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THIRUVANANTHAPURAM, KERALA, INDIA-695011



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DR ALI SHAFEEQ

MBBS, MD, DM

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**DEPARTMENT OF CARDIOLOGY
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND
TECHNOLOGY
THIRUVANANTHAPURAM, KERALA, INDIA - 695011**



DEPARTMENT OF CARDIOLOGY, SCTIMST, TRIVANDRUM

DECLARATION BY CANDIDATE

I, **Dr. Ali Shafeeq**, hereby declare that the project in this book, titled “**Retrospective Study of Patients Undergoing Permanent Pacemaker Implantation at Index Admission for Surgical Aortic Valve Replacement**” was undertaken by me under the supervision of the faculty, Department of Cardiology, Sree Chitra Tirunal Institute for Medical Sciences and Technology



Dr. Ali Shafeeq

PDF (Cardiac Electrophysiology)

Forwarded



Dr. Krishnamoorthy K.M.

Professor and Head,
Department of Cardiology
SCTIMST,



Dr. Narayanan Namboodiri K.K.

Professor and Program Coordinator,
Department of Cardiology
SCTIMST, Thiruvananthapuram

**RETROSPECTIVE STUDY OF PATIENTS UNDERGOING PERMANENT
PACEMAKER IMPLANTATION AT INDEX ADMISSION FOR SURGICAL
AORTIC VALVE REPLACEMENT**

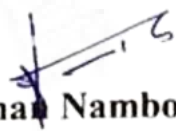
Primary Investigator (PI):



Dr. Ali Shafeeq

PDF, Department of Cardiology
SCTIMST, Thiruvananthapuram

Co-Primary Investigator (Co-PI):



Dr. Narayanan Namboodiri K.K.

Professor, Department of Cardiology
SCTIMST, Thiruvananthapuram

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INTRODUCTION

Calcific aortic valve is a progressive condition and its prevalence increases to 9.8% at 80 - 90 years of age. The only possible treatment for aortic stenosis is either surgical aortic valve replacement in the past or transcatheter aortic valve replacement which has emerged as an alternative treatment option in the recent years. The occurrence of conduction disturbances after surgical valve replacement is not uncommon. It is an important event as patients may have to undergo permanent pacemaker implantation with added risks of long term pacing of right ventricle in addition to prolonged hospital stay and costs. Aortic valve disease itself is accompanied by conduction disturbances and surgical valve replacement can worsen these conditions resulting in PPI. Previously published studies have shown pre-operative and operative risk factors resulting in PPI after SAVR.

The aim of this study is to assess clinical ECG, echocardiography and surgical variables that can predict PPI after SVAR during index hospitalization.

REVIEW OF LITERATURE

Calcific aortic stenosis is the most common valvular heart disease which progress from sclerosis to chronic inflammation and finally severe stenosis. It affects 0.2% of people at 50 to 59 years of age and increases to 9.8% of people at 80-89 years of age^{1,2}. The initiation and progression of calcific aortic valve disease occurs in two distinct phases. In the first phase, there is deposition of lipid accompanied by injury and inflammation and in the propagation phase, VICs (valvular interstitial cells) assume an osteoblastic phenotype resulting in osteogenic differentiation and calcification with similarities to skeletal bone formation³. This results in calcific deposits in the tricuspid aortic valve whereas BAV have more than twice the incidence of osteogenic calcification. However, dystrophic calcification accounts for majority of the cases ⁴.

Finally, the cusps of the valve progressively thickens and calcifies leading to restriction of the valve resulting in obstruction of the valve. The increase in after load on the ventricle leads to hypertrophy of the left ventricle which results in normalizing of the LV wall tension and maintains cardiac output. However, as the disease progresses there is decompensation of the LV resulting in symptoms, heart failure and death, if left untreated. There is mortality of 50% when symptoms develop in patients with severe aortic stenosis⁵.

The main causes for aortic stenosis are congenital, degenerative and rheumatic. Patients with BAV with a prevalence of 0.5 to 2 % in the general population, develops valve stenosis early in life in contrast to those patients with tricuspid aortic valves. These patients also have more severe calcification due to the higher mechanical stress on the valve cusps⁶.

To this day, no preventive or therapeutic medical treatment has been found for calcific aortic valve stenosis and the only possible treatment has been either surgical valve replacement or transcatheter valve replacement. This treatment is based on the seminal natural history study done on a group of relatively younger patients almost 50 years ago and validated by more recent study^{7,8}. If intervention is done at indicated times for valve replacement, this returns the mortality curve to that of normal population⁹. However, there are still periprocedural risks including development of left bundle branch block, acute kidney injury, stroke, bleeding complications and death that need to be taken into consideration when planning aortic valve replacement. The Society of Thoracic Surgeons and German Aortic Valve Registry reports, less than 3% for the overall 30 day mortality in isolated aortic valve replacement¹⁰.

A high incidence of conduction disturbances occurs following surgical valve replacement. This is mainly because of the close anatomical relationship between the aortic valve and important structures of the conduction system of the heart. The left bundle is positioned superficially on the crest of interventricular septum and is closely related to the base of the interleaflet triangle separating the right coronary cusps and non-coronary cusps of the aortic valve. This close anatomical relationship also results in deposition of calcium on the conduction system resulting in occurrence of LBBB and atrioventricular block in patients with aortic valve stenosis¹¹. Prolonged HV conduction has been shown on electrophysiological assessment of conduction system disease in aortic valve stenosis¹². The morphological lesions in the conduction system of patients who died within 30 days of surgical aortic valve replacement has been examined in a histological study¹³. It has shown three types. First, old lesions consistent with chronic degeneration and fibrosis. Second, hemorrhagic lesions resulting from perioperative non-trauma and third, recent non-traumatic lesions. The most common traumatic lesion

was laceration of conduction system fibers by sutures taken to seat the prosthetic valve in the annulus. The other lesions were caused by pressure on the conduction system by calcification and by seating of the prosthetic valve on the native annulus. High rates of conduction systems diseases in a population undergoing sutureless valve supports the above notion. In a study that was conducted in patients undergoing sutureless aortic valve replacement, 9% developed complete heart block and 17% required postprocedural permanent pacemaker implantation¹⁴. It follows from this data that patients who develop conduction disturbances after SAVR is less likely to recover and becomes permanent as the most common damage is traumatic injury during the surgery. Other cases may have transient damage and are like to recover. This is because of the transient nature of the conduction disturbances as these may be caused by resultant edema from operative trauma.

Aortic valve disease itself is accompanied by conduction disturbances which includes high rate of bundle branch blocks and atrioventricular blocks. Surgical aortic valve replacement results in worsening of these disturbances and PPI need to be done in order to prevent sudden death¹⁵.

The requirement for pacemaker implantation is as low as 0.7% in CABG whereas this rises to 5 to 6 % after valve surgery and is even more in redo valve procedures, that is an incidence of 10%¹⁶

The prevalence of permanent pacemaker implantation after surgical aortic valve replacement has been 3 to 6% and has been varying by the decade^{16,17}. The risk of permanent pacemaker implantation after SAVR varies from 2.4 to 8.9%^{18,19}. These incidences not only increase the hospital stay incurring additional costs but also

increases related pacemaker procedure related complications and pacemaker induced cardiomyopathy which leads to adverse outcomes²⁰.

Baseline conduction disturbances are reported to be a risk factor for new pacemaker implantation after surgical aortic valve replacement²¹. In another study, baseline conduction system disease was seen in 16% of the population of patients with aortic valve disease and following SAVR this number increased to 44 %²². Similar results were seen in another study emphasizing that PPI as an additional procedure of SAVR in those patients with baseline conduction system disorders, advanced age, and those with valve size more than 24mm²³. Those patients who had undergone PPI after valve surgery have second degree or third degree AV Block as the main indication. Second degree AV Block occurred in 12.4 to 44% while third degree AV block was seen in 42.3 to 87.5% of patients who had valve surgery^{24,25,26}.

The surgical suturing technique also increases risk for the development of CHB post SAVR by pressure on the conduction system by valve ring and residual calcific material. It has been shown in a study that continuous rather than interrupted sutures increases risk for PPI following SAVR²⁷. A study on new onset AVB requiring PPI after sutureless AVR has shown that the incidence was decreased by 61%. The reasons were more careful symmetrical and thorough decalcification and more intrannular valve positioning reducing compression on the subannular structures and preserving the conduction system.

Longer bypass time and aortic cross clamp time can result in ischemic damage and conduction system disturbances post operatively^{29,30}. In a series of patients undergoing isolated AVR, CPBT > 110min and ACT >70min were shown to be independent risk factors for PPI. Similar results have been shown in another study³¹.

The timing for pacemaker implantation after SAVR has been recommended as not more than seven days if the postoperative block does not resolve in 48 hours³². Another study has proposed early implantation of pacemaker, if the postoperative block persists for more than 48 hours³³. It has been recommended early implantation by fifth day postoperatively, if the patient is dependent on pacemaker or if spontaneous rhythm does not recover in high risk patients like those with conduction disturbances prior to surgery and those undergoing AVR. The proposed range is no more than one week, aside from cases where physicians may delay implantation due to fluctuating conduction disorders, questionable indications and active infections.

In a cohort of patients who were followed up, more than 30 % patients were pacemaker independent after 6 months of follow up. Further, at 12 year follow up, additional 8% of patients were independent from pacemaker activity³⁴. This suggests that the recovery occurs mostly in the first 6 months rather than the following years. In this series of the patients, PPI occurred in the first month in almost 50% of patients. In this study predictors of pacemaker dependency was CABG and AVR³⁵. The prevalence of pacing dependency varies in the literature between 2 to 63%^{36,37}. The definition of pacemaker dependency in literature is highly variable and difficult to evaluate. It is generally accepted that pacemaker dependency is the absence of intrinsic heart rhythm, potentially resulting in bradyarrhythmia related symptoms. Third degree AVB is generally considered as leading to pacemaker dependency whereas SSS and AF causes intermittent dependency. Several preoperative (LBBB, endocarditis, PV dysfunction), perioperative (duration of bypass time) and post-operative (persistent of CHB) predictors of long term dependency has been identified. However, there is less agreement in the studies^{38,39}.

AIMS AND OBJECTIVES

Hypothesis:

Preoperative clinical characteristics, ECG, Echo and surgical variables can predict PPI in patients undergoing aortic valve replacement during index hospitalization.

Aim:

To evaluate the predictors of PPI after surgical aortic valve replacement during index hospitalization.

Objective:

To compare clinical characteristics, ECG, Echo and surgical variables between patients who have undergone PPI and those without PPI, after surgical aortic valve replacement.

MATERIALS AND METHODS

Study Center

The study was conducted at Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram.

Study Design

Retrospective observational study.

Study Period

January 2004 to December 2020.

Study Population

All patients who had undergone permanent pacemaker implantation at index admission for aortic valve replacement was included in the study.

Samples Size

The aim was to enroll 200 patients, 100 from case and 100 from control cohort. However, only 50 cases could be collected due to missing data. Therefore 50 cases were included in control cohort.

Inclusion Criteria

All patients who had undergone surgical aortic valve replacement followed by permanent pacemaker implantation at index admission.

Exclusion Criteria

1. Patients who had undergone permanent pacemaker implantation prior to surgical aortic valve replacement.
2. Patients who had redo aortic valve replacement surgery.
3. Patients who had infective endocarditis.

ETHICAL CONSIDERATIONS AND INFORMED CONSENT

This is a retrospective study involving medical records only. Therefore patient consent was waived by Institutional Ethics Committee.

CONFLICT OF INTEREST

None

FINANCIAL SUPPORT

None

METHODOLOGY

A retrospective analysis of all the patients who had undergone surgical aortic valve replacement and subsequently permanent pacemaker implantation during same hospitalization at the institution between Jan 2004 to Dec 2020 were included in the study. The data was collected from medical records including patient files, surgical notes and pacemaker interrogation records. Patients who had other valve surgery, second or third degree atrioventricular block, infective endocarditis and redo valve procedure were excluded from the study. Baseline demographic, electrocardiogram and echocardiogram data were obtained from patients medical records. All ECG data were obtained based on the ECG done 24 hours prior to admission for the surgery. Similarly, data for the echocardiogram was also obtained from the echo done prior to the surgery. Operative variables were gathered from surgical notes of the respective patients. All patients had aortic valve replacement performed by midline sternotomy using standard surgical techniques. Temporary epicardial pacemaker was inserted in all patients at the end of the surgery. Patients' heart rhythm out of operation theatre was noted from the twelve lead ECG recorded in the postoperative CCU. Indication for pacemaker and

permanent pacemaker implantation procedure details were collected from pacemaker implantation notes. Rhythm of the patient and percentage of RV paced beats at one year follow up was determined from the electronic records of the 12 lead ECG and pacemaker interrogation notes recorded at the time of follow up in pacemaker clinic.

STATISTICAL ANALYSIS

The data was analyzed by using R version 4.1.2 statistical software. Continuous variables were presented as mean $\pm$ standard deviation or median. Categorical variables were presented as absolute numbers or percentages. Chi-Square test of independence was used for comparison of categorical variables and for quantitative variables Wilcoxon rank sum test with continuity correction was used. Differences were considered statistically significant at p values less than 0.05. The predictors for PPI during index admission for AVR was examined by bivariable and multivariable analyses. Logistic regression analysis was used to generate a multivariate model including all potential predictors of PPI at index admission for AVR.

RESULTS

A total of 50 patients were identified for the study group consisting of those patients who had undergone permanent pacemaker implantation following surgical aortic valve replacement during the index hospitalization. A total of 3 patients who had undergone permanent pacemaker implantation prior to SAVR, two redo-AVR and another infective endocarditis patient were excluded from the study.

The clinical profile of these patients are shown in **Table 1 and 2**.

Table 1: Characteristics of Patient Undergoing PPI at index hospitalization after SAVR

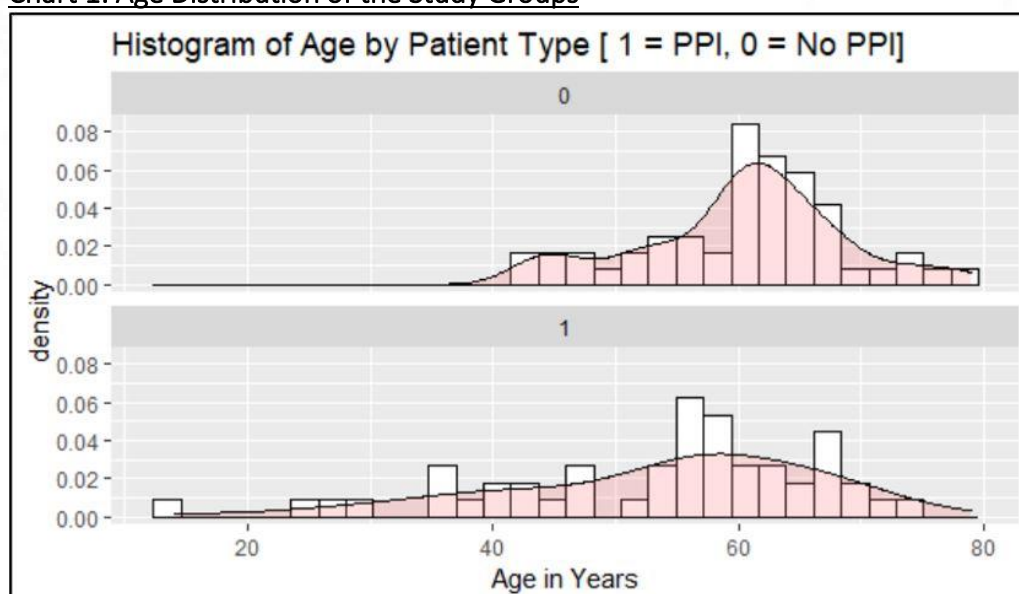
Demographic characters	All patients (n=103)	PPI patients (n=50)	No PPI Patients (n=53)
Age (in years)	57 (± 11.5)	56 (± 13.3)	61 (± 8.3)
Female <i>n</i> (%)	46 (45%)	21 (42%)	25 (47%)
Male <i>n</i> (%)	57 (55%)	29 (58%)	28 (53%)
Height (in cms)	159 (± 8.1)	158 (± 7.7)	159 (± 8.2)
Weight (in Kgs)	63 (± 10.3)	59 (± 8.1)	67 (± 11.1)
BMI (in Kg/m2)	24.9 (± 3.8)	24.0 (± 3.2)	24.9 (± 4.1)
NYHA Class			
NYHA CLASS II <i>n</i> (%)	77 (75%)	39 (78%)	38 (72%)
NYHA CLASS III <i>n</i> (%)	26 (25%)	11 (22%)	15 (28%)
Creatinine	0.98 (± 0.24)	1.0 (± 0.21)	0.90 (± 0.27)

Table 2: Comorbid conditions of Patient Undergoing PPI at index hospitalization after SAVR

Comorbidity	PPI patients (n=50)	No PPI Patients (n=53)	P - Value
Smoker <i>n</i> (%)	6 (12%)	4 (8%)	0.6673
Hypertension <i>n</i> (%)	12 (24%)	22 (42%)	0.09315
Diabetes <i>n</i> (%)	11 (22%)	17 (32%)	0.3539
DLP <i>n</i> (%)	10 (20%)	8 (15%)	0.6924
COPD <i>n</i> (%)	1 (2%)	5 (9%)	0.2344
CAD <i>n</i> (%)	26 (52%)	46 (87%)	0.0002806

The mean age of the case cohort of 50 patients was 56 years and out of this 29(58%) were males (**Chart 1**).

Chart 1: Age Distribution of the Study Groups



There were 11(22%) patients in NYHA FC III and rest of them were in NYHA FC II. Hypertension was more in the 22(42%) in the control cohort whereas it was 12(24%) in case cohort. Similarly, Diabetes was more, 17(32%), in the control cohort whereas it was 11(22%) in the case cohort. There was no statistically significant relationship between comorbid variables and the case cohort.

The most frequent preoperative conduction disturbance seen on the ECG was first degree AVB seen in 15(30%) of patients in the case cohort vs, 1(2%) seen in the control cohort (**Table 3**).

Table 3: Preoperative ECG variables

ECG	PPI patients (n=50)	No PPI Patients (n=53)	P - Value
Sinus Rhythm	34 (68%)	52 (98%)	0.0001186
SSS	2 (4%)	0 (0%)	0.44
PR Interval	160 (± 39.7)	160 (± 21.9)	0.7107
QRS Duration	90 (± 28.6)	100 (± 25.1)	0.1242
1 ^o AVB	15 (30%)	1 (2%)	0.0002478
LBBB	7 (14%)	2 (4%)	0.1368
RBBB	3 (6%)	5 (9%)	0.7776
LVH	29 (58%)	28 (53%)	0.742
LVHS	22 (44%)	22(42%)	0.9553

However, mean PR interval was 160msec in both groups. There were 2(4%) patients with sick sinus syndrome, 7(14%) with LBBB, 3(6%) with RBBB in the case cohort whereas it was 0(0%), 2(4%) and 5(9%) respectively in the control cohort. The mean QRS was 90msec +/- 28.6 vs 100msec +/-25.1, in the case cohort vs the control cohort. Sinus rhythm and first degree AV Block showed significant statistical relationship with PPI patients.

The preoperative Echocardiographic variables are shown in **Table 4**.

Table 4: Echocardiography Variables of the Study Groups

Echo	PPI patients (n=50)	No PPI Patients (n=53)	P - Value
LA, <i>mm</i>	36 (± 5.9)	37 (± 5.4)	0.3862
Aorta, <i>mm</i>	33 (± 6.9)	32 (± 5.8)	0.5188
Annulus, <i>mm</i>	21 (± 2.6)	21 (± 2.0)	0.8834
LVD, <i>mm</i>	50 (± 9.1)	47 (± 6.5)	0.04824
LVS, <i>mm</i>	31 (± 8.1)	29 (± 6.1)	0.03067
EF, %	65 (± 10.4)	69 (± 10.4)	0.1941
IVSDd, <i>mm</i>	13 (± 2.5)	12 (± 3.1)	0.7012
IVSDs, <i>mm</i>	15 (± 2.6)	16 (± 154.9)	0.1485
Peak AV Gradient, <i>mmHg</i>	89 (± 15.1)	93 (± 18.7)	0.1123
AR Severity			
Moderate AR	8 (16%)	0 (0%)	0.0002081
Severe AR	11 (22%)	3 (6%)	

Left ventricular EF was 65 % +- 10.4 vs 69% +- 10.4 in case vs control cohort respectively. The peak aortic valve stenotic gradient was 89mmHg +-15.1 vs 93+-18.7 in case vs control cohort respectively. There was no significant difference in aortic annulus between the two groups. Aortic regurgitation in the form of moderate, 8(16%) and severe AR, 11(22%) was seen more commonly in the case cohort group. In the control cohort it was 0(0%) and 3(6%) respectively. Left ventricular diastolic and systolic dimensions only showed statistically significant relationship with PPI patients.

The operative findings and procedure variables are shown in **Table 5**.

Table 5: Surgical Variables of the Study Groups

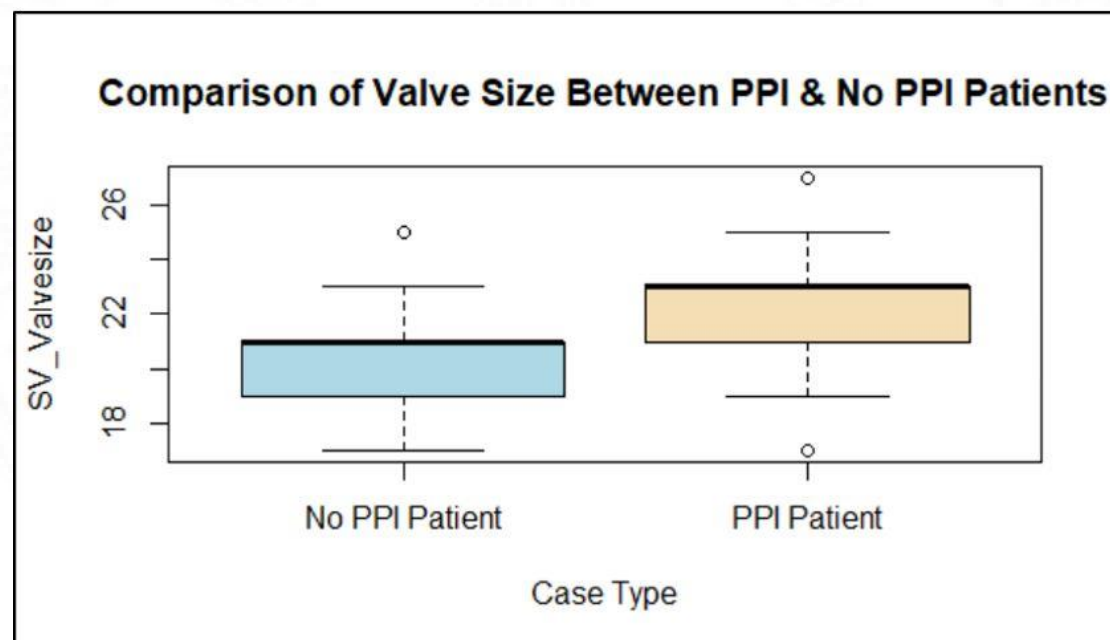
Surgical Variables	PPI patients (n=50)	No PPI Patients (n=53)	P - value
Trileaflet aortic valve	23 (46%)	30 (57%)	0.3794
Bicuspid aortic valve	27 (54%)	23 (43%)	0.3794
Rheumatic aortic valve	9 (18%)	0 (0%)	0.003925
Valve size	23 (± 2.4)	21 (± 1.6)	9.634e-05
Metallic valve	34(68%)	21(40%)	0.007192
Bioprosthetic valve	16 (32%)	32 (60%)	0.00714
Ca in AV	40 (80%)	51(96%)	0.02394
Ca in aortic annulus	24 (48%)	44(83%)	0.000397
Ca in aorta	8(16%)	3(6%)	0.1679
Ca in IVS	5(10%)	0(0%)	0.05724
Ca in OMV	6(12%)	2(4%)	0.2338
Decalcification	40 (80%)	42(79%)	1
Procedure to aorta	7 (14%)	2 (4%)	0.1368
Ablation	2 (4%)	0 (0%)	0.4497
Myomectomy	2 (4%)	0 (0%)	0.4497
CABG	7 (14%)	1 (2%)	0.05394
TBT, min	117 (± 38.3)	97 (± 23.3)	0.0009316
ACCT, min	81 (± 29.7)	68 (± 16.0)	0.004308
Min Temp, degree Celsius	28 (± 4.4)	30 (± 1.0)	1.19306

The aortic valve morphology observed during the surgical procedure was 23(46%) with tricuspid aortic valve disease, 27(54%) with bicuspid aortic valve and 9(18%) with rheumatic aortic valve disease in the case cohort. In the control cohort, there was 30(57%) with tricuspid and 23(47%) with bicuspid aortic valve disease. There was no one in the control cohort with rheumatic aortic valve disease. Annular calcification was seen more commonly seen in the control cohort, that is 44(83%) vs 24(48%) in the case cohort. However, calcification extending to aorta, interventricular septum and aorto-mitral valve was more commonly seen in the case cohort that is 19 vs 5 patients. However, decalcification of the annulus did not differ between the two groups. The size of the valve implanted was slightly more in the case cohort than the control cohort that is 23 mm +/-2.4 vs 21 mm +/-1.6 respectively. Bioprosthetic valves were implanted more in the control cohort, 32(60%) vs case cohort 16(32%) respectively. Metallic

valves were implanted more in the case cohort, that is 34(68%) vs 21 (40%) in control cohort respectively. Aortic cross clamp time (81min +/-29.7) and total by pass time (117min+/- 38.3) were higher in the case cohort than the control cohort (68min +/- 16 and 97min +/- 23.3 respectively). Statistically significant relationship with PPI was seen in prosthetic valve size, metallic valve, bioprosthetic valve, rheumatic aortic valve, calcific aortic valve, annular calcium, total bypass time and aortic cross clamp time, among surgical variables.

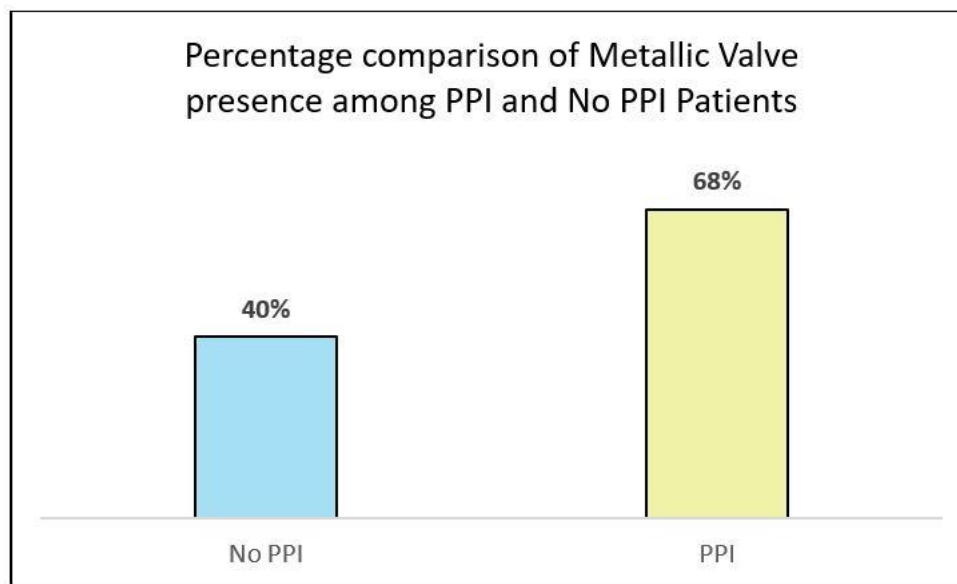
Finally, those variables which showed statistically significant relationship with PPI was used to analyze predictors for PPI at index admission for SAVR. The prosthetic valve size and metallic prosthetic valve only, showed statistically significant relationship with PPI patients by multiple logistic regression method (**Chart 2 and 3**).

Chart 2: Comparison of Valve Size between the Study Groups



Based on the fitted model, if we hold SV Valve Size constant, the odds of having a PPI occurring among those with a Metallic Vale over the odds of having a PPI among those who did not have a metallic valve is $\exp(0.927) = 2.5$. This means people with metallic valve are 2.5 times more likely to undergo a PPI after AVR.

Chart 3: Percentage Comparison of Metallic Valve among the Study Group



Based on the fitted model, if we hold Metallic Valve constant, we will observe a 47% ($\exp(0.385)$) increase in the odds of undergoing PPI with every 1 unit increase in valve size.

The most common indication for permanent pacing was complete heart block which was observed in 44 (88%) patients (**Table 6**).

Table 6: Pacing Variables for Cases Only

Pacing Variables		PPI patients (n=50)
Electrophysiology Studies		6(12%)
Indication for PPI	SSS	1 (2%)
	AH Block	1 (2%)
	Infrasisian block	2 (4%)
	High Grade AVB	2 (4%)
	CHB	44 (88%)
Mode of Pacing	VVI	39 (78%)
	DDD	11 (22%)
	VDD	1 (2%)
Threshold	A	0 ($\pm$ 0.66)
	V	1 ($\pm$ 0.18)
Impedance	A	0 ($\pm$ 212.9)
	V	640 ($\pm$ 130.4)

All these patients had complete heart block on coming off by pass and was shifted to CCU on epicardial pacing. The number of days patient was observed before implantation of permanent pacemaker was 8 $\pm$ 8.4 days. Most common reason for delay beyond seven days was financial reasons. A total of 6 (12%) of patients

underwent EPS before decision to implant pacemaker was done. This was in 2:1 AV Block and SSS. The total duration of hospital stay after peacemaker implantation was 6+/-4.9 days.

There were no implantation related complications in the study group. However, there was one mortality related to SAVR complicated by intrathoracic bleeding. One patient was noted to have pocket hematoma on follow up. This was managed conservatively. One more patient had pocket site infection resulting in explanation of PG and lead.

At one year follow up, 12 lead ECG and pacemaker interrogation report was searched in electronic medical records for presence of intrinsic rhythm. All patients with intrinsic rhythm on ECG had less than 30 % of paced QRS recorded on pacemaker interrogation report. Hence these patients ECG was further analyze to see recovery of conduction disturbance at the time of permanent pacemaker implantation. It was seen that out of 9 patients 8 had recovered to first degree AV block and one to Sinus Rhythm (**Table 7 and 8**).

Table 7: One Year Follow Up for Cases Only

One Year Follow Up		PPI patients (n=50)
ECG	SR	3(6%)
	PR Interval	0 (± 104.5)
	1 ^o AVB	10 (20%)
	High Degree AVB	0 (0%)
	CHB	34 (68%)
	JR	0(0%)
	AF	1(2%)
	QRSd Paced	160 (± 25.1)
	QRSd Instrinsic	0 (± 52.9)
	Threshold	
	A	0 (± 0.38)
	V	1 (± 0.27)
Impedance	A	0 (± 216.2)
	V	570 (± 158.0)
Less than 30% paced		10 (20%)

Table 8: Characteristics of Patients Paced <30%

#	Age	Sex	Time to PPI (days)	Indication for pacing	EPS	Rhythm at 1 year follow up	Intrinsic QRS	Paced QRS%
1	14	M	7	CHB	N	SR	Present	12%
2	68	M	24	HGAVB - CHB	N	1 ⁰ AVB	Not Present	7.80%
3	48	M	13	CHB	N	1 ⁰ AVB	Present	2.50%
4	38	M	26	CHB	N	1 ⁰ AVB	Present	7%
5	55	M	10	CHB	N	1 ⁰ AVB	Present	24%
6	55	F	13	CHB	N	1 ⁰ AVB	Present	5%
7	25	F	17	2:1AVB	Y(AHB)	1 ⁰ AVB	Present	0%
8	61	F	3	CHB	N	1 ⁰ AVB	Not Present	12%
9	46	M	23	HGAVB	N	1 ⁰ AVB	Present	20%

DISCUSSION

In this study, we have identified 50 patients who had undergone permanent pacemaker implantation during index admission for SAVR. The control cohort of patients were hemodynamically similar with no statistical difference in LV dimensions and peak gradients, though slightly higher number of patients with AR was seen in the case cohort.

Baseline conduction disturbances has been observed in many studies as degenerative aortic valve disease progresses. This may be inherent degenerative disease affecting conduction fibers as well as infiltration of conduction system fibers with calcification associated with the disease⁴⁰. Electrophysiological assessments also have shown longer HV interval in patients with AS^{12,41}. Several studies have shown pre-existing conduction disturbances to be associated with high risk for permanent pacemaker implantation^{21,22,23}. This study also has shown more number of patients with conduction disturbances on preoperative ECG.

The most common being first degree AV Block in 15 (30%) patients in the case cohort. In another study first degree AV block was not associated with PPM implantation although it was found that significant number of patients had developed first degree AV Block on follow up⁴².

Aortic regurgitation was more common in the case cohort in this study. Previous studies have shown that aortic regurgitation was more commonly associated with need for permanent pacemaker implantation following SAVR^{43,44}. Similar to previous studies, cases in the case study group received larger size aortic valves (23mm+/-2.4 vs 21mm+/- 1.6). This probably increases the compressive effect resulting in traumatic edema or permanent damage of the conduction system.

In this study presence of calcium was noted from the surgical notes. No PPI group had more number of cases with annular calcification. However, presence of calcium in LVOT was seen in more patients in the PPI group. It is well recognized that mechanical stress resulting from sutures, compression from residual calcification and directly from prosthetic valve can damage the conduction system. The presence of aortic calcium may be an additional factor exposing the conduction system to stress postulated⁴⁵. The close anatomical relationship of HIS bundle and membranous septum localized between RCC and NCC is central to development of AVB during surgery. A study conducted in TAVI patients has shown that presence of more calcium beneath the NCC increases the risk of injury to LBB. This risk increased when the valve has been oversized, highlighting that it is not only the calcium but compression by the size of the valve⁴⁶. Decalcification in the annular region was seen in equal numbers in both groups. During SAVR, valve is positioned intra annular or supra annular position avoiding the compression on the conduction system and meticulous decalcification can also avoid injuring the conduction system. In this study almost equal number of patients in both groups had bicuspid aortic valve disease. It is known that BAV is associated with ascending aorta pathology, heavy calcification and raphe increasing the fragility of the aorta and complications. However, a previous study⁴⁷ did not show increased risk for permanent pacemaker implantation associated with BAV disease.

In this study cardiopulmonary bypass time and ACT are higher in the PPI group than the non PPI group. Several studies have shown that prolonged ischemic time by these variables resulted in postoperative conduction disturbances^{29,30,31}.

The main indication for permanent pacemaker implantation in this study has been intraoperative complete heart block. Patients had undergone pacemaker implantation

within an average 7 days after onset of conduction disturbances. This is slightly higher than the recommended time interval⁴⁸.

One year follow up ECG and pacemaker clinic records were analyzed for conduction recovery and ventricular pacing percentage. Those patients who had intrinsic sinus beats on ECG were specifically selected for this observation. These patients were found to have <30% paced QRS on follow up pacemaker interrogation. There were total nine patients in this group. All had improvement in their conduction disease from complete heart block to first degree AVB except for one patient who had recovered to sinus rhythm. In a study including 72 patients it was seen that AVB after cardiac surgery recovered in 90 % of patients within seven days ⁴⁹. The mean time for implantation of pacemaker in these groups is more than 7 days, within the recommended time. However it is seen that recovery occurs even beyond 7 days in some patients. In another study recovery occurred within 6 months and 50% occurred within the first month ³⁴.

LIMITATION

It was not possible to make significant statistical comparison between the two study groups and limited variables were predictive of the outcome of permanent pacemaker implantation due to smaller sample size, retrospective and single centre study.

CONCLUSION

In this study it is observed that permanent pacemaker implantation at index hospitalization for surgical aortic valve replacement is more common in those patients with metallic valve and larger size of the prosthetic valve. It was also seen that intraoperative complete heart block resulted in more permanent pacemaker implantation. This could be the result of mechanical stress on the conduction system during the surgical process.

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