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# Electrocardiographic and clinical predictors of permanent pacemaker insertion following Perceval sutureless aortic valve implantation

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ABSTRACT

*Background:* Sutureless aortic valve replacement surgery (AVR) is a reasonable alternative surgical approach in those patients with aortic stenosis who would benefit from reduced cross clamp time, such as elderly and high-risk patients. We sought to evaluate the incidence of pacemaker (PM) implantation following sutureless AVR and to analyse possible pre-operative electrocardiographic and clinical predictors of PM implantation.

*Methods and results:* Between November 2013 and March 2015, 58 patients (male 43%, age 77.9 ± 4.9 years) having undergone sutureless AVR with a Perceval prosthesis (Sorin Biomedica Cardio Srl, Saluggia, Italy) were taken into consideration for our analysis. During a mean follow up of 13.8 ± 5.0 months (median 13 months), 14 patients (24.1%) underwent pacemaker (PM) implantation following sutureless AVR procedure. Among these patients, 12 (86%) presented III degree atrioventricular (AV) block, 1 (7%) presented II degree AV block, and remaining one (7%) severe symptomatic bradycardia. The comparison of pre-operative characteristics between PM group and no PM group highlighted that QRS duration, EuroSCORE II index and chronic renal dysfunction were significantly associated with the development of AV conduction abnormalities/symptomatic bradycardia requiring PM implantation (respectively, $p = 0.01$, $p = 0.02$ and $p = 0.03$).

*Conclusions:* The incidence of PM implantation after sutureless AVR was 24.1% in the present study. The EuroSCORE II, QRS duration and renal dysfunction were significantly associated with higher risk of AV conduction abnormalities/symptomatic bradycardia requiring PM placement.



## Introduction

Aortic stenosis is a condition with significant mortality in the presence of symptoms, and requires mechanical intervention to reduce this risk. In the absence of intervention, this condition is associated with very high mortality rates with up to 75% of patients dying within 3 years of symptom onset [1]. Standard aortic valve replacement surgery (AVR) is the gold standard treatment for symptomatic aortic stenosis in elderly patients deemed suitable for this operation [2]. It is noted however, that many patients with severe aortic stenosis over the age of 75 are turned down for standard AVR, often on the basis of age and comorbidities [3,4]. It is because of these factors that techniques such as sutureless AVR and transcatheter aortic valve implantation (TAVI) have become increasingly used in patients deemed to be at high risk for standard AVR.

Whilst TAVI techniques clearly have their merits [5,6], there is a recognised risk for serious vascular complications [6], prosthetic valve regurgitation (PVR) [7], and stroke [8]. With regard to mortality, the median survival time post-TAVI is 3.4 years [9]. Sutureless AVR is considered in patients with aortic stenosis who would benefit from reduced cross clamp time, such as elderly and high-risk patients. It serves as an alternative surgical approach to standard surgical AVR and TAVI. There is some data to suggest that the use of a sutureless valve may reduce post-operative complications [10], and also has the potential for reducing complexity in those patients deemed at higher risk of intra-operative complications [11]. The purpose of this study was to evaluate the incidence of pacemaker (PM) implantation following sutureless aortic valve replacement using the Perceval S bioprosthesis (Sorin Biomedica Cardio Srl, Saluggia, Italy). In addition we sought to evaluate whether there were any pre-operative predictive indicators to identify those patients at higher risk of atrioventricular (AV) conduction

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abnormalities/symptomatic bradycardia requiring PM implantation using this surgical technique.

## Methods

Between November 2013 and March 2015, all consecutive patients having undergone sutureless AVR with a Perceval prosthesis (Sorin Biomedica Cardio Srl, Saluggia, Italy) were taken into consideration for our analysis. The Perceval sutureless aortic valve (Sorin Biomedica Cardio Srl, Saluggia, Italy) is a collapsible, stent-mounted aortic valve bioprosthesis that can be placed in a sutureless fashion with a conventional surgical technique. The valve is available in 4 sizes: small (21 mm), medium (23 mm), large (25 mm), and extra large (27 mm). An informed consent for the use of personal data and follow-up contact was also signed by all patients.

### *Surgical procedure*

In the study period, a total of 58 patients were operated on with (n = 26, 45%) or without associated coronary artery bypass grafting (CABG). One procedure was a redo AVR. In isolated AVR, a partial upper J-sternotomy or a right anterior hemithoracotomy was performed. The Perceval implantation technique has been described previously [10]. General anaesthesia with oro-tracheal intubation and standard cardiopulmonary bypass were used in all patients.

### *Data collection*

All baseline data were retrospectively collected and analysed. Electrocardiograms were analysed by two cardiologists blinded to clinical data. Heart rhythm, PR interval, QRS duration (QRSd), presence and degree of atrioventricular block, right bundle branch block (RBBB) and left bundle branch block (LBBB) were recorded. Briefly, the following electrocardiography (ECG) parameters were obtained: heart rate, junctional rhythm, paced rhythm, sinus rhythm, atrial fibrillation, LBBB, RBBB, PR interval, QRSd, QT interval, Tpeak-to-Tend (TpTe) interval, ST-segment abnormalities, evidence of prior myocardial infarction (pathological Q-waves) and negative T-waves. The QT intervals were adjusted for heart rate using Bazett correction and were evaluated in ECGs in which at least 6 leads were measurable. The TpTe interval was measured from Tpeak to Tend in the lead $V_5$; if $V_5$ was not suitable, lead $V_4$ first or $V_6$ was used [12]. This measurement was made using three consecutive QRS complexes and calculating the average.

In our population, the indication for PM implantation was established by an experienced cardiologist in the presence of atrioventricular conduction block or symptomatic severe sinus bradycardia and in case of brady-tachy syndrome if an adequate rate control could not be achieved using antiarrhythmic medication such as beta blockers, calcium channel blockers and digoxin.

The following patient characteristics and major preoperative risk factors were entered into the central database: age, gender, EuroSCORE II, height, weight, body surface area, hypertension, dyslipidemia, diabetes, ischaemic cardiomyopathy, left ventricular ejection fraction, left atrial diameter, interventricular septum thickness, peak and mean aortic valve gradient, aortic valve area, previous cerebrovascular accidents (transient ischaemic attack/stroke), chronic renal dysfunction (creatinine clearance <60 ml/min per 1.73 $m^2$ [13]), chronic obstructive pulmonary disease. The EuroSCORE II is a predictive model for 30-days operative mortality after cardiac operations in adults. This model provides a good clinical performance and a much better calibration correcting the well-known risk overestimation of the previous version [14].

The following surgical factors with a potential impact on conduction disorders were also recorded: associated procedures (e.g. CABG, catheter ablation, other valve surgery), valve size [27 mm (named as XL), 25 mm (or L), 23 mm (or M), 21 mm (or S)], conventional (4 atm) or reduced ballooning (2 atm), operators. The results were obtained mainly with the aim to search for any correlation with the rates of postoperative pacemaker implantation.

### *Statistical analysis*

Continuous variables were shown as mean ± standard deviation if data were normally distributed or as median (IQR) if data have non-normal distribution. Categorical variables were summarized as frequencies (%). Continuous variables were compared by the two-tailed paired *t*-test and categorical variables by the $\chi 2$ test.

Multivariate analysis was performed using a conditional logistic regression model including all the variables predictive of AV conduction disease/marked sinus bradycardia requiring PM implantation with a $p < 0.1$ on univariate analysis.

The EuroSCORE II was not included in the multivariate model being a scoring system already including lots of variables usually used to predict the operatory risk. A p value <0.05 was deemed statistically significant. Statistical analysis was performed using SPSS 20.0.0 (IBM Inc., Armonk, New York, USA).

## Results

### *Baseline characteristics*

During the study period a total amount of 58 consecutive patients (male 43%, age 77.9 ± 4.9 years) with severe aortic stenosis having undergone a sutureless AVR procedure were included. Twenty-eight patients (48%) underwent an isolated AVR procedure; in the rest of study population AVR was performed in combination with coronary artery bypass graft (CABG) in 26 patients (45%), surgical pulmonary vein isolation in 2 (3%), tricuspidal valve replacement (TVR) in 1 (2%) and both TVR and mitral valve replacement (MVR) in 1 (2%). The mean hospital stay was 17.4 ± 19.9 days (median 12 days) and the mean intensive care unit stay was 4.6 ± 3.2 days (median 4 days).

Baseline characteristics are listed in Table 1.

### *Pacemaker implantation*

During a mean follow up of 13.8 ± 5.0 months (median 13 months), 14 patients (24.1%) underwent dual-chamber pacemaker (PM) implantation after the sutureless AVR procedure. Among these patients, 12 (86%) presented III degree AV block, 1 (7%) presented II degree AV block with pauses >3 s, and remaining one (7%) severe symptomatic sinus bradycardia (Table 2). The mean time to PM implantation was 5.4 ± 3.6 days (median 5 days). Ten out of 14 (71%) were found completely PM-dependent after the PM implantation. The Table 1 also shows the most significant demographic, procedural and clinical characteristics of those patients having undergone postoperative PM implantation.

### *Valve size and operators*

The bioprosthetic aortic valves were small in 9 patients (16%), medium in 22 (38%), large in 20 (34%) and extralarge in 7 (12%) (Table 3). The proportion of the aortic prosthesis sizes did not differ between "PM group" and "no PM group". The risk of pacemaker implantation was not also related to the surgeon who had performed the procedure (Table 3). All the procedures were performed by 2 surgeons. The operator 1 performed 38 procedures (66%) and the operator 2 performed the remaining 20 (34%). Among 38 procedures performed by the operator 1, 11 (29%) were followed by the PM implantation compared with 3 out of 20 (15%) performed by the operator 2 ($p = 0.2$).

**Table 1**
Baseline characteristics and comparison between the 2 groups in terms of clinical, ECG and echocardiographic features.

| | Whole group (N = 58) | No PM group (N = 44) | PM group (N = 14) | p value |
|---|---|---|---|---|
| Age (years) | 77.9 ± 4.9 | 78.1 ± 5.2 | 77.5 ± 4.0 | 0.7 |
| Male gender | 25 (43) | 17 (39) | 8 (57) | 0.3 |
| Body mass index (kg/m$^2$) | 28.9 ± 4.4 | 28.3 ± 4.5 | 30.8 ± 3.9 | 0.07 |
| Hypertension | 43 (74) | 31 (70) | 12 (86) | 0.5 |
| Diabetes | 22 (38) | 15 (34) | 7 (50) | 0.4 |
| Dyslipidemia | 37 (64) | 29 (66) | 8 (57) | 0.5 |
| Chronic obstructive pulmonary disease | 7 (12) | 5 (11) | 2 (14) | 0.9 |
| Coronary artery disease | 30 (52) | 23 (52) | 7 (50) | 0.5 |
| Previous cerebrovascular disease | 9 (16) | 5 (11) | 4 (29) | 0.2 |
| Chronic renal dysfunction | 13 (22) | 7 (16) | 6 (43) | 0.03 |
| EuroSCORE II (%) | 3.9 ± 4.5 | 3.1 ± 4.1 | 6.3 ± 5.1 | 0.02 |
| ECG rhythm | | | | |
| - sinus rhythm | 52 (89) | 40 (91) | 12 (86) | 0.7 |
| - atrial fibrillation | 5 (9) | 3 (7) | 2 (14) | |
| • paroxysmal | 2 (40) | 0 | 2 | |
| • persistent | 3 (60) | 3 | 0 | |
| - ectopic atrial rhythm | 1(2) | 1(2) | 0 (0) | |
| PR interval (ms) | 181.7 ± 31.2 | 183.0 ± 33.2 | 177.7 ± 25.4 | 0.6 |
| QRS duration (ms) | 102.9 ± 23.2 | 98.8 ± 21.4 | 115.9 ± 24.6 | 0.01 |
| Heart rate (bpm) | 71.8 ± 13.7 | 72.6 ± 12.8 | 69.6 ± 16.3 | 0.5 |
| QTc interval (ms) | 437.6 ± 27.5 | 437.1 ± 23.6 | 439.1 ± 37.9 | 0.8 |
| TpTe max (ms) | 87.9 ± 12.6 | 86.3 ± 11.0 | 92.9 ± 16.0 | 0.1 |
| Right bundle branch block | 9 (16) | 5 (11) | 4 (29) | 0.2 |
| Left bundle branch block | 12 (21) | 8 (18) | 4 (29) | 0.5 |
| Left atrial diameter (mm) | 42.7 ± 8.2 | 42.9 ± 8.9 | 42.2 ± 5.4 | 0.8 |
| Interventricular septum thickness (mm) | 13.9 ± 9.5 | 14.4 ± 10.8 | 12.3 ± 3.2 | 0.5 |
| Left ventricular ejection fraction (%) | 56.6 ± 8.4 | 57.0 ± 8.1 | 55.4 ± 9.5 | 0.5 |
| Peak aortic valve gradient (mmHg) | 73.8 ± 25.4 | 73.6 ± 24.9 | 74.4 ± 27.6 | 0.9 |
| Mean aortic valve gradient (mmHg) | 44.0 ± 16.2 | 44.5 ± 16.5 | 42.6 ± 16.1 | 0.7 |
| Aortic valve area (cmq) | 0.69 ± 0.20 | 0.72 ± 0.30 | 0.59 ± 0.15 | 0.1 |

Categorical variables are expressed as absolute and percentage (in brackets). Continuous variables are expressed as mean ± SD if data were normally distributed. PM: pacemaker. ECG: electrocardiogram. TpTe max: the maximum value of Tpeak-to-Tend (interval between the peak and the end of T wave) [12].

**Table 3**
Comparison between the 2 groups in terms of valve size, type of procedure and operator.

| | Whole group (N = 58) | No PM group (N = 44) | PM group (N = 14) | p value |
|---|---|---|---|---|
| Prosthetic valve size | | | | |
| - small | 9 (16) | 7 (16) | 2 (14) | 0.67 |
| - medium | 22 (38) | 18 (41) | 4 (29) | |
| - large | 20 (34) | 15 (34) | 5 (36) | |
| - extralarge | 7 (12) | 4 (9) | 3 (21) | |
| Type of procedure | | | | |
| - isolated AVR | 28 (48) | 23 (52) | 5 (36) | 0.36 |
| - AVR and CABG | 26 (45) | 18 (41) | 8 (57) | |
| - AVR and PVI | 2 (3) | 2 (5) | 0 (0) | |
| - AVR and TVR | 1 (2) | 1 (2) | 0 (0) | |
| - AVR, TVR and MVR | 1 (2) | 0 (0) | 1 (7) | |
| Surgeons | | | | |
| - Operator 1 | 38 (66) | 27 (64) | 11 (69) | 0.52 |
| - Operator 2 | 20 (34) | 17 (36) | 3 (31) | |

Categorical variables are expressed as absolute and percentage (in brackets). PM: pacemaker. AVR: aortic valve replacement. CABG: coronary artery bypass graft. PVI: pulmonary vein isolation. TVR: tricuspid valve replacement. MVR: mitral valve replacement. NS: nonsignificant.

*Echocardiographic findings*

Left ventricular ejection fraction, interventricular septum thickness and left atrial diameter are listed in Table 1. No echocardiographic parameters were associated with increased risk of post-operatory pacemaker implantation (Table 1). Mean values of baseline transaortic peak and mean gradients were 73.8 ± 25.4 mmHg and 44.0 ± 16.2 mmHg, respectively; after the procedure, transaortic peak and mean gradients significantly decreased to 22.1 ± 8.7 mmHg and 11.8 ± 4.8 mmHg, respectively (both $p < 0.0001$). Aortic valve area (AVA) also significantly increased after the sutureless AVR from 0.69 ± 0.27 cm$^2$ to 1.39 ± 0.55 cm$^2$ ($p < 0.0001$). Fourteen patients (24%) presented postoperative paravalvular leak: among them 12 (86%) were mild and 2 (14%) moderate.

*Predictors of pacemaker implantation*

The comparison of pre-operative characteristics between PM group and no PM group highlighted that QRSd, EuroSCORE II index and chronic renal dysfunction were significantly associated with post-operative PM implantation (respectively, $p = 0.01$, $p = 0.02$ and $p =$

**Table 2**
Characteristics of patients having undergone post-operatory pacemaker implantation.

| Patients | age | gender | BMI (kg/m$^2$) | Procedure | Valve size | PM indications | Time to implant (days) | Septum thickness (mm) | QRS duration (ms) | Bundle branch block (LBBB or RBBB) | Euro-SCORE II (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No.1 | 82 | M | 29.7 | AVR + CABG | XL | III degree AVB | 3 | 12.2 | 156 | RBBB | 18.8 |
| No.2 | 73 | M | 19.6 | AVR + CABG | L | III degree AVB | 9 | 19.4 | 98 | Absent | 12.3 |
| No.3 | 81 | M | 29.7 | AVR + CABG | L | III degree AVB | 7 | 9.3 | 148 | RBBB | 7.7 |
| No.4 | 71 | F | 33.2 | AVR | S | III degree AVB | 1 | 9.7 | 144 | LBBB | 3.7 |
| No.5 | 75 | F | 29.0 | AVR | M | III degree AVB | 3 | 10.4 | 138 | LBBB | 2.5 |
| No.6 | 76 | M | 32.0 | AVR | M | III degree AVB | 4 | 9.9 | 92 | absent | 3.2 |
| No.7 | 84 | F | 31.6 | AVR + CABG | M | III degree AVB | 8 | 11.8 | 86 | Absent | 3.2 |
| No.8 | 73 | F | 37.8 | AVR + CABG | M | II degree AVB type 2 & pauses >3 s | 11 | 12.5 | 104 | Incomplete RBBB | 2.4 |
| No.9 | 82 | M | 26.6 | AVR + CABG | XL | III degree AVB | 3 | 10.2 | 102 | Absent | 6.2 |
| No.10 | 78 | M | 35.9 | AVR | L | III degree AVB | 9 | 12.5 | 104 | Absent | 13.9 |
| No.11 | 76 | M | 35.6 | AVR + MVR + TVR | L | Severe sinus bradycardia (<40 bpm) | 10 | 11.7 | 102 | Incomplete LBBB | 3.5 |
| No.12 | 76 | M | 27.8 | AVR + CABG | XL | III degree AVB | 6 | 18.6 | 142 | RBBB | 3.5 |
| No.13 | 81 | F | 30.7 | AVR | L | III degree AVB | 1 | 11.5 | 118 | Incomplete LBBB | 3.7 |
| No.14 | 77 | F | 26.9 | AVR | S | III degree AVB | 1 | 10 | 88 | Absent | 3.1 |

Categorical variables are expressed as absolute and percentage (in brackets). BMI: body mass index. CT: computed tomography. PM: pacemaker. LVEF: left ventricular ejection fraction. Gender, M: male, F: female. Procedure, AVR: aortic valve replacement; MVR: mitral valve replacement; TVR: tricuspidal valve replacement. CABG: coronary artery bypass graft. AVB: atrio-ventricular block. Valve size, XL: extralarge, L: large, M: medium, S: small. Postoperatory CT pattern, R/O: round/oval, F: flattened, I: inverted. NA: not available.

**Table 4**
Univariate and multivariate logistic regression analysis for the risk of pacemaker implantation after the procedure.

| | Univariate analysis | | | Multivariate analysis | | |
|---|---|---|---|---|---|---|
| | OR | 95%CI | p value | OR | 95%CI | p value |
| Male gender | 2.11 | 0.62–7.17 | 0.2 | | | |
| Age (years) | 0.98 | 0.86–1.10 | 0.7 | | | |
| Body mass index (kg/m$^2$) | 1.14 | 0.99–1.31 | 0.07 | 1.18 | 0.99–1.40 | 0.06 |
| PR interval (ms) | 0.99 | 0.98–1.01 | 0.6 | | | |
| QRS duration (ms) | 1.03 | 1.01–1.06 | 0.02 | 1.04 | 1.01–1.08 | 0.009 |
| Heart rate (bpm) | 0.98 | 0.94–1.03 | 0.5 | | | |
| QTc interval (ms) | 1.00 | 0.98–1.02 | 0.8 | | | |
| TpTe max (ms) | 1.04 | 0.99–1.09 | 0.1 | | | |
| Right bundle branch block | 3.04 | 0.69–13.46 | 0.1 | | | |
| Left bundle branch block | 1.75 | 0.44–7.03 | 0.4 | | | |
| Hypertension | 2.32 | 0.45–11.95 | 0.3 | | | |
| Dyslipidemia | 0.64 | 0.19–2.21 | 0.5 | | | |
| Diabetes mellitus | 1.87 | 0.55–6.33 | 0.3 | | | |
| Coronary artery disease | 0.87 | 0.26–2.91 | 0.8 | | | |
| Previous cerebrovascular disease | 3.04 | 0.69–13.46 | 0.1 | | | |
| Chronic renal dysfunction | 5.14 | 1.37–19.33 | 0.01 | 11.10 | 2.04–60.46 | 0.005 |
| LVEF (%) | 0.98 | 0.91–1.05 | 0.5 | | | |
| Left atrial diameter (mm) | 0.99 | 0.92–1.06 | 0.8 | | | |
| Septal thickness (mm) | 0.92 | 0.72–1.17 | 0.5 | | | |
| EuroSCORE II | 1.15 | 1.01–1.31 | 0.04 | | | |

AF: atrial fibrillation. BMI: body mass index. LA: left atrium. CAD: coronary artery disease. BP: blanking period. HR: hazard ratio. CI: confidence intervals. TpTe max: the maximum value of Tpeak-to-Tend (interval between the peak and the end of T wave). LVEF: left ventricular ejection fraction.

0.03) (Table 1). The remaining demographic, clinical, procedural and echocardiographic parameters were not significantly related to PM implantation (Table 1). Combined procedures (CABG, TVR, MVR) were not associated with increased risk of AV conduction disease requiring PM implantation; even the single types of CABG did not present a correlation with higher rate of conduction disease and PM implantation.

As the Table 4 shows, univariate analysis confirmed these findings. Of note, the multivariate model including QRSd, chronic renal dysfunction and body mass index showed that both QRSd and chronic renal dysfunction remained strongly associated with increased risk of postoperative PM implantation (OR 1.04, 95%CI 1.01–1.08, p = 0.009 and OR 11.10, 95%CI 2.04–60.46, p = 0.005, respectively). Therefore, each 10 ms increase in QRSd was found to increase 10.4 times more the likelihood of PM implantation; also presence of a baseline chronic renal dysfunction was also found to increase 11.1 times more the likelihood of PM implantation. Of note, each 1-point increase in the EuroSCORE II scoring system was found to increase by 15% the likelihood of a postoperative PM implantation.

### *Other complications*

Three post-operatory deaths (5.2%) occurred in the study population: a patient having undergone isolated AVR procedure died after 3 days because of cardiogenic shock and cardiac arrest; another one having undergone combined AVR + CABG died from cardiogenic shock 6 days post-procedure; the third death occurred 8 days post-procedure due to acute respiratory sepsis caused by Klebsiella pneumonia leading to respiratory insufficiency. Other peri-procedural and post-procedural complications were: 2 (3.4%) bacterial pneumonia successfully treated with antibiotical therapy; 2 (3.4%) significant pleural effusions requiring drainage with thoracentesis (respectively 1300 and 750 ml of hemorragic fluids drained) with a good resolution; 1 (1.7%) acute renal failure in a patient with pre-existing chronic kidney disease, with a prompt resolution and a favorable outcome.

## Discussion

With the availability of alternative interventional techniques in severe aortic stenosis, patient selection is of paramount importance with respect to the intervention chosen. To achieve the best outcome for an individual patient with severe aortic stenosis, a tailored approach regarding choice of treatment must be made, taking into account comorbidities, demographic factors and the pre-operative assessment.

Of the data that is currently available regarding sutureless AVR, the incidence of permanent pacemaker (PM) implantation is nearly 4 times higher than standard AVR, with rates of PM implantation with standard AVR being described as 4.1% in a study by Erdogan et al. [15], and 8.5% in a study by Dawkins et al. [16]. The published rates of pacemaker implantation post-TAVI range from 6% to 34% [17–23]. In a Canadian multicentre cohort study of 215 patients, the rate of PM implantation with the Perceval S bioprosthesis (Sorin Biomedica Cardio Srl, Saluggia, Italy) was 17% [24]. A meta analysis examining differences in short-term outcomes between sutureless and conventional aortic valve prostheses found a significantly higher rate of PM implantation with sutureless valves (9.1% vs 2.4%; p = 0.025) [25].

Our study revealed a high percentage of PM insertions following sutureless AVR at our centre at 24.14% of 58 patients. It is noted that this population is an elderly cohort with a mean age of 77.9 ± 4.9 years, and that of the 14 patients who underwent PM implant, 8 (57%) had a concomitant procedure.

The Cavalier Trial is the largest trial to date examining outcomes of patients' receiving the Perceval sutureless valve. It is a prospective multicentre study of 658 patients, and the rate of PM implantation in this population was 11.6% [26].

A recent study by Vogt et al. looked specifically at the incidence and predictors of permanent pacemaker insertion in 258 patients undergoing sutureless AVR using the Perceval bioprosthesis [27]. The incidence was found to be 10.5% (27 patients), and RBBB was found to be an independent pre-operative predictor of PM insertion (p < 0.001), and there was a trend towards QRSd even though this variable was not a predictor of PM insertion (p = 0.06).

In the present study we found QRSd to be a significant predictor of PM insertion, as was chronic renal failure, with p values of 0.009 and 0.005 respectively by univariate analysis. In contrast to the study by Vogt et al., we did not find RBBB to be a significant predictor of PM insertion, nor did we find a significant association with age. This might be explained by our relatively small sample size.

Of note, there was some similarity with our findings regarding QRSd.

We used the EuroSCORE II scoring system, which we found had a significant correlation in predicting post-operative PM insertion. Indeed, each 1-point increase in the EuroSCORE II scoring system was found to increase by 15% the likelihood of a postoperative PM implantation. Of note, the study by Vogt et al. and the Cavalier Trial both used the original EuroSCORE scoring system, which has been superseded by the EuroSCORE II scoring system since 2011. The former trial did not find any association between the EuroSCORE log and post-operative PM insertion.

With regards to our finding of increased PM insertions in those patients with chronic renal disease, as this condition has a strong association with advanced vascular calcification, it is possible that the decalcification of the aortic annulus may be more limited in these patients. This in turn, may lead to a stiffer, less-compliant aortic root, requiring higher deployment pressures, and potentially compromising the underlying conduction tissue.

## Limitations

The most important limitation of this study is related to its observational design. In addition, as all data have been collected in a single centre, the results should not be generalized. The relatively small number of patients may also represent another limitation of our study.

## Conclusions

In conclusion, the incidence of PM implantation after sutureless AVR was 24.1% in the present study.

Interestingly, the EuroSCORE II, a chronic kidney dysfunction and QRSd were significantly associated with AV conduction abnormalities and symptomatic bradycardia requiring PM insertion post-Perceval sutureless AVR.

## Declaration Competing of Interest

None.

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