Original Article

Ventricular pacing dependency after transcatheter aortic valve replacement: a prospective cohort

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Background: Atrioventricular conduction disturbance occurs in a significant number of patients undergoing transcatheter aortic valve replacement (TAVR). However, not all cases are ventricular pacing-dependent. Thus, we aimed to study the incidence, predictors, and outcomes of new ventricular pacing dependency (VpDep) after TAVR.

Methods: We prospectively analyzed 130 consecutive transfemoral TAVR cases performed in Ramathibodi Hospital between 2015 and 2020. Three patients with prior ventricular pacing-dependent on cardiac implantable electronic devices (CIEDs) were excluded. The endpoints were VpDep at 1 month and all-cause mortality at the follow-up period end in 2021. The effects of variables on VpDep and all-cause mortality were evaluated using multivariate binary logistic regression and Cox regression analyses, respectively. First-degree atrioventricular block (AVB) was considered severe when the PR interval was >300 ms.

Results: Of the 127 patients [mean age, 81.8 years; 62.2% females; 67.7% balloon-expandable (BE) device], 7 patients (5.5%) had CIEDs implanted before TAVR that were not ventricular pacing-dependent. TAVR was successfully performed in 126 (99.2%) patients. Periprocedural stroke, cardiac tamponade, and major bleeding occurred in 2 (1.6%), 4 (3.1%), and 4 (3.1%) patients, respectively. The VpDep incidence at 1 month was 7.9% (n=10) among all patients and 34.5% among those with CIEDs (n=29). VpDep was more likely to occur in patients with pre-existing right bundle branch block (RBBB) [odds ratio (OR), 21.38; 95% confidence interval (CI): 3.28–139.33; P=0.001] and severe 1st degree or Mobitz I AVB (OR, 14.79; 95% CI: 1.65–132.74; P=0.016). After a mean follow-up of 25.8 months [standard deviation (SD), 21.2 months], death from any cause occurred in 18 patients (14.2%). However, VpDep was not associated with an increased mortality.

Conclusions: In this real-world cohort, pre-existing conduction abnormalities were significantly associated with a higher risk of VpDep. Mortality was similar between patients with and without VpDep.

Keywords: Pacemaker; transcatheter aortic valve replacement (TAVR); atrioventricular block (AVB); aortic stenosis

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Introduction

Background and rationale

Atrioventricular (AV) conduction disturbance is a common consequence of transcatheter aortic valve replacement (TAVR), and many require permanent pacemaker (PPM) implantation (1,2). However, conduction disturbances may resolve over time and ventricular pacing dependency (VpDep) may occur only in a proportion of patients with PPMs (3-5). VpDep could lead to ventricular dysfunction (6) and affect the long-term prognosis of patients who undergo TAVR.

Knowledge gap

The incidence of VpDep has been calculated based on variable selection criteria (5). However, most of them excluded patients who already had a PPM even though there was no VpDep.

Objective

This study is sought to analyze the incidence, predictors, and outcomes of new VpDep in a cohort of patients with and without prior PPM who underwent TAVR using all types of devices.

The study has been registered in Thai Clinical Trial Registration (study ID: TCTR20220726005). We present this article in accordance with the STROBE reporting checklist (available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-63/rc).

Highlight box

Key findings

- New VpDep occurred in less than 10% of all patients underwent TAVR.
- Among patients with pacemaker implanted before or within 1 month after TAVR, approximately one-third developed new VpDep.
- New VpDep was not linked with higher mortality.

What is known and what is new?

- Pacemaker implantation is one of the most common complications among patients underwent TAVR.
- Less than half of individuals with pacemakers following TAVR became pacemaker dependent.

What is the implication, and what should change now?

- Because the majority of TAVR patients with pacemakers are not VpDep, they should be regularly monitored and have their pacemaker properly programmed to prevent excessive ventricular pacing.

Methods

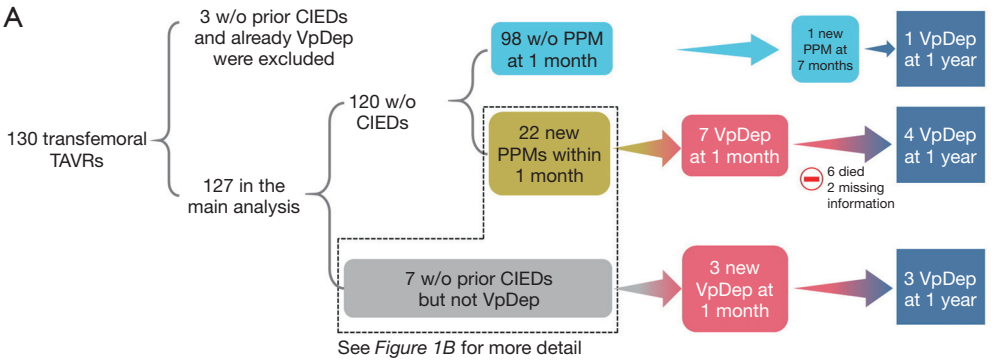
The Ramathibodi transcatheter aortic valve replacement registry (RACR) consecutively collected data on all TAVRs performed in a tertiary care cardiac center in Thailand. The registry was designed to provide information on short- and long-term clinical outcomes in patients treated with government-approved TAVR devices. Patients with severe, symptomatic, aortic stenosis were screened and selected by a multidisciplinary heart team using clinical and anatomical imaging information.

The first 130 consecutive patients who underwent transfemoral TAVR between 2015–2020 were studied for VpDep at 1 month and all-cause mortality at the end of the follow-up period in 2021. Patients who had already been implanted with a cardiac implantable electronic device (CIED) that required ventricular pacing were excluded from the analysis (*Figure 1*). This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University (No. COA. MURA2021/673; August 16, 2021). Informed consent was taken from all the patients.

Procedures and TAVR devices

Transesophageal echocardiography and/or computed tomography was used for anatomical guidance and aortic annulus sizing. The device selection and sedation choice were left to the cardiac team's discretion. The procedure was performed in a cardiac catheterization laboratory or hybrid operating room. After the procedure, all patients were monitored with continuous electrocardiography (ECG) for at least 72 h.

Implantation depth was assessed angiographically after device deployment. A total of 10 mL of the contrast agent was injected to assess the position of the prostheses. The maximum distance between the intraventricular end of the prosthesis and the aortic annulus at the level of each of the three cusps was measured using the HeartVision 2 system (GE Medical Systems SCS, France). The measurements were performed by an interventional cardiologist who was blinded to the results.



		Time after TAVR	
		1 month	1 year
Incidence of VpDep (n/N, %)	Among patients with CIEDs	10/29, 34.5%	8/22, 34.4%
	Among all patients in the cohort	10/127, 7.9%	8/119, 6.9%

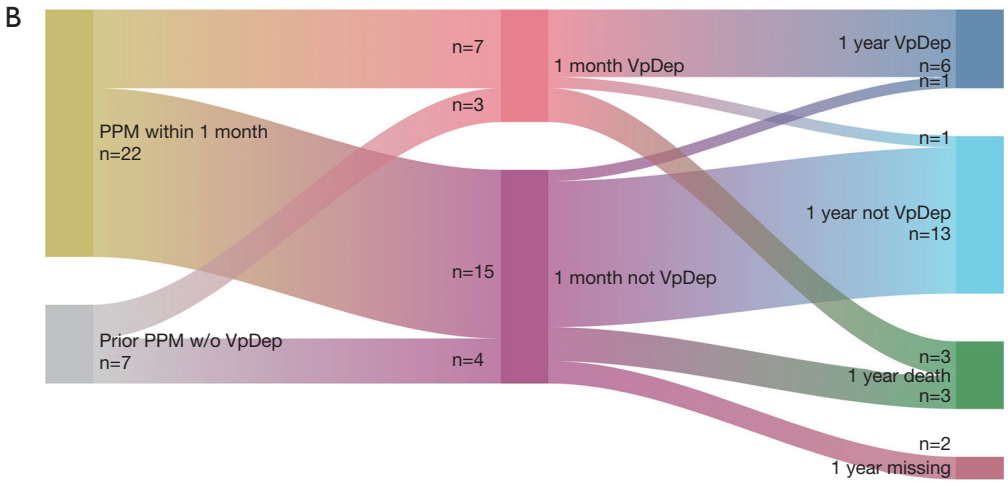


Figure 1 Study flow, incidence of VpDep, and changes in dependency status over time. (A) Pacemaker status and dependency of all patients. The main cohort included 127 patients, 7 of whom already had CIEDs implanted before the procedure but not dependent on ventricular pacing, and 22 received new PPM implantation within 1 month of the procedure. The incidence of VpDep was 6.7% overall and 34.4% in patients with prior CIEDs. (B) Changes in VpDep status between 1 month and 1 year among patients implanted with PPM within 1 month or before TAVR (n=29). One year missing referred to patients with missing information at 1 year after the procedure. TAVR, transcatheter aortic valve replacement; w/o, without; CIEDs, cardiac implantable electronic devices; VpDep, ventricular pacing dependence; PPM, permanent pacemaker.

Data collection

Patient characteristics, valvular parameters, procedural data, and clinical outcomes were collected from a dedicated database. All patients were followed-up for 30 days for clinical improvement and major adverse cardiovascular events (MACEs), and another follow-up during 2021 for all-cause mortality. For those with CIEDs, device settings data and VpDep were recorded at the index procedure (if implanted before), and 1 month and 1 year after the index procedure. Two groups of authors were tasked with assessing VpDep status and the occurrence of MACEs. Both were uninformed of the other's outcomes. All follow-ups were performed on the basis of clinical visits or phone calls.

Definitions

Major bleeding, major vascular complications, and acute kidney injury were defined according to the

standardized endpoints by the Valve Academic Research Consortium-2 consensus (7). Procedure-related conduction disturbances included new or worsening AV conduction requiring an electrophysiological study (EPS) or PPM implantation.

MACEs at 30 days consisted of death, stroke, myocardial infarction, valve dysfunction, hospitalization for valve-related symptoms or worsening heart failure (HF), and the need for cardiovascular intervention, as defined by the Valve Academic Research Consortium-2 consensus (7).

Severe 1st degree atrioventricular block (AVB) was diagnosed in a patient of 1st degree AVB with a PR interval of >300 ms (8).

VpDep was defined as the occurrence of symptoms and signs that create emergent or urgent clinical situations upon abrupt cessation of pacing, or the absence of an intrinsic ventricular rate of >30 bpm (9). New VpDep included patients with newly implanted CIEDs within 1 month of the index procedure who had developed VpDep. Among patients with prior CIEDs, those who did not have VpDep, but developed it 1 month after the procedure were also considered to have new VpDep. VpDep was evaluated in the pacemaker clinic by either a cardiac electrophysiologist or device specialist.

EPS and PPM

A persistently high-grade AVB after 48 h was the primary indication for PPM implantation. In patients who developed new-onset or worsening left bundle branch block (LBBB) that persisted beyond 48 hours, we performed an EPS and prophylactically implanted a PPM for HV interval ≥65 ms.

The CIED types were selected according to standard guidelines (8). Briefly, single-chamber PPMs were selected for patients with chronic atrial fibrillation (AF), cardiac resynchronization therapy (CRT) for those who needed frequent ventricular pacing and in those with left ventricular systolic function (LVEF) <50%, and dual-chamber PPMs for those without the above conditions.

Pacemaker programming was tailored to each patient's specific condition and was left to the discretion of the electrophysiology team. Atrioventricular delay (AVD) was extended to allow intrinsic ventricular conduction, but was not too excessive to avoid hemodynamic disadvantages. An algorithm to reduce unnecessary ventricular pacing was used, as appropriate. In patients with chronotropic incompetence, the response rate was turned on.

Statistical analysis

All analyses were performed using SAS software, version 9.04.01 (SAS OnDemand for Academics; SAS Institute Inc., Cary, NC, USA). Categorical variables are expressed as numbers and percentages, and continuous variables are expressed as means and standard deviations (SDs). Fisher's exact test and one-way analysis of variance were used to compare the differences in baseline characteristics.

The new VpDep predictors were analyzed using multivariate binary logistic analysis. Variables included in the model were age, sex, and variables that had a significance level of <0.01 in the univariate analyses.

The effect of the variables on all-cause mortality was estimated using the Cox proportional hazards model. Hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated. Kaplan-Meier survival curves were plotted and compared using the log-rank test. The proportional assumption was validated using the Schoenfeld residuals. Statistical significance was set at $P<0.05$.

Results

Of the 130 consecutive patients who underwent transfemoral TAVRs, 3 were excluded because they had CIEDs implanted before the procedure, and had VpDep. Therefore, 127 patients were included in the analysis (*Figure 1A*).

The study population (*Table 1*) was mainly elderly (81.8 years; SD, 6.3 years) females (n=79, 62.2%) with an intermediate STS mortality score (6.1%; SD, 4.5%). CIEDs were implanted in 7 patients (5.5%). Pre-existing conduction abnormalities were recorded as follows: 10 patients (7.9%) with right bundle branch block (RBBB) and 7 (5.5%) with severe 1st degree or Mobitz I AVB (Sev 1st/Mobitz I). More information on population characteristics is available in Table S1.

TAVR was successfully performed in 126 (99.2%) patients. One patient (0.8%) experienced an annulus rupture and died during the procedure. Periprocedural stroke, cardiac tamponade, and major bleeding occurred in 2 (1.6%), 4 (3.1%), and 4 (3.1%) patients, respectively (Table S2). The implantation depths at non-, right-, and left-coronary cusps were 3.9 mm (SD, 2.45 mm), 4.8 mm (SD, 2.54 mm), and 4.2 mm (SD, 2.73 mm), respectively (*Table 1*).

New conduction abnormalities and VpDep

New conduction abnormalities were observed in 37 patients

Table 1 Comparisons between patients with 1-month VpDep and independency (n=127)

Characters	Total (n=127)	VpDep at 1 month		
		Independent (n=117)	Dependent (n=10)	P
Age (years), mean (SD)	81.8 (6.3)	81.7 (6.1)	83.7 (8.0)	0.075
Female, n (%)	79 (62.2)	75 (64.1)	4 (40.0)	0.131
LVEF (%), mean (SD)	62.3 (13.7)	62.8 (13.4)	56.3 (15.6)	0.125
AVA (cm^2), mean (SD)	0.7 (0.20)	0.7 (0.20)	0.7 (0.18)	0.535
MPG (mmHg), mean (SD)	48.9 (11.90)	49.6 (11.85)	40.1 (8.91)	0.025
STS mortality score (%), mean (SD)	6.1 (4.5)	6.2 (4.7)	4.7 (1.7)	0.722
LVOT calcification, n (%)	15 (11.8)	15 (16.9)	0 (0.0)	0.273
Bicuspid valve, n (%)	3 (2.4)	3 (2.6)	0 (0.0)	0.608
Pre-existing severe 1st degree or Mobitz I AVB, n (%)	7 (5.5)	4 (3.4)	3 (30.0)	<0.001
Pre-existing RBBB, n (%)	10 (7.9)	6 (5.1)	4 (40.0)	<0.001
Valve type, n (%)				0.587
BE	86 (67.7)	80 (68.4)	6 (60.0)	
SE	41 (32.3)	37 (31.6)	4 (40.0)	
Implantation depth (mm)				
At NCC, mean (SD)	3.9 (2.45)	3.9 (2.49)	4.0 (2.04)	0.419
At RCC, mean (SD)	4.8 (2.54)	4.8 (2.61)	5.1 (1.58)	0.169
At LCC, mean (SD)	4.2 (2.73)	4.7 (2.76)	5.4 (2.35)	0.206
Mean (SD)	4.5 (2.48)	4.5 (2.54)	4.8 (1.85)	0.664
HV interval (ms)				0.073
Numbers of patients with data (%)	13 (10.2)	11 (9.4)	2 (20.0)	
Mean (SD)	62.9 (17.7)	61.3 (18.9)	72.0 (0.0)	
Indication for PPM implantation after TAVR, n (%)				0.755
Complete AVB	18 (72.0)	12 (10.3)	6 (60.0)	
New LBBB and HV interval ≥65 ms	5 (20.0)	4 (3.4)	1 (10.0)	
High grade AVB and HV interval ≥65 ms	1 (4.0)	1 (0.9)	0 (0.0)	
Sick sinus syndrome	1 (4.0)	1 (0.9)	0 (0.0)	
Ventricular pacing at 30 days (%), mean (SD)	40.9 (22.8)	12.2 (15.9)	95.6 (7.2)	<0.001
Ventricular pacing at 1 year (%), mean (SD)	46.9 (44.1)	31.1 (36.8)	85.3 (37.6)	0.004
Death, n (%)	18 (14.2)	16 (13.7)	2 (20.0)	0.633

VpDep, ventricular pacing dependence; SD, standard deviation; LVEF, left ventricular ejection fraction; AVA, aortic valve area; MPG, mean peak gradient; STS, Society of Thoracic Surgeons; LVOT, left ventricular outflow tract; AVB, atrioventricular block; RBBB, right bundle branch block; BE, balloon-expandable; SE, self-expanding; NCC, non-coronary cusp; RCC, right coronary cusp; LCC, left coronary cusp; TAVR, transcatheter aortic valve replacement; PPM, permanent pacemaker; LBBB, left bundle branch block.

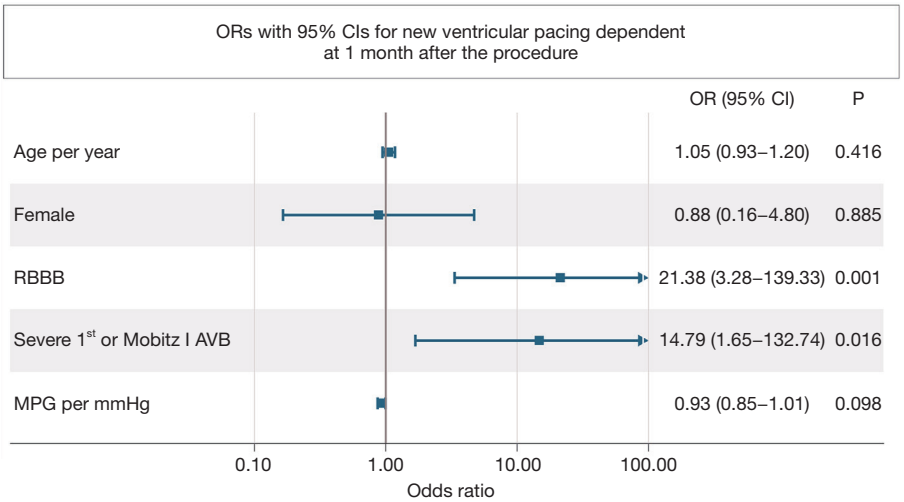


Figure 2 Predictors of 1-month pacemaker dependency by multivariate* binary logistic regression. *, variables included in the model were age, sex, and variables that had P value of <0.01 in univariate analysis. OR, odds ratio; CI, confidence interval; RBBB, right bundle branch block; AVB, atrioventricular block; MPG, mean peak gradient.

(29.1%), with complete AVB being the most common abnormality (n=13, 10.2%). A total of 25 patients (19.7%) underwent PPM implantation after the procedure. Most implantations (n=22, 17.3%) were performed within the first 7 days (Figure S1). Of these, seven patients (31.8%) were classified to have VpDep 1 month after the procedure (*Figure 1A*). Among the patients who had CIEDs implanted prior to the procedure (n=7), three (42.9%) had VpDep at the 1-month follow-up. Therefore, a new 1-month VpDep occurred in 10 patients (7.9% of all patients in the cohort). The rate of VpDep, calculated based on the total number of patients with CIEDs, was 34.5% at 1-month and 34.4% at 1-year. Among patients implanted with PPM within 1 month or before TAVR (n=29), six patients died and two were unable to be reached at a 1-year follow up. Of the 21 patients remained, 19 (90.5%) had the same VpDep status at 1 month and 1 year (*Figure 1B*). The indications, pacing device types, and pacemaker settings of all patients treated with CIEDs are shown in Tables S3,S4.

Patients with new VpDep at 1-month follow-up (*Table 1*) were more likely to have pre-existing RBBB (n=4, 40%) than those without new VpDep (n=6, 5.1%; P<0.001). They were also more likely to have pre-existing Sev 1st/Mobitz I (n=3, 30%) than those without new VpDep (n=4, 3.4%; P<0.001). In the multivariate analysis, pre-existing RBBB [odds ratio (OR), 21.38; 95% CI: 3.28–139.33; P=0.001] and Sev 1st/Mobitz I (OR, 14.79; 95% CI: 1.65–132.74; P=0.016) were independently associated with the occurrence of new VpDep (*Figure 2*).

TAVR device types and new VpDep

The most common device type was a balloon-expandable (BE) device (n=86, 67.7%). The details of all the valve models are presented in Table S2. The mean implantation depth (Table S5) was deeper in self-expanding (SE) device than in BE device (6.6 mm, SD, 3.22 *vs.* 3.5 mm, SD, 1.22 mm, respectively; P<0.001). The rate of new pacemaker implantation within 1 month) was significantly lower in patients treated with BE (n=10, 12.0%) than in those treated with SE (n=12, 32.4%; P=0.008). However, the incidence of new VpDep at 1-month follow-up was similar between the groups (BE: n=6, 7.0% *vs.* SE: n=4, 9.8%; P=0.587; *Table 2*).

Outcomes

Thirty days after the index procedure, 2 patients (1.6%) died, 4 (3.1%) had a stroke, and 1 (0.8%) developed pacemaker infection requiring removal (Table S2). After a follow-up period of 25.8 months (range, 0–117 months; SD, 21.2 months), 18 patients (14.2%) had died. Kaplan-Meier curves with between-group comparisons are shown in Figures S2,S3. New pacemaker implantation (HR, 2.11; 95% CI: 0.78–5.72; P=0.143) and VpDep at 1-month (HR,

Table 2 Incidence of new pacemaker implantation and new VpDep by types of TAVR device

New PPM or new VpDep at 1 mo	Value, n/N, %	P
New PPM at 1 mo		0.008
BE device without prior CIED (n=83)	10/83, 12.0	
SE device without prior CIED (n=37)	12/37, 32.4	
New VpDep at 1 mo		0.587
BE device		
BE device with prior CIED (n=3)	1/3, 33.3	
BE device without prior CIED (n=83)	5/83, 6.0	
Total (n=86)	6/86, 7.0	
SE device		
SE device with prior CIED (n=4)	2/4, 50.0	
SE device without prior CIED (n=37)	2/37, 5.4	
Total (n=41)	4/41, 9.8	

VpDep, ventricular pacing dependency; TAVR, transcatheter aortic valve replacement; PPM, permanent pacemaker; mo, month; BE, balloon-expandable; CIED, cardiac implantable electronic device; SE, self-expanding.

Table 3 HR and 95% CI for all-cause mortality (n=127)

Variables	HRs (95% CI)	P
Age (per year)	1.02 (0.95–1.10)	0.613
Female	0.86 (0.54–1.38)	0.535
Baseline LVEF (per 1%)	0.97 (0.94–1.00)	0.032
STS mortality score (per 1 point)	1.05 (1.02–1.08)	0.003
Old CVA	3.29 (1.01–10.79)	0.049
AF or AFL	3.99 (1.13–14.16)	0.032
Pre-existing RBBB	2.90 (0.83–10.17)	0.096
SE TAVR device	0.86 (0.30–2.44)	0.773
New pacemaker implantation within 30 days	2.11 (0.78–5.72)	0.143
New VpDep at 1 month	1.34 (0.28–6.45)	0.720

HR, hazard ratio; CI, confidence interval; LVEF, left ventricular ejection fraction; STS, Society of Thoracic Surgeons; CVA, cerebrovascular accident; AF, atrial fibrillation; AFL, atrial flutter; RBBB, right bundle branch block; SE, self-expanding; TAVR, transcatheter aortic valve replacement; VpDep, ventricular pacing dependency.

1.34; 95% CI: 0.28–6.45; P=0.720) follow-up were not associated with an increased risk of death (*Table 3*).

Discussion

Key findings

In this real-world cohort of patients who underwent TAVR without prior VpDep, 7.9% (n=10/127) developed new VpDep 1 month after the procedure. Patients with pre-existing RBBB or Sev 1st/Mobitz I had a >10-fold risk of developing new VpDep. The occurrence of new VpDep was not associated with an increased risk of death.

Explanations of findings and comparison to similar researches

TAVR has become the default therapy for severe aortic stenosis in selected patients, mostly older patients and/or patients with intermediate and high surgical risks. The procedure has now expanded to include younger and low-risk patients (10). One of the major concerns is the need for ventricular pacing after the procedure. Long-term right ventricular pacing is known to increase the risk of HF and all-cause mortality (6,11). Therefore, new VpDep development after TAVR in patients with or without prior PPM could be prognostic. In a large cohort from Israel (12), a high pacing burden was associated with worsened LVEF, but not with higher mortality. Pacemaker dependency reportedly occurs more frequently in patients with baseline RBBB (5,13). Here, we showed that new VpDep occurred in less than 10% of all cases and was not associated with higher mortality after 2 years of follow-up. Underlying conduction abnormalities were strongly associated with new VpDep. Approximately 40% of patients with pre-existing Sev 1st/Mobitz or RBBB developed new VpDep 1 month after the procedure.

Previous studies (5,13,14) have reported a wide range of VpDep rates. In a meta-analysis (5), the average VpDep rate in patients with PPM at 1-year follow-up was 47.5% (7–89%). Among these studies, the definition of VpDep has not been uniform and the population has been varied. In the REPRISE III trial (14), a cutoff point of 30 bpm in the absence of native rhythm was used to declare VpDep. All devices implanted in REPRISE III were SE; the reported VpDep rates were 43% and 50% at 1 month and 1 year, respectively. In a trial evaluating the incidence of VpDep following Lotus valve implantation (3), a cutoff point of 40 bpm was used to define VpDep. At 30-day and 1-year,

57% and 38% of patients were pacing-dependent, respectively. In a large single-center cohort including patients treated with both BE and SE devices (13), the rates of VpDep using a cutoff point of 40 bpm were 35.7% and 33.3% at 1 month and 1 year, respectively. However, none of these trials included patients with prior use of CIEDs. In the present study, we used a cutoff point of 30 bpm to diagnose VpDep in the absence of a native rhythm. Both the BE and SE devices were included. Patients with prior CIEDs use who did not have VpDep were also included. The VpDep rates in our analysis, calculated based on all patients with CIEDs, were approximately 34% at both 1 month and 1 year. Among patients with prior CIEDs use (n=7), the rate increased to 42.9% at both 1 month and 1 year.

Deep implantation has been associated with conduction disturbances (15,16) and pacemaker dependency (14). The significance of implantation depth between different devices also varied. In addition, the optimal depth has not been consistently defined. The average implantation depths in patients with new conduction disturbances were reportedly 7.1 mm in BE and 5.2 mm in SE (15,16). In the REPRISE III trial (14), a comparison between the Lotus valve and the CoreValve systems showed that one of the predictors of pacemaker dependency at 30 days was implantation depth. The mean implantation depth in REPRISE III was >6 mm compared to our average depth of <5 mm. We chose different TAVR valves based on anatomical suitability and found no significant differences in the implantation depth between the VpDep and non-VpDep groups.

The rate of PPM implantation within 1 month of the procedure was 17%. The number is comparable to the rate reported in the registry that included both BE and SE devices (2). SE device was associated with higher rate of PPM implantation than BE device (32% *vs.* 12%, P=0.008), similar to previous studies (1,2,17,18). Our pacemaker rate was relatively high as we had relatively low thresholds for pacemaker implantation. Most pacemaker implantations were performed during the index TAVR procedure visit (88% within 7 days of the index procedure). However, we showed that the incidence of new VpDep did not differ between the BE and SE devices.

Implications

Our results support pacemaker interrogation and adjustment as early as 1 month. Of all patients with PPM after TAVR, approximately two-thirds did not depend on ventricular pacing at 1 month, and most remained independent of ventricular pacing at 1 year. An appropriate pacemaker setup in this group of patients would reduce unnecessary ventricular pacing and likely improve long-term outcomes.

Strengths and limitations

One of our study's strengths was the real-world setting. All TAVR devices were registered. Despite the fact that the number of people with prior PPM was small, they were excluded from the majority of trials.

Our study has several limitations. The sample size was relatively small. The trial design was not powered to detect an effect on mortality and was not allowed to assume causality. The device selection and approach to PPM implantation were based on a single-center experience. Although the maximum follow-up time was more than 9 years, the mean follow-up time was 25.8 months, which might not be long enough to detect the consequences of VpDep. The associations of new conduction abnormalities and VpDep were reported with wide CI, indicating that a larger sample size is required to make any firm inferences from the data.

Conclusions

In a real-world cohort of TAVR patients, new VpDep occurred in fewer than 10% of all patients and one-thirds in patients with CIEDs, and was not linked with increased mortality. Patients who had no prior conduction abnormalities were less likely to be VpDep. Pacemaker programming should therefore be adjusted in this group of patients to avoid unnecessary ventricular pacing. More research with a larger sample size and a longer follow-up period are needed to corroborate these findings.

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Footnote

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Data Sharing Statement: Available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-63/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://cdt.amegroups.com/article/view/10.21037/cdt-23-63/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the local human research ethics committee (No. COA. MURA2021/673; August 16, 2021) and informed consent was taken from all the patients.

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Supplementary

Table S1 Baseline characteristics (n=127)

Characters	Value
Age (years), mean (SD)	81.8 (6.3)
Female, n (%)	79 (62.2)
NYHA, n (%)	
1	1 (0.8)
2	50 (39.4)
3	69 (54.3)
4	7 (5.5)
Diabetes mellitus, n (%)	90 (70.9)
Hypertension, n (%)	32 (25.2)
Dyslipidemia, n (%)	33 (26.0)
Smoker, n (%)	
Never	117 (92.1)
Current smoker	7 (5.5)
Ex-smoker	3 (2.4)
Coronary artery disease, n (%)	55 (43.3)
AF, n (%)	105 (82.7)
Bicuspid valve, n (%)	3 (2.4)
Prior CIEDs, n (%)	7 (5.5)
GFR (mL/min/1.73 m^2), mean (SD)	55.8 (22.60)
Body mass index (kg/m^2), mean (SD)	24.3 (4.27)
LVEF (%), mean (SD)	62.3 (13.7)
STS mortality score (%), mean (SD)	6.1 (4.5)
EuroScore II (%), mean (SD)	5.0 (5.2)
Preexisting bundle branch block, n (%)	
Intraventricular conduction delay	1 (0.8)
RBBB	9 (7.1)
RBBB and left anterior fascicular block	1 (0.8)
Preexisting AVB, n (%)	
1st degree AVB	14 (11.0)
Severe 1st degree AVB (PR interval >300 ms)	6 (4.7)
Mobitz I	1 (0.8)
Baseline rhythm, n (%)	
Sinus	119 (93.7)
AF or flutter	8 (6.3)

SD, standard deviation; NYHA, New York Heart Association; AF, atrial fibrillation; CIEDs, cardiac implantable electronic devices; GFR, glomerular filtration rate; LVEF, left ventricular ejection fraction; STS, Society of Thoracic Surgeons; RBBB, right bundle branch block; AVB, atrioventricular block.

Table S2 Procedural characteristics and outcomes (n=127)

Characters	Value
TAVR models, n (%)	
Absolute Neo	17 (13.4)
EVOLUT	6 (4.7)
Portico	18 (14.2)
S3	62 (48.8)
SAPIEN XT	24 (18.9)
Type of TAVR devices, n (%)	
BE	86 (67.7)
SE	41 (32.3)
AVA (cm^2), mean (SD)	
Before TAVR	0.7 (0.20)
30 days after TAVR	1.7 (0.43)
Mean peak gradient (mmHg), mean (SD)	
Before TAVR	48.9 (11.90)
30 days after TAVR	10.5 (5.20)
Post-procedural paravalvular leak, n (%)	
None	40 (31.5)
1+	65 (51.2)
2+	19 (15.0)
3+	3 (2.4)
Implantation depth (mm), mean (SD)	
At non-coronary cusp	3.9 (2.45)
At right coronary cusp	4.8 (2.54)
At left coronary cusp	4.7 (2.73)
Procedural time (min), mean (SD)	93.5 (47.08)
Procedural success, n (%)	126 (99.2)
Acute complication, n (%)	39 (30.7)
Conduction disturbances	28 (22.0)
Major bleeding	4 (3.1)
Cardiac tamponade	4 (3.1)
Acute kidney injury	4 (3.1)
Stroke	2 (1.6)
Death	1 (0.8)
30-day major adverse events, n (%)	27 (21.3)
PPM implantation, n (%)	22 (17.3)
Stroke, n (%)	4 (3.1)
Infection of pacemaker system required extraction, n (%)	1 (0.8)
Death, n (%)	2 (1.6)
Death at the end of follow up, n (%)	18 (14.2)
Follow-up time (months), mean (SD)	25.8 (21.21)
Follow-up time (months), range	0–117

TAVR, transcatheter aortic valve replacement; BE, balloon-expandable; SE, self-expanding; AVA, aortic valve area; SD, standard deviation; PPM, permanent pacemaker.

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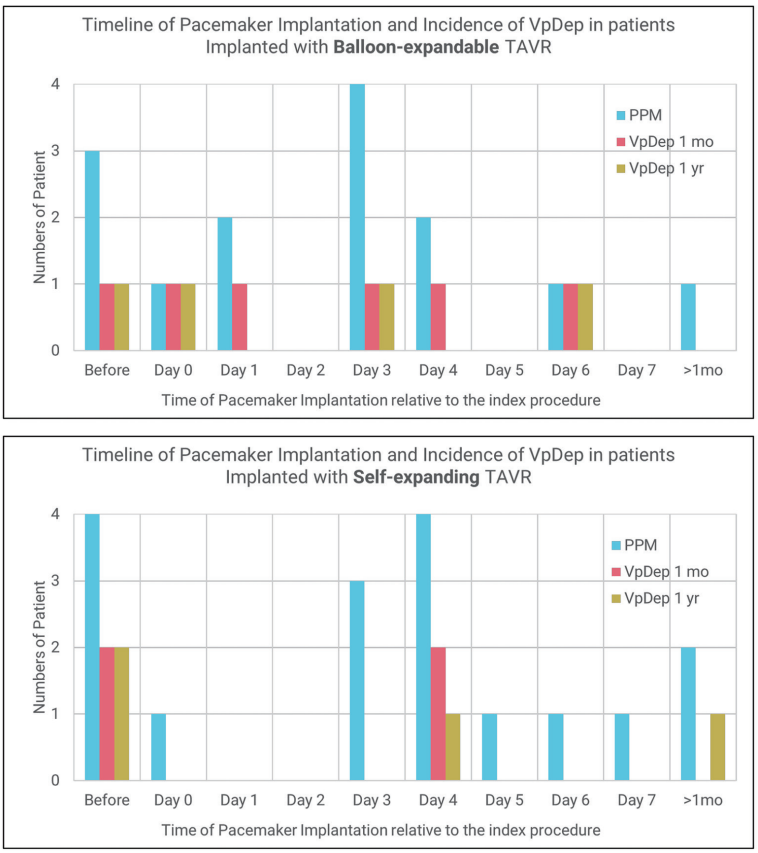

Figure S1 Timeline of pacemaker implantation and incidence of VpDep by type of devices. VpDep, ventricular pacing dependency; TAVR, transcatheter aortic valve replacement; PPM, permanent pacemaker; mo, months; yr, years.

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Table S3 Conduction disturbances and pacemaker implantation (n=127)

Characters	Value
Type of new conduction disturbances, n (%)	
Complete AVB	13 (10.2)
High grade AVB	3 (2.4)
LBBB	11 (8.7)
Intraventricular conduction delay	2 (1.6)
1st degree AVB	8 (6.3)
EP study performed, n (%)	13 (10.2)
HV interval (ms), mean (SD)	62.9 (17.7)
Time to new PPM (days), mean (SD)	47.5 (130.6)
New PPM, n (%)	25 (19.7)
Implanted ≤7 days after TAVR	22 (17.3)
Implanted >7 days to 180 days after TAVR	0 (0.0)
Implanted >180 days after TAVR	3 (2.4)
Indications for PPM implantation, n (%)	
Implanted ≤7 days after TAVR	
Complete AVB	15 (11.8)
New LBBB and HV interval ≥65 ms	5 (3.9)
High grade AVB and HV interval ≥65 ms	1 (0.8)
Sick sinus syndrome	1 (0.8)
Implanted >7 days after TAVR	
Complete AVB	3 (2.4)
New LBBB and HV interval ≥65 ms	0 (0.0)
High grade AVB and HV interval ≥65 ms	0 (0.0)
Sick sinus syndrome	0 (0.0)
Types of pacemaker, n (%)	
Single-chamber	1 (0.8)
Dual-chamber	23 (18.1)
Cardiac resynchronization system	1 (0.8)
New VpDep at 30 days, n (%)	10 (7.9)

AVB, atrioventricular block; LBBB, left bundle branch block; EP, electrophysiologic; PPM, permanent pacemaker; TAVR, transcatheter aortic valve replacement; VpDep, ventricular pacing dependency.

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Table S4 Pacemaker indications, parameters, and pacing dependency (n=32)

Patient ID	Time from TAVR to PPM	Valve	Indication	Type	Mode	LRL	URL	sAVD/pAVD	%VP 1 month/ 1 year	New VpDep at 1 month	VpDep at 1 year
77	7 years before	Portico	SSS	dPPM	DDDR	60	110	320/350	36/19	N	N
74	4 years before	S3	SSS	dPPM	DDD	50	130	330/360	3/6	N	N
129	3 years before	S3	SSS	dPPM	DDD	50	110	250/280	77/100	Y	Y
110	1 year before	S3	High grade AVB	dPPM	DDD	60	120	310/340	54.8/59.6	N	N
137	6 months before	EVOLUT	SSS	dPPM	AAIR ↔ DDDR	60	110	MVP	34.5/17.9	N	N
63	2 months before	Portico	Symptomatic bifascicular block	dPPM	DDD	50	100	200/230	100/99.9	Y	Y
109	2 months before	EVOLUT	High grade AVB	dPPM	DDD	60	120	270/300	99.7/99.9	Y	Y
116	Same day	AN	CHB	dPPM	DDD	60	110	300/330	2/2	N	N
141	Same day	S3	CHB	dPPM	DDD	60	110	200/220	100/100	Y	Y
21	1 day after	SAPIEN XT	CHB	dPPM	DDD	60	110	250/280	8/23	N	N
119	1 day after	S3	CHB	sPPM	VVI	50	NA	NA	100/NA	Y	Death
55	3 days after	S3	CHB	dPPM	DDD	60	120	200/220	0.1/16.4	N	N
64	3 days after	Portico	New LBBB, HV ≥65	dPPM	DDD	60	120	240/260	0.1/NA	N	Death
70	3 days after	Portico	CHB	dPPM	DDDR	50	120	325/350	20/43	N	N
79	3 days after	Portico	New LBBB, HV ≥65	dPPM	DDD	60	110	325/350	0.1/0.1	N	N
83	3 days after	S3	SSS, new 1st AVB	dPPM	AAIR ↔ DDDR	60	120	MVP	2.9/100	N	Y
106	3 days after	S3	High grade AVB, HV ≥65	dPPM	DDD	60	120	330/360	27.6/MS	N	MS
134	3 days after	S3	New LBBB, HV ≥65	dPPM	DDD	60	100	300/330	96/0.1	Y	N
40	4 days after	Portico	CHB	dPPM	DDD	60	120	Search AV+ at 300	4/5	N	N
73	4 days after	S3	New LBBB, HV ≥65	dPPM	DDI	40	NA	NA	0.1/NA	N	Death
80	4 days after	AN	CHB	dPPM	DDD	60	120	240/260	90/NA	Y	Death
94	4 days after	EVOLUT	CHB	dPPM	DDD	60	120	300/320	8.4/MS	N	MS
98	4 days after	S3	CHB	dPPM	DDD	60	120	270/300	97.7/NA	Y	Death
114	4 days after	AN	CHB	dPPM	DDD	50	120	200/230	100/99	Y	Y
135	4 days after	AN	CHB	dPPM	DDD	60	120	AV search+ at 300	22.8/0.1	N	N
58	5 days after	Portico	CHB	dPPM	DDD	60	120	200/230	0.2/NA	N	Death
4	6 days after	SAPIEN XT	CHB	dPPM	DDD	60	110	200/220	97/98.5	Y	Y
30	6 days after	Portico	CHB	dPPM	DDD	60	120	240/260	7.7/0.1	N	N
72	7 days after	Portico	New LBBB, HV ≥65	dPPM	DDD	50	120	250/275	0.1/0.1	N	N
81	7 months after	AN	CHB, HFrEF	CRT	DDD	60	110	160/180	98.9*	N	Y
66	1 year after	S3	CHB	dPPM	DDD	50	100	250/280	36.6*	N	NA
86	18 months after	AN	CHB	dPPM	DDD	60	100	180/200	100*	N	NA

*, data recorded at 1 month after implantation. TAVR, transcatheter aortic valve replacement; PPM, permanent pacemaker; LRL, lower rate limit; URL, upper rate limit; sAVD, sensed atrioventricular delay; pAVD, paced atrioventricular delay; %VP, ventricular pacing percentage; VpDep, ventricular pacing dependency; SSS, sick sinus syndrome; dPPM, dual-chamber pacemaker; DDDR, dual-chamber, rate-modulated pacing; N, no; DDD, dual-chamber pacing; Y, yes; AAIR, single-chamber atrial, rate-modulated pacing; MVP, managed ventricular pacing; AVB, atrioventricular block; AN, Absolute Neo; CHB, complete heart block; sPPM, single-chamber pacemaker; VVI, single-chamber ventricular pacing; NA, not applicable; LBBB, left bundle branch block; AV, atrioventricular; DDI, dual-chamber pacing without AV synchrony; MS, data missing; HFrEF, heart failure with reduced ejection fraction; CRT, cardiac resynchronization therapy.

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Table S5 Implantation depth, pacemaker implantation and VpDep by type of TAVR devices (n=127)

Characters	Type of TAVR devices		P
	BE (n=86)	SE (n=41)	
Implantation depth (mm)			
At NCC, mean (SD)	3.1 (1.32)	5.7 (3.34)	<0.001
At RCC, mean (SD)	3.9 (1.37)	6.8 (3.30)	<0.001
At LCC, mean (SD)	3.6 (1.32)	7.1 (3.37)	<0.001
Mean (SD)	3.5 (1.22)	6.6 (3.22)	<0.001
Prior CIEDs, n (%)	3 (3.5)	4 (9.8)	0.148
New pacemaker within 1 month, n (%)	10 (11.6)	12 (29.3)	0.014
Indication for pacemaker implanted within 1 month, n			0.451
Complete AVB	6	9	
New LBBB and HV interval ≥65 ms	2	3	
High grade AVB and HV interval ≥65 ms	1	0	
Sick sinus syndrome	1	0	
New VpDep at 30 days, n (%)	6 (7.0)	4 (9.8)	0.587
Prior CIEDs, n	1	2	
Without prior CIEDs, n	5	2	
VpDep at 1 year, n (%)	4 (4.7)	4 (9.8)	0.268
Prior CIEDs, n	1	2	
Without prior CIEDs, n	3	2	

VpDep, ventricular pacing dependency; TAVR, transcatheter aortic valve replacement; BE, balloon-expandable; SE, self-expanding; NCC, non-coronary cusp; SD, standard deviation; RCC, right coronary cusp; LCC, left coronary cusp; CIEDs, cardiac implantable electronic devices; AVB, atrioventricular block; LBBB, left bundle branch block.

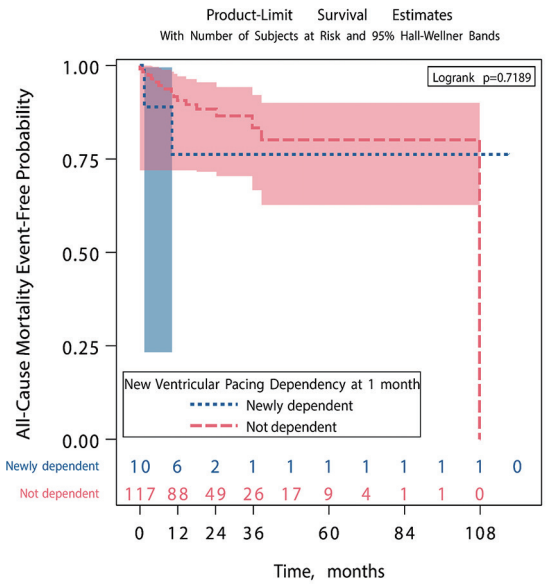

Figure S2 Kaplan-Meier survival estimates by new VpDep. VpDep, ventricular pacing dependency.

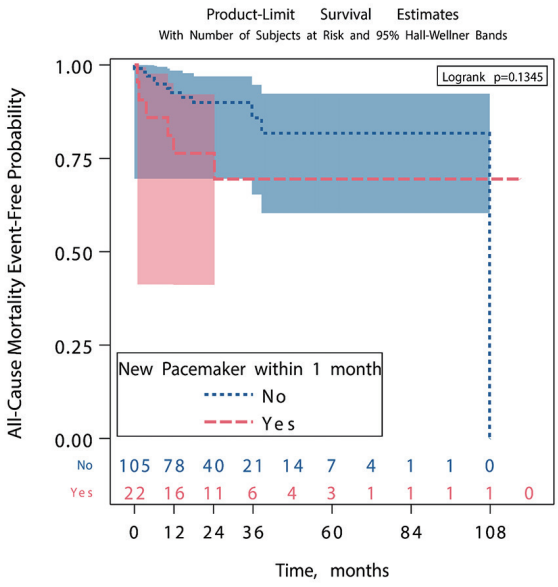

Figure S3 Kaplan-Meier survival estimates by new PPM implanted within 1 month after the procedure. PPM, permanent pacemaker.

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