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Original article

Meta-analysis of transcatheter aortic valve implantation for bicuspid versus tricuspid aortic valves

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ABSTRACT

Background: We performed meta-analysis and meta-regression of transcatheter aortic valve implantation (TAVI) for the bicuspid aortic valve (B-AV) versus the tricuspid aortic valve (T-AV).
Methods: MEDLINE and EMBASE were searched through June 2018 using PubMed and OVID. We included comparative studies of TAVI patients with B-AV versus T-AV reporting at least one of postprocedural transcatheter valve regurgitation (TVR)/pacemaker implantation (PMI) incidence and early (30-day or in-hospital)/late (including early) mortality. For each study, crude (unadjusted) data regarding TVR/PMI incidence and early/late mortality in both the B-AV and T-AV groups were used to generate risk ratios (RRs). Study-specific estimates were combined in the random-effects model. Using meta-regression, we assessed potential confounders identified in preliminary meta-analysis.
Results: We identified 12 eligible studies including a total of 1045 B-AV and 4069 T-AV patients. Pooled analysis demonstrated an association of B-AV with a statistically significant increase in TVR incidence (RR, 1.42; $p = 0.006$) but no statistically significant difference in PMI incidence ($p = 0.54$) and 30-day ($p = 0.11$)/midterm (1-year to 2-year) mortality ($p = 0.99$) between patients with B-AV and those with T-AV. All meta-regression coefficients of 6 identified potential confounders (age, mean aortic valve gradient, aortic valve area, left ventricular ejection fraction, aortic calcification, and B-AV types) for the outcomes (TVR/PMI incidence and early/late mortality) were statistically non-significant.
Conclusions: Postprocedural PMI incidence and 30-day/midterm (1-year to 2-year) mortality after TAVI may be similar between patients with B-AV and those with T-AV despite the significant association of B-AV with increased postprocedural TVR incidence.

Introduction

Transcatheter aortic valve implantation (TAVI) may bring about less favorable results in aortic stenosis due to the bicuspid aortic valve (B-AV) than in that due to the tricuspid aortic valve (T-AV) because of the following theoretical concerns: geometric mismatch between the ovoid B-AV annulus and the circular transcatheter prosthesis due to increases in annular ellipticity and asymmetric calcification [1] may result in paravalvular leakage or leaflet asymmetry, and questionable B-AV annulus strength may potentially lead to annular rupture or aortic dissection [2]. Postprocedural ≥moderate transcatheter valve regurgitation (TVR) and pacemaker implantation (PMI) occur respectively in approximately 12% and 18% of TAVI patients with B-AV [2], which are more frequent than in the PARTNER [Placement of Aortic Transcatheter Valves] II SAPIEN 3 trial [3] (3.4% and 11.2%) and the CoreValve Evolut R study [4] (3.4% and 11.7%) and may be associated with increased early and late mortality. Focusing postprocedural TVR/PMI incidence and early/late mortality, we performed meta-analysis and meta-regression analysis of TAVI for patients with B-AV versus those with T-AV.

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Methods

All comparative observational studies of outcomes after TAVI for patients with B-AV versus those with T-AV were identified using a 2-level search strategy. First, databases including MEDLINE and EMBASE were searched through June 2018 using Web-based search engines (PubMed and OVID). Search terms included *bicusp* or *bicuspid*; *tricusp* or *tricuspid*; *percutaneous*, *transcatheter*, *transluminal*, *transarterial*, *transapical*, *transaortic*, *transcarotid*, *transaxillary*, *transsubclavian*, *transubclavian*, *transiliac*, *transfemoral*, *transiliofemoral*, or *transcaval*; *aortic valve*; and *implantation* or *replacement*. Second, relevant studies were identified through a manual search of secondary sources including references of initially identified articles, reviews, and commentaries. All references were downloaded for consolidation, elimination of duplicates, and further analyses.

Studies considered for inclusion met the following criteria: the design was a comparative study of B-AV versus T-AV; the study population was patients undergoing TAVI; outcomes included at least one of postprocedural TVR/PMI incidence and early (30-day or in-hospital)/late (including early) mortality. Postprocedural TVR included both central and paravalvular regurgitation, because evaluating the presence and severity of regurgitation should include an assessment of both central and paravalvular components with a combined measurement of 'total' aortic regurgitation reflecting the total volume load imposed on the left ventricle (LV) according to the Valve Academic Research Consortium-2 Consensus Document [5].

Data regarding baseline patient, echocardiographic, and procedural (including TAVI device type) characteristics, duration of follow-up, TVR/PMI incidence and early/late mortality were abstracted (as available) from each individual study. Baseline patient and procedural characteristics were limited to those reported in $\geq$5 studies.

For each study, crude (unadjusted) data regarding TVR/PMI incidence and early/late mortality in both the B-AV and T-AV groups were used to generate risk ratios (RRs) and 95% confidence intervals. Study-specific estimates were combined using inverse variance-weighted averages of logarithmic RRs in the random-effects model. Publication bias was assessed graphically using a funnel plot and mathematically using the linear-regression test.

To assess potential confounders, we performed meta-regression analysis using the following strategy. First, for each study, we generated RRs, mean differences (MDs), and standardized MD (SMD) for each baseline patient, echocardiographic, and procedural characteristic using data regarding dichotomous data (for RRs) and continuous values (for MDs and SMDs) in both the B-AV and T-AV groups. Second, these study-specific estimates were combined in preliminary random-effects meta-analysis. Third, as potential confounders, we selected factors with a statistically significant difference between the B-AV and T-AV groups in the preliminary meta-analysis. Prevalence of B-AV type (types 0, 1, and 2) were also included in potential confounders. Finally, restricted maximum-likelihood random-effects meta-regression analysis was performed to determine whether the effects of B-AV on the outcomes (TVR/PMI incidence and early/late mortality) were modulated by these potential confounders. The meta-regression graph depicts the effect of B-AV on the outcomes (plotted as a logarithmic RR for the outcome on the y-axis) as a function of a given factor (plotted as a point estimate of an RR/MD/SMD for the potential confounder on the x-axis).

All analyses were conducted using Review Manager version 5.3 (available from http://tech.cochrane.org/revman) and Comprehensive Meta-Analysis version 3 (Biostat, Englewood, NJ, USA).

Results

As illustrated in Supplementary Fig. S1, we identified 12 eligible studies [6–17] including a total of 1045 B-AV and 4069 T-AV patients. Patients with B-AV and T-AV were matched with propensity score in 2 studies by De Biase et al. [8] and Yoon et al. [17], and using logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE), annulus diameter, delivery route, and type and size of the implanted bioprosthesis in a study by Kochman et al. [12]. Baseline patient, echocardiographic, and procedural characteristics are summarized in Table 1. Postprocedural TVR incidence was reported in 11 studies [8–15,17], postprocedural PMI incidence and early (30-day) mortality in all the 12 studies, and midterm (1-year to 2 year) mortality in 7 studies [7,9,12,13,15–17] (Table 2).

Pooled analysis demonstrated an association of B-AV with a statistically significant increase in TVR incidence (RR, 1.42; $p = 0.006$; Fig. 1), but no statistically significant difference in PMI incidence ($p = 0.54$; Fig. 2), 30-day mortality ($p = 0.11$; Fig. 3), and midterm mortality ($p = 0.99$; Fig. 4) between patients with B-AV and those with T-AV.

To assess publication bias, we generated a funnel plot of the logarithm of effect size (RR) versus the precision (reciprocal of standard error) for each study. There was no statistically significant funnel-plot asymmetry for TVR incidence (2-tailed $p = 0.23$; Supplementary Fig. S2), PMI incidence (2-tailed $p = 0.90$; Supplementary Fig. S3), 30-day mortality (2-tailed $p = 0.68$; Supplementary Fig. S4), and midterm mortality (2-tailed $p = 0.72$; Supplementary Fig. S5).

At least 5 studies reported 24 baseline patient, echocardiographic, and procedural characteristics (Table 1). Pooled analysis indicated that patients were younger (MD, −0.95 years; $p = 0.002$; Supplementary Fig. S6), mean aortic valve gradient (MAVG) was higher (MD, 1.98 mm Hg; $p = 0.004$; Supplementary Fig. S7), aortic valve area (AVA) was smaller (MD, −0.03 cm^2; $p = 0.03$; Supplementary Fig. S8), LV ejection fraction (LVEF) was lower (MD, −2.93%; $p = 0.003$; Supplementary Fig. S9), and aortic valve calcification (AVC) was greater (SMD, 0.50; $p = 0.0002$; Supplementary Fig. S10) in patients with B-AV than in those with T-AV. There was no statistically significant difference in all the other 19 characteristics (Supplementary Figs. S11–S29) between B-AV and T-AV, which suggests that these factors may not modulate the effects of B-AV on the outcomes. Subsequently, we performed meta-regression analysis of the 6 potential confounders (age, MAVG, AVA, LVEF, AVC, and B-AV types) for the outcomes (TVR/PMI incidence and early/midterm mortality). All meta-regression coefficients of age, MAVG, AVA, AVC, and B-AV types for the outcomes were statistically non-significant (Supplementary Figs. S30–S60 and Table 3). These findings suggest that the effects of B-AV on the outcomes (TVR/PMI incidence and early/midterm mortality) may not be modulated by these 6 factors (age, MAVG, AVA, AVC, and B-AV types).

Discussion

The present analysis suggests that postprocedural PMI incidence and 30-day/midterm (1-year to 2-year) mortality after TAVI may be similar between patients with B-AV and those with T-AV despite the significant association of B-AV with increased postprocedural TVR incidence. These results were based on crude (unadjusted) data, and there were significant differences in 5 potential confounders (age, MAVG, AVA, LVEF, and AVC) between patients with B-AV and those with T-AV. Our meta-regression analysis, however, suggests that these 6 factors (including B-AV types) may not modulate the effects of B-AV on the outcomes (TVR/PMI incidence and early/midterm mortality).

Table 1
Baseline patient, echocardiographic, and procedural characteristics.

Study	References	Patient number					Age (years)				Men (%)				Body mass index (kg/m^2)			
		Bicuspid				Tricuspid	Bicuspid	Tricuspid	*p*	MD	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	MD
		Total	Type (%)															
			0	1	2													
Arai (2017)	[6]	10	0	90.0	10.0	143	81.3 ± 5.1	82.6 ± 6.2	0.547	−1.3	N/A	4.9	0.046	N/A	24.6 ± 5.2	26.5 ± 5.4	0.316	−1.9
Costopoulos (2014)	[7]	21	N/A			447	76.7 ± 7.1	79.8 ± 7.4	0.06	−3.1	57.1	47.4	0.38	1.20	26.6 ± 4.4	26.1 ± 4.6	0.70	0.5
De Biase (2018)[a]	[8]	83	7.2	92.8	0	166	81.4 ± 7.6	82.9 ± 5.7	0.07	−1.5	68.7	65.1	0.57	1.06	33.9 ± 54.3	33.8 ± 54.9	0.99	0.1
German TAVI (Bauer) (2014)	[9]	38	N/A			1357	80.7 ± 6.6	81.8 ± 6.2	N/S	−1.1	44.7	42.0	N/S	1.07	26 ± 5	27 ± 8	N/S	−1
Hayashida (2013)	[10]	21	0	85.7	14.3	208	82.0 ± 7.0	83.2 ± 6.5	0.29	−1.2	57.1	53.4	0.82	1.07	24.7 ± 4.1	26.1 ± 4.3	0.16	−1.4
Kawamori (2018)	[11]	41	4.9	61.0	0	239	80 (70.5–83.0)	83 (78.0–87.0)	0.003	−3	68.3	59.4	0.282	1.15	N/A			
Kochman (2014)[b]	[12]	28	N/A			84	77.6 ± 5.5	79.1 ± 6.8	0.70	−1.5	46.4	47.6	1.00	0.98	N/A			
Liao (2018)	[13]	87	56.3	43.7	0	70	73.4 ± 6.4	74.3 ± 7.0	0.39	−0.9	57.5	64.3	0.39	0.89	22.2 ± 3.7	22.1 ± 3.7	0.80	0.1
Liu (2015)	[14]	15	73.3	26.7	0	25	75.4 ± 5.7	75.8 ± 5.5	0.81	−0.4	60.0	68.0	0.61	0.88	23.6 ± 4.8	21.7 ± 3.1	0.32	1.9
Sannino (2017)	[15]	88	13.6	85.2	1.1	735	80.2 ± 8.4	81.8 ± 7.9	0.081	−1.6	60.2	52.9	0.194	1.14	27.0 ± 6.8	27.6 ± 6.6	N/S	−0.6
Xiong (2018)	[16]	67	61.2	38.8	0	49	74.0 (68.0–77.0)	75.0 (68.0–79.0)	0.51	−1.0	59.7	57.1	0.78	1.04	22.2 ± 3.9	21.6 ± 3.3	0.37	0.6
Yoon (2017)[a]	[17]	546	12.7	85.7	1.6	546	77.2 ± 8.2	77.2 ± 8.8	0.91	0.0	62.8	60.6	0.48	1.04	N/A			

Study	STS-PROM (%)				Logistic EuroSCORE (%)				NYHA functional class III/IV (%)				Hypertension (%)			
	Bicuspid	Tricuspid	*p*	MD	Bicuspid	Tricuspid	*p*	MD	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR
Arai (2017)	N/A				19.0 ± 12.5	18.1 ± 11.0	0.840	0.9	90.0	99.3	0.723	0.91	80.0	69.9	0.138	1.14
Costopoulos (2014)	7.6 ± 4.2	7.8 ± 7.3	0.91	−0.2	23.9 ± 12.0	24.4 ± 17.3	0.88	−0.5	71.4	67.3	0.70	1.06	66.7	77.2	0.27	0.86
De Biase (2018)[a]	5.1 ± 3.3	5.1 ± 2.9	0.99	0.0	N/A	57.8	54.2	N/A	1.07	72.3	71.7	0.92	1.01			
German TAVI (Bauer) (2014)	N/A				18 ± 10	20 ± 13	N/S	−2	84.2	89.0	N/S	0.95	N/A			
Hayashida (2013)	N/A				19.9 ± 11.9	20.1 ± 11.4	0.90	−0.2	90.5	88.0	1.00	1.03	57.1	68.3	0.33	0.84
Kawamori (2018)	N/A				N/A				90.2	92.1	0.443	0.98	85.4	89.5	0.290	0.95
Kochman (2014)[b]	N/A				19.2 ± 9.0	18.8 ± 8.7	0.99	0.4	71.4	78.6	0.61	0.91	60.7	65.5	0.82	0.93
Liao (2018)	7.9 ± 4.0	8.6 ± 4.4	0.27	−0.7	N/A	92.0	87.1	0.32	1.06	49.4	45.7	0.64	1.08			
Liu (2015)	5.6 ± 4.1	7.5 ± 5.9	0.18	−1.9	16.1 ± 11.1	21.8 ± 14.7	0.22	−5.7	86.7	84.0	1.00	1.03	33.3	56.0	0.17	0.60
Sannino (2017)	7.4 ± 3.9	7.6 ± 3.9	N/S	−0.2	N/A				N/A				80.7	83.3	0.518	0.97
Xiong (2018)	6.5 (4.4–9.3)	8.3 (5.2–9.5)	0.24	−1.8	N/A				91.0	83.7	0.23	1.09	44.8	55.1	0.27	0.81
Yoon (2017)[a]	4.6 ± 4.6	4.3 ± 3.0	0.29	0.3	16.1 ± 12.0	16.9 ± 13.9	0.58	−0.8	80.4	78.4	0.48	1.03	70.0	70.5	0.89	0.99

Study	Diabetes mellitus (%)				Coronary artery disease (%)				Myocardial infarction (%)				Atrial fibrillation (%)			
	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR
Arai (2017)	20.0	25.9	0.809	0.77	N/A				N/A				N/A			
Costopoulos (2014)	28.6	30.2	0.87	0.95	N/A				19.0	19.7	0.94	0.97	N/A			
De Biase (2018)[a]	19.3	15.7	0.47	1.23	47.0	48.8	0.78	0.96	2.4	1.2	0.46	2.00	16.9	19.9	0.56	0.85
German TAVI (Bauer) (2014)	36.8	34.0	N/S	1.08	68.4	60.0	N/S	1.14	N/A			N/A				
Hayashida (2013)	4.8	24.0	0.05	0.20	47.6	58.2	0.37	0.82	4.8	8.7	1.00	0.55	N/A			
Kawamori (2018)	24.4	32.6	0.293	0.75	46.3	59.0	0.130	0.79	N/A				22.0	25.9	0.587	0.85
Kochman (2014)[b]	39.3	34.5	0.82	1.14	50.0	64.3	0.26	0.78	39.3	31.0	0.49	1.27	N/A			
Liao (2018)	16.1	18.6	0.68	0.87	36.8	38.6	0.82	0.95	N/A				21.8	17.1	0.46	1.27
Liu (2015)	0.0	12.0	0.44	0.23	20.0	36.0	0.48	0.56	0.0	0.0	1.00	N/A	6.7	8.0	1.00	0.83
Sannino (2017)	33.0	38.5	0.645	0.86	69.3	66.3	0.471	1.05	N/A				17.0	19.3	0.789	0.88
Xiong (2018)	20.9	24.5	0.65	0.85	29.9	36.7	0.44	0.81	3.0	2.0	0.99	1.46	20.9	12.2	0.22	1.71
Yoon (2017)[a]	23.4	23.3	>0.99	1.01	N/A				N/A				N/A			

Study	Previous PCI (%)				Previous CABG (%)				Cerebrovascular (CV) disease (%)					COPD (%)			
	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR		Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR
Arai (2017)	10.0	14.7	0.731	0.68	10.0	6.3	0.575	1.59	Stroke	10.0	0.7	0.409	14.30	0.0	2.1	0.663	1.87
Costopoulos (2014)	28.6	21.5	0.44	1.33	N/A					19.0	16.1	0.72	1.18	33.3	30.6	0.79	1.09
De Biase (2018)[a]	36.1	39.8	0.55	0.91	4.8	4.8	1	1.00		6.0	6.6	0.85	0.91	N/A			
German TAVI (Bauer) (2014)	34.2	35.0	N/S	0.98	13.2	18.0	N/S	0.73	Stroke	13.2	8.0	N/S	1.64	21.1	24.0	N/S	0.88

Table1 (*Continued*)

Study	Previous PCI (%)				Previous CABG (%)				Cerebrovascular (CV) disease (%)					COPD (%)			
	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR		Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR
Hayashida (2013)	19.0	22.6	1.00	0.84	9.5	13.5	1.00	0.71		4.8	6.3	1.00	0.76	23.8	24.0	1.00	0.99
Kawamori (2018)	N/A				N/A				N/A					19.5	23.8	0.543	0.82
Kochman (2014)[b]	21.4	35.7	0.24	0.60	14.3	25.0	0.30	0.57	Stroke	28.6	16.7	0.27	1.71	21.4	20.2	1.00	1.06
Liao (2018)	8.0	11.4	0.47	0.70	N/A					14.9	11.4	0.52	1.31	57.5	64.3	0.39	0.89
Liu (2015)	20.0	12.0	0.82	1.67	0.0	0.0	1.00	N/A		0.0	8.0	0.52	0.33	26.7	16.0	0.68	1.67
Sannino (2017)	N/A				N/A				Stroke	19.3	18.0	0.556	1.08	17.0	20.3	0.602	0.84
Xiong (2018)	N/A				N/A				N/A					53.7	71.4	0.05	0.75
Yoon (2017)[a]	22.2	23.4	0.66	0.95	11.4	12.3	0.70	0.93	CV accident	14.1	12.6	0.53	1.12	17.9	15.0	0.23	1.20

Study	Chronic kidney disease (%)					Peripheral arterial disease (%)				Mean AV gradient (mm Hg)				AV area (cm^2)			
		Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	RR	Bicuspid	Tricuspid	*p*	MD	Bicuspid	Tricuspid	*p*	MD
Arai (2017)	N/A	N/A	46.4 ± 20.0	48.3 ± 13.5	0.789	−1.9	0.67 ± 0.16	0.65 ± 0.14	0.707	0.02							
Costopoulos (2014)		52.4	57.5	0.64	0.91	33.3	29.8	0.73	1.12	54.4 ± 17.9	52.5 ± 16.0	0.65	1.9	0.70 ± 0.23	0.75 ± 0.50	0.65	−0.05
De Biase (2018)[a]	N/A					N/A				47.8 ± 15.5	46.4 ± 14.7	0.18	1.4	0.6 ± 0.2	0.7 ± 0.3	0.29	−0.1
German (TAVI (Bauer) (2014)	CRI	57.9	61.0	N/S	0.95	10.5	24.0	N/S	0.44	47.1 ± 19.6	49.6 ± 19.1	N/S	−2.5	0.68 ± 0.22	0.68 ± 0.43	N/S	0.00
Hayashida (2013)		57.1	59.6	0.82	0.96	23.8	32.7	0.47	0.73	47.8 ± 18.6	48.1 ± 17.0	0.94	−0.3	0.67 ± 0.11	0.65 ± 0.14	0.66	0.02
Kawamori (2018)	N/A					9.8	20.9	0.094	0.47	49.1 ± 14.1	44.1 ± 11.4	0.012	5.0	0.58 ± 0.18	0.68 ± 0.18	0.003	−0.10
Kochman (2014)[b]		42.9	42.9	1.00	1.00	21.4	34.5	0.24	0.62	55.5 ± 17.6	52.5 ± 18.9	0.96	3.0	0.6 ± 0.1	0.6 ± 0.2	0.24	0.0
Liao (2018)		11.5	18.6	0.21	0.62	48.3	41.4	0.39	1.17	65.4 ± 20.1	60.5 ± 16.5	0.102	4.9	N/A			
Liu (2015)		26.7	48.0	0.18	0.56	13.3	16.0	1.00	0.83	64.1 ± 19.5	54.3 ± 14.2	0.08	9.8	0.47 ± 0.13	0.59 ± 0.14	0.02	−0.12
Sannino (2017)		51.1	44.9	0.227	1.14	39.8	29.8	0.033	1.33	46.9 ± 16.9	44.3 ± 13.6	0.102	2.6	0.65 ± 0.17	0.69 ± 0.19	0.049	−0.04
Xiong (2018)		11.9	16.3	0.5	0.73	35.8	26.5	0.29	1.35	63.0 (47.0–85.0)	59.0 (47.5–67.5)	0.15	4.0	N/A			
Yoon (2017)[a]	N/A					15.2	15.6	0.93	0.98	49.7 ± 17.7	48.5 ± 17.1	0.25	1.2	0.7 ± 0.2	0.7 ± 0.2	0.86	0.0

Study	Aortic regurgitation grade (0–4)				Left ventricular ejection fraction (%)				AV calcification (MDCT)						Transfemoral approach (%)			
	Bicuspid	Tricuspid	*p*	MD	Bicuspid	Tricuspid	*p*	MD		Bicuspid	Tricuspid	*p*	SMD		Bicuspid	Tricuspid	*p*	RR
Arai (2017)	1.00 ± 0.86	1.02 ± 0.57	0.912	−0.02	52.6 ± 18.5	56.4 ± 13.0	0.566	−3.8	AV calcium volume (mm^3)	1076.7 ± 320.2	582.7 ± 357.7	0.008	1.38		70.0	87.4	N/A	0.80
Costopoulos (2014)	1.05 ± 0.94	0.98 ± 0.97	0.74	0.07	N/A				N/A						71.4	83.9	N/A	0.85
De Biase (2018)[a]	N/A				52.5 ± 15.6	55.3 ± 3.9	0.15	−2.8	Calcium scoring (mm^3)	2798.3 ± 2606.6	1694.3 ± 1695	<0.01	0.54		98.8	98.8	1	1.00
German TAVI (Bauer) (2014)	N/A				50 ± 16	53 ± 15	N/S	−3	N/A						81.6	88.0	N/S	0.93
Hayashida (2013)	0.95 ± 0.74	0.83 ± 0.70	0.98	0.12	47.5 ± 14.5	53.9 ± 14.3	0.04	−6.4	AV calcification degree (%)	32.2 ± 10.1	28.4 ± 11.9	0.39	0.32		61.9	50.5	N/A	1.23
Kawamori (2018)	N/A				61.0 (45.0–68.0)	64.0 (55.0–68.0)	0.372	−3.0	AV calcification index (Agaston score)	3710.9 ± 1893.8	3063.3 ± 2010.0	0.056	0.32		97.6	98.7	0.471	0.99
Kochman (2014)[b]	1.3 ± 1.1	1.2 ± 0.9	0.6	0.1	48.1 ± 13.1	49.8 ± 14.0	0.69	−1.7	N/A						78.6	77.4	N/A	1.02
Liao (2018)	N/A				55.0 (42.0–68.0)	62.0 (46.8–68.0)	0.35	−7.0	STJ calcium volume (mm^3)	656.5 (384.6–923.3)	505.4 (180.4–890.7)	0.048	0.33		100.0	100.0	N/A	1.00
Liu (2015)	1.8 ± 0.9	2.4 ± 0.7	0.01	−0.6	51.1 ± 12.6	51.0 ± 12.7	0.90	0.1	N/A						86.7	92.0	1.00	0.94
Sannino (2017)	N/A				N/A				N/A						88.6	87.1	N/A	1.02
Xiong (2018)	N/A				55.0 (39.0–68.0)	63.0 (50.5–68.5)	0.18	−8.0	N/A						98.5	100.0	0.99	0.99
Yoon (2017)[a]	N/A				51.6 ± 15.0	51.6 ± 15.2	0.99	0.0	N/A						79.1	78.8	0.93	1.00

Study	Transcatheter valve (%)															
	Self-expandable															
	Total			A-valve		CoreValve		Evolut R		Lotus		Portico		VitaFlow		
	Bicuspid	Tricuspid	RR	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	
Arai (2017)	0.0	0.0	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Costopoulos (2014)	61.9	41.4	1.50	0.0	0.0	61.9	41.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
De Biase (2018)[a]	22.9	62.0	0.37	N/A		N/A		19.3	59.0	3.6	2.4	0.0	0.6	N/A		
German TAVI (Bauer) (2014)	68.4	82.0	0.83	0.0	0.0	68.4	82.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Hayashida (2013)	47.6	16.3	2.91	0.0	0.0	47.6	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Kawamori (2018)	0.0	0.0	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Kochman (2014)[b]	82.1	82.1	1.00	0.0	0.0	82.1	82.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Liao (2018)	100.0	100.0	1.00	N/A		N/A		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Liu (2015)	100.0	100.0	1.00	33.3	24.0	66.7	76.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Table1 (*Continued*)

Study	Transcatheter valve (%)														
	Self-expandable														
	Total			A-valve		CoreValve		Evolut R		Lotus		Portico		VitaFlow	
	Bicuspid	Tricuspid	RR	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid	Bicuspid	Tricuspid
Sannino (2017)	47.7	40.1	1.19	N/A		N/A		N/A		N/A		N/A		N/A	
Xiong (2018)	100.0	100.0	1.00	58.2	59.2	35.8	32.7	0.0	0.0	6.0	4.1	0.0	0.0	0.0	4.1
Yoon (2017)[a]	42.3	42.9	0.99	0.0	0.0	30.2	31.3	4.2	2.9	7.9	8.6	0.0	0.0	0.0	0.0

Study	Transcatheter valve (%)						
	Balloon-expandable						
	Total			SAPIEN		SAPIEN 3	
	Bicuspid	Tricuspid	RR	Bicuspid	Tricuspid	Bicuspid	Tricuspid
Arai (2017)	100.0	100.0	1.00	0.0	0.0	100.0	100.0
Costopoulos (2014)	38.1	58.6	0.65	38.1	58.6	0.0	0.0
De Biase (2018)[a]	60.2	36.7	1.64	N/A		60.2	36.7
German TAVI (Bauer) (2014)	31.6	18.0	1.76	31.6	18.0	0.0	0.0
Hayashida (2013)	52.4	83.7	0.63	52.4	83.7	0.0	0.0
Kawamori (2018)	100.0	100.0	1.00	0.0	0.0	100.0	100.0
Kochman (2014)[b]	17.9	17.9	1.00	17.9	17.9	0.0	0.0
Liao (2018)	0.0	0.0	N/A	0.0	0.0	0.0	0.0
Liu (2015)	0.0	0.0	N/A	0.0	0.0	0.0	0.0
Sannino (2017)	52.3	59.7	0.88	N/A		N/A	
Xiong (2018)	0.0	0.0	N/A	0.0	0.0	0.0	0.0
Yoon (2017)[a]	57.7	57.1	1.01	28.4	27.5	29.3	29.7

Continuous variables are expressed as number, mean ± standard deviation, or median (interquartile range).
AV, aortic valve; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; CRI, chronic renal insufficiency; EuroSCORE, European System for Cardiac Operative Risk Evaluation; MD, mean difference; MDCT, multidetector computed tomography; N/A, not available; N/S, not significant; NYHA, New York Heart Association; RR, risk ratio; SMD, standardized MD; STJ, sinus tubular junction; PCI, percutaneous coronary intervention; STS-PROM, Society of Thoracic Surgery-Predicted Risk Of Mortality; TAVI, transcatheter aortic valve implantation.
[a] Propensity-score matched (1:2 [7] and 1:1 [16]).
[b] Matched (1:3) using logistic EuroSCORE, annulus diameter, delivery route, and type and size of the implanted bioprosthesis.

Table 2
Postprocedural TVR/PMI incidence and early/late mortality.

Study	References	Transcatheter valve regurgitation (TVR)						Pacemaker implantation (PMI)					
		Patient number				Incidence rate (%)		Patient number				Incidence rate (%)	
		Bicuspid		Tricuspid		Bicuspid	Tricuspid	Bicuspid		Tricuspid		Bicuspid	Tricuspid
		Total	TVR	Total	TVR			Total	PMI	Total	PMI		
Arai (2017)	[6]	10	0	143	8	0.0	5.6	10	0	143	12	0.0	8.4
Costopoulos (2014)	[7]	21	5	447	97	23.8	21.7	21	3	447	67	14.3	15.0
De Biase (2018)[a]	[8]	83	3	166	4	3.6	2.4	83	12	166	17	14.5	10.2
German TAVI (Bauer) (2014)	[9]	38	9	1357	204	23.7	15.0	38	6	1357	475	15.8	35.0
Hayashida (2013)	[10]	21	4	208	31	19.0	14.9	21	3	208	15	14.3	7.2
Kawamori (2018)	[11]	41	1	239	3	2.4	1.3	41	9	239	23	22.0	9.6
Kochman (2014)[b]	[12]	28	9	84	19	32.1	22.6	28	8	84	28	28.6	33.3
Liao (2018)	[13]	82	1	69	0	1.2	0.0	87	21	70	20	24.1	28.6
Liu (2015)	[14]	15	0	25	1	0.0	4.0	15	2	25	3	13.3	12.0
Sannino (2017)	[15]	75	4	639	32	5.3	5.0	88	20	735	133	22.7	18.1
Xiong (2018)	[16]	67	N/A	49	N/A	N/A	N/A	67	17	49	11	25.4	22.4
Yoon (2017)[a]	[17]	546	57	546	37	10.4	6.8	546	84	546	84	15.4	15.4

Study	Early mortality							Late mortality						
	Follow-up	Patient number				Mortality rate (%)		Follow-up	Patient number				Mortality rate (%)	
		Bicuspid		Tricuspid		Bicuspid	Tricuspid		Bicuspid		Tricuspid		Bicuspid	Tricuspid
		Total	Died	Total	Died				Total	Died	Total	Died		
Arai (2017)	30 days	10	0	143	1	0.0	0.7	N/A						
Costopoulos (2014)	30 days	21	3	447	16	14.3	3.6	1 year	19	6	378	52	31.6	13.8
De Biase (2018)[a]	30 days	83	4	166	5	4.8	3.0	N/A						
German TAVI (Bauer) (2014)	30 days	38	4	1357	149	10.5	11.0	1 year	38	5	1357	271	13.2	20.0
Hayashida (2013)	30 days	21	1	208	17	4.8	8.2	N/A						
Kawamori (2018)	30 days	41	0	239	1	0.0	0.4	N/A						
Kochman (2014)[b]	30 days	28	1	84	6	3.6	7.1	1 year	23	5	70	14	21.7	20.0
Liao (2018)	30 days	87	8	70	3	9.2	4.3	Median, 668 (IQR, 402–1073) days	87	11	70	9	12.6	12.9
Liu (2015)	30 days	15	1	25	2	6.7	8.0	N/A						
Sannino (2017)	30 days	88	3	735	23	3.4	3.1	1 year	88	7	735	68	8.0	9.3
Xiong (2018)	30 days	67	6	49	2	9.0	4.1	1 year	67	6	49	5	9.0	10.2
Yoon (2017)[a]	30 days	546	20	546	18	3.7	3.3	2 years	546	66	546	73	12.1	13.4

IQR, interquartile range; N/A, not available; PMI, pacemaker implantation; TAVI, transcatheter aortic valve implantation; TVR, ttranscatheter valve regurgitation.
[a] Propensity-score matched (1:2 [7] and 1:1 [16]).
[b] Matched (1:3) using logistic EuroSCORE, annulus diameter, delivery route, and type and size of the implanted bioprosthesis.

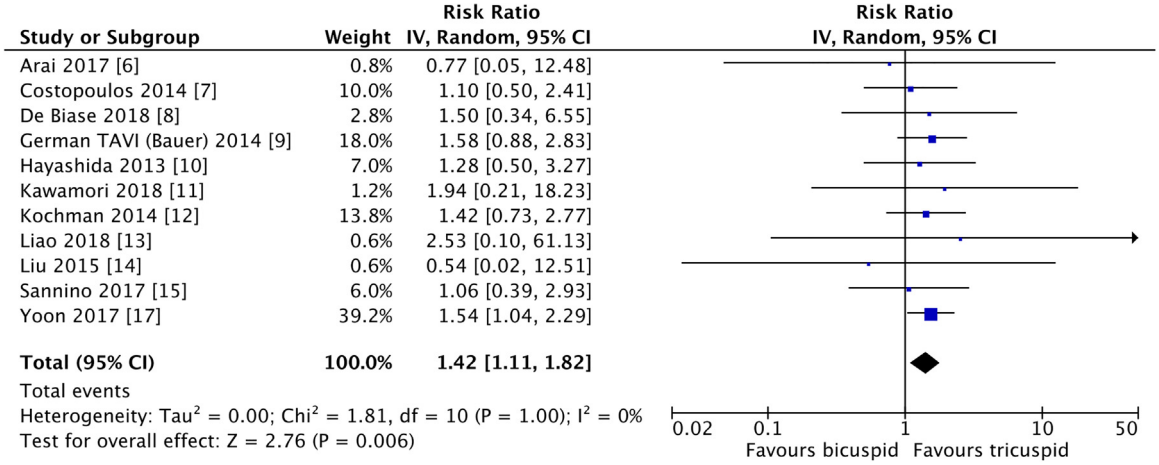

Fig. 1. Forest plot of risk ratios of the bicuspid aortic valve for incidence of ≥moderate transcatheter valve regurgitation after transcatheter aortic valve implantation (TAVI). CI, confidence interval; IV, inverse variance.

Kanjanahattakij et al. [18] recently performed meta-analysis of a similar topic, in which databases were searched through 20 December 2017 and a total of 9 studies with 854 B-AV and 3615 T-AV patients were included. In the present meta-analysis, we searched databases through June 2018 and included a total 12 studies with 1045 B-AV and 4069 T-AV patients. The recent [18] and present meta-analysis concluded similar results such as increased TVR incidence but similar PMI incidence and 30-day/midterm mortality. Dissimilarly to the recent meta-analysis [18], we performed meta-regression analysis and demonstrated that the effects of B-AV on the outcomes (TVR/PMI incidence, early/midterm mortality) were not modulated by 25 confounders

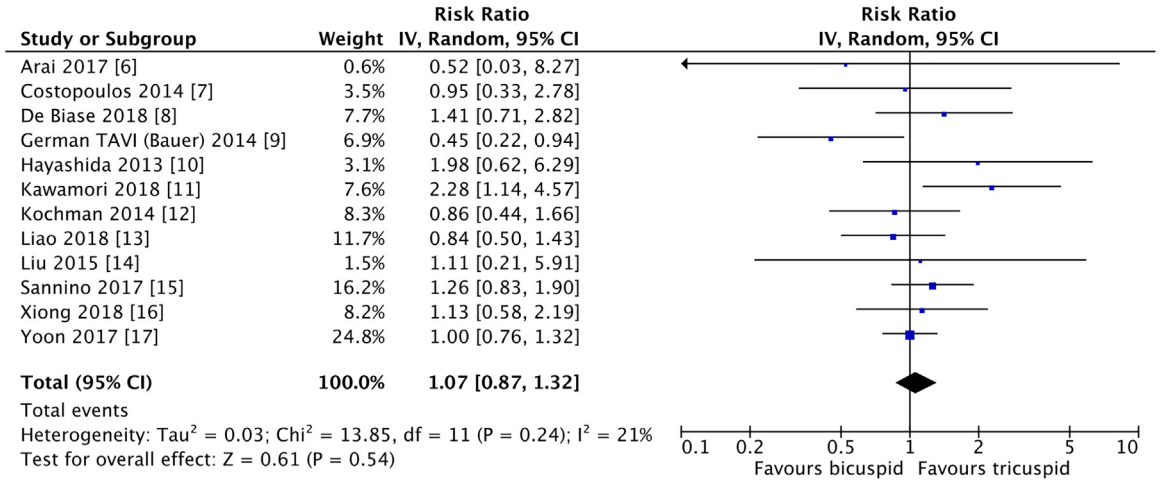

Fig. 2. Forest plot of risk ratios of the bicuspid aortic valve for incidence of pacemaker implantation after transcatheter aortic valve implantation (TAVI). CI, confidence interval; IV, inverse variance.

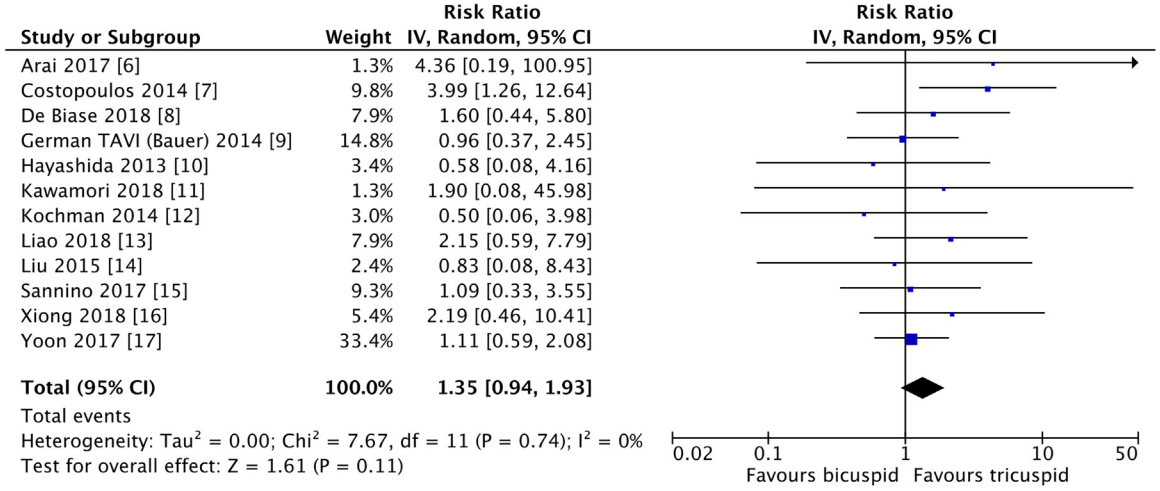

Fig. 3. Forest plot of risk ratios of the bicuspid aortic valve for 30-day mortality after transcatheter aortic valve implantation (TAVI). CI, confidence interval; IV, inverse variance.

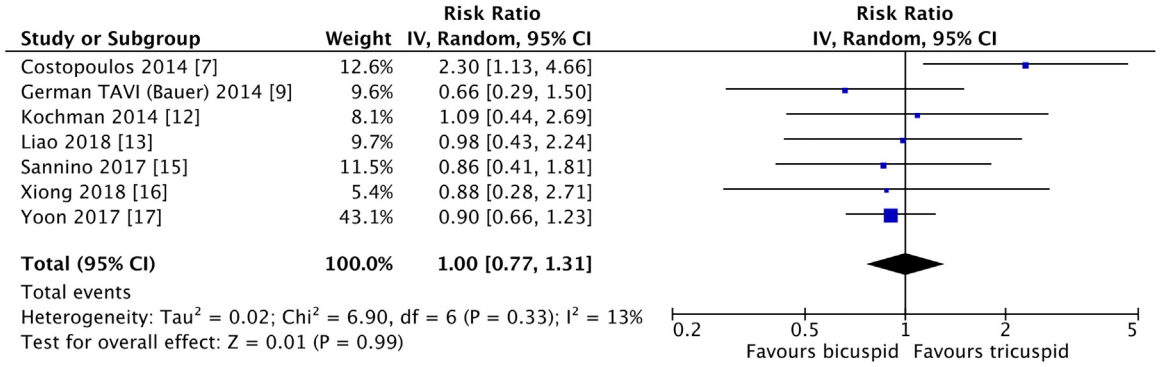

Fig. 4. Forest plot of risk ratios of the bicuspid aortic valve for midterm (1-year to 2-year) mortality after transcatheter aortic valve implantation (TAVI). CI, confidence interval; IV, inverse variance.

examined. The present meta-regression analysis suggests that B-AV types may not modulate the effects of B-AV on the outcomes. Yousef et al. [19], however, reported that 30-day (0% versus 25.0%; $p < 0.001$)/1-year mortality (3.0% versus 36.7%; $p < 0.01$) and composite early safety (at 30 days) endpoints (20.5% versus 43.8%; $p = 0.05$) after TAVI are lower in type-1 (with left and right fusion) B-AV patients than in other-type B-AV patients. Whereas, in a study by Liao et al. [13], there was no difference in 30-day (10.2% versus 7.9%; $p = 0.44$) and cumulative mortality (10.2% versus 15.8%; $p = 0.42$) after TAVI between type-0 and type-1 B-AV patients.

In patients with B-AV, valved stents are constantly mis-deployed, which may distort the valve. In an anatomical study [1] performed in patients undergoing scheduled surgical aortic valve replacement, although the circular deployment of stents was significantly less observed in B-AV than in T-AV (14.3% versus 68.4%, $p = 0.004$), the elliptic deployment was more common in B-

Table 3
Summary of meta-regression analysis.

Potential confounder		Outcome							
		Postprocedural TVR		Postprocedural PMI		Early mortality		Midterm mortality	
		Coefficient	2-sided p	Coefficient	2-sided p	Coefficient	2-sided p	Coefficient	2-sided p
Age (years)		0.0900	0.5053	−0.1705	0.1650	−0.3074	0.1462	−0.2245	0.1128
Mean aortic valve gradient (mm Hg)		−0.0273	0.6777	0.0964	0.4534	0.0508	0.5174	0.0541	0.5187
Aortic valve area (cm^2)		2.4492	0.6085	−0.8156	0.8851	−5.4202	0.3329	−12.0722	0.1834
Left ventricular ejection fraction (%)		0.0117	0.8725	−0.0338	0.8698	−0.0680	0.3898	0.0012	0.9829
Aortic valve calcification		−0.5124	0.7331	−1.5252	0.3348	0.9793	0.5751	NES	NES
Bicuspid type (%)	0	−0.0022	0.9075	−0.0063	0.2670	0.0077	0.4822	0.0011	0.9089
	1	0.0032	0.8804	0.0019	0.7531	−0.0080	0.4952	−0.0011	0.9116
	2	−0.0128	0.7515	0.0197	0.6526	−0.0464	0.5262	−0.0234	0.9290

TVR, transcatheter valve regurgitation; NES, not enough studies; PMI, pacemaker implantation.

AV than in T-AV (78.6% versus 10.5%). Furthermore, the presence of a periprosthetic gap (gap between the stent external surface and the inner surface of the aortic valve) was observed in 100% and 33.3% in the triangular and circular shape of stent deployment, respectively [1]. These findings can explain more frequent postprocedural TVR demonstrated in the present analysis.

Postprocedural ≥moderate [20], even mild [21], TVR is associated with an increase in follow-up mortality. Our previous meta-analysis [20] of 17 studies enrolling 15,131 patients demonstrated a statistically significant 2.12-fold increase in ≥1-year mortality with ≥moderate TVR [hazard ratio (HR), 2.12; $p < 0.00001$]. Another meta-analysis of ours [21] including 25 studies with 21,018 patients indicated higher ≥6-month mortality in patients with mild TVR than those with none/trivial TVR (HR 1.26, $p < 0.001$). In the present analysis, however, 30-day and midterm (1-year to 2-year) mortality was comparable between patients with B-AV and those with T-AV (Figs. 2 and 3) despite more frequent TVR in those with B-AV than in those with T-AV (Fig. 1), which suggests that multiple factors (not only TVR) affecting the prognosis of T-AV patients may determine mortality of B-AV patients [17].

In 3 studies [8,12,17] included in the present analysis, outcomes after TAVI were investigated in the matched (with propensity score [8,17] and using the 4 afore-mentioned factors [12]) B-AV and T-AV patients. Between patients with B-AV and those with T-AV, 30-day (4.8% versus 3.0%, $p = 0.47$ [8]; 3.6% versus 7.1%, $p = 0.68$ [12]; 3.7% versus 3.3%, $p = 0.87$ [17]) and midterm mortality (21.7% versus 20.0%, $p = 1.00$ [12]; 17.2% versus 19.4% [Kaplan–Meier estimate], $p = 0.28$ [17]) was similar. On the one hand, postprocedural PVR incidence was similar between patients with B-AV and those with T-AV (3.6% versus 2.4% [8]; 32.1% versus 22.6%, $p = 0.45$ [12]) in 2 studies; on the other hand, PVR was more frequent in B-AV patients than T-AV patients (10.4% versus 6.8%, $p = 0.04$) in another study [17]. In two studies [9,13], multivariate logistic and Cox proportional hazards regression analysis was applied, and no association of B-AV with higher TVR incidence (adjusted OR, 1.306; $p = 0.538$ [13]) and 1-year mortality (adjusted HR, 0.64; 95% CI, 0.29–1.41 [9]) was reported. The remaining seven studies except for the five above-mentioned studies [8,9,12,13,17] provided only crude (unadjusted) data on TVR and 30-day/midterm mortality. We extracted crude data from all the 12 studies and combined them in the present meta-analysis. Unlike propensity-score matched studies, there are probable differences between patients with B-AV and those with T-AV in the other observational studies. We accessed differences in 24 baseline patient, echocardiographic, and procedural characteristics between patients with B-AV and those with T-AV (Table 1) and confirmed no differences in 19 factors (Supplementary Figs. S6–S24). There were significant differences in the remaining five factors (age, MAVG, AVA, LVEF, AVC), which were considered as potential confounders (Figs. 5–9). Subsequent meta-regression analysis, however, suggests that these six factors (including B-AV types) may not modulate the effects of B-AV on the outcomes (Supplementary Figs. S25–S60 and Table 3).

In a study by Sannino et al. [15], there was no difference in 1-year mortality after TAVI between patients with B-AV and those with T-AV when stratified according to early- versus new-generation devices. Also in a study by Yoon et al. [17], there were no significant differences in 1-year mortality between patients with B-AV and those with T-AV in both early- (14.5% versus 13.7%; $p = 0.80$) and new-generation device groups (4.5% versus 7.4%, $p = 0.64$). Although postprocedural ≥moderate TVR incidence in the early-generation device group was more frequent in patients with B-AV than in those with T-AV (15.9% versus 10.3%, $p = 0.03$), that in the new-generation device group was similar between patients with B-AV and in those with T-AV (2.7% versus 1.8%, $p = 0.53$ [17]). Further investigations regarding a role of new-generation devices for B-AV would be required.

Although not focused in the present analysis, there may be differences in incidence of several outcomes and complications after TAVI between patients with B-AV and those with T-BV. According to the three matched studies [8,12,17] included in the present analysis, device success was less frequent (73.5% versus 93.4%, $p < 0.01$ [8]; 85.3% versus 91.4%, $p = 0.002$ [17]), hospital stay was longer (8.2 ± 4.1 versus 6.8 ± 2.4 days, $p < 0.01$ [8]), TAVI-in-TAVI (implantation of 2 valves) (10.8% versus 3.0%, $p = 0.03$ [8]; 14.8% versus 1.5%, $p = 0.002$ [17]), conversion to surgery (2.0% versus 0.2%, $p = 0.006$ [17]), and aortic root injury (1.6% versus 0%, $p = 0.004$ [17]) were more frequent in patients with B-AV than those with T-AV. Despite more frequent incidence of serious complications such as conversion to surgery and aortic root injury [17], 30-day mortality was similar [8,12,17].

The present results should be interpreted with caution in the context of their limitations. First, we used only crude (unadjusted) data from observational studies (although including the three matched studies [8,12,17]). Study-level adjustment of confounders was performed in the five studies included in the present analysis, using propensity-score [8,17] or 4-variable matching [12] and multivariate logistic and Cox proportional hazards regression analysis [9,13]. Using meta-regression analysis, we assessed the five potential confounders (age, MAVG, AVA, LVEF, and AVC) identified in preliminary meta-analysis, which suggests that the effects of B-AV on the outcomes (TVR/PMI incidence and early/midterm mortality) may not be modulated by these six factors (including B-AV types). Second, publication bias in favor of T-AV may militate our results. Exhaustively searching available literature, however, minimized the risk. Furthermore, the established statistical test did not detect funnel-plot asymmetry suggesting

publication bias. Third, we focused on limited outcomes, i.e. postprocedural TVR/PMI and early/midterm mortality. Future meta-analysis including more comparative studies would be required.

Conclusions

Postprocedural PMI incidence and 30-day/midterm (1-year to 2-year) mortality after TAVI may be similar between patients with B-AV and those with T-AV despite the significant association of B-AV with increased postprocedural TVR incidence.

Conflict of interest

The authors have no conflict of interest to disclose.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jjcc.2019.03.018.

References

[1] Zegdi R, Ciobotaru V, Noghin M, Sleilaty G, Lafont A, Latrémouille C, et al. Is it reasonable to treat all calcified stenotic aortic valves with a valved stent? Results from a human anatomic study in adults. J Am Coll Cardiol 2008;51:579–84.
[2] Reddy G, Wang Z, Nishimura RA, Greason KL, Yoon SH, Makkar RR, et al. Transcatheter aortic valve replacement for stenotic bicuspid aortic valves: systematic review and meta analyses of observational studies. Catheter Cardiovasc Interv 2018;91:975–83.
[3] Kodali S, Thourani VH, White J, Malaisrie SC, Lim S, Greason KL, et al. Early clinical and echocardiographic outcomes after SAPIEN 3 transcatheter aortic valve replacement in inoperable, high-risk and intermediate-risk patients with aortic stenosis. Eur Heart J 2016;37:2252–62.
[4] Manoharan G, Walton AS, Brecker SJ, Pasupati S, Blackman DJ, Qiao H, et al. Treatment of symptomatic severe aortic stenosis with a novel resheathable supra-annular self-expanding transcatheter aortic valve system. JACC Cardiovasc Interv 2015;8:1359–67.
[5] Kappetein AP, Head SJ, Généreux P, Piazza N, van Mieghem NM, Blackstone EH, et al. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the Valve Academic Research Consortium-2 consensus document. Eur Heart J 2012;33:2403–18.
[6] Arai T, Lefèvre T, Hovasse T, Morice MC, Romano M, Benamer H, et al. The feasibility of transcatheter aortic valve implantation using the Edwards SAPIEN 3 for patients with severe bicuspid aortic stenosis. J Cardiol 2017;70:220–4.
[7] Costopoulos C, Latib A, Maisano F, Testa L, Bedogni F, Buchanan L, et al. Comparison of results of transcatheter aortic valve implantation in patients with severely stenotic bicuspid versus tricuspid or nonbicuspid valves. Am J Cardiol 2014;113:1390–3.
[8] De Biase C, Mastrokostopoulos A, Philippart R, Desroche LM, Blanco S, Rehal K, et al. Aortic valve anatomy and outcomes after transcatheter aortic valve implantation in bicuspid aortic valves. Int J Cardiol 2018;266:56–60.
[9] Bauer T, Linke A, Sievert H, Kahlert P, Hambrecht R, Nickenig G, et al. Comparison of the effectiveness of transcatheter aortic valve implantation in patients with stenotic bicuspid versus tricuspid aortic valves (from the German TAVI Registry). Am J Cardiol 2014;113:518–21.
[10] Hayashida K, Bouvier E, Lefèvre T, Chevalier B, Hovasse T, Romano M, et al. Transcatheter aortic valve implantation for patients with severe bicuspid aortic valve stenosis. Circ Cardiovasc Interv 2013;6:284–91.
[11] Kawamori H, Yoon SH, Chakravarty T, Maeno Y, Kashif M, Israr S, et al. Computed tomography characteristics of the aortic valve and the geometry of SAPIEN 3 transcatheter heart valve in patients with bicuspid aortic valve disease. Eur Heart J Cardiovasc Imaging 2018;19:1408–18.
[12] Kochman J, Huczek Z, Scisło P, Dabrowski M, Chmielak Z, Szymański P, et al. Comparison of one- and 12-month outcomes of transcatheter aortic valve replacement in patients with severely stenotic bicuspid versus tricuspid aortic valves (results from a multicenter registry). Am J Cardiol 2014;114:757–62.
[13] Liao YB, Li YJ, Xiong TY, Ou YW, Lv WY, He JL, et al. Comparison of procedural, clinical and valve performance results of transcatheter aortic valve replacement in patients with bicuspid versus tricuspid aortic stenosis. Int J Cardiol 2018;254:69–74.
[14] Liu XB, Jiang JB, Zhou QJ, Pu ZX, He W, Dong AQ, et al. Evaluation of the safety and efficacy of transcatheter aortic valve implantation in patients with a severe stenotic bicuspid aortic valve in a Chinese population. J Zhejiang Univ Sci B 2015;16:208–14.
[15] Sannino A, Cedars A, Stoler RC, Szerlip M, Mack MJ, Grayburn PA. Comparison of efficacy and safety of transcatheter aortic valve implantation in patients with bicuspid versus tricuspid aortic valves. Am J Cardiol 2017;120:1601–6.
[16] Xiong TY, Wang X, Li YJ, Liao YB, Zhao ZG, Wei X, et al. Less pronounced reverse left ventricular remodeling in patients with bicuspid aortic stenosis treated with transcatheter aortic valve replacement compared to tricuspid aortic stenosis. Int J Cardiovasc Imaging 2018;34:1761–7.
[17] Yoon SH, Bleiziffer S, De Backer O, Delgado V, Arai T, Ziegelmueller J, et al. Outcomes in transcatheter aortic valve replacement for bicuspid versus tricuspid aortic valve stenosis. J Am Coll Cardiol 2017;69:2579–89.
[18] Kanjanahattakij N, Horn B, Vutthikraivit W, Biso SM, Ziccardi MR, Lu MLR, et al. Comparing outcomes after transcatheter aortic valve replacement in patients with stenotic bicuspid and tricuspid aortic valve: a systematic review and meta-analysis. Clin Cardiol 2018;41:896–902.
[19] Yousef A, Simard T, Webb J, Rodés-Cabau J, Costopoulos C, Kochman J, et al. Transcatheter aortic valve implantation in patients with bicuspid aortic valve: a patient level multi-center analysis. Int J Cardiol 2015;189:282–8.
[20] Takagi H, Umemoto T. ALICE (All-Literature Investigation of Cardiovascular Evidence) Group. Impact of paravalvular aortic regurgitation after transcatheter aortic valve implantation on survival. Int J Cardiol 2016;221:46–51.
[21] Ando T, Briasoulis A, Telila T, Afonso L, Grines CL, Takagi H. Does mild paravalvular regurgitation post transcatheter aortic valve implantation affect survival? A meta-analysis. Catheter Cardiovasc Interv 2018;91:135–47.