Conduction disturbance after isolated surgical aortic valve replacement in degenerative aortic stenosis

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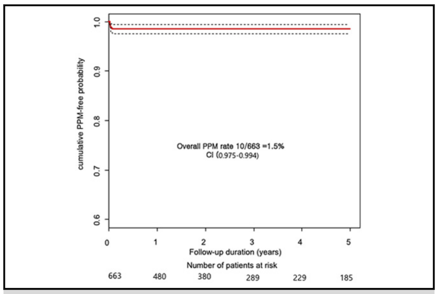
ABSTRACT

Objective: Conduction disturbances are common in patients with aortic stenosis. We investigated the incidence, reversibility, and prognosis of conduction disorders requiring permanent pacemaker implantation in patients with degenerative aortic stenosis after isolated aortic valve replacement.

Methods: This was a retrospective study conducted at a tertiary care center. We evaluated the incidence of conduction disturbances in patients who underwent isolated surgical aortic valve replacement for aortic stenosis between January 2005 and May 2015. Relevant clinical information was obtained from the patients' medical records.

Results: We reviewed results of 663 patients with pathologically proven degenerative aortic stenosis (bicuspid aortic valve, n = 285 [43.0%]) who underwent isolated aortic valve replacement (mechanical valve, n = 310 [46.8%]). Patients' mean age was 67.1 ± 8.1 years, and 362 were male (54.6%). Immediate postoperative intraventricular conduction disorders occurred in 56 patients (8.4%), and atrioventricular block occurred in 68 patients (10.3%). Ten patients with symptomatic second-degree or third-degree atrioventricular block underwent permanent pacemaker implantation within 30 days of aortic valve replacement. During the mean follow-up period of 1288 ± 1122 days, 64 patients (9.7%) developed irreversible conduction disorders (bundle branch block n = 24 and first-degree atrioventricular block n = 42). Of the 10 patients requiring permanent pacemakers, 4 remained depend on the permanent pacemaker during follow-up. Beyond 30 days after aortic valve replacement, 1 patient underwent permanent pacemaker implantation for de novo conduction disturbance 44 months postoperatively.

Conclusions: After isolated aortic valve replacement, permanent pacemaker implantation for conduction disturbance is rare (n = 10/663, 1.5%). Isolated aortic valve replacement for degenerative aortic stenosis has a low risk of conduction disturbances during long-term follow-up. (J Thorac Cardiovasc Surg 2017;154:1556-65)



Kaplan–Meier curve of PPM-free survival.

Central Message

The incidence of conduction disorders requiring PPM implantation after isolated AVR in patients with AS is low.

Perspective

Eleven patients (1.5%) underwent PPM implantation for treating conduction disorders after isolated AVR. During an average 3.5-year follow-up, most conduction disorders were reversible. This suggests that close observation and delayed PPM implantation are clinically reasonable in such patients.

See Editorial Commentary page 1566.

Transient conduction disorders are frequently encountered after open surgery. However, the reported incidence of conduction disorders after cardiac surgery varies. The incidence is known to be higher in patients who have undergone multiple surgeries or multivalve surgery, and in cases of coronary artery bypass combined with valve surgery than in those who have undergone isolated valve surgery. In isolated aortic valve replacement (AVR), the

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Scanning this QR code will take you to supplemental tables and video for this article.

Abbreviations and Acronyms

AF	= atrial fibrillation
AS	= aortic stenosis
AVB	= atrioventricular block
AVR	= aortic valve replacement
BMI	= body mass index
ECG	= electrocardiogram
IVCD	= intraventricular conduction delay
LBBB	= left bundle branch block
PPM	= permanent pacemaker
RBBB	= right bundle branch block
TAVI	= transcatheter aortic valve implantation

incidence of permanent pacemaker (PPM) implantation varies from 1.1% to 7.2%, but these values were obtained from studies that included cases of AVR with multiple causes.[1-3]

Potential risk factors for PPM implantation after isolated AVR include preexisting conduction disorders, bicuspid aortic valve, female sex, prolonged cardiopulmonary bypass time, redo operation, and a history of aortic regurgitation and myocardial infarction.[4,5]

Previous studies have yielded conflicting results regarding the reversibility of post-AVR conduction disorders. Therefore, the decision for early PPM implantation in post-AVR conduction disorders is controversial.[6-8] This study aimed to evaluate the incidence and prognosis of conduction disturbances requiring PPM implantation after isolated AVR in patients with pathologically proven degenerative aortic stenosis (AS).

MATERIALS AND METHODS

Patients

This is a retrospective study that evaluated the development of conduction disturbances in patients who underwent isolated surgical AVR for degenerative AS. Patients were recruited between January 2005 and May 2015 from a single tertiary care center in Seoul, Korea. Their clinical information was obtained from the hospital's electronic medical record system. We included 663 patients with pathologically proven degenerative AS in the final analysis.

Clinical Parameters

Clinical and surgical information were acquired by a thorough chart review. The demographic and clinical characteristics evaluated were age, sex, medical comorbidities, and medication data. All operations were performed through median/upper sternotomy. No stentless valves were included, and no annular enlargement procedures were performed. Surgical data included bypass time, crossclamp time, morphology of native valve (bicuspid, tricuspid), prosthesis type (tissue, mechanical), and prosthesis size. Follow-up days were calculated on the basis of patients' outpatient clinic charts or last hospital discharge date. Major cardiovascular events or deaths were reviewed and described.

Evaluation of Conduction Disturbances

Electrocardiogram (ECG) data were reviewed and analyzed at baseline (preoperative), within 30 days after surgery, and more than 30 days after surgery. At each time point, we reviewed ECGs with respect to (1) rhythm (sinus rhythm, atrial fibrillation [AF], atrial flutter, and junctional or pacemaker rhythm); (2) presence and type of conduction disturbances; and (3) measurable intervals (PR, QRS, and corrected QT intervals). Prespecified conduction disorders included (1) intraventricular conduction disorders including bundle branch block and nonspecific intraventricular conduction delay (IVCD); and (2) atrioventricular conduction disorders such as first-degree atrioventricular block (AVB), second-degree AVB (Mobitz type 1), and symptomatic second- or third-degree AVB. We reviewed all ECG data (including Holter data) from the preoperative period to the most recent follow-up date. In patients with implantable devices, device-related data such as the device type and mode, and pacemaker dependency were obtained. Pacemaker dependency was defined as the presence of an intrinsic escape rhythm of less than 40 beats/min and a percentage of pacing more than 80%. Our study protocol was approved by the Institutional Review Board of Asan Medical Center (Seoul, South Korea; Institutional Review Board No. S2015-2282-0001).

Statistical Analysis

Statistical analysis was performed using R 3.1.2 statistical software (R Development Core Team, 2014). All variables were assessed for normality using the Shapiro–Wilk method. Continuous variables were examined with the *t* test when appropriate and were expressed as mean ± standard deviation. Continuous variable that are not normally distributed were described as median ± interquartile range using Mann–Whitney *U* test. Categoric variables were described using frequencies. Predictors of PPM were identified by univariate analysis ($P < .2$) and were included as independent variables in a stepwise logistic regression analysis. For predictors of conduction disturbances, we performed the complementary log-log model with random-effects for correlated interval-censored event time data that accounted for patient clustering effects.[9]

RESULTS

Patient Characteristics

A total of 663 patients with pathologically proven degenerative AS who underwent isolated AVR and had ECG data were included. The mean age of the study population was 67.1 ± 8.1 years, and 362 patients were male (54.6%). The mean follow-up duration was 1288 ± 1122 days. During this time, 10 patients (1.5%) received an implantable PPM for post-AVR conduction disorders (Figure 1), with 39 patients (5.9%) lost to follow-up. There were no significant differences in baseline and operative variables between patients with PPM and patients without PPM (Table 1). The prevalence of medical conditions, including hypertension, diabetes, cerebrovascular disease, chronic lung disease, coronary artery disease, chronic kidney disease, and arrhythmias diagnosed before AVR, was comparable between patients with PPM and patients without PPM. Overall, 43% of patients had bicuspid aortic valves and 46.8% of patients had implanted mechanical aortic valves. On average, implanted valves were 21.7 ± 2.1 mm in diameter. There were no statistically significant differences between the PPM and non-PPM groups for cardiopulmonary bypass time and aortic crossclamping time ($P = .15$ and $P = .81$, respectively). Baseline rhythm also was compared between the 2 groups

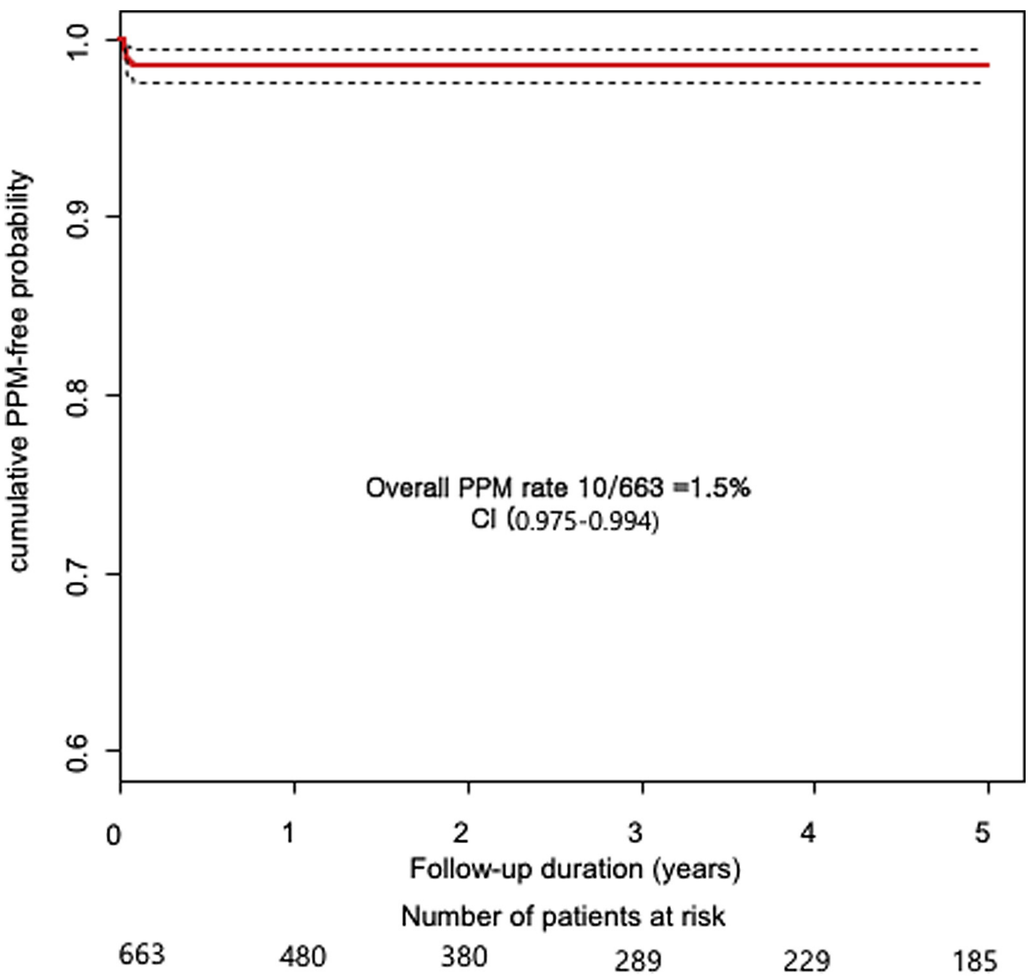


FIGURE 1. Kaplan–Meier curve of PPM-free survival. *PPM*, Permanent pacemaker; *CI*, confidence interval.

(Table 1). Overall, 518 patients (78.1%) were in sinus rhythm and 31 patients (4.7%) had AF (Figure 2). Preexisting conduction disorders were identified in 114 patients (17.2%), including 55 patients with intraventricular conduction disorders and 72 patients with atrioventricular conduction disorders. Six patients (60.0%) in the PPM group had baseline intraventricular conduction disorders. Three patients had preexisting left bundle branch block (LBBB), and 3 patients had right bundle branch block (RBBB) (Figure 3). Compared with the non-PPM patients, the PPM group had higher rates of conduction disorders ($P < .001$) and atrial arrhythmias ($P < .01$) at baseline (Figure 4).

Conduction Disorders After Aortic Valve Replacement

Description of conduction disorder after aortic valve replacement is summarized in Video 1. Table 2 summarizes the prevalence of conduction disorders at different time points during follow-up.

Intraventricular Conduction Disturbance

Immediate postoperative intraventricular conduction disorders occurred in 56 patients (8.4%). New LBBB occurred postoperatively in 34 patients, RBBB occurred in 20 patients, and IVCD occurred in 2 patients. Of the 56 patients with intraventricular conduction disorders, 4 underwent PPM implantation within 30 days after surgery because of bifascicular or trifascicular block. Three of these patients had bundle branch block at baseline, but the other patient was in sinus rhythm at baseline and developed symptomatic bifascicular block after AVR. Of the 4 patients with PPMs, 2 remained PPM dependent with persistent intraventricular conduction disorders, whereas the other 2 recovered. Intraventricular conduction disturbances developed in 11 patients (RBBB, n = 7; LBBB, n = 4) more than 30 days after surgery. One of these patients required an implantable PPM on postoperative day 1331 for new-onset RBBB. This patient had baseline first-degree AVB and left posterior fascicular block developed after AVR, and then suddenly RBBB developed

TABLE 1. Characteristics of the patients

Clinical variables	Total (N = 663)	No PPM (N = 653)	PPM (N = 10)	*P* value
Baseline characteristics				
Age (y)	67.1 ± 8.1	67.1 ± 8.0	67.5 ± 8.6	.61
Sex, male	362 (54.6%)	357 (54.8%)	5 (50.0%)	.68
BMI (kg/m^2)	24.6 ± 3.4	24.6 ± 3.4	24.4 ± 3.0	.69
Hypertension	294 (44.3%)	287 (44.2%)	6 (60.0%)	.51
Diabetes mellitus	111 (16.7%)	110 (16.9%)	1 (9.1%)	.43
Cerebral vascular attack	21 (3.2%)	21 (3.2%)	0	.49
Chronic pulmonary disease	17 (2.6%)	17 (2.6%)	0	.54
Congestive heart failure	11 (1.7%)	10 (1.5%)	1 (10.0%)	.10
Chronic kidney disease	32 (4.8%)	31 (4.8%)	1 (10.0%)	.48
Coronary artery disease	51 (7.7%)	49 (7.5%)	2 (20.0%)	.29
Arrhythmia	36 (5.4%)	35 (5.4%)	1 (10.0%)	.58
Operative characteristics				
Bicuspid aortic valve	285 (43.0%)	280 (42.9%)	5 (50.0%)	.59
Valve type, mechanical	310 (46.8%)	304 (46.6%)	5 (50.0%)	.62
Valve size (mm)	21.7 ± 2.1	21.8 ± 2.1	21.9 ± 1.7	.81
Cardiopulmonary bypass time (min)	110.5 ± 32.9	110.5 ± 32.9	113.5 ± 37.1	.16
Aortic crossclamping time (min)	70.3 ± 21.8	70.4 ± 21.9	70.3 ± 21.0	.83
Baseline ECG				
Sinus rhythm	518 (78.1%)	515 (78.8%)	3 (30.0%)	<.01
Atrial arrhythmia*	31 (4.7%)	29 (4.4%)	2 (20.0%)	<.01
Conduction disorders†	114 (17.2%)	109 (16.7%)	5 (45.5%)	<.001
Intraventricular	55 (8.3%)	50 (7.7%)	6 (60.0%)	<.001
LBBB	38 (5.7%)	36 (5.5%)	3 (30.0%)	<.001
RBBB	16 (2.4%)	13 (2.0%)	3 (30.0%)	<.001
Other intraventricular conduction disorders	1 (0.2%)	1 (0.2%)	0	.84
Atrioventricular	72 (10.9%)	70 (10.7%)	0	<.001
First-degree AVB	70 (10.6%)	70 (10.6%)	0	<.001
Second-degree AVB (Mobitz type 1)	2 (0.3%)	2 (0.3%)	0	.71

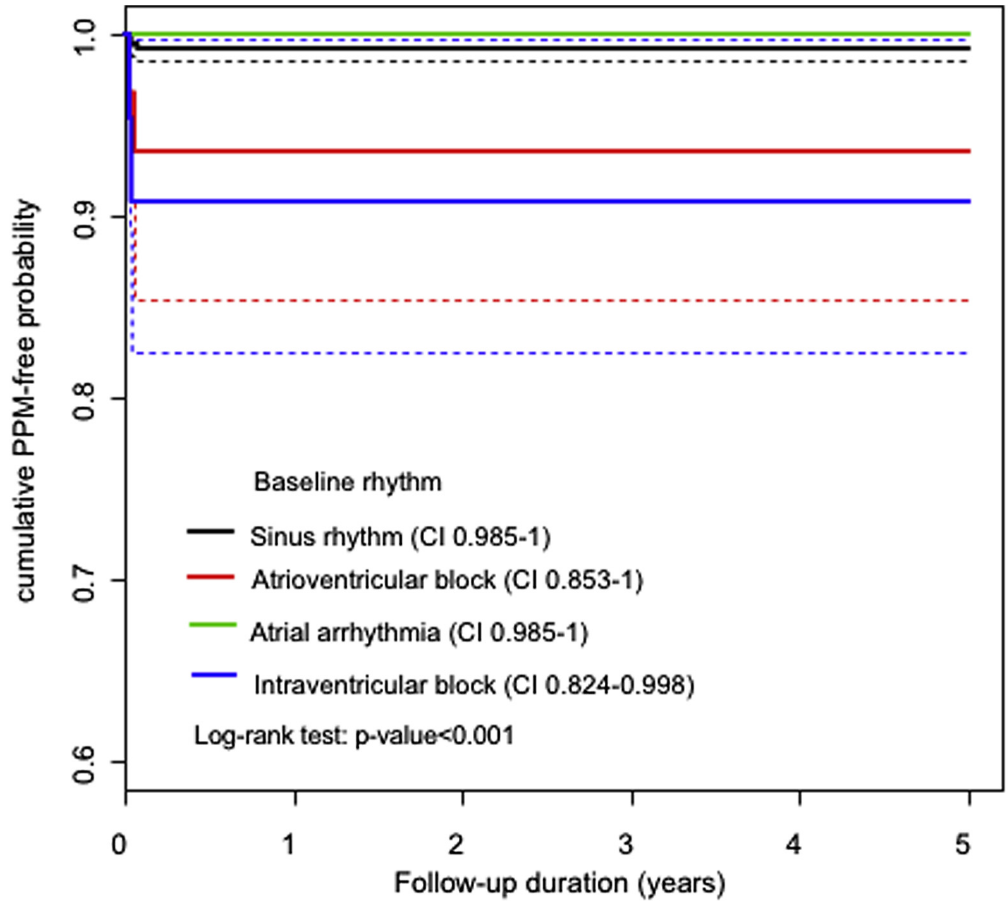
PPM, Permanent pacemaker; *BMI*, body mass index; *ECG*, electrocardiogram; *LBBB*, left bundle branch block; *RBBB*, right bundle branch block; *AVB*, atrioventricular block. *Overlapping cases exist between atrial arrhythmia and conduction disorders. †Overlapping cases exist between atrioventricular and intraventricular block.

that presented with syncopal episodes requiring PPM implantation. This patient was not included in the statistical analysis because PPM implantation after 3 years was thought to be irrelevant to surgery.

Predictors of Intraventricular Conduction Disturbance

Mechanical valve implantation was the only predictor of post-AVR intraventricular conduction disturbance leading to PPM implantation (odds ratio, 1.8 within 30 days after surgery [$P = .02$] and 2.2 >30 days after surgery [$P = .004$]). Because of possible dynamic change of rhythm disturbances, we analyzed the data with a multistate analysis for predicting IVCD (Table E1). Univariate analysis showed advanced age, low body mass index (BMI), female sex, presentation with congestive heart failure, chronic kidney disease, coronary artery disease, mechanical valve implantation, larger prosthetic valve size, and no history of hypertension were predictors for new-onset intraventricular conduction disorders after surgery. The multivariate analysis showed advanced age, low BMI, presentation with congestive heart failure, coronary artery disease, mechanical valve implantation, larger prosthetic valve size, and no history of hypertension were predictors for intraventricular conduction disturbance.

Atrioventricular conduction disturbance. Immediate postoperative AVB occurred in 68 patients (10.3%). The majority of these cases (58 patients) had first-degree AVB. The remaining patients had third-degree AVB. Of 10 patients with third-degree AVB, 6 underwent PPM within 30 days after surgery. Of the 4 patients without PPM, 2 recovered from third-degree AVB to first-degree AVB: 1 of new-onset LBBB with third-degree AVB to LBBB without AVB and 1 of third-degree AVB to AF without AVB within 7 days. At more than 30 days after AVR, first-degree AVB developed in 37 patients, but no additional cases required PPM implantation for symptomatic second- or third-degree AVB.



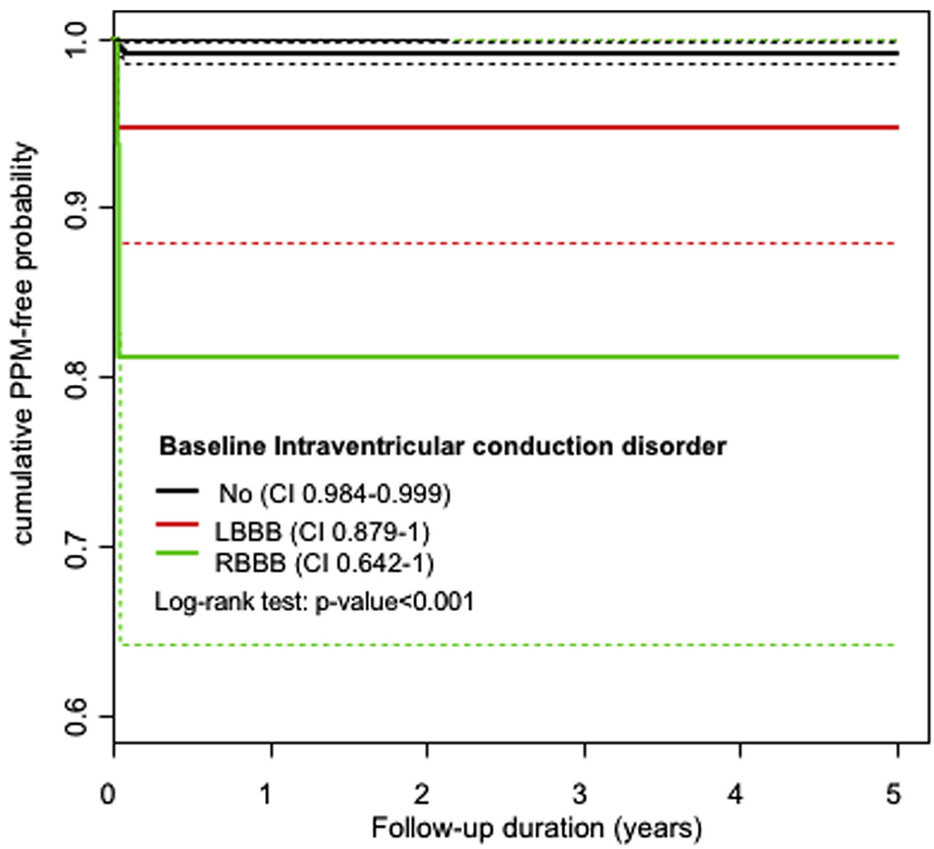
Number at risk	0	1	2	3	4	5
Sinus	518	384	298	229	181	146
Atrial arrhythmia	31	20	19	15	14	11
Atrioventricular block	71	49	38	26	19	16
Interventricular block	43	27	25	19	15	12

FIGURE 2. Kaplan–Meier curve of PPM-free survival according to baseline rhythm. *PPM*, Permanent pacemaker; *CI*, confidence interval.

Predictors of Atrioventricular Conduction Disturbance

There were no predicting factors identified for post-AVR atrioventricular conduction disorders.

Incidence of irreversible conduction disturbance. There were 64 cases of irreversible conduction disturbances (Table 3). We defined irreversible conduction disturbances as conduction disorders that occurred immediately after AVR and that persisted throughout long-term follow-up. Irreversible intraventricular conduction disturbance occurred in 24 patients (LBBB, n = 8; RBBB, n = 16), 6 of whom also developed simultaneous first-degree AVB. Irreversible AVB occurred in 46 patients. However, only 4 of these patients had persistent symptomatic second- or third-degree AVB, and the majority (n = 42/46) had first-degree AVB.



Number at risk	0	1	2	3	4	5
No	608	446	351	268	212	171
LBBB	38	25	22	16	14	11
RBBB	16	8	6	5	3	3

FIGURE 3. Kaplan–Meier curve of PPM-free survival according to baseline intraventricular conduction disorder. *PPM*, Permanent pacemaker; *CI*, confidence interval; *LBBB*, left bundle branch block; *RBBB*, right bundle branch block.

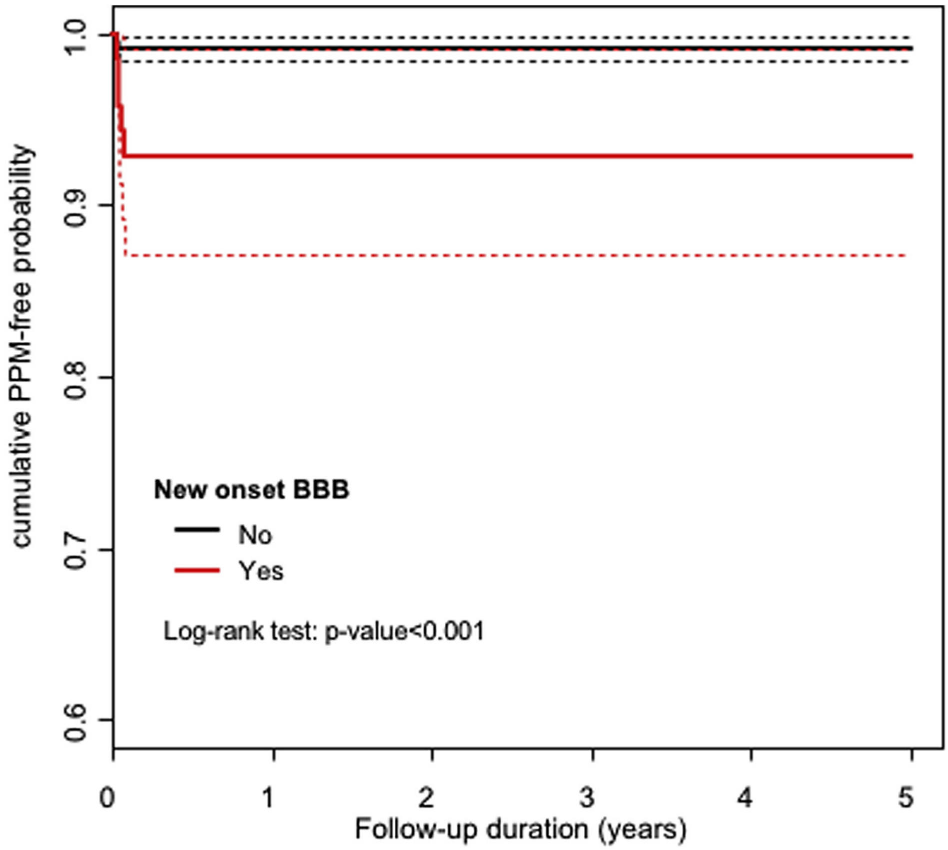
Incidence of permanent pacemaker implantation. Overall, 10 patients (1.5%) underwent a PPM implantation during follow-up (Table E2).

Mortality and Major Cardio-Cerebrovascular Events

During the mean follow-up period of 1288 ± 1122 days, 39 patients died (5.9%). Eight patients died within 30 days after surgery (1.2%). One death was related to ventricular arrhythmia, and 7 deaths were related to infection. Of the 31 deaths more than 30 days after surgery, 1 patient with a PPM died of pneumonia-related sepsis 4 months after PPM implantation. The remaining 30 deaths were in patients without PPM and were due to infection (n = 6), malignancy (n = 12), spontaneous splenic rupture (n = 1), and unknown causes (n = 6). The other 5 deaths (0.8%) were classified as major cardio-cerebrovascular events during follow-up and were due to cardiac arrest related to ventricular arrhythmia (n = 1), progressive congestive heart failure (n = 1), and cerebrovascular attack (n = 3).

DISCUSSION

In the present study, 10 patients (1.5%) required PPM implantation to manage conduction disorders that occurred after isolated AVR over a 3.5-year follow-up period (Figure 1). This rate of PPM implantation after isolated AVR is



Number at risk	0	1	2	3	4	5
No	592	434	345	265	209	170
New onset BBB	71	46	35	24	20	15

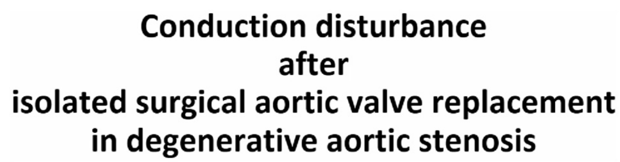
FIGURE 4. Kaplan–Meier curve of PPM-free survival curve according to newly developed intraventricular conduction disorder after AVR. *PPM*, Permanent pacemaker; *BBB*, bundle branch block.

comparable to the results of previous reports. We found that a significant proportion of conduction disorders were reversible during follow-up.

Risk Factors for Permanent Pacemaker Implantation and Conduction Disorders After Aortic Valve Replacement

One of the strongest risk factors for PPM implantation in our study was preexisting intraventricular conduction disorders. Prolonged PR interval (>200 ms), RBBB, and LBBB on preoperative ECG have been reported to be associated with an increased risk of PPM after cardiac valve surgery (Figures 2 and 3).[10] In the present study, first-degree AVB was not associated with PPM implantation, although we identified a significant number of patients with first-degree AVB during follow-up. However, discussion of their prognosis is beyond the scope of the present study.

We also identified baseline rhythm as a risk factor for PPM implantation after AVR. Patients with baseline atrial arrhythmias had higher rates of PPM implantation compared with those with baseline sinus rhythm. Previous studies have showed that preoperative AF increases the rate of mortality and morbidity after AVR.[11,12] However, the status of atrial arrhythmias as a risk factor for PPM implantation after AVR has not been established. Patients with atrial arrhythmias often have other underlying conduction disorders and vice versa, including sinus node dysfunction and intranodal and infranodal conduction disorders.[13,14] These conditions may be associated with the autonomic dysfunction observed in these arrhythmias.[15-17] Although it is difficult to



VIDEO 1. Video of the author's presentation of this study regarding conduction disorders leading to PPM after isolated AVR in patients with degenerative AS. Video available at: http://www.jtcvsonline.org/article/S0022-5223(17)31182-0/fulltext.

generalize our results, we showed that atrial arrhythmias at baseline carry a substantial risk of PPM implantation. We did not identify any other baseline patient characteristics or surgical parameters that increased the PPM implantation risk.

The possible risk factors we identified for de novo intraventricular conduction disorder were advanced age, low BMI, presentation with congestive heart failure, coronary artery disease, mechanical valve implantation, larger prosthetic valve size, and no history of hypertension. Advanced age with congestive heart failure and coronary artery disease are known predictors of IVCD, which reflects underlying higher comorbidity. Larger prosthetic valve size and low BMI are related to IVCD development after AVR in regard to possible mechanical injury to the conduction system. It is interesting that patients without hypertension carried a higher risk for IVCD development, because patients with a history of hypertension had more medical attention on a regular basis with medical treatment, which acted as a cardioprotective factor. In a previous report by Ferrari and colleagues,[18] tissue valve implantation had a higher incidence of PPM implantation after AVR compared with mechanical valve implantation, and this was due to the differences in ages between the 2 groups. In our study, there was no correlation between PPM implantation and valve type. However, in our study, IVCD was related to mechanical valve implantation. This is because mechanical valve implantation rate was higher in our study population (46.8%) than in the report by Ferrari and colleagues,[18] and this may explain the differences in results. Further studies are needed to clarify this issue.

We did not identify any predictive factors for the development of atrioventricular conduction disorders. Development of symptomatic second- or third-degree AVB is considered to have more clinical relevance than first-degree AVB in practice. Although the clinical significance of first-degree AVB has not been clarified, there is evidence that it can lead to a poor prognosis.[19] Further long-term observational studies with a larger number of patients with AVR are warranted to elucidate the prognosis for and predicting first-grade AVB in this population.

Anatomic Considerations of Conduction Disorders After Aortic Valve Replacement

The anatomic relationship between the conduction system and the aortic valve is the major explanation for the occurrence of conduction disorders due to direct surgical trauma after AVR.[20,21] Underlying histologic abnormalities in the conduction system of patients with aortic valve disease have been suggested, including pressure-induced mechanical, ischemic, and age-related degenerative changes related to aging. Microscopic and macroscopic structural abnormalities also might be associated with aortic valve diseases.[22] Furthermore, the recent introduction of transcatheter aortic valve implantation (TAVI) has provided additional clues regarding the association between conduction disorders and AVR. In normal anatomy, immediately below the ventriculoarterial junction, the His bundle penetrates the interventricular septum, between the right and noncoronary aortic leaflets, giving rise to the left bundle branch. This is the location where the prosthetic valve is implanted. Any direct trauma or mechanical stress to this region during

TABLE 2. Conduction disorders according to time

Conduction disorder	Baseline (N = 663)	POD <30 d (N = 655)	POD >30 d (N = 624)
Sinus rhythm	518 (78.1%)	392 (59.8%)	443 (71.0%)
Conduction disorders*	114 (17.2%)	179 (27.3%)	172 (27.6%)
Intraventricular	55 (8.3%)	104 (15.9%)	80 (12.8%)
LBBB	38 (5.7%)	69 (10.5%)	46 (7.4%)
RBBB	16 (2.4%)	32 (4.9%)	32 (5.1%)
Other intraventricular conduction disorder	1 (0.2%)	3 (0.5%)	2 (0.3%)
Atrioventricular	72 (10.9%)	115 (17.6%)	119 (19.1%)
First-degree AVB	70 (10.6%)	101 (15.4%)	112 (17.9%)
Second-degree AVB (Mobitz type 1)	2 (0.3%)	0	0
Symptomatic second- or third-degree AVB	0	14 (2.1%)	4 (0.6%)
Pacemaker rhythm	0	0	3 (0.5%)

POD, Postoperative day; *LBBB*, left bundle branch block; *RBBB*, right bundle branch block; *AVB*, atrioventricular block. *Overlapping cases exist between atrioventricular and intraventricular block.

TABLE 3. Irreversible conduction disorders in 64 patients

Intraventricular*	24
LBBB	8
RBBB	16
Other intraventricular conduction disorder	0
Atrioventricular*	46
First-degree AVB	42
Second-degree AVB (Mobitz type 1)	0
Symptomatic second- or third-degree AVB (including Mobitz type 2 and third-degree AVB)	4

LBBB, Left bundle branch block; *RBBB*, right bundle branch block; *AVB*, atrioventricular block. *Six patients had comorbid intraventricular block and AVB.

the surgical procedure may damage the specialized conduction system and cause infra-Hisian disease. In addition, acute and subacute edema and ischemia related to aortic valve surgery may give transient or permanent damage to the bundle of His at the region of the membranous septum and right trigone beneath the noncoronary/right coronary leaflets. The aforementioned factors are related to anatomic proximity and associated with the development of new conduction abnormalities.[23]

Recent advances in TAVI,[24] new techniques[25,26] and sutureless valve insertions[27,28] still carry a potential risk for conduction disorders leading to PPM implantation, given the close anatomic relationship between the aortic valve and the cardiac conduction system.[29] TAVI and sutureless valve implantation was associated with a higher risk of PPM implantation and higher incidence of conduction disorders compared with surgical AVR with sutured valve implantation.[24,28] TAVI recently has been considered in patients with low to intermediate operative risk.[30] However, given the higher risk for conduction disorders with TAVI compared with surgical AVR, the decision for TAVI in low- to intermediate-risk patients should be made with caution.

Timing of Decision for Permanent Pacemaker Implantation

Some investigators recommend early PPM implantation in patients with conduction disorders after AVR because of the poor prognosis and low reversibility of symptomatic second- or third-degree AVB, and of intraventricular conduction disorders involving multiple fascicles.[7,28,31] However, other studies reported cases of pacemaker nondependency after PPM implantation associated with the recovery of atrioventricular or intraventricular conduction disorders during follow-up.[32,33] A significant proportion of conduction disorders were reversible in our study. Furthermore, not all cases of conduction disorders in which PPM implantation was indicated persisted throughout long-term follow-up. This suggests that a significant proportion of patients recover from de novo conduction disturbances who develop post-AVR. On the basis of our experience, we suggest that in newly developed conduction disturbance after AVR it may be appropriate to wait for 2 weeks for possible surgery-related acute trauma of the conduction system to recover. However, additional studies are required to define the optimal timing of PPM.

Study Limitations

This is a retrospective study conducted in a single tertiary care center and based on review of documented ECG and Holter data. The majority of patients had 5 or more documented ECGs during the immediate postoperative period and at least 3 ECGs annually during follow-up. Given that the mean follow-up duration was 3.5 years, 10 or more ECGs per patient were available to be reviewed per patient. However, evaluating conduction disorders and underlying arrhythmias by these data might be insufficient and might have led to an underestimation of the true results, given the limited number and temporal nature of the data. Furthermore, the incidence of sinus node dysfunction and paroxysmal AVB with variable presentation could not be accurately evaluated because of the unpredictability of these rhythms and difficulty in obtaining an ECG during a symptomatic episodes.[34] In addition, 39 patients (5.9%) had no ECG data after 30 days, because they were referred to the local hospital for follow-up. Within 30 days, even they had no de novo conduction disturbance; however, their data might change during the follow-up. A final limitation of our study was that it was not possible to determine which factors were predictive of the incidence of conduction disorders that led to PPM implantation after AVR because of the low occurrence rates of the PPM implantation. However, there were predictors for intraventricular conduction disorder after AVR with multistate analysis.

CONCLUSIONS

The incidence of conduction disorders requiring PPM implantation after isolated AVR in AS patients is very low. Moreover, a significant proportion of patients only developed transient conduction disorders, confirming that persistent conduction disorders with PPM dependency after AVR are rare.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: aortic valve stenosis, heart block, heart valve prosthesis implantation, pacemaker artificial

TABLE E1. Predictors of intraventricular conduction disorder

Conduction disorder	Univariate analysis: Hazard ratio	Univariate analysis: 95% CI	Univariate analysis: *P* value	Multivariate analysis: Hazard ratio	Multivariate analysis: 95% CI	Multivariate analysis: *P* value
Intraventricular conduction disorder						
Age	1.025	1.018-1.031	<.001	1.017	1.008-1.026	<.001
BMI (kg/m^2)	0.960	0.950-0.974	<.001	0.966	0.952-0.981	<.001
Sex (female)	1.263	1.141-1.398	<.001			
Hypertension	0.882	0.797-0.976	.015	0.885	0.798-0.980	.019
CHF	3.698	2.888-4.736	<.001	3.678	2.880-4.701	<.001
CKD	1.476	1.211-1.799	<.001			
CAD	1.378	1.173-1.619	<.001	1.275	1.084-1.500	.004
Mechanical valve	1.492	1.346-1.654	<.001	1.179	1.017-1.366	.029
Valve size	1.067	1.044-1.092	<.001	1.074	1.049-1.099	<.001
LBBB						
Age	1.036	1.027-1.044	<.001	1.028	1.016-1.040	<.001
Sex (female)	1.587	1.388-1.815	<.001	1.405	1.207-1.634	<.001
Hypertension	0.693	0.607-0.792	<.001	0.639	0.557-0.733	<.001
CHF	1.859	1.305-2.647	.001			
CKD	2.355	1.908-2.907	<.001	2.794	2.249-3.473	<.001
Mechanical valve	1.771	1.546-2.029	<.001	1.277	1.055-1.545	.012
Valve size	1.102	1.072-1.134	<.001	1.078	1.042-1.114	<.001
RBBB						
BMI (kg/m^2)	0.911	0.889-0.935	<.001	0.912	0.889-0.935	<.001
COPD	1.678	1.090-2.584	.019	1.859	1.185-2.914	.007
CHF	4.583	3.349-6.271	<.001	8.201	5.792-11.615	<.001
CKD	0.323	0.179-0.583	<.001	0.179	0.096-0.334	<.001
CAD	1.549	1.218-1.971	<.001	1.639	1.285-2.090	<.001

CI, Confidence interval; *BMI*, body mass index; *CHF*, congestive heart failure; *CKD*, chronic kidney disease; *CAD*, coronary artery disease; *LBBB*, left bundle branch block; *RBBB*, right bundle branch block; *COPD*, chronic obstructive pulmonary disease.

TABLE E2. Characteristics of patients with permanent pacemaker implantations according to date of implantation

Patient	Baseline rhythm	POD to PPM (d)	Native valve type	Valve type, valve size (mm)	Rhythm before PPM	PPM dependency*	Rhythm after PPM
PPM <30 d (n = 10)							
M, 56 y	RBBB	8	Bicuspid	Mechanical, 25	Trifascicular block	N	First AVB
F, 65 y	Sinus	9	Bicuspid	Mechanical, 21	CAVB, AF with SVR	Y	AF, pacing
M, 68 y	AF with SVR, LBBB	10	Bicuspid	Mechanical, 23	CAVB	N	AF, LBBB
M, 73 y	LBBB	11	Tricuspid	Mechanical, 23	Trifascicular block	Y	Pacing
M, 80 y	LBBB	13	Tricuspid	Tissue, 19	Bifascicular block	N	LBBB
F, 77 y	Sinus	13	Tricuspid	Tissue, 19	CAVB	Y	Pacing
F, 81 y	RBBB	13	Bicuspid	Tissue, 19	CAVB	N	First AVB, RBBB
F, 78 y	RBBB	14	Tricuspid	Tissue, 21	CAVB	N	RBBB
M, 58 y	AF with SVR	19	Bicuspid	Mechanical, 19	AF with SVR, Bifascicular block	N	AF
F, 64 y	Sinus	28	Tricuspid	Mechanical, 23	Bifascicular block	Y	Pacing

POD, Postoperative day; *PPM*, permanent pacemaker; *M*, male; *RBBB*, right bundle branch block; *N*, no; *AVB*, atrioventricular block; *F*, female; *CAVB*, complete atrioventricular block; *AF*, atrial fibrillation; *SVR*, slow ventricular response; *Y*, yes; *LBBB*, left bundle branch block. *PPM dependency was defined as pacing rate greater than 80%.