valve deterioration; TAV, transcatheter aortic valve. [Color figure can be viewed at wileyonlinelibrary.com]

Overall, while TAVR provides promising medium-term durability in young bicuspid AS patients, caution is still warranted. Rigorous long-term surveillance of valve function remains essential to maximize outcomes and guarantee long-term valve durability in this patient population.

4.3 | Impact of TAV Design and Sizing Strategy on Durability Outcomes

In bicuspid AS patients with Sievers type 1 and larger aortic annuli, SEV and BEV demonstrated similar TAV durability outcomes. However, in the smaller annuli subgroup, the incidence of severe BVD was significantly higher following TAVR with BEV, primarily driven by the presence of immediate postprocedural PPM. This finding aligns with recent results from the SMART (Small Annuli Randomized to Evolut or SAPIEN) trial (conducted predominantly in patients with tricuspid AS), which reported a significantly higher rate of BVD following the use of BEVs in patients with small annuli as compared to SEVs (41.6% vs. 9.4%, $p < 0.001$) [32]. Similar trends have also been reported in other trials and observational studies [33–38]. However, there is currently no convincing evidence linking severe BVD (or PPM) with poor long-term clinical outcomes in tricuspid nor bicuspid AS cohorts. While we did observe a twofold increase in the incidence of SVD and BVF at 5 years in patients with immediate postprocedural PPM, these differences did not reach statistical significance (Figure 6). Future studies are warranted to clarify these findings (Central illustration 1).

Importantly, TAV downsizing is not infrequently used in bicuspid AS cases with excessive leaflet calcification and/or a long, calcified raphe; this is to mitigate the potential risk of aortic annulus rupture (in case of BEV) and severe valve under-expansion/infolding (in case of SEV). Supra-annular sizing resulting in TAV down-sizing has demonstrated favorable 30-day outcomes [39, 40], and when this approach was compared to annular sizing or nominal TAV sizing, similar device success rates were reported [41]. However, the long-term effects of supra-annular sizing are unclear [42], and expert consensus continues to recommend annular sizing as the primary approach for most bicuspid AS patients [43]. Interestingly, our findings show that nominal TAV sizing is associated with better 5-year durability outcomes compared to TAV downsizing, thereby providing evidence in favor of maintaining annular sizing in bicuspid AS patients. However, maintaining annular or nominal TAV sizing in excessively calcified bicuspid anatomies needs to be balanced against the risk of annular rupture, valve infolding, valve under-expansion, and leaflet pin-wheeling. These procedural complexities highlight the need for further research and technological developments to enable operators to achieve both optimal acute and longer-term procedural outcomes, particularly in younger patients with complex anatomies and longer life expectancies. In this regard, future development of calcium debulking strategies, such as intravascular lithotripsy applied to the aortic valve, and "tricuspidization" of bicuspid aortic valves using leaflet modification techniques may hold promise as adjunctive techniques in anatomically challenging bicuspid AS cases.



CENTRAL ILLUSTRATION 1 | Long-term durability of transcatheter aortic valves (TAVs) in patients with bicuspid AS. [Color figure can be viewed at wileyonlinelibrary.com]

4.4 | Limitations

Our findings should be interpreted in light of several limitations. First, this was a retrospective study and may have been subject to selection bias, since patients without 2 years of echo follow-up were excluded from the main analysis, potentially favoring the inclusion of those with better outcomes. Second, as is common in retrospective studies, some essential data were missing in certain patients. Specifically, EOA was not consistently measured during follow-up at all centers, and this may have led to an underestimation of the rates of PPM. To address this concern, we made extra efforts to minimize the risk of misclassification of patients in whom there were no available EOA data by referencing available measurements of transprosthetic gradient and other echo follow-up data. Third, echocardiographic measurements were collected from multiple centers; this may have introduced variability in data collection and reporting practices, despite adherence to guidelines. Finally, the choice of TAV devices and procedural techniques also varied among participating centers, which may have introduced heterogeneity in the results and influenced durability outcomes. Further prospective studies with standardized protocols and longer follow-up are needed to confirm these findings and to improve our understanding of long-term TAV durability in patients with bicuspid AS.

5 | Conclusions

In this large multicentre cohort of patients with bicuspid AS, TAVR demonstrated favorable valve durability outcomes over a 5-year follow-up period that were similar to those observed in tricuspid AS cohorts. Hence, TAVR appears to be a viable option for younger bicuspid AS patients, although attention is needed to valve type and sizing strategy to optimize outcomes.

Conflicts of Interest

Annette Maznyczka reports travel grants from Edwards Lifesciences, Abbott, Boston Scientific, and Medtronic. Arif Khokhar has received speaker fees from Boston Scientific and consulting fees from Machnet Medical. Stefan Toggweiler has received honoraria from Medtronic, Boston Scientific, Biosensors, Edwards Lifesciences, Hi-D Imaging, Abbott Vascular, Medira, Shockwave, Teleflex, atHeart Medical, Cardiac Dimensions, Polares Medical, Amarin, Sanofi, AstraZeneca, ReCor Medical, Daiichi Sankyo, Bayer, Armira; has received institutional research grants from Edwards Lifesciences, Abbott Vascular, Boston Scientific, Fumedica, Novartis, Boehringer Ingelheim, Polares Medical, and holds equity in Hi-D Imaging. Marianna Adamo has reported speaker honoraria from Abbott Vascular and Edwards Lifesciences. Matteo Montorfano received consultant fees from Abbott, Boston Scientific, Kardia, and Medtronic. Martin Swaans has received consultancy fees from Abbott Vascular, Bioventrix, Boston Scientific, Cardiac Dimensions, Edwards Lifesciences, GE Healthcare, Medtronic, Philips Healthcare, P&F, and Siemens Healthcare. Joanna Wykrzykowska has received an institutional grant from Medtronic and speaker's honoraria (also to the institution) from Boston Scientific and Sinomed. Tau Hartikainen has received travel grants from Boston Scientific and Novartis. Stephane Noble has received an institutional grant from Abbott, consulting and speaker fees from Medtronic, and travel support to attend meetings from Edwards Lifesciences and Abbott. Darren Mylotte reports institutional research grants from Boston Scientific and Medtronic; and is a consultant for Boston Scientific, Medtronic, and MicroPort. Stephen Brecker has received grant support, consultant, and speaker fees from Medtronic. Pierfrancesco Agostoni has received consulting fees from Abbott, Boston Scientific, iVascular, Teleflex, and Terumo. Matjaž Bunc has served as a consultant or proctor for Medtronic, Edwards Lifesciences, Abbott, Medtronic, and Meril. Hélène Eltchaninoff received honoraria for lectures from Edwards Lifesciences. Daniel Blackman reports consulting fees from Medtronic Plc. and Abbott Vascular, honoraria from Medtronic Plc., Abbott Vascular, and Edwards Lifesciences, and participation in data safety/monitoring/advisory board for Medtronic Plc. and Abbott Vascular. Nicolas Van Mieghem has received institutional research grants from Abbott, Boston Scientific, Edwards Lifesciences, Medtronic, Meril, Pie Medical, PulseCath BV, Teleflex, and consultancy fees from Abbott, Abiomed, Alleviant Medical Inc., AncorValve, Anteris, Approxima Srl, Bolt Medical, Boston Scientific, Daiichi Sankyo, LUMA Vision, Materialise, Medtronic, Pie Medical, Polares, PulseCath BV, Siemens. Won-Keun Kim reports proctor/speaker fees/advisory board participation for Abbott, Boston Scientific, Edwards Lifesciences, and Meril Life Sciences. Thomas Pilgrim reports research, travel, or educational grants to the institution without personal remuneration from Biotronik, Boston Scientific, Edwards Lifesciences, and ATSens; speaker fees and consultancy fees to the institution from Biotronik, Boston Scientific, Edwards Lifesciences, Abbott, Medtronic, Biosensors, and Highlife. Bernard Prendergast has received lecture fees from Edwards Lifesciences; and has served on a trial steering committee for Medtronic and a data safety and monitoring committee for Valvosoft. Didier Tchétché is a consultant for Abbott Vascular, Edwards Lifesciences, Medtronic, Boston Scientific, T-Heart, and Caranx Medical. Ole De Backer received institutional research grants and consulting fees from Abbott, Boston Scientific, and Medtronic. The other authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to restrictions related to participant privacy and confidentiality.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.