

Aortic valve endocarditis in patients with bicuspid and tricuspid aortic valves



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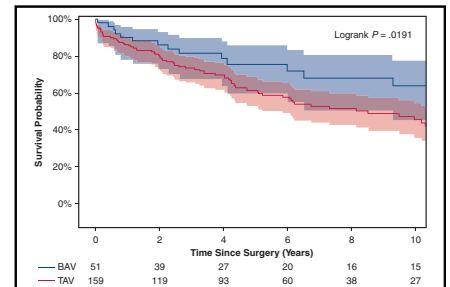
ABSTRACT

Objective: To determine the long-term survival and rate of reoperation after surgical treatment of infective endocarditis (IE) in patients with a bicuspid aortic valve (BAV) and patients with a tricuspid aortic valve (TAV).

Methods: Between 1997 and 2017, 210 patients underwent surgical treatment for native aortic valve endocarditis, including 51 patients with BAV (24%) and 159 patients with TAV (76%). Data were obtained from the Society of Thoracic Surgeons data warehouse and hospital medical record review, supplemented with surveys and national death index data for more complete follow-up.

Results: Compared with the TAV IE group, the BAV IE group was significantly younger (42 years vs 54 years) and had lower incidence rates of hypertension, coronary artery disease, and congestive heart failure (CHF). There were no significant between-group differences in postoperative stroke, sepsis, pacemaker requirement, or in-hospital mortality (2.0% vs 4.4%). Liver disease was a risk factor for operative mortality (odds ratio [OR], 13; 95% CI, 3.3-30; $P = .0002$). The 10-year survival rate was 64% for the BAV group versus 46% for the TAV group ($P = .0191$). Significant risk factors for long-term mortality were intravenous drug use (hazard ratio [HR], 4.5; $P < .0001$), preoperative renal failure requiring dialysis (HR, 4.13; $P < .0001$), CHF (HR, 1.7; $P = .04$), and liver disease (HR, 2.6; $P = .02$). The HR for BAV was 0.67 (95% confidence interval [CI], 0.3-1.4). The 10-year postoperative cumulative incidence of reoperation was significantly higher in the BAV patients compared with the TAV patients (5.7% vs 4.5%; $P = .045$) with an HR of 2.4 (95% CI, 0.8-7.1; $P = .11$) for BAV.

Conclusions: BAV patients develop IE requiring surgery at a younger age than TAV patients, but have significantly better long-term survival. Early detection of BAV is important to prevent IE and provide aggressive surgical treatment should IE occur. (JTCVS Open 2021;8:228-36)



Long-term survival of patients with bicuspid aortic valve and tricuspid aortic valve with infective endocarditis.

CENTRAL MESSAGE

Compared with patients with a tricuspid aortic valve, patients with a bicuspid aortic valve are at increased risk of developing endocarditis at a younger age but demonstrate better long-term survival after surgical treatment.

PERSPECTIVE

Compared with patients with a tricuspid aortic valve (TAV), those with a bicuspid aortic valve (BAV) are at increased risk of developing infective endocarditis (IE) at a younger age owing to intrinsic factors of the aortic valve, but have superior long-term survival. It is important to BAV early to provide recommendations for prevention of BAV endocarditis and to provide aggressive surgical treatment if IE occurs.

See Commentaries on pages 237 and 239.

▶ Video clip is available online.

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Abbreviations and Acronyms

- AI = aortic insufficiency
- AVR = aortic valve replacement
- BAV = bicuspid aortic valve
- HR = hazard ratio
- IE = infective endocarditis
- IQR = interquartile range
- IV = intravenous
- OR = odds ratio
- TAV = tricuspid aortic valve

Patients with bicuspid aortic valve (BAV) develop infective endocarditis (IE) at significantly higher rates than the general population. According to an analysis of selected case series, 10% to 30% of patients with BAV develop IE, and 25% of all IE cases develop in patients with BAV.¹ In a longitudinal population-based study of the total burden of IE in patients with BAV, Michelena and colleagues² reported an 17-fold higher incidence of IE in patients with native BAV compared with the general population. Patients with BAV IE also experienced significant morbidity, with 67% requiring surgical treatment and a mortality rate of 22%.² Despite the known risks of IE developing in patients with BAV and significant operative morbidity and mortality, long-term outcomes related to IE in this population have not been well studied. Data for population-based cohorts of patients with BAV IE and TAV IE with longitudinal follow-up is still lacking. Thus, we conducted this study to compare short-term and long-term morbidity and mortality outcomes after surgical treatment of IE in patients with BAV compared with patients with TAV and provide evidence to guide the management of IE in patients with BAV.

METHODS

This study was approved by the Institutional Review Board at the University of Michigan (HUM00142927; 2018) and a waiver of informed consent was obtained.

Patient Selection

Between 1997 and 2017, 210 patients with native aortic valve IE underwent surgery for aortic valve replacement (AVR) or root replacement at the University of Michigan. Patients were divided into 2 groups based on the presence of a BAV (n = 51) or TAV (n = 159). Patients with prosthetic valve endocarditis were excluded, because we were studying aortic valve IE in native BAV and TAV. The Society of Thoracic Surgeons data warehouse was used to identify the relevant cohort and to determine the preoperative, operative, and postoperative variables. These data were supplemented by medical chart review for specified variables. Survival and reoperation data were collected by medical record review and supplemented with surveys (including letters and phone calls) and National Death Index³ data through December 31, 2018, the study's end date. Completeness of follow-ups for death and reoperation were calculated based on the ratio of the observed person-time and potential person-time follow-up

TABLE 1. Preoperative and demographic data

Variable	TAV group (N = 159)	BAV group (N = 51)	P value
Age, y, median (IQR)	54 (44-65)	42 (30-56)	<.0001
Female sex, n (%)	42 (26)	7 (14)	.062
Coronary artery disease, n (%)	35 (22)	5 (9.8)	.053
Diabetes, n (%)	31 (20)	9 (18)	.770
Dyslipidemia, n (%)	46 (29)	14 (27)	.839
Hypertension, n (%)	92 (58)	20 (39)	.020
Current smoker, n (%)	34 (21)	15 (29)	.238
Lung disease, n (%)			.445
None	132 (83)	44 (86)	
Mild	12 (7.6)	4 (7.8)	
Moderate	7 (4.4)	3 (5.9)	
Severe	8 (5.0)	0 (0)	
Pneumonia, n (%)	16 (10)	5 (9.8)	.957
Intravenous drug use, n (%)	25 (16)	4 (7.8)	.156
Depression, n (%)	18 (11)	4 (7.8)	.480
Alcohol use (>8 drinks/wk), n (%)	7 (4.4)	4 (7.8)	.468
Liver disease, n (%)	15 (9.4)	7 (14)	.384
Previous myocardial infarction, n (%)	28 (18)	7 (14)	.517
Congestive heart failure, n (%)	94 (59)	21 (41)	.025
Stroke, n (%)	29 (18)	12 (24)	.406
Sepsis, n (%)*	30 (19)	6 (12)	.242
Cardiogenic shock, n (%)	14 (8.8)	6 (12)	.585
Arrhythmia, n (%)	17 (11)	3 (5.9)	.416
Previous cardiac surgery, n (%)			.150
CABG	6 (3.8)	0 (0)	
Root replacement	3 (1.9)	0 (0)	
Ascending replacement	1 (0.6)	1 (2.0)	
Arch replacement	0 (0)	0 (0)	
Mitral valve replacement	2 (1.3)	0 (0)	

Significant P values are in bold type. TAV, Tricuspid aortic valve; BAV, bicuspid aortic valve; IQR, interquartile range; CABG, coronary artery bypass grafting. *Based on retrospective chart review in patients with documented sepsis in the context of a suspected or proven infection via blood cultures and a systemic inflammatory response syndrome.

in the study.⁴ The median follow-up was calculated as the median time from the date of surgery to when the patient was last known to be alive or experienced an event.

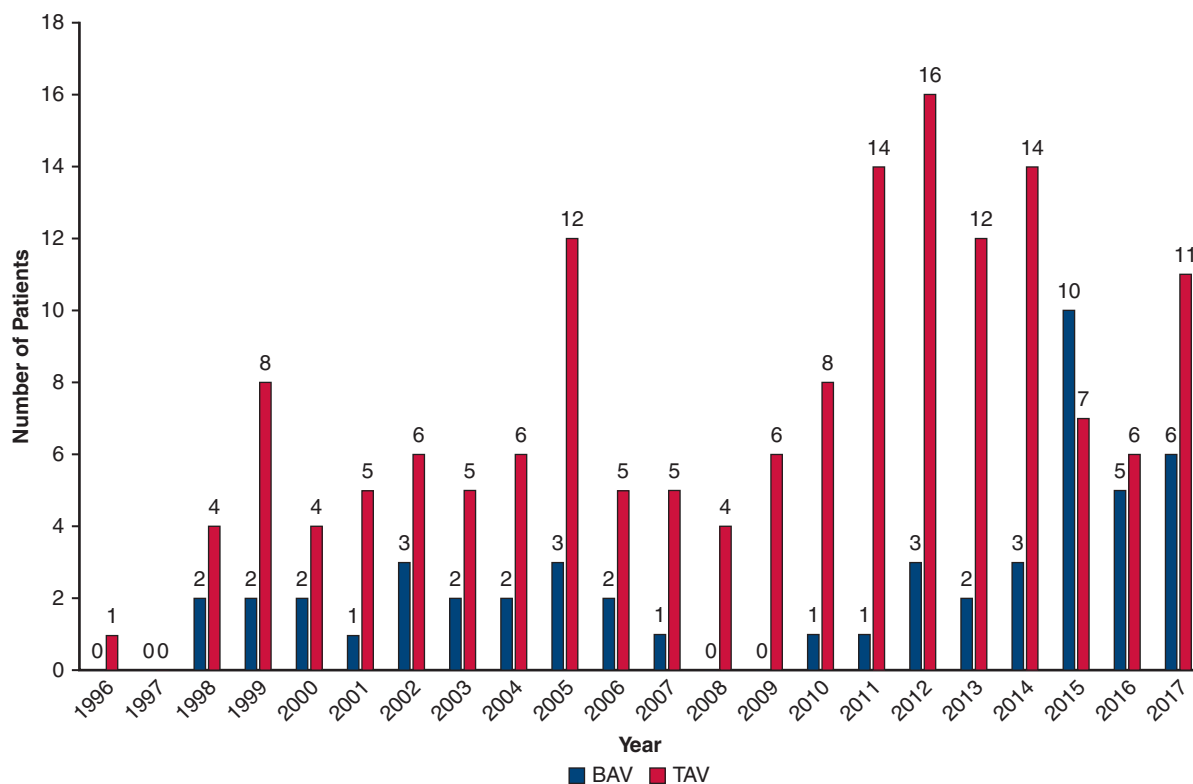


FIGURE 1. Total number of patients with surgical infective endocarditis (IE) in the bicuspid aortic valve (BAV) group and tricuspid aortic valve (TAV) group, 1996 to 2017.

Operative Technique

In patients with infected aortic valves that could not be repaired, AVR was performed. Three types of prostheses were used: bioprosthesis (stented and stentless valves), homografts, and mechanical valves. Before early 2000, we used homografts; we later switched to stentless valves for their accessibility and lower cost, and also uses stented valves when appropriate. Mechanical valves were used in younger patients. We reported the detailed surgical technique previously.⁵ In brief, radical debridement of infected tissue was essential in preparation for valve implantation. In patients without root abscess, the infected leaflets were removed and the root was extensively debrided of any necrotic tissue. Any defect of the aortic root was patched with autologous pericardium or bovine pericardium if necessary. Routine AVR was completed with a prosthesis.

In patients with root abscess, if the cavity involved less than one-third (1 sinus) of the aortic annulus, the cavity was patched with autologous pericardium or bovine pericardium followed by the AVR. If the abscess involved more than one-third (2 sinuses) of the aortic annulus, then either a total root replacement with separate reimplantation of the 2 coronary buttons or patch repair of the cavity and modified inclusion aortic root repair was completed. Stentless valves, homografts, and mechanical valve composite valve grafts were used for total root replacement. For patients with root abscess and with a destroyed aortomitral curtain, we directly anastomosed the stentless valve or homograft to the mitral valve annulus and muscular septum after extensive debridement and then reimplanted the 2 coronary buttons.

Statistical Analysis

Continuous data are presented as median (interquartile range [IQR]), and categorical data are presented as number (%). Univariate comparisons between groups were performed using the χ^2 test for categorical data. The

Kolmogorov–Smirnov D test and Cramer–von Mises tests were used to test the normality of the data. The Wilcoxon rank-sum test was performed for continuous data. Univariable logistic regression was used to calculate the odds ratio (OR) of risk factors for operative mortality, including BAV, liver disease, and emergent status. Survival curves were estimated using the Kaplan–Meier method with the log-rank test to test the significance of survival differences. The Cox proportional hazards regression model was used to calculate the adjusted hazard ratios (HRs) for mortality since surgery, adjusting for group, age (modeled as a binary variable owing to violation of the proportional hazards assumption), sex, history of intravenous (IV) drug use, coronary artery disease, cardiogenic shock, congestive heart failure, preoperative sepsis, preoperative liver disease, and preoperative renal failure requiring dialysis. The variables entered into the logistic model and Cox model were chosen to identify the independent risk factors and were based on variables used in previous reports in the literature and in clinical practice. We examined the proportional hazards assumption using supremum tests for martingale residuals. $P < .05$ was considered to indicate statistical significance. Cumulative incidence function curves were adjusted for death as a competing risk using a cause-specific model to assess the incidence of reoperation after surgery. Gray's test was used to assess whether the difference in the cumulative incidence function curves between groups was significant. Statistical analyses were performed with SAS (SAS Institute, Cary, NC).

RESULTS

Demographic and Preoperative Results

The 2 groups shared similar demographics for the majority of categories. One difference between the groups was in age of onset of IE; patients with BAV presented with IE at a

TABLE 2. Operative data

Variable	TAV group (N = 159)	BAV group (N = 51)	P value
Causative microorganism, n (%)			.001
Staphylococci	51 (32)	14 (27)	.534
<i>Staphylococcus aureus</i>	32 (20)	8 (16)	
Coagulase-negative Staphylococci	19 (12)	6 (12)	
Streptococci	46 (29)	26 (51)	.004
Enterococci	35 (22)	2 (3.9)	.003
Culture-negative	16 (10)	4 (7.8)	.638
Fungal	3 (5.1)	1 (2.0)	.973
Others*	8 (5.0)	4 (7.8)	.452
Aortic insufficiency			.694
Moderate	24 (15)	6 (12)	
Severe	102 (64)	36 (71)	
Aortic stenosis, n (%)	52 (33)	27 (53)	.009
Calcified valve leaflets, n (%)	17 (11)	15 (29)	.001
Root aneurysm, n (%)	2 (1.3)	0 (0)	1.000
Ascending aneurysm, n (%)	6 (3.8)	7 (14)	.010
Status, n (%)			.133
Elective	6 (3.8)	2 (3.9)	
Urgent	129 (81)	35 (69)	
Emergent	24 (15)	14 (27)	
Incidence, n (%)			.413
First cardiac surgery	140 (88)	47 (92)	
Reoperation	19 (12)	4 (7.8)	
CPB time, min, median (IQR)	184 (138-242)	197 (151-265)	.105
Cross-clamp time, min, median (IQR)	146 (107-190)	159 (118-205)	.149
Aortic valve repair, n (%)	4 (2.4)	1 (2.0)	.821
AVR, n (%)	75 (47)	25 (49)	.818
Root replacement, n (%)	84 (53)	26 (51)	.818
Prosthetic aortic valve size, mm, median (IQR)	25 (23-26)	26 (25-27)	.0002
Prostheses used, n (%)			.163
Bioprosthesis	148 (93)	44 (86)	
Stentless valve	67 (42)	21 (41)	
Stented valve	65 (44)	18 (35)	
Homograft	16 (10)	5 (12)	
Mechanical valve	7 (4.8)	6 (12)	
CABG, n (%)	17 (11)	4 (7.8)	.384
Mitral valve procedure, n (%)			.113
Repair	49 (31)	11 (22)	
Replacement	20 (13)	3 (5.9)	

(Continued)

TABLE 2. Continued

Variable	TAV group (N = 159)	BAV group (N = 51)	P value
Tricuspid valve procedure, n (%)			.107
Repair	27 (17)	3 (5.9)	
Replacement	1 (0.6)	0 (0)	
Ascending procedure	17 (11)	10 (20)	.098

Significant P values are in bold type. TAV, Tricuspid aortic valve; BAV, bicuspid aortic valve; CPB, cardiopulmonary bypass; IQR, interquartile range; AVR, aortic valve replacement; CABG, coronary artery bypass grafting. *Organisms with positive blood cultures not otherwise categorized.

much younger average age than those with TAV (42 years [IQR, 30-56 years] vs 54 years [IQR, 44-65 years]; $P < .0001$). Patients with BAV also had lower rates of coronary artery disease (9.8% vs 22%; $P = .05$), hypertension (39% vs 58%; $P = .02$), and congestive heart failure (41% vs 59%; $P = .03$). There were no significant between-group differences in cases of diabetes, lung disease, pneumonia, or IV drug use (Table 1).

There was no change in the proportions of BAV IE and TAV IE treated at our institution after 2007, when the American Heart Association changed antibiotic prophylaxis guidelines for patients with BAV (25% BAV IE and 75% TAV IE pre-2008 vs 24% BAV IE and 76% TAV IE in 2008-2017; $P = .91$) (Figure 1).

Intraoperative Results

Streptococcus species were more often the causative organism of IE in patients with BAV (51% vs 29% for the TAV group; $P = .004$), whereas *Enterococcus* species were more often the causative organism in patients with TAV (22% vs 3.9% in the BAV group; $P = .003$). Patients with BAV had a higher rate of aortic stenosis compared with patients with TAV (53% vs 33%; $P = .009$). They also had larger prosthetic aortic valves implanted (average size, 26 mm [IQR, 25-27 mm] vs 25 mm [IQR, 23-26 mm]; $P = .0002$). The BAV group had higher proportions of calcified aortic valve leaflets (29% vs 11%; $P = .001$) and ascending aneurysms (14% vs 3.8%; $P = .02$), and a greater percentage of patients with BAV underwent emergent operations for IE (27% vs 15%; $P = .05$) (Table 2).

Operative Results

There were no significant differences in operative mortality (2.0% for BAV vs 5.0% for TAV) or most postoperative complications (including stroke, sepsis, and new-onset renal failure requiring dialysis) or mortality between the BAV and TAV groups. Significant risk factors for operative mortality identified on multivariate logistic analysis included preoperative liver disease (OR, 13; 95% CI, 3.4-30; $P < .0001$) (Table 3).

TABLE 3. Univariate logistic regression analysis of operative mortality

Variable	OR	95% Wald CI	P value
BAV	0.53	0.09-3.16	.49
Liver disease	13.0	3.34-30.3	<.0001
Emergent status	2.54	0.65-9.92	.18

OR, Odds ratio; CI, confidence interval; BAV, bicuspid aortic valve.

Long-Term Outcomes

The median follow-up for death was 3.7 years (95% CI, 1.6-7.3 years). Completeness of follow up for survival was 100% with national death index data and medical chart review. The long-term survival was significantly greater in patients with BAV compared with patients with TAV (10-year survival, 63.8% vs 45.5%; $P = .019$) (Figure 2). The presence of IV drug use was a significant risk factor for long-term mortality (HR, 4.5; 95% CI, 2.3-8.6; $P < .0001$), as was congestive heart failure (HR, 1.7; 95% CI, 1.0-2.8; $P = .04$), liver disease (HR, 2.6; 95% CI, 1.2-5.7; $P = .02$), and preoperative renal failure requiring dialysis (HR, 4.1; 95% CI, 2.5-6.8; $P < .0001$). The HR of BAV versus TAV was 0.67 (95% CI, 0.3-1.4; $P = .26$) (Table 4).

The median follow-up time for reoperation was 3.6 years (95% CI, 1.5-7.2 years). The percentage completion of follow-up for reoperation was 94%. The 10-year postoperative cumulative incidence of reoperation was significantly higher in the BAV group compared with the TAV group (5.7% vs 4.5%; $P = .045$) (Figure 3). The HR of BAV

for reoperation was 2.4 (95% CI, 0.8-7.1; $P = .11$). A total of 15 patients required reoperation. Recurrent endocarditis (50%) and valve deterioration (50%) were the most common indications for reoperation in the patients with TAV, and valve deterioration (86%) was the most common indication in the patients with BAV.

DISCUSSION

In this study, we found that patients with BAV and TAV had similar operative outcomes with acceptable operative mortality. Preoperative liver disease was a significant risk factor for operative mortality (Table 3). IV drug use, preoperative liver disease, congestive heart failure, and preoperative renal failure requiring dialysis were risk factors for long-term mortality (Table 4). Long-term survival was significantly greater in the BAV group compared with the TAV group (10-year survival, 64% vs 46%) (Figure 2), but the BAV group had a higher cumulative incidence of reoperation at 10 years postoperatively (Figure 3).

Although only 2% of the population has a BAV, we found that 24% of patients with IE had BAV. This finding is consistent with other studies.⁶⁻⁸ The disproportionate incidence of IE in patients with BAV is observed despite significantly fewer preoperative risk factors relative to those with TAV IE, such as previous cardiac surgery, a well-known risk factor for IE.⁹⁻¹¹ We found that patients with TAV had significantly higher rates of hypertension, coronary artery disease, and congestive heart failure (Table 1). In contrast to patients with TAV IE, patients

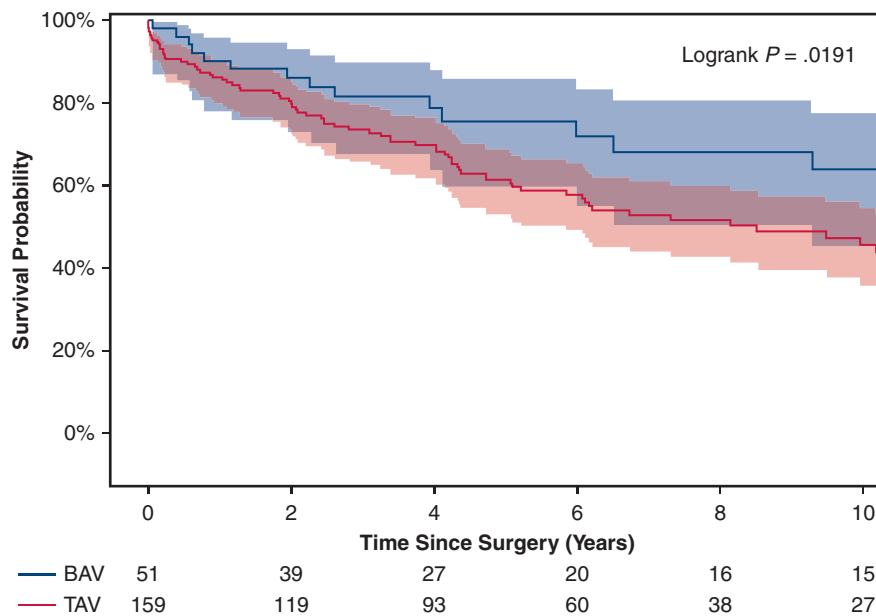


FIGURE 2. Kaplan-Meier analysis of the long-term survival of patients with surgical infective endocarditis (IE) in the bicuspid aortic valve (BAV) group and tricuspid aortic valve (TAV) group. The 10-year survival was 63.8% (95% confidence interval [CI], 45%-78%) for the BAV group and 45.5% (95% CI, 36%, 55%) for the TAV group.

TABLE 4. Cox proportional hazards regression for long-term mortality

Variable	HR	95% CI	P value
Bicuspid aortic valve	0.67	0.33-1.4	.26
Age	1.0	1.0-1.0	.06
Female sex	0.97	0.6-1.6	.89
Intravenous drug abuse	4.5	2.3-8.6	<.0001
Coronary artery disease	1.2	0.68-2.2	.50
Cardiogenic shock	1.2	0.5-2.7	.65
Congestive heart failure	1.7	1.0-2.8	.04
Preoperative sepsis	0.55	0.26-1.2	.12
Liver disease	2.6	1.2-5.7	.02
Preoperative renal failure requiring dialysis	4.1	2.5-6.8	<.0001

Significant P values are in bold type. Age violated the PH assumption as a continuous variable, so it was modeled as a binary variable (≥ 60 vs <60). HR, Hazard ratio; CI, confidence interval.

with BAV IE were relatively healthier and younger, and surgical intervention for IE was more likely to be their first cardiac surgery. Several other studies have reported similar results.¹²⁻¹⁴ These results suggest that there are other reasons for the discrepancy in the incidence of IE in BAV and TAV populations.

Our results demonstrate that patients with BAV were significantly more likely to have calcified aortic valve leaflets or aortic stenosis at the time of operation. This is not surprising, because aortic stenosis is considered the most common complication of BAV.¹⁵ Patients with BAV have previously been shown to have earlier onset of valve

thickening and a higher incidence of aortic stenosis compared with the general population.¹⁶ The underlying pathophysiology is thought to be related to the abnormal shear stress of turbulent blood flow across bicuspid valves, which over time may lead to endocardial tissue damage, fibrosis, and subsequent valve calcification, which can increase the likelihood of formation of infectious vegetation on valves.^{11,16-18} The severe calcification could be one reason why native BAV may be more susceptible to bacterial infection and help explain our findings in the BAV group. In addition, we found that a greater proportion of patients with BAV had an ascending aortic aneurysm or severe aortic insufficiency (AI) at the time of operation compared with patients with TAV. The AI may be related to the annular dilation and the prolapse of the BAV, which therefore also increases the susceptibility of BAVs to bacterial infection.^{19,20} Furthermore, there is growing evidence of genetically-weaker aortic walls in patients with BAVs, with studies noting decreased aortic fibrillin, elastin fragmentation, increased smooth muscle cell apoptosis, aortic extracellular matrix degeneration, and cystic medial necrosis patients with BAV.²⁰⁻²⁵ These genetic abnormalities further increase the risk of developing ascending aortic aneurysms, AI, and subsequent IE. For patients with BAV, the combination of turbulent blood flow through the BAV, greater leaflet calcification, and increased rates of ascending aortic aneurysm and AI may contribute to their increased susceptibility to IE. Owing to this damage to the BAV from valvulopathy and hemodynamics, patients with BAV may be more susceptible to oral bacterial flora such as

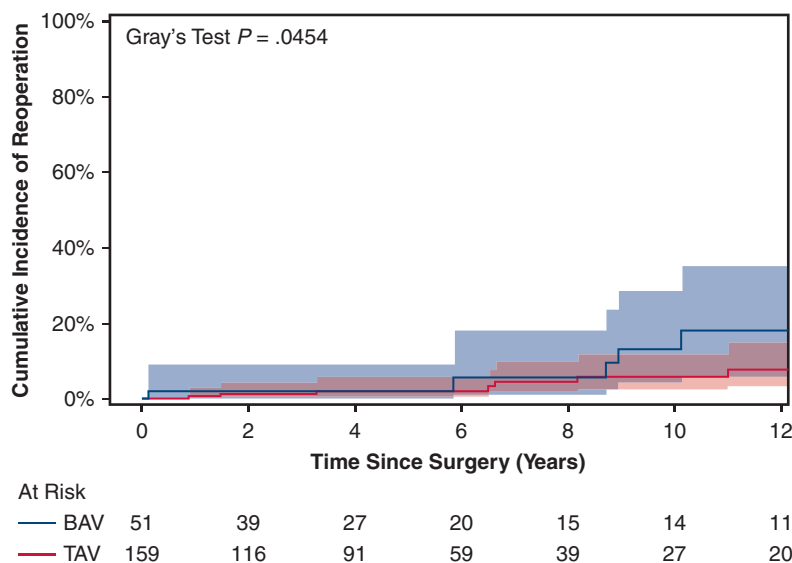


FIGURE 3. Cumulative incidence of reoperation in patients with surgical infective endocarditis (IE) in the bicuspid aortic valve (BAV) group and tricuspid aortic valve (TAV) group. The 15-year incidence of reoperation was 17.9% (95% confidence interval [CI], 6.0%-35%) in the BAV group and 7.70% (95% CI, 3.1%-24%) in the TAV group.

Streptococcus. These factors all increase the risk of developing IE from transient bacteremia due to everyday activities, such as eating and brushing teeth, in patients with BAV.

There were no significant differences in operative mortality or postoperative complications between the patients with BAV IE and those with TAV IE (Table 5). Even though the patients with BAV were at greater risk for developing IE at an earlier age and with fewer comorbidities, Kaplan-Meier analysis demonstrated a significantly greater long-term survival rate in these patients compared with patients with TAV IE (Figure 2). Although other studies have demonstrated similar significant differences in long-term survival, they were often limited by shorter follow-up periods—typically between 1 and 5 years.^{8,12-14} We also observed a significantly different cumulative incidence of reoperation at 15 years, with 17.9% for BAV IE versus 7.7% for TAV IE ($P = .0454$) (Figure 3). Although few other studies have reported reoperation rates for patients with BAV IE, our results are similar to Goland and colleagues' finding of a 7.1% reoperation rate for BAV IE repair after a follow-up of 15 years.²⁶ Interestingly, although recurrent IE was the indicated reason for the majority of TAV IE reoperations, recurrent IE was not the indication for reoperation in any patients in the BAV IE group. This finding identifies the native diseased valve as a risk factor for IE in patients with BAV. After replacement of the diseased BAV, the rate of recurrent endocarditis decreased. However, those patients still underwent reoperation owing to structural deterioration of the bioprosthesis.

Interestingly, the BAV IE group had significantly more cases of *Streptococcus* IE than the TAV IE group, but better 5-year and 10-year survival rates (Figure 2). This trend is supported by the finding that although *Streptococcus* species infections are associated with dental procedures and poor oral hygiene, *Streptococcus* IE has been associated with lower risk of mortality in the intensive care unit and better overall outcomes.²⁷ Furthermore, recent studies have suggested that dental procedure-induced IE in patients with BAV is less common than previously thought. Poor oral hygiene is another important contributor to the development of IE.^{6,28-30} This suggests that greater emphasis should be placed on proper oral hygiene practices and routine dental follow-up for IE risk mitigation instead of antibiotic prophylaxis.³¹

Despite our findings, other methods of IE prevention are still warranted. Kiyota and colleagues⁸ described how a majority of patients with BAV were unaware of their condition until the onset of a major morbidity. Tribouilloy and colleagues¹² noted that in 92% of their patients with BAV IE, the presence of BAV was not discovered until IE was diagnosed. Considering the mounting evidence that those with BAVs are at greater risk of developing IE despite being younger and having fewer comorbidities than those with

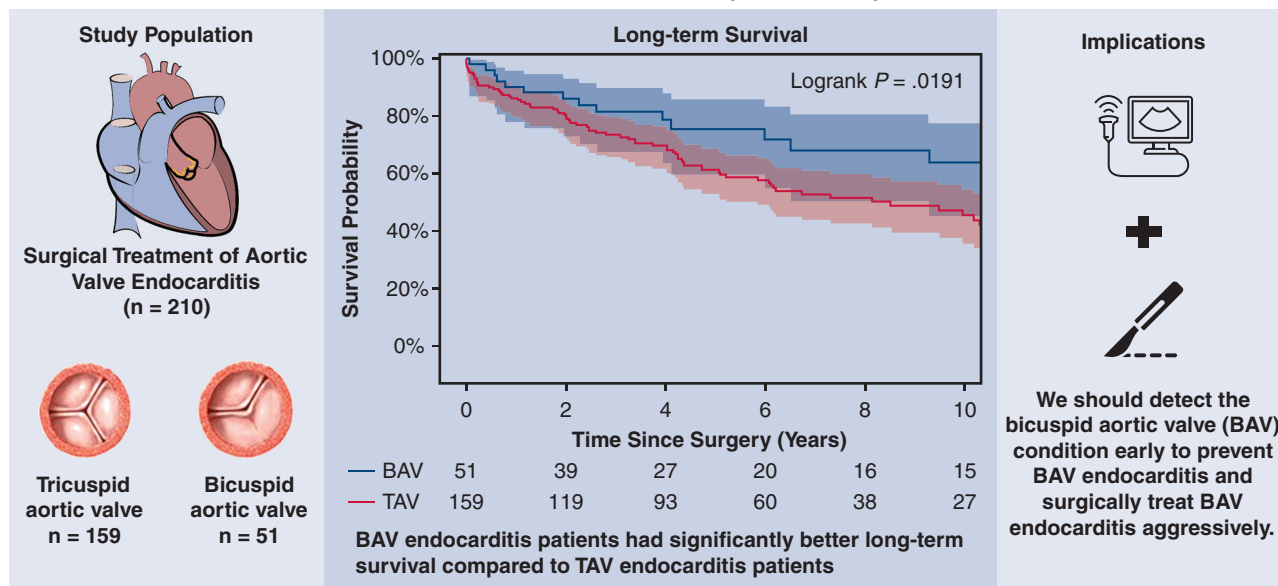
TABLE 5. Postoperative data

Variable	TAV group (N = 159)	BAV group (N = 51)	P value
Red blood cell units infused, median (IQR)	3.0 (1.0-5.0)	2.0 (0.0-4.0)	.160
Reoperation for bleeding, n (%)	7 (4.4)	1 (2.0)	.683
Planned delayed closure, n (%)	1 (0.6)	0 (0)	1.000
Sternal dehiscence, n (%)	0 (0)	0 (0)	1.000
Sepsis, n (%)	4 (2.5)	1 (2.0)	1.000
Stroke, n (%)	1 (0.6)	2 (3.9)	.146
ICU stay, d, median (IQR)	2.3 (0.0-6.1)	1.2 (0.0-4.0)	.178
Duration of ventilation, h, median (IQR)	11 (2.4-24)	5.4 (1.9-22)	.290
Pneumonia, n (%)	8 (5.0)	2 (3.9)	1.000
Cardiac arrest, n (%)	5 (3.1)	0 (0)	.339
Device, n (%)			.526
Pacemaker	9 (5.7)	2 (3.9)	
ICD	1 (0.6)	0 (0)	
New-onset renal failure on dialysis, n (%)	11 (7.1)	2 (4.0)	.738
Multisystem organ failure, n (%)	1 (0.6)	0 (0)	1.000
Gastrointestinal event, n (%)	13 (8.2)	5 (9.8)	.718
Atrial fibrillation, n (%)	44 (28)	8 (16)	.084
Intraoperative mortality, n (%)	3 (1.9)	0 (0)	1.000
In-hospital mortality, n (%)	7 (4.4)	1 (2.0)	.683
30-d mortality, n (%)	8 (5.0)	1 (2.0)	.691
Operative mortality, n (%)*	8 (5.0)	1 (2.0)	.691

TAV, Tricuspid aortic valve; BAV, bicuspid aortic valve; IQR, interquartile range; ICU, intensive care unit; ICD, implantable cardioverter defibrillator. *Operative mortality is based on the Society of Thoracic Surgeons definition and includes all deaths, regardless of cause, occurring during the hospitalization in which the operation was performed, even if after 30 days (including patients transferred to other acute care facilities); and all deaths, regardless of cause, occurring after discharge from the hospital, but before the thirtieth postoperative day.

TAVs, it is important to identify patients with BAV early. As such, earlier identification of BAVs allows for earlier patient education regarding the importance of maintaining proper oral hygiene and routine dental follow-up. At our institution, all family members of BAV patients are advised to undergo echocardiography, and patients with detected murmurs could also undergo echocardiography for earlier identification of BAV. We recommend screening as early

Aortic Valve Endocarditis in Patients with Bicuspid and Tricuspid Aortic Valves



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FIGURE 4. Summary of this study of patients with surgical infective endocarditis (IE) with a bicuspid aortic valve (BAV) and a tricuspid aortic valve (TAV), describing long-term survival in these patients and implications. Long-term survival was significantly better in the BAV group compared with the TAV group (64% vs 46%).

as possible in childhood, because BAV is a congenital defect. The pediatrician and cardiologist can detect BAV with a heart murmur on physical examination, especially in patients with a family history of BAV. In patients with BAV, scrupulous oral hygiene is advised.

Study Limitations

This is a single-center, retrospective study and thus is of limited breadth. The cases of IE included only surgical IE cases, and the BAV IE sample size was relatively small. The significant difference in age between the 2 groups might have had a significant impact on difference in

long-term surgical outcomes, although age was not identified as a significant risk factor for mortality in our multivariable analysis. Our short-term mortality is also limited by the possibility of a type II error. Our follow-up for reoperation was 94%, which could have slightly underestimated our rate of reoperation. The cause-specific hazard model was limited in lacking the inclusion of all potential confounders given data limitations. The 20-year span of our study also could have limited the homogeneity of our results; however, the majority of cases of aortic valve IE were treated by the same aortic surgeons, and surgical techniques remained similar since the initiation of data collection.

CONCLUSIONS

Compared with patients with a TAV, patients with a BAV developed IE at a younger age and with fewer comorbidities, and had better long-term survival after surgical treatment (Figure 4). Early detection of a BAV condition is important to prevent IE and provide aggressive surgical treatment should IE occur (Video 1).

Conflict of Interest Statement

Dr Patel reported financial relationships with Medtronic, WL Gore, and Edwards Lifesciences. Dr Deeb reported a financial relationship with Medtronic. All other authors reported no conflicts of interest.



VIDEO 1. Discussion of the key findings in patients with bicuspid aortic valve endocarditis. Video available at: [https://www.jtcvs.org/article/S2666-2736\(21\)00302-8/fulltext](https://www.jtcvs.org/article/S2666-2736(21)00302-8/fulltext).

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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