A proposed algorithm for management of patients with left bundle branch block post-TAVR: 1-year follow-up

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BACKGROUND Transcatheter aortic valve replacement (TAVR) has revolutionized the management of aortic stenosis and has become the standard of care across a broad spectrum of patients with aortic stenosis. However, it is still associated with high incidence of conduction abnormalities, particularly new left bundle branch block (LBBB). Management of these patients remains a challenge.

OBJECTIVE The study sought to assess the clinical outcomes of patients with post-TAVR conduction disorders managed according to a prespecified institutionally developed algorithm.

METHODS A retrospective analysis including all patients undergoing TAVR in our institute between October 2018 and December 2022 was performed. Patients with new LBBB were managed according to the algorithm comprising QRS width and electrophysiology study. In-hospital and 1-year clinical outcomes were assessed.

RESULTS A total of 230 patients were included in the present analysis. Seventy (30.4%) patients developed new LBBB after TAVR. Overall, 44 (19.1%) patients required permanent pacemaker (PPM) implantation: 20 (8.7%) patients with Mobitz II, complete atrioventricular block, or alternating bundle branch block; 21 (9.1%) patients with persistent new LBBB; and 3 (1.3%) patients per physician discretion. During 1-year follow-up, only 3 patients required late PPM implantation, of whom there was only 1 patient with new LBBB. There was no difference in mortality or heart failure hospitalizations between the per PPM and no PPM groups. Multivariable analysis identified atrial fibrillation, chronic kidney disease, and pre-TAVR right bundle branch block as independent predictors for PPM implantation following TAVR.

CONCLUSION Our findings suggest that the presented algorithm may serve as a safe and efficacious strategy for management of patient with post-TAVR LBBB, although the PPM implantation rate may be further reduced.

KEYWORDS TAVR; LBBB; Atrioventricular block; HV interval; Pacemaker

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Introduction

Aortic stenosis is the most common valvular pathology among elderly patients in industrialized nations.[1] In the last decades, transcatheter aortic valve replacement (TAVR) revolutionized the treatment of symptomatic high-risk patients with severe aortic stenosis and subsequently in intermediate- and low-risk populations as well.[2]

It is well known that TAVR is associated with high incidence of new-onset conduction disturbances and pacemaker implantations.[1] The pathophysiological mechanism of these conduction disorders is primarily mechanical and is affected by the patient's anatomy, underlying conduction disorders, type of valve implanted, and depth of implantation.[3–6]

The 2 most common conduction disturbances after TAVR are new-onset left bundle branch block (LBBB) and high-degree atrioventricular block (HDAVB).[7] While patients with HDAVB require permanent pacemaker implantation (PPI), the management of LBBB is less clear.[8]

According to the European Society of Cardiology 2021 guidelines, patients with persistent HDAVB of more than 48 hours, or alternating bundle branch block should undergo PPI. Nevertheless, the recommendations regarding other conduction abnormalities are more variable. In case of persistent new-onset LBBB, ambulatory continuous electrocardiography (ECG) monitoring or electrophysiology study (EPS) should be performed (class IIa).[8] According to the American Heart Association guidelines, patients with new and persistent LBBB following TAVR should be carefully monitored

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KEY FINDINGS

- Clinically based algorithm comprising electrocardiography and electrophysiology study findings enhance decision making for permanent pacemaker implantation (PPI) in patients with new-onset persistent left bundle branch block following transcatheter aortic valve replacement (TAVR).
- Patients who were managed according to the algorithm and were discharged without a permanent pacemaker exhibited a very low rate of late PPI, with comparable rates of mortality and heart failure hospitalizations to those who received a pacemaker, highlighting the safety of the algorithm.
- Multivariable analysis identified atrial fibrillation, chronic kidney disease, and pre-TAVR right bundle branch block as independent predictors for PPI following TAVR.

(class IIa), while PPM should be considered as well, regardless of QRS duration (class IIb).[9] Furthermore, a recent comprehensive survey conducted by the European Heart Rhythm Association concluded that there is a clear need for dedicated management protocols in TAVR patients.

Given the risk of late atrioventricular block (AVB) in patients with post-TAVR LBBB and the absence of clear criteria for pacemaker implantations that lead to inconsistent management of these patients, we opted to develop a detailed protocol comprising ECG and EPS findings to enhance decision making and to improve safety of patients with new-onset persistent LBBB post-TAVR.

The aim of the present study was to evaluate the clinical outcomes of patients with conduction disorders after TAVR who were managed according to our prespecified electrophysiology-guided algorithm (Figure 1) including mortality, heart failure (HF) hospitalizations, and late pacemaker implantations. Predictors for PPI post-TAVR were also assessed.

Methods

Study population

This is a single-center retrospective study including all consecutive patients who underwent TAVR between October 1, 2018, and December 31, 2022, in a tertiary medical center. The study adhered to the Helsinki declaration guidelines and was approved by the institutional review board of Soroka University Medical Center.

Exclusion criteria comprised individuals with a history of prior cardiac implantable electronic device, subjects who died during hospitalization, and those with missing data.

In adherence to our protocol, 12-lead ECG was methodically conducted in all patients before TAVR, immediately postprocedure, and daily thereafter until discharge from cardiology department. Patients with a new-onset LBBB after TAVR were routinely monitored in the intensive cardiac care unit with a temporary pacemaker for at least 24 hours following the procedure. Patients with new-onset persistent LBBB exceeding 48 hours after TAVR were managed

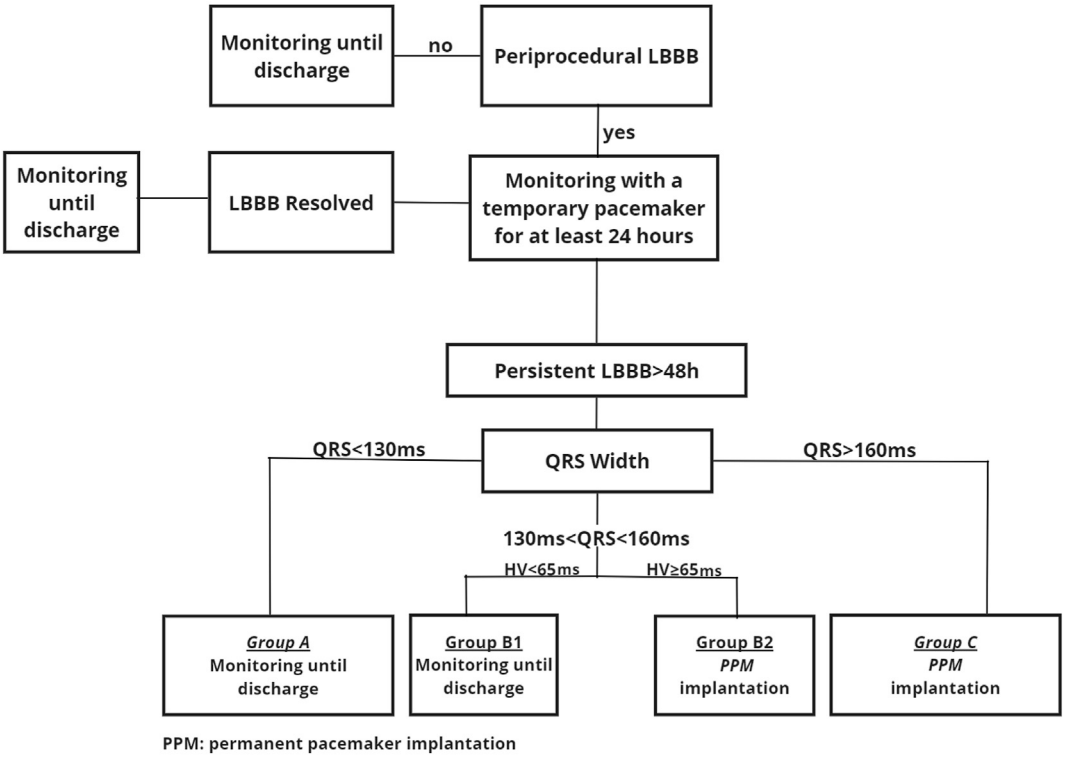
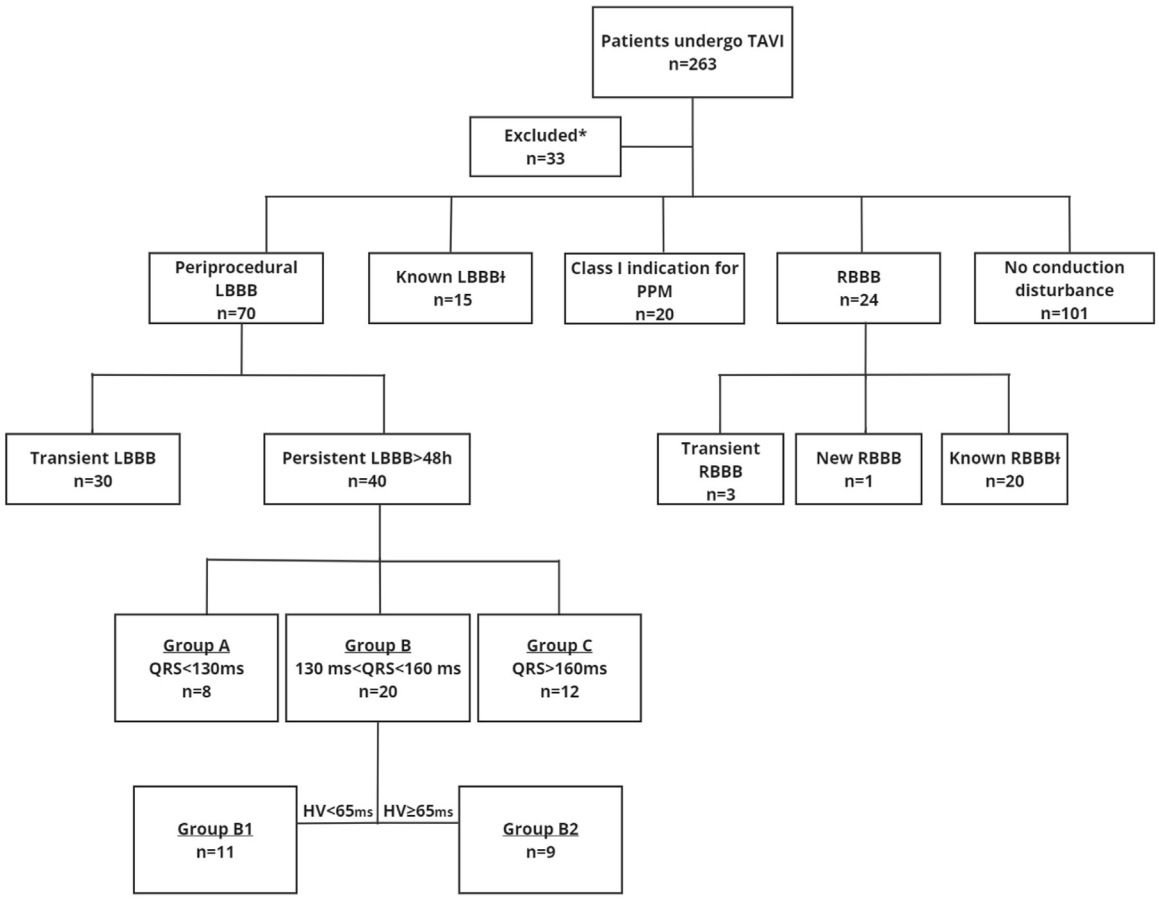


Figure 1 Electrocardiography and electrophysiology study–based algorithm for decision making regarding permanent pacemaker implantation after transcatheter aortic valve replacement. LBBB = left bundle branch block; PPM = permanent pacemaker.



*Excluded: 25 patients (9.5%) with previous CIED, 4 patients (1.1%) who died during or immediately post procedure, 4 patients (1.5%) with missing data.
ł3 patients received a PPM due to QRS and/or PR prolongation and at the physician's discretion. see results.

Figure 2 Flow chart of the study cohort. LBBB = left bundle branch block; PPM = permanent pacemaker; RBBB = right bundle branch block; TAVR = transcatheter aortic valve replacement.

according to a specific ECG- and EPS-guided algorithm as outlined in Figure 1.

Patients were stratified into 2 groups: those who required PPI during hospitalization (PPM) and those who did not require PPI during hospitalization (no PPM). Patients with Mobitz type II, complete atrioventricular block (CAVB), or alternating bundle branch block, as well as those exhibiting new-onset LBBB with a QRS width surpassing 160 ms (group C), underwent pacemaker implantation. Patients with LBBB of 130 to 160 ms underwent EPS for assessment of HV interval and infra-Hisian block. Those with an HV interval $\geq$65 ms or infra-Hisian block underwent PPI (group B2), whereas patients with HV interval $<$65 ms and no evidence of infra-Hisian block (group B1) were managed conservatively. Patients with LBBB of $>$130 ms (group A) were monitored until discharge and did not require an EPS (Figures 1 and 2).

The following parameters were obtained during the EPS: baseline HV interval, HV interval during atrial pacing, and antegrade Wenckebach cycle length. Infranodal block was assessed during straight atrial pacing, and in selected patients with HV interval $<$65 ms and long Wenckebach cycle length, it was also assessed after isoproterenol administration.

The study outcomes included all-cause mortality, HF hospitalizations, and the need for late pacemaker implantation during 1-year follow-up. Additionally, the study aimed to identify predictors for pacemaker implantation post-TAVR.

Data collection and definitions

Comprehensive data, including patient characteristics, past medical history, laboratory tests, TAVR procedural information, ECG, pacemaker implantation reports, echocardiographic measurements, computerized tomography results, and 1-year clinical outcomes, were systematically extracted. These details were collected from our institutional electronic medical records and further supplemented by the national health information exchange network. All patient records were anonymized and de-identified prior to analysis.

ECG measurements included heart rhythm, rate, PR interval, QRS duration, and morphology. Left anterior and posterior fascicular hemiblocks, LBBB, and right bundle branch

Table 1 Pre-TAVR baseline characteristics and echocardiographic and computed tomography parameters

Variable	No PPM (n = 186)	PPM (n = 44)	*P* value*
Age, y	80 ± 6	81 ± 6	.3
Female	111 (60%)	17 (39%)	.012
BMI, kg/m^2	27 ± 5	29 ± 6	.026
Diabetes	97 (52%)	25 (57%)	.6
Hypertension	164 (88%)	42 (95%)	.3
CAD	149 (80%)	39 (89%)	.2
Dyslipidemia	164 (88%)	39 (89%)	>.9
COPD	22 (12%)	5 (11%)	>.9
AF	50 (27%)	20 (45%)	.016
CKD	49 (26%)	20 (45%)	.013
Echocardiography			
LVEF, %	55 ± 13	51 ± 11	.002
AVA index, cm^2/m^2	0.41 ± 0.12	0.43 ± 0.11	.4
Aortic valve area, cm^2	0.72 ± 0.22	0.76 ± 0.17	.045
IVS, cm	1.17 ± 0.20	1.21 ± 0.22	.15
Mean aortic gradient, mm Hg	46 ± 17	41 ± 12	.10
LVOT diameter, cm	2.00 ± 0.18	2.07 ± 0.19	.039
Computed tomography			
Calcium score, HU	2376 ± 1237	2746 ± 1146	.03
LVOT area, cm^2	3.9 ± 0.86	4.29 ± 0.86	.003

Values are mean ± SD or n (%).

AF = atrial fibrillation; AVA = aortic valve area; BMI = body mass index; CAD = coronary artery disease; CKD = chronic kidney disease; COPD = constructive obstructive pulmonary disease; IVS = interventricular septum; LVEF = left ventricular ejection fraction; LVOT = left ventricular outflow tract; PPM = permanent pacemaker; TAVR = transcatheter aortic valve replacement.

*Wilcoxon rank sum test; Pearson's chi-square test; Fisher's exact test.

block (RBBB) were defined according to the American Heart Association/American College of Cardiology Foundation/Heart Rhythm Society recommendations for the standardization and interpretation of ECG.[10]

Statistical analysis

Following the application of inclusion and exclusion criteria, the study population was stratified into 2 cohorts based on their postprocedural electrophysiology findings: PPM and no PPM. Univariate analysis results are presented as mean ± SD for continuous variables. Categorical variables are reported as counts and proportions out of available cases. Differences in quantitative variables between groups were analyzed using unpaired *t* test or the nonparametric Kruskal-Wallis test.

We assessed the risk for permanent pacemaker implantation post-TAVR by a multivariable logistic regression modeling, which included predictors such as age, atrial fibrillation, chronic kidney disease, prosthesis-to-left ventricular outflow tract (LVOT) diameter ratio, pre-TAVR ECG LBBB and pre-TAVR ECG RBBB, that were chosen a priory by a certified cardiologist according to clinical experience and pervious cardiology reports. We reported the result as odds ratio (OR) with 95% confidence interval (CI).

We used Kaplan-Meier analysis with log-rank testing to assess rates of 1-year mortality and 1-year HF hospitalizations. The patients were followed up over a 365-day period after their TAVR procedure. For the Kaplan-Meier analysis of HF hospitalizations, patients were censored if they died earlier than 1 year after their TAVR procedure. The graphs represent Kaplan-Meier curves with the number of subjects at risk and the number of events in the period. Neither 1-year mortality nor 1-year HF hospitalizations reached their median survival time.

We used a *P* value of <.05 to indicate statistical significance in all analyses. R statistical software, version 4.2.3 (R Foundation for Statistical computing), was used for all analyses.

Results

A total of 263 patients underwent TAVR at our institution between October 1, 2018, and December 31, 2022. Among these, 33 (12.5%) patients were excluded for the following reasons: pre-existing cardiac implantable electronic device (n = 25), mortality during or immediately following TAVR (n = 4), and incomplete data (n = 4). The remaining 230 patients were stratified into 2 categories based on their postprocedural electrophysiology findings: those who required PPI during hospitalization (n = 44 [19.2%]) and those who did not require PPI during hospitalization (n = 186 [80.8%]).

Overall, 44 (19.2%) patients underwent PPI during hospitalization. Among them, 20 (45.5%) patients met class I indication for PPI due to Mobitz type II, CAVB, or alternating bundle branch block. Additionally, 70 (30.4%) patients developed new LBBB after TAVR. Among them, 40 (17.4% of total cohort) patients exhibited persistent LBBB beyond 48 hours, categorizing them as having new-onset persistent LBBB. The management of patients with new-onset persistent LBBB is depicted in Figure 1. Within the subset of this group, 21 (8.7% of total cohort) patients

Table 2 TAVR procedural details and in-hospital follow-up

Variable	No PPM (n = 186)	PPM (n = 44)	*P* value*
Prosthesis type			.6
Self-expandable	121 (65)	27 (61)	
Balloon expandable	65 (35)	17 (39)	
Prosthesis type			.5
Acurate Neo I/Acurate Neo II	24 (13.2)	1 (2.3)	
Evolut R/Evolut Pro/Evolut Pro Plus	92 (50.8)	25 (58.1)	
Sapien S3	65 (36)	17 (39.5)	
Prosthesis diameter, cm	2.67 ± 0.26	2.75 ± 0.34	.008
Prosthesis diameter to LVOT diameter ratio (per echocardiography)	1.34 ± 0.17	1.34 ± 0.17	.3
Prosthesis area to LVOT area ratio (per CT)	1.48 ± 0.27	1.45 ± 0.36	.9
Post-TAVR			
LVEF, %	57 ± 13	52 ± 10	.005
AR degree			.026
None	96 (52)	29 (66)	
Mild	89 (48)	14 (32)	
Moderate	0 (0)	1 (2.3)	
Mean aortic gradient, mm Hg	9 ± 5	9 ± 4	.7
Hospital length of stay, d	5.86 ± 3.68	7.82 ± 3.32	<.001

Values are n (%) or mean ± SD.

AR = aortic regurgitation; CT = computed tomography; LVEF = left ventricular ejection fraction; LVOT= left ventricular outflow tract; PPM = permanent pacemaker; TAVR = transcatheter aortic valve replacement.

*Wilcoxon rank sum test; Pearson's chi-square test; Fisher's exact test.

underwent pacemaker implantation due to (1) broad QRS duration >160 ms (n = 12, group C) or (2) pathological EPS with HV interval ≥65 ms (n = 9, group B2), as defined in our algorithm. Ultimately, 3 patients received PPI during hospitalization due to baseline LBBB or RBBB with postprocedural QRS widening or PR prolongation, according to physician's discretion: (1) an 84-year-old female with pre-TAVR LBBB with QRS widening to 170 ms and PR prolongation to 310 ms, (2) a 77-year-old male with known LBBB who developed QRS widening to 180 ms and PR prolongation to 270 ms, and (3) a 75-year-old male with baseline bifascicular block (RBBB and left anterior hemi block [LAHB]) and QRS widening to 180 ms post-TAVR. The remaining 186 (80.8%) patients did not require PPI during their hospital stay.

Twenty patients with post-TAVR LBBB of 130 to 160 ms underwent EPS (groups B1 and B2). The mean HV interval was 53.5 ± 5.6 ms in group B1 and 80.7 ± 12.4 ms in group B2, and the mean antegrade Wenckebach cycle length was 471 ± 93 ms in group B1 and 586 ms ± 196 ms in group B2.

The PPM group is characterized by higher prevalence of male sex (61% vs 40%, $P = .012$), body mass index (29 ± 6 kg/m^2 vs 27 ± 5 kg/m^2, $P = .026$), atrial fibrillation (45% vs 27%, $P = .016$), and chronic kidney disease (45% vs 26%, $P = .013$) (Table 1). Echocardiographic parameters including aortic valve area (0.76 ± 0.17 cm^2 vs 0.72 ± 0.22 cm^2, $P = .045$) and LVOT diameter (2.07 ± 0.19 cm vs 2.00 ± 0.18 cm, $P = .039$) were greater among the PPM group vs the no PPM group. Patients in the PPM group had a greater implantable prosthesis diameter (2.75 ± 0.34 cm vs 2.67 ± 0.26 cm, $P = .008$), although the prosthesis diameter-to-LVOT ratio was not significantly different between the 2 groups (Table 2). Left ventricular ejection fraction was higher in patients without a PPM (55 ± 13% vs 51 ± 11%, $P = .002$). Baseline computed tomography also revealed several differences between the PPM and no PPM groups. Both calcium score and LVOT area were higher among the PPM group (2746 ± 1146 HU vs 2376 ± 1237 HU, $P = .03$; and 4.29 ± 0.86 cm^2 vs 3.9 ± 0.86 cm^2, $P = .003$, respectively). Interestingly, post-TAVR aortic regurgitation was more prevalent among patients who did not require PPI.

Table 3 describes the ECG parameters before and after TAVR. Pre-TAVR conduction abnormalities were noted in 47 patients: 31 (13.4%) had RBBB, 16 (6.9%) had LBBB, and 12 (5.2%) had bifascicular block (RBBB + LAHB). Of them, 11 (4.7%) patients with RBBB, 3 (1.3%) with LBBB, and 4 (1.7%) with bifascicular block required PPI during hospitalization.

In univariate analysis, the pre-TAVR QRS was significantly wider (115 ± 22 ms vs 105 ± 20 ms, $P < .01$) among the PPM compared with the no PPM group. Additionally, the prevalence of pre-TAVR RBBB was notably higher among the PPM group (25% vs 11%, $P = .013$). Also, PR prolongation (ΔPR) (26 ± 45 ms vs 8 ± 18 ms, $P < .05$) and QRS widening (ΔQRS) (29 ± 21 ms vs 6 ± 9 ms, $P < .05$) were significantly greater in the PPM group compared with the no PPM group.

Detailed information regarding PPI including indication, timing, and pacing percentages is presented in Table 4.

In multivariate logistic regression analysis, atrial fibrillation (OR 2.65, 95% CI 1.27–5.59, $P = .009$), chronic kidney disease (OR 2.18, 95% CI 1.03–4.59, $P = .04$), and pre-

Table 3 ECG parameters pre- and post-TAVR

Variable	Pre-TAVR ECG			Post-TAVR ECG			Difference between pre- and post-TAVR		
	No PPM (n = 186)	PPM (n = 44)	*P* value*	No PPM (n = 186)	PPM (n = 44)	*P* value*	No PPM (n = 186)	PPM (n = 44)	*P* value*
PR length, ms	188 ± 30	201 ± 40	.12	195 ± 31	227 ± 61	.002	8 ± 18	26 ± 45	.027
QRS duration, ms	105 ± 20	115 ± 22	.007	121 ± 22	155 ± 19	<.001	6 ± 9	29 ± 21	.027
RBBB	20 (11)	11 (25)	.013	23 (12)	5 (13)	>.9			
LBBB	13 (7.0)	3 (6.8)	>.9	61 (33)	30 (75)	<.001			
LAHB	28 (15)	12 (27)	.057	31 (17)	11 (28)	.11			
Bifascicular block	8 (4.3)	4 (9.1)	.3	8 (4.3)	4 (10)	.2			
IVCD	41 (22)	13 (30)	.3	50 (27)	1 (2.5)	<.001			

Values are mean ± SD or n (%).

IVCD = interventricular conduction delay; LAHB = left anterior hemi block; LBBB = left bundle branch block; PPM = permanent pacemaker; RBBB = right bundle branch block; TAVR = transcatheter aortic valve replacement.

*Wilcoxon rank sum test; Pearson's chi-square test; Fisher's exact test.

TAVR RBBB (OR 3.46, 95% CI 1.38–8.53, $P = .007$) were independently associated with PPI after TAVR during hospitalization (Table 5).

As expected, patients in the PPM group had longer hospitalization duration (7.8 ± 3.3 days vs 5.8 ± 3.6 days, $P < .001$) (Table 2). The clinical outcomes including 1-year mortality, 1-year HF hospitalizations, and late pacemaker implantation are presented in Table 6. There was no difference in mortality (11% vs 9.1%, $P = .6$) or HF hospitalizations (18% vs 11%, $P = .4$) between the 2 groups at 1-year follow-up. These findings are illustrated in the Kaplan-Meier curves (Figure 3). Most importantly, only 3 patients required late pacemaker implantation during 1-year follow-up, of whom only 1 patient with new-onset persistent LBBB that was managed according to the algorithm: (1) an 80-year-old male with new-onset persistent LBBB, QRS of 150 ms, and HV of 56 ms (group B1) presented with syncope and CAVB 9-days after TAVR; (2) a 79-year-old female with baseline RBBB who developed transient CAVB 40 days after TAVR due to infective endocarditis with aortomitral continuity involvement (she underwent leadless pacemaker implantation and survived at 1-year follow-up); and (3) a 78-year-old female with a known bifascicular block (RBBB and LAHB) who presented with syncope and transient CAVB 7-days after TAVR, without any changes in QRS morphology or width compared with pre-TAVR ECG. Notably, the patient was discharged with amiodarone therapy due to new-onset atrial fibrillation after TAVR.

Discussion

TAVR has emerged as a cornerstone treatment for severe aortic stenosis. Despite its widespread use, the occurrence of new-onset LBBB post-TAVR remains prevalent, affecting approximately 10% to 40% of patients, raising significant electrophysiological concerns.[7,11]

As mentioned, the management of patients with post-TAVR conduction abnormalities is considerably variable. According to the 2021 European Society of Cardiology pacing guidelines, individuals exhibiting persistent new LBBB with QRS duration >150 ms or PR interval >240 ms may undergo either a noninvasive monitoring approach or an EPS-guided strategy, with PPI recommended in the presence of infra-Hisian conduction disease.[8] However, the superiority of one approach over the other remains uncertain. Additionally, an expert consensus algorithm devised in 2019 by the *Journal of the American College of Cardiology* scientific expert panel suggests continuous ECG monitoring upon hospital discharge, invasive EPS-guided strategy, or PPI depending on the QRS and PR width.[12] The uncertainty surrounding patients with post-TAVR LBBB is appropriately highlighted in a comprehensive survey conducted by the European Heart Rhythm Association. The survey revealed that only 63% of the 117 participating centers had a standardized management protocol in place for advanced conduction disorders such as LBBB or AVB following TAVR. The authors concluded that "there is considerable room for improving the management of patients with conduction disorders after TAVI, and a clear need for dedicated management protocols in TAVI patients."[13]

In the present study, 40 (17.4%) of 230 patients exhibited persistent LBBB beyond 48 hours in accordance with the literature reports.[11,14] Eventually, 44 (19.1%) of 230 patients underwent PPI during hospitalization, including 20 (8.7%) patients meeting class 1 indication due to Mobitz type II, CAVB, or alternating bundle branch block; 21 (9.1%) patients with new-onset persistent LBBB, stratified according to the algorithm as necessitating PPI; and 3 (1.3%) patients per physician discretion (Figure 2). These data are consistent with the current literature reporting of 4% to 30% PPI after TAVR.[14,15] Our protocol includes a recommendation for PPI in patients with persistent new LBBB and QRS >160 ms. The recommendation is based on a large study indicating a high risk for sudden cardiac death among patients with post-TAVR LBBB >160 ms.[16] It is also inferred from the American Heart Association guidelines that suggest to consider PPI in patients with post-TAVR persistent LBBB (class IIB), and a scientific expert panel suggesting PPI when the QRS is >150 ms, indicating of high risk for CAVB.[9,12]

Table 4 CIED implantation during 1-year post-TAVR

	Post-TAVR ECG*	Timing of CIED†	Indication/group	CIED type	RV pacing (%)‡
In hospital					
#1	NOP-LBBB	7	B2	DDDR	40
#2	NOP-LBBB	6	B2	CRTD	100
#3	NOP-LBBB	8	B2	DDDR	100
#4	NOP-LBBB	7	B2	DDDR	0
#5	NOP-LBBB	6	B2	DDDR	1
#6	NOP-LBBB	14	B2	DDDR	94
#7	NOP-LBBB	8	B2	CRTP	93
#8	NOP-LBBB	6	B2	DDDR	0
#9	NOP-LBBB	6	B2	DDDR	0
#10	NOP-LBBB	5	C	VVI	11
#11	NOP-LBBB	6	C	DDDR	0
#12	NOP-LBBB	7	C	CRTP	90
#13	NOP-LBBB	5	C	DDDR	1
#14	NOP-LBBB	5	C	DDDR	0
#15	NOP-LBBB	6	C	CRTP (His bundle)	100
#16	NOP-LBBB	6	C	DDDR	0
#17	NOP-LBBB	5	C	CRTD	98
#18	NOP-LBBB	4	C	DDDR	18
#19	NOP-LBBB	6	C	DDDR	0
#20	NOP-LBBB	7	C	DDDR	0
#21	NOP-LBBB	4	C	DDDR	64
#22	Temporary pacemaker rhythm	4	CAVB >48 h	DDDR	100
#23	New LBBB, QRS 145 ms	5	Intermittent HDAV >48 h	DDDR	1
#24	Bifascicular block, QRS 140 ms	5	CAVB >48 h	CRTP	100
#25	Bifascicular block, QRS 150 ms	7	Intermittent CAVB >48 h	VDD	32
#26	Known RBBB, QRS 120 ms	2	CAVB >24 h	DDD	0
#27	New LBBB, QRS 140 ms	9	Intermittent Mobitz II >24 h	DDDR	1
#28	ICLBBB, PR 380 ms	4	CAVB >48 h	DDDR	99
#29	Temporary pacemaker rhythm	5	CAVB >48 h	CRTP	53
#30	Bifascicular block, QRS 140 ms	5	CAVB >48 h	DDDR	92
#31	New LBBB, QRS 150 ms, PR 300 ms	4	HDAVB >48 h	DDDR	41
#32	New LBBB, QRS 165 ms	4	Alternating BBB	DDDR	0
#33	New LBBB, QRS 160 ms	2	Intermittent CAVB >24 h	DDDR	49
#34	Temporary pacemaker rhythm	2	CAVB >24 h	CRTD	96
#35	Temporary pacemaker rhythm	2	CAVB >24 h	VVI	100
#36	Temporary pacemaker rhythm	3	CAVB >48 h	CRTD	100
#37	Temporary pacemaker rhythm	4	CAVB >48 h	DDDR	0
#38	Temporary pacemaker rhythm	2	CAVB >24 h	DDDR	88
#39	RBBB 130 ms, PR 390 ms	4	Alternating BBB	DDDR	100
#40	Known RBBB QRS 200 ms, PR 480 ms	14	CAVB >48 h	DDDR	97
#41	New LBBB, QRS 170 ms	6	Intermittent CAVB >48 h	DDDR	99
#42	Known LBBB, QRS 180 ms, PR 270 ms	5	QRS widening, PR prolongation§	CRTD	100
#43	Known LBBB, QRS 170 ms, PR 310 ms	6	QRS widening, PR prolongation§	VDD	42
#44	Known bifascicular block, QRS 180 ms	7	QRS widening§	CRTP	99
Postdischarge					
#1	NOP-LBBB	11	CAVB	CRTP	94
#2	Known Bifascicular block, QRS 130 ms	8	CAVB	DDDR	0
#3	Known RBBB, QRS 130 ms	40	CAVB	VVI (MICRA)	0

CAVB = complete atrioventricular block; CIED = cardiac implantable electronic device; ECG = electrocardiography; HDAVB = high-degree atrioventricular block; ICLBBB = incomplete left bundle branch block; LBBB = left bundle branch block; NOP-LBBB = new-onset persistent left bundle branch block; RBBB = right bundle branch block; RV = right ventricular; TAVR = transcatheter aortic valve replacement.

*Within 24–48 hours.

†Days after TAVR.

‡Measured at last device clinic follow-up.

§Per physician discretion; see text.

The HV interval in patients after TAVR, serving as an indicator for pacemaker implantation, lacks uniform definition, resulting in slight variability in the literature.[17] While the accepted threshold for patients with syncope and bifascicular block is 70 ms, our algorithm adopts a more conservative approach, considering HV interval over 65 ms as predictive for PPI. This is approved by previous studies demonstrating that the cutoff value for HV interval in EPS-guided therapy for PPI after TAVR should be in the range of 65 to 75 ms.[17,18]

Table 5 Univariate and multivariate analysis to identify predictors for pacemaker implantation post-TAVR

	Univariate analysis			Multivariate analysis		
Variable	No PPM (n = 186)	PPM (n = 44)	*P* value	Odds ratio	95% CI	*P* value
Age, y	80 ± 6	81 ± 6	.3	1.04	0.98-1.11	.2
AF	50 (27)	20 (45)	.016	2.65	1.27-5.59	.009
CKD	49 (26)	20 (45)	.013	2.18	1.03-4.59	.04
Prosthesis diameter-to LVOT-ratio	1.34 ± 0.17	1.34 ± 0.17	.03	0.81	0.08-5.89	.8
LBBB	13 (7.0)	3 (6.8)	>.9	0.82	0.12-3.50	.8
RBBB	20 (11)	11 (25)	.013	3.46	1.38-8.53	.007

Values are mean ± SD or n (%).

AF = atrial fibrillation; CI = confidence interval; CKD = chronic kidney disease; LBBB = left bundle branch block; LVOT = left ventricular outflow tract; PPM = permanent pacemaker; RBBB = right bundle branch block; TAVR = transcatheter aortic valve replacement.

One of the most substantial and dismal complications associated with post-TAVR LBBB is late AVB postdischarge.[19,20] In the Ambulatory Electrocardiographic Monitoring for the Detection of High-Degree Atrio-Ventricular Block in Patients With New-onset PeRsistent LEft Bundle Branch Block After Transcatheter Aortic Valve Implantation (MARE) study, a multicenter prospective trial that included 103 patients with post-TAVR new LBBB, 15% displayed high-degree AVB during 12-month follow-up period, emphasizing the clinical need for improved management of patients with new-onset persistent LBBB after TAVR.[21] In the present study, only 1 patient with post-TAVR LBBB required late PPI, representing 5.2% of patients with persistent LBBB who were discharged without PPI (groups A and B1) or 2.5% of all patients with persistent new LBBB after TAVR (groups A, B, and C). This is a significantly low rate of postdischarge PPI compared with previously reported algorithms,[19,22–24] further supporting the safety of the current algorithm. In a large study monitoring 1,059 patients discharged after TAVR without a pacemaker, the overall rate of late pacemaker implantation within 1 year was 5.9%. Furthermore, among this study population, 10% of patients with new-onset LBBB who were discharged without a pacemaker received a pacemaker at a later time.[22] In another study monitoring patients with conduction disturbances after TAVR, the rate of late pacemaker implantation was 15.2% among the LBBB subgroup during 1 year of follow-up after the procedure.[24]

The literature extensively discusses predictors of permanent pacemaker implantations following TAVR. Conveniently, these predictors can be categorized into various factors, including clinical parameters, anatomical considerations, conduction abnormalities, periprocedural factors, prosthesis type, and diameter. In our analysis, we found that atrial fibrillation, chronic kidney disease, and baseline RBBB were independently associated with PPI post-TAVR. These findings are in line with the results described in a previous large meta-analysis.[14,25,26]

Ultimately, we also assessed the clinical outcomes of all patients who were managed according to our institutional EPS-guided algorithm. Importantly, our analysis did not reveal any difference in mortality (11% vs 9.1%, *P* = .6) or HF hospitalizations (18% vs 11%, *P* = .4) between the PPM group and those in the no PPM group, respectively, implying that there was no excess of mortality among patients who were discharged without a PPM. Given the study results, the presented algorithm appears as a reliable guide for management of post-TAVR new LBBB.

Table 6 1-year clinical outcomes

Variable	No PPM (n = 186)	PPM (n = 44)	*P* value*
1-y HF hospitalizations	21 (11)	8 (18)	.4
1-y mortality	17 (9.1)	5 (11)	.6
Late PPM	3 (1.6)	0 (0)	>.9

Values are n (%).

HF= heart failure; PPM = permanent pacemaker.

Limitations

The main limitations of the present study are its retrospective design and single-center nature. Additionally, the algorithm used could introduce bias regarding predictors for PPI, as the wider QRS width observed in the PPM group is partly related to our protocol criteria indicative of PPI in patients with new-onset persistent LBBB >160 ms. Our protocol suggests PPI in all patients with a QRS >160 ms; nevertheless, a higher cutoff should also be evaluated or EPS performance for all patients with a QRS >130 ms to lessen the rate of PPI, if patient safety is not comprised. Notably, the algorithm adopts a relatively conservative approach, considering HV over 65 ms as predictive for PPI, which may lead to a slightly higher rate of PPI compared with greater HV values of 70 to 75 ms.

Due to statistical considerations and based on our sample size, only a limited number of variables could be included in the multivariable analysis. The variables chosen for the present analysis were selected based on their clinical relevance and existing data in the literature. However, we cannot exclude that other parameters not included in the present analysis may also guide decision making for pacemaker implantation after TAVR.

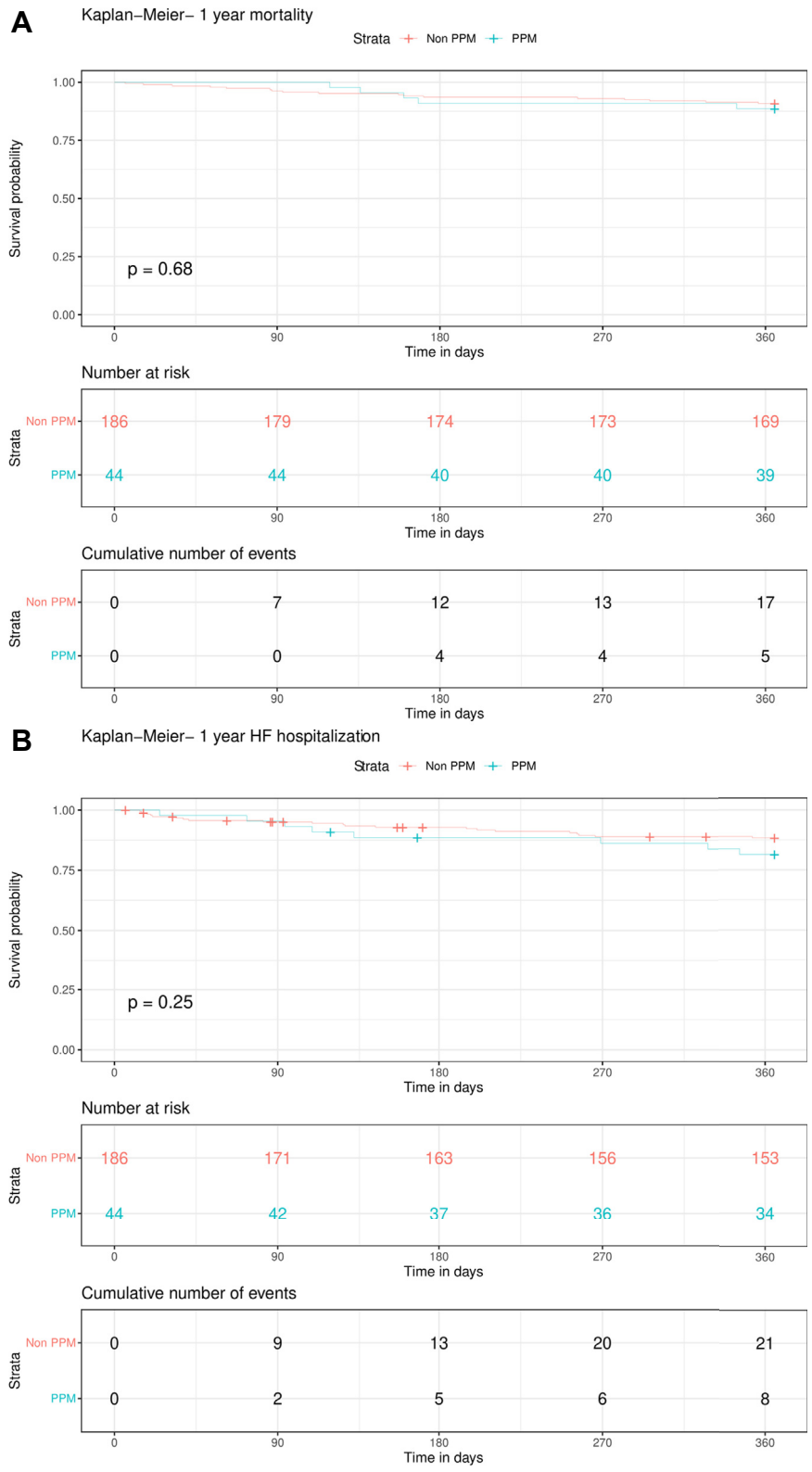


Figure 3 A: Kaplan-Meier curve demonstrating the probability of 1-year mortality in the permanent pacemaker (PPM) group (blue) vs no PPM group (red). B: Kaplan-Meier curve demonstrating the probability of 1-year heart failure hospitalizations in the PPM group (blue) vs no PPM group (red).

Conclusion

The absence of established guidelines for management of new-onset LBBB post-TAVR highlights the need for effective and validated algorithms to improve decision making in this patient population. Our institute-specific algorithm demonstrates a promising safe and efficacious protocol

for management of new-onset LBBB after TAVR, with comparable rates of device placement during hospitalization to the published data and a very low rates of late pacemaker implantations. The safety of the present algorithm is further supported by absence of increased mortality in the no PPM group at 1 year follow-up. Future prospective studies with larger, multicenter cohorts are warranted to validate our findings, assess generalizability and improve the present protocol.

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