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Changes in the Pacemaker Rate After Transition From Edwards SAPIEN XT to SAPIEN 3 Transcatheter Aortic Valve Implantation

The Critical Role of Valve Implantation Height

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ABSTRACT

OBJECTIVES The aim of this study was to analyze the pacemaker implantation rate (PMIR) with the new balloon-expandable Edwards SAPIEN 3 valve (S3) and the factors associated with it.

BACKGROUND The introduction of the S3 for transcatheter aortic valve replacement (TAVR) has led to a reduction in paravalvular regurgitation. There are, however, concerns that the new design may increase the PMIR.

METHODS The first 206 patients treated with the S3 were compared with 371 preceding patients treated with SAPIEN XT valves. Patients who previously underwent pacemaker or implantable cardioverter defibrillator implantation or transapical and valve-in-valve procedures were excluded from the analysis. All patients were monitored for at least 7 days. Previous and new conduction abnormalities were documented, and prosthesis implantation height was assessed for the S3.

RESULTS There were no significant differences in baseline characteristics between groups. The PMIR was, however, significantly higher for the S3 (19.1% vs. 12.2%; $p = 0.046$). The mean implantation height was significantly lower in patients requiring PMI (67%/33% vs. 72%/28% aortic/ventricular stent extension, $p = 0.032$). On multivariate regression analysis, implantation height was the only independent predictor of PMI (odds ratio: 0.94 [95% confidence interval: 0.90 to 0.99]; $p = 0.009$). It increased from 68%/32% to 75%/25% when comparing the first with the second half of S3 implantations ($p < 0.0001$). This change was associated with a significant decrease in PMIR from 25.9% to 12.3% ($p = 0.028$), no longer different from the XT valve (12.2%).

CONCLUSIONS The PMIR after TAVR is higher with the S3 than with the XT and is independently associated with the implantation height. This increase in the PMIR may be avoided by intending an aortic stent extension >70%.
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ABBREVIATIONS AND ACRONYMS

AV = atrioventricular

AVCA = atrioventricular conduction abnormality

LVOT = left ventricular outflow tract

MDCT = multidetector computed tomography

PMIR = pacemaker implantation rate

PPM = permanent pacemaker

PPMIR = permanent pacemaker implantation rate

PVR = paravalvular regurgitation

ROC = receiver-operating characteristic curve

S3 = Edwards SAPIEN 3 valve

TAVR = transcatheter aortic valve replacement

XT = Edwards SAPIEN XT valve

Transcatheter aortic valve replacement (TAVR) has become an accepted treatment alternative for severe aortic stenosis in patients at high surgical risk (1,2). Atrioventricular conduction abnormalities (AVCAs) are a common complication after TAVR (3–7) and are associated with an increased permanent pacemaker (PPM) implantation rate (PPMIR) (8–10). This remains one of the concerns with this intervention, particularly when considering even lower risk patients for TAVR. In general, the reported occurrence of AVCAs and need for PPM implantation was markedly lower for balloon-expandable valves than for self-expandable valves (10–12). Studies with the balloon-expandable Edwards SAPIEN XT valve (XT) (Edwards Lifesciences, Irvine, California) have reported an average PPMIR of ~6% (range, from 4% to 13%) (13). The recent introduction of the next generation of balloon-expandable valve of the Edwards SAPIEN family, the Edwards SAPIEN 3 valve (S3) (Edwards Lifesciences) was suggested to lead to a marked reduction in paravalvular regurgitation (PVR) (14). This valve incorporates a new adaptive external tissue seal aimed at reducing PVR and its newly designed stent allowing for a lower delivery profile is 3 to 4 mm longer than in the XT. The

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PPMIR after TAVR with the S3 reported in the release study of the valve was 13.3% (14), a rate higher than usually reported with the previous generations of the balloon-expandable valve (15). The markedly higher PPMIR reported for the self-expanding CoreValve (Medtronic, Minneapolis, Minnesota) (range, 24% to 33%) (10) was suggested to be caused by the design-related extension of the stent deeper into the left ventricular outflow tract (LVOT) (8). Higher implantation of the valve was indeed reported to reduce the PPMIR (16). The longer stent of the S3 that may extend deeper into the LVOT may also result in a higher rate of AVCAs compared with the previous valve generation. It remains, however, currently unclear whether the PPMIR indeed differs between S3 and XT TAVR and which mechanisms may explain such differences. The aim of the present study was, therefore, to compare the PPMIR between patients undergoing TAVR using S3 and XT valves and to identify risk factors for the development of AVCAs and need for a PPM after S3 implantation, considering in particular the role of the implantation height of the valve.

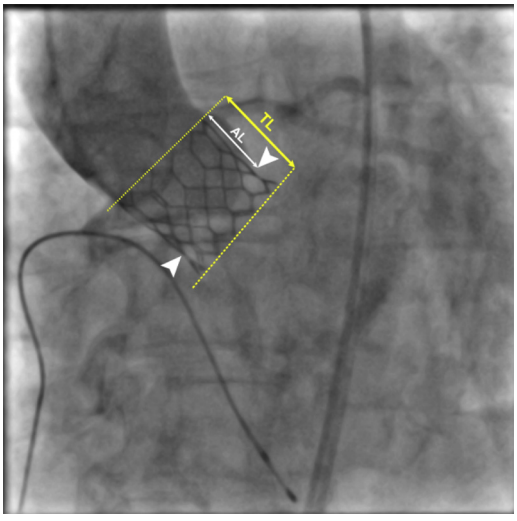
METHODS

All patients undergoing TAVR at our institution with the XT and the S3 between January 2010 and January 2015 were screened. Inclusion criteria for the final study population were that the patients 1) did not have a pacemaker or implantable cardioverter-defibrillator before TAVR, 2) were treated for severe native aortic stenosis (no valve-in-valve implantation), and 3) underwent implantation via transfemoral access.

All patients underwent a thorough clinical and echocardiographic evaluation before being considered for TAVR. The indication for TAVR was established by the multidisciplinary heart team including cardiologists and cardiac surgeons. Clinical records of the patients were reviewed, and all relevant information regarding AVCAs or PPM implantation before and during implantation was collected. All patients were monitored for 7 days after TAVR with continuous electrocardiographic telemetry after implantation. Specific guidelines for PPM implantation in the setting of TAVR are currently lacking. The decision to implant a PPM was left to the discretion of the local interdisciplinary team including valvular heart disease and electrophysiology experts. In order to account for possible differences in PPM implantation threshold in the study groups, we classified the PPM implantation into 2 groups of indications according to current guidelines (17): the Class I/IIa indication group of patients includes those with a "therapeutic" indication, whereas the Class IIb indication group includes those with "prophylactic" PPM implantation indications. All patients underwent 12-lead electrocardiographic and echocardiographic evaluation before discharge. The degree of PVR was defined according to the Valve Academic Research Consortium criteria (18).

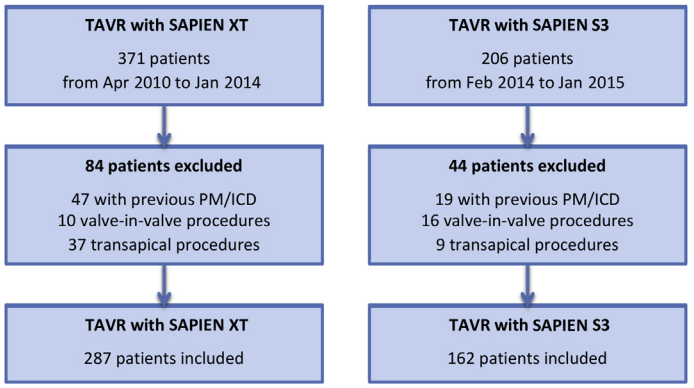
The implantation height in the S3 group was analyzed by off-line evaluation of procedural fluoroscopy. A single still frame of the pre- and post-implantation aortic angiographies was selected for each patient. The implantation height was assessed quantitatively by 2 experienced investigators (G.K. and H.B.) who were blind to the objectives of the study. Interobserver discrepancies were resolved by consensus. The native aortic valve annulus was defined as the connection line of the deepest points of cusp insertions in the pre-implantation angiography. Identification of the same line in the post-implantation angiography by direct comparison was attempted. The final stent length and the distance from the native aortic annulus to the aortic

FIGURE 1 Analysis of the Valve Implantation Height of the Edwards SAPIEN 3 Valve



The total length (TL) of the stent **(yellow arrowed line)** is assessed by measuring the distance between the 2 ends of the stent **(yellow dashed lines)**. The aortic length (AL) **(white arrowed line)** is the distance between the aortic end of the stent and the aortic annulus **(white arrowheads)**. For details, see also Methods section. The implantation height is defined as the percentages of the stent lying in the aorta and the left ventricular outflow tract.

FIGURE 2 Study Flow Chart



The flowchart provides information about the included and excluded patients in the SAPIEN 3 and SAPIEN XT groups. ICD = implantable cardioverter-defibrillator; PM = pacemaker; TAVR = transcatheter aortic valve replacement.

end of the stent were measured. The implantation height was expressed as the percentage of the stent lying on the aortic and the ventricular sides (Figure 1).

The valve size selection was at the discretion of the operators who were aware of the multidetector computed tomography (MDCT) size recommendation provided by the vendor specifications. An S3 was considered oversized when the S3 nominal area was greater than the systolic MDCT annular area. The percentage of oversizing (positive percentage) or undersizing (negative percentage) was calculated using the following formula: % oversizing = (S3 nominal area/MDCT annular area − 1) × 100. In addition, to further analyze a possible effect of the sizing of the valve in the PPMIR, we also categorized patients in the S3 group depending on the percentage of MDCT area oversizing/undersizing in the following categories: <0% (undersizing); 0% to 10%; 10% to 20%; and >20% (oversizing).

All patients signed an informed consent for interventional treatment and data collection allowing intrainstitutional retrospective data analysis.

STATISTICAL ANALYSIS. Quantitative data were expressed as the mean ± SD. Categorical variables were expressed as counts and percentages. Quantitative variables adjusting to a normal distribution were compared by the Student *t* test. Nonnormal variables were compared with the Wilcoxon test. Comparison of categorical variables was performed with the chi-square test or the Fisher exact test, as appropriate. A multivariate regression analysis was performed to assess for independent predictors of PPM implantation after S3 implantation. Pearson's correlation was used to describe the temporal changes in the implantation height in the S3 group over time. The optimal value of implantation height was assessed based on the combination between sensitivity and specificity as measured by receiver-operating characteristic curve analysis.

All reported p values are 2 sided, and p values <0.05 were considered statistically significant. Statistical analysis were performed using IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, New York). To account for a possible selection bias and therefore a possible lack of comparability of the XT and S3 groups, propensity score matching was performed using the MatchIt Package for R (R Foundation for Statistical Computing, Vienna, Austria) with a nearest-neighbor 1-to-1 matching method.

RESULTS

During the defined study period, 206 patients underwent TAVR with the S3 (recent cohort) and 371

TABLE 1 Baseline Characteristics of the Study Groups by Valve Type

	SAPIEN XT Valve (n = 287)	SAPIEN 3 Valve (n = 162)	p Value
Age, yrs	82.1 ± 6.0	82.1 ± 6.1	0.998
Male	107 (37.3)	61 (37.7)	0.938
Logistic EuroSCORE I	22.6 ± 15.8	24.1 ± 12.2	0.526
Previous AVCA (any)	110 (39)	50 (30.9)	0.085
First-degree AV block	57 (20.2)	28 (17.3)	0.450
Second-degree AV block (Mobitz type I)	4 (1.4)	0 (0)	0.075
Right bundle branch block	31 (11)	9 (5.6)	0.054
Left bundle branch block	33 (11.7)	18 (11.1)	0.851
Left anterior hemiblock	9 (3.2)	4 (2.5)	0.066
Left posterior hemiblock	0 (0)	0 (0)	–
Valve size, mm			
23	104 (36.2)	73 (45.1)	0.020
26	147 (51.2)	61 (37.7)	
29	36 (12.5)	28 (17.3)	

Values are mean ± SD or n (%).
AV = atrioventricular; AVCA = atrioventricular conduction abnormality.

patients received the XT (preceding cohort). After exclusion of those patients with a previously implanted pacemaker or implantable cardioverter-defibrillator (9.2% in the S3 group and 12.7% in the XT group), transapical implantations (7.8% in the S3 group and 10.0% in the XT group) and valve-in-valve procedures (4.4% in the S3 group and 2.7% in the XT group), 162 patients treated with the S3 and 287 patients treated with the XT remained for further analysis (Figure 2). Baseline characteristics of the 2 groups are presented in Table 1. There were no significant differences in age, sex, baseline risk profile or pre-existing conduction abnormalities between the 2 groups. In the XT group, the most frequently implanted valve size was 26 mm (51.2% vs. 37.7% in the S3 group), whereas in the S3 group, 23-mm was the most frequently used valve size (45.1% vs. 36.2% in the XT group). This difference in implanted valve sizes was statistically significant (p = 0.02). Table 2 shows the post-procedural outcome. The in-hospital mortality (all-cause mortality during index procedure hospitalization) was 2.2% for the entire cohort and did not significantly differ between groups. The mean length of stay was 8 days.

TABLE 2 Post-Procedural Outcome

	SAPIEN XT Valve (n = 287)	SAPIEN 3 Valve (n = 162)	p Value
In-hospital mortality (mean stay, 8 days)	7 (2.4)	3 (1.9)	0.686
New AVCA (any)	83 (28.9)	64 (39.5)	0.022
PPM implantation	35 (12.2)	31 (19.1)	0.046
Class I/IIa indication	30 (85.7)	29 (93.5)	0.433
Class IIb indication	5 (14.3)	2 (6.5)	
New first-degree AV block	23 (8.0)	18 (11.1)	0.274
New second-degree AV block (Mobitz type I)	2 (0.7)	0 (0)	0.538
New second-degree AV block (Mobitz type II)	4 (1.4)	1 (0.6)	0.658
New right bundle branch block	6 (2.1)	4 (2.5)	0.794
New left bundle branch block	31 (10.8)	21 (13.0)	0.492
New left anterior hemiblock	0 (0)	0 (0)	–
New third-degree AV block	30 (10.5)	28 (17.3)	0.038
PVR			
None	78 (26.1)	74 (45.3)	0.001
Trace	90 (31.8)	46 (28.6)	
Mild	90 (31.8)	35 (21.7)	
Mild to moderate	21 (7.4)	7 (4.3)	
Moderate	8 (2.8)	0 (0.0)	

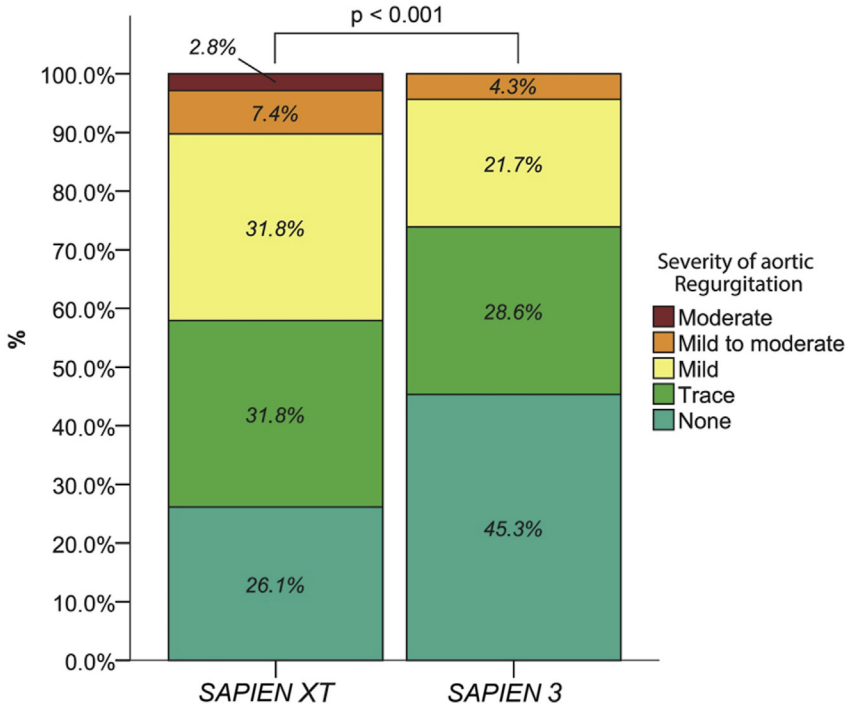
Values are n (%).
PPM = permanent pacemaker; PVR = paravalvular regurgitation; other abbreviations as in Table 1.

A significant reduction in PVR was observed in the S3 group compared with the XT group (Table 2, Figure 3). The percentage of patients with no PVR increased from 26.1% to 45.5%. The percentage of patients with mild to moderate PVR decreased from 7.4% to 4.3%. Although 2.8% of patients with XT valves had moderate PVR, none of the S3 patients had moderate or severe PVR.

The development of new AVCAs of any type was, however, significantly higher in the S3 group (39.0% vs. 28.9%; p = 0.022). The PPMIR was also significantly higher in the S3 group (19.1% vs. 12.2%; p = 0.049). The results of the propensity score analysis were consistent with the results of the unmatched analysis, confirming a significant difference in the PPMIR (12.6% in the XT group and 22.1% in the S3 group; p = 0.017). Table 2 shows the specific AVCAs that developed in both groups. Only the development of third-degree atrioventricular (AV) block was significantly more frequent in the S3 group. The indication for PPM implantation in those patients in whom new AVCAs developed was a Class I/IIa indication in 30 patients in the XT group (85.7% of all PM implantations in this group) and in 29 patients (93.5% of all PM implantations in this group) in the S3 group, with no significant differences between groups.

The characteristics of S3 patients with and without a need for PPM implantation are presented in Table 3. Patients who received a PPM after TAVR did not significantly differ from those without a need for a PPM with regard to age (83.9 ± 4.3 vs. 81.7 ± 6.4 years; p = 0.07), sex (35.5% vs. 38.2% male, p = 0.782), logistic EuroSCORE (18.4 ± 9.0 vs. 25.6 ± 12.5; p = 0.08), and aortic valve calcium score

FIGURE 3 Severity of Paravalvular Regurgitation in the SAPIEN 3 and SAPIEN XT Groups



(3,090 ± 1,577 in the S3 group vs. 3,199 ± 1,980 in the XT group; p = 0.77). Among pre-existing AVCAs, right bundle branch block was significantly more frequent in patients who eventually required a PPM after TAVR (16.1% vs. 3.1%; p < 0.014). Regarding procedural characteristics, the mean implantation height of the S3 was significantly lower in patients requiring a PPM (67%/33% vs. 72%/28% aortic/ventricular stent extension, p = 0.032 (Figure 4).

Mean area oversizing was 7.4 ± 11.1% in the S3 group. Undersizing was present in 42 patients (27.8%). MDCT area oversizing percentages of 0% to 10%, 10% to 20%, and >20% were present in 46 patients (28.4%), 46 (28.4%), and 17 (10.4%), respectively. Mean area oversizing was 6.6 ± 10.5% in those patients who did not require a PPM and 10.9 ± 12.9% in those patients who required PPM with no significant difference between groups (p = 0.06). MDCT area undersizing and oversizing percentages of <10%, 10-20%, and >20% were present in 37 patients (30.6%), 38 (31.4%), 34 (28.1%), and 12 (9.9%) in the cohort of patients who did not require a PPM and in 5 patients (16.7%), 8 (26.7%), 12 (40.0%), and 5 (16.7%) in the cohort of patients who required a PPM, with no significant differences between groups (p = 0.268).

On multivariate logistic regression analysis including the presence of a pre-existing right bundle branch block, implantation height, valve sizing, age, and sex, implantation height remained the only independent predictor of the need for PPM implantation (odds ratio: 0.95 [95% confidence interval: 0.91 to 0.99]; p = 0.025). By receiver-operating characteristic curve analysis, implantation heights of 73%/27% aortic/ventricular resulted as the best cutoff in terms of a reduction in the PPMIR for the S3 (sensitivity, 59%; specificity, 83%; area under the curve, 70.1%). The PPMIR in patients with implantation heights of 73%/27% aortic/ventricular or more (n = 77) was 6.5% compared with 32.9% in those with an implantation height <73%.

During the study period, a significant increase in implantation height of the S3 was observed over time (Figure 5) (r = 0.447; p < 0.001). However, the mean area oversizing did not change significantly over time (r = 0.11; p = 0.179).

In order to analyze the influence of this observed temporal trend of a progressively higher implantation of the valve on the PPMIR in the S3 group, we compared the first 50% of patients with the second 50%. The significant increase in the implantation height from 68%/32% to 75%/25% aortic/ventricular

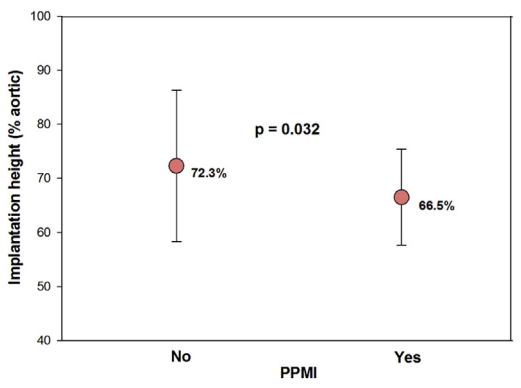
TABLE 3 Characteristics of Patients With and Without the Need for TAVR-Related Pacemaker Implantation

	No PPM Implantation (n = 131)	PPM Implantation (n = 31)	p Value
Age, yrs	81.7 ± 6.4	83.9 ± 4.3	0.070
Male	50 (38.2%)	11 (35.5%)	0.782
Logistic EuroSCORE I	25.6 ± 12.5	18.4 ± 9.0	0.078
Previous AVCA (any)	37 (28.2)	13 (41.9)	0.138
First-degree AV block	23 (17.6)	5 (16.1)	0.850
Second-degree AV block (Mobitz type I)	0 (0)	0 (0)	–
Right bundle branch block	4 (3.1)	5 (16.1)	0.014
Left bundle branch block	14 (10.7)	4 (12.9)	0.724
Left anterior hemiblock	3 (2.3)	1 (3.2)	0.576
Calcium score of the native aortic valve	3,090 ± 1,577	3,199 ± 1,980	0.772
Valve size (nominal diameter), mm			
23	57 (43.5)	16 (51.6)	0.299
26	53 (40.5)	8 (25.8)	
29	21 (16.0)	7 (22.6)	
Mean area oversizing, %	6.6 ± 10.5	10.9 ± 12.9	0.06
Area undersized (<0%)	37 (30.6)	5 (16.7)	0.268
Area oversizing 0–10%	38 (31.4)	8 (26.7)	
Area oversizing 10%–20%	34 (28.1)	12 (40.0)	
Area oversizing >20%	12 (9.9)	5 (16.7)	
Implantation height (% of stent length in the aorta)	72.3 ± 14.0	66.5 ± 8.9	0.032

Values are mean ± SD or n (%).
TAVR = transcatheter aortic valve replacement; other abbreviations as in Tables 1 and 2.

stent extension ($p < 0.0001$) was associated with a significant decrease in the PPMIR from 25.9% to 12.3% ($p = 0.028$) (Figure 6). The mean area oversizing did not significantly differ between the 2 groups (8.8 ± 10.4% in the first 50% of patients) and 6.1 ± 11.6% in the second 50% of patients ($p = 0.13$).

FIGURE 4 Mean Implantation Height of the Valve (% Aortic) in Those Patients Who Did Not (No) and Those Who Required (Yes) a Pacemaker



The **error bars** indicate the SD.

MDCT area undersizing and oversizing percentages of 0% to 10%, 10% to 20%, and >20% were present in 16 patients (21.3%), 22 (29.3%), 28 (37.3%), and 9 (12.0%) in the cohort of patients in the first period and in 26 (34.2%), 24 (31.6%), 18 (23.7%), and 8 (10.5%) in the cohort of patients who required a PPM, with no significant differences between groups ($p = 0.20$).

DISCUSSION

The present study highlights that the development of a new TAVR valve design intended to overcome limitations of the technique may indeed successfully reduce 1 complication but at the expense of increasing another one. Thus, careful clinical evaluation of each new valve generation is essential. The new generation of the balloon-expandable S3 has been suggested to successfully decrease the rate and degree of paravalvular leakage (14)—one major concern in TAVR—but the new valve design has apparently the potential to significantly increase the PPMIR required after TAVR. The present study confirms the marked reduction in PVR with the new stent design but highlights that this may indeed occur at the expense of a higher PPMIR. More importantly, the study demonstrates that a relatively "high" implantation of the S3 with little extent of the stent into the LVOT may reduce this risk and may keep the PPMIR in the same range as observed with the previous generation of the XT.

PVR has repeatedly been reported to be associated with a worse outcome after TAVR with regard to heart failure rate as well as survival (19). A successful reduction of PVR by an improved valve design raises hope to also improve outcome, although this still needs to be demonstrated.

How much concern is appropriate when such a decrease in PVR is reached at the expense of an increasing PPMIR? Again, solid data to answer this question are lacking. Although controversial data have been published on the impact of PPM implantation associated with TAVR (20,21), it is unlikely that PPM implantation does not adversely affect the long-term outcome in particular when moving away from very elderly high-risk surgical patients. A recent analysis of the PARTNER (Placement of AoRtic TraNscathetER Valves) trial and registry showed that PPMIR was indeed associated with a longer duration of hospitalization and higher rates of repeat hospitalization as well as the composite of mortality and repeat hospitalization at 1 year (15).

FIGURE 5 Pearson Correlation Analysis of Implantation Height and the Cumulative Number of Patients Treated With the SAPIEN 3 Valve

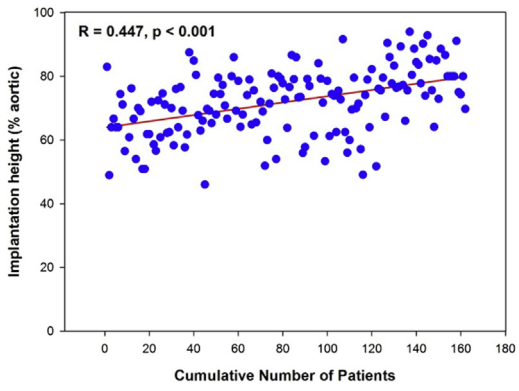
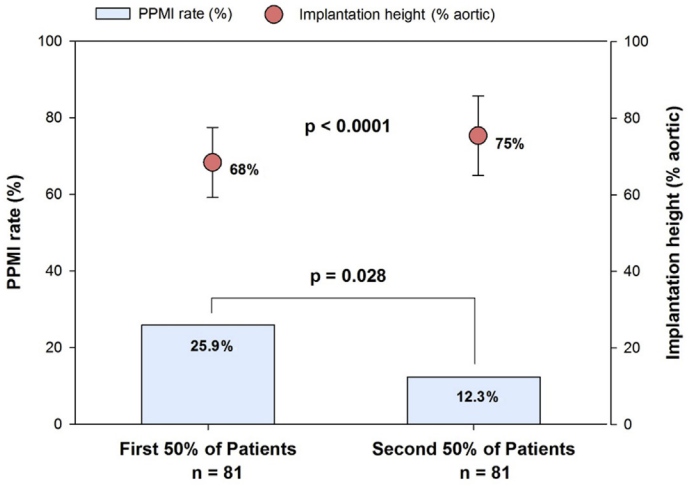


FIGURE 6 Permanent Pacemaker Implantation Rate and Mean Implantation Height in the First and Second 50% of SAPIEN 3 Implantations



The columns show the permanent pacemaker implantation (PPMI) rate in the SAPIEN 3 groups after dividing the cohort into the first 50% of patients and the second 50% of patients treated with SAPIEN 3. The mean implantation height of the valve (% aortic) ± SD in each group is shown.

To the best of our knowledge, our study is the first comparison of a large group of patients treated with the S3 and XT demonstrating a significant increase in AVCAs and a higher PPMIR with the S3 compared with the XT valve. The pivotal S3 trial (14) reported a PPMIR of 13.3%. Although this percentage is higher than the previously reported 6% for the XT (10), no comparison of valve generations is possible from this study nor were predictors of PPM implantation analyzed. Tarantini et al. (22) recently reported an increase in PPMIR with the S3 compared with the XT, but their study included only a very small group of 29 patients treated with the new-generation valve. Nevertheless, their results are similar. The PPMIR was similar to ours in both the S3 (20.7% vs. 19.1%) and XT (10.0% vs. 13.0%). In our study, the higher rate of AVCAs of any type observed in the S3 group (39.5% vs. 28.9% in the XT group) was primarily driven by the higher incidence of third-degree AV block. New-onset left bundle branch block was observed in 13% of patients in the S3 group, a lower rate than the 18% reported in the release study (14), and it was not associated with a higher PPMIR in the S3 group. However, the presence of a right bundle branch block before TAVR was associated with PPM implantation in the S3 group on univariate analysis (16.1% vs. 3.1%; p = 0.014), but this association was not significant on multivariate analysis. The degree of MDCT area oversizing by the valve could play a role in the development of conduction abnormalities after TAVR with the previous XT generation (23). However, in our study, the MDCT diameter oversizing was not related to the rate of PPMI in the S3 group, neither on univariate analysis nor after including it in the multivariate analysis.

Our study shows that a deeper position of the S3 in the LVOT is independently associated with a higher PPMIR after TAVR. This association may also explain the difference in PPMIR between the S3 and XT. The stent of the S3 is 3 to 4 mm longer than that of the XT and tends to reach deeper into the LVOT, particularly when implanted in a similar way as far as the intended relationship of aortic to ventricular stent length is concerned.

The association between implantation height and PMIR has been well described in studies of TAVR using the self-expandable CoreValve device (Medtronic Inc.) (12). Although the overall PPMIR was low, such an association was even reported in studies of the XT as well. Urena et al. (3) reported a deeper implantation height evaluated by transesophageal echocardiography to be associated with a higher rate of persistent left bundle branch block, which in turn determined higher risk of complete AV block and PPM implantation. Another study evaluating patients receiving either the XT or the self-expandable CoreValve also reported an independent association between the implantation height evaluated by callipered angiography with a higher rate of persistent left bundle branch block and AV block (4).

In their small group of 29 patients treated with the S3, Tarantini et al. (22) found a significantly lower implantation height in those patients requiring PPM implantation after TAVR. The maximum extension of the valve into the LVOT was 8.2 ± 2.0 mm in patients who required a PPM, and 76% of these had an implantation height of ≤60%/40% aortic/ventricular. Patients not requiring a PPM had a maximal stent extension of 5.0 ± 2.4 mm in the LVOT and an aortoventricular ratio <60/40% in 47.6%. From their results, the authors recommend keeping the stent length in the LVOT <8 mm to avoid development of AV block. This would result in an aortic percentage of the stent length >56%, >60%, and >64% for 29-, 26-, and 23-mm valves, respectively. From our results in a much larger study group, this position appears to be still too deep, and an aortic percentage approximately >70% should be intended. Originally, the company advised positioning the central marker of the valve within a few millimeters below and above the insertion points of the valve cusps. However, to avoid an implantation depth associated with an increased PMIR, a marker position slightly above the insertion points is required. Following this strategy, mean implantation height increased over time in our series. When dividing the cohort in the first and second 50% of patients, we observed a significant reduction in the PMIR in the second 50% of the patients in the S3 group, in which the mean implantation height was 75%/25% aortic/ventricular. In this group, the PMIR (12.3%) was similar to the PMIR in the XT group (12.2%) of our series. Thus, our study suggests that an optimization of the implantation technique intending a shorter extension of the stent into the LVOT significantly reduces the PMIR, reaching values similar to those found with the previous balloon-expandable valve generation.

STUDY LIMITATIONS. The study was nonrandomized, retrospective, and observational. However, baseline patient characteristics did not significantly differ between the XT and S3 groups, and the results were confirmed with a propensity score-matching analysis.

Calcium score was only analyzed in patients receiving the S3, and it does not provide information regarding the distribution of valve calcification, and therefore its influence on the rate of AVCAs, PPM implantation, and PVR in our study remains unknown. The reported PMIR in this study represents the in-hospital occurrence of PPM need. Patients were monitored for at least 7 days. The mean hospital stay after TAVR was 8 days. PPM implantations after discharge or after patient transfer were not systematically addressed. Thus, some cases of late development of AV block and late PPM implantation may have been missed, and the PPMIR underestimated.

CONCLUSIONS

In this study, the incidence of PPM implantation after TAVR was significantly higher with the S3 than with the XT, and it was independently associated with the implantation height of the valve. A progressive change in the implantation technique toward a higher implantation resulted in a significant reduction in the PPMIR. The results suggest that the initially observed increase in PPMIR with the S3 compared with the XT can apparently be eliminated by optimizing the implantation height of the valve, keeping the extension of the stent into the LVOT short. It appears advisable to aim at an aortic extension of >70% of the total length of the stent.

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PERSPECTIVES

WHAT IS KNOWN? The new stent design of a new generation of balloon-expandable valves has raised concerns with regard to a potential increase in procedure-related pacemaker requirement. Our results show that the S3 has the potential to markedly increase the pacemaker rate compared with the XT.

WHAT IS NEW? This pacemaker rate is strongly related to the implantation height of the stent, and a change in interventional strategy aiming at a high implantation resulting in an aortic extension of the stent >70% may bring the pacemaker rate back to the range previously observed with the XT.

WHAT IS NEXT? These results may have a major impact on the recommendations for how to implant the S3 in order to avoid unnecessarily high pacemaker rates with their negative impact on long-term outcome after this intervention.

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