Atrioventricular Conduction in Patients Undergoing Pacemaker Implant Following Self-Expandable Transcatheter Aortic Valve Replacement

Short Title: Atrioventricular Conduction in Self-Expandable TAVR

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ABSTRACT

Background: Heart block requiring a pacemaker is common after self-expandable transcatheter aortic valve replacement (SE-TAVR); however, conduction abnormalities may improve over time. Optimal device management in these patients is unknown.

Objective: To evaluate the long-term, natural history of conduction disturbances in patients undergoing pacemaker implantation following SE-TAVR.

Methods: All patients who underwent new cardiac implantable electronic device (CIED) implantation at Michigan Medicine following SE-TAVR placement between 01/01/2012 and 9/25/2017 were identified. Electrocardiogram and device interrogation data were examined during follow-up to identify patients with recovery of conduction. Logistic regression analysis was used to compare clinical and procedural variables to predict conduction recovery.

Results: Following SE-TAVR, 17.5% of patients underwent device placement for new atrioventricular (AV) block. Among 40 patients with an average follow up time of 17.1±8.1 months, 20 (50%) patients had durable recovery of AV conduction. Among 20 patients without long term recovery, 4 (20%) had transient recovery. The time to transient conduction recovery was 2.2±0.2 months with repeat loss of conduction at 8.2±0.9 months. On multivariate analysis, larger aortic annular size (OR 0.53 [0.28 - 0.86]/mm, P=0.02) predicted lack of conduction recovery.

Conclusions: Half of the patients undergoing CIED placement for heart block following SE-TAVR recovered AV conduction within several months and maintained this over an extended follow up period. Some patients demonstrated transient recovery of conduction before recurrence of conduction loss. Larger aortic annulus diameter was negatively associated with conduction recovery.

KEYWORDS

-Transcutaneous aortic valve replacement

-Pacemaker

-Atrioventricular block

-Conduction recovery

-Device therapy

INTRODUCTION

The advent of transcatheter aortic valve replacement (TAVR) has led to a new paradigm for the treatment of severe aortic stenosis[1]. While overall safety outcomes are attractive, a common complication of TAVR is the development of high-grade or complete atrioventricular (AV) conduction block which can occur in 8-40% of patients[2, 3]. Many patients who require a permanent pacemaker post-TAVR eventually recover AV conduction and do not remain pacemaker dependent [4, 5]. The significance of this recovery and the optimal device-management strategy in these patients are unknown. Delaying implantation immediately post-TAVR may identify those patients whose conduction block is a transient phenomenon. However, the majority of devices post-TAVR are placed within 48 hours[6, 7]. This is done both to facilitate patient recovery and discharge, as well as for patient safety given the lack of predictors on recurrence of heart block and the highly variable time to conduction recovery.

Pacemaker implantation is higher with the use of self-expandable valves [8, 9]. These prostheses exert a continual outward force post-deployment which could impact long-term recovery of conduction. In this study, we sought to evaluate the long-term, natural history of conduction disturbances in patients receiving cardiac implantable electronic devices (CIED) following TAVR using self-expandable valves and to determine long-term pacing requirements.

METHODS

Study Subjects

The subjects of this study were patients who underwent pacemaker or implantable cardiac defibrillator placement due to conduction disturbances in the periprocedural period (within two weeks) after TAVR using self-expandable valves. All patients at Michigan Medicine who underwent TAVR between 01/01/2012 and 9/25/2017 were identified through the Society for Thoracic Surgeons and the American College of Cardiology Transcatheter Valve Therapy (STS/ACC TVT) registry. Patients who had balloon expandable valves, those with existing CIEDs, and those who had CIEDs placed for reasons other than new atrioventricular block were excluded. AV block was defined as continuous or intermittent third-degree heart block, second degree type II heart block, or symptomatic second degree type I AV block. Patients who did not have a minimum of twelve months of follow-up (due to either death, loss of CIED related follow-up, or less than 12 months of CIED follow-up at the time of the study) were excluded. The University of Michigan Institutional Review Board approved the study protocol prior to data collection.

Data Collection

Baseline demographic, clinical, and procedural data were obtained from the STS/ACC TVT registry or through review of medical records where appropriate. Aortic annulus perimeter was derived from computed tomography (CT) planimetry performed for pre-procedural planning. Imaging and measurements were performed in accordance with the SCCT Expert Consensus document[10]. Calculated area oversizing was derived from the following formula: oversizing (%) = (TAVR perimeter/annulus perimeter -1) x100[11, 12].

At each follow-up device interrogation, native conduction was assessed by temporarily programming the CIED to VVI 30. Patients were routinely evaluated at one week and two months post implantation; follow-up then occurred every six months unless clinicians felt more frequent in-office evaluation was warranted. Device intracardiac electrograms and EKGs were reviewed when available to characterize AV node conduction into normal (1:1 AV conduction with a PR interval <200ms), 1st degree AV block, 2nd degree type I AV block, or third-degree AV block. For patients in atrial fibrillation, complete heart block was defined as a regular junctional rhythm at less than 50 bpm. Patients were deemed to have no recovery of AV nodal conduction if they had complete heart block, high grade AV block, or a native ventricular rate of less than 50 bpm in the absence of normal AV nodal conduction. Pacemaker programming mode, percentage of atrial and ventricular pacing, and sensed/paced AV intervals were also collected.

Statistical Analysis

Patients were classified into two groups based upon whether or not they had sustained recovery of AV nodal conduction at the end of their follow-up period. Those who had only transient recovery of AV nodal conduction were included in the no-recovery group. Patient and procedural characteristics were compared to identify factors associated with recovery of conduction. Data were compared using the Fisher's exact t-test or chi-square for categorical variables and the student's t-test or Mann-Whitney test for continuous variables where appropriate. Data is expressed as means±standard deviations or medians[interquartile range] where appropriate. Kaplan-Meyer curves were created to track recovery of AV node conduction over time. Univariate logistic regression analysis was performed. Variables with a univariate P value <0.10 were then incorporated into a multivariate analysis. All statistical testing was performed on R version 3.4.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

General Population

A total of 701 patients underwent TAVR over the study period including 524 (75%) with a self-expandable valve. Among the total population, 128 patients (18%) had pre-existing pacemakers (n=85) or ICD (n=43). Among the remaining 573 patients who underwent TAVR (n=422 self-expandable valve, n=151 balloon expandable valve) and did not have a pre-

existing CIED, 14% (n=82) underwent device placement for new AV block (Figure 1). New CIED utilization rates among patients receiving self-expandable valves was 17.5% (74/422) and for patients receiving balloon expandable valves was 5% (8/151). Age, pre-existing conduction block, the use of self-expandable valves, and diabetes were associated with an increased risk of requiring a CIED post TAVR implantation (Table 1).

CIED Population

We evaluated 40 patients who received a CIED for AV conduction abnormality following self-expandable TAVR. The mean patient age was 78.2±9.9 years, 53% of the population were male (n=21), and the mean ejection fraction was 57±14% (Table 2). Patients with less than one-year follow-up, patients who died within one year of follow-up, and patients with a CIED placed for reasons other than AV block, were excluded. Thirteen patients were excluded due to death which occurred during the index hospitalization for TAVR placement (n=3), or within 12 months due to cardiovascular (n=4) or non-cardiovascular causes (n=5). Cardiovascular causes of death included progression of systolic congestive heart failure in three patients, and diastolic heart failure in one patient. Deaths during the index hospitalization for TAVR included sepsis in two patients, and complications from COPD in one patient. There were no deaths related to CIED placement.

Of the CIEDs implanted, 34 (85%) were dual chamber pacemakers, 4 (10%) were cardiac resynchronization therapy-defibrillators (CRT-D), 1 (2%) was a CRT-pacemaker, and 1 (2%) was a dual-chamber implantable cardioverter defibrillator (ICD). The average time between TAVR placement to CIED implantation was 2.4±2.4 days with 17/40 devices placed at the time of TAVR implantation. The indication for CIED implantation included CHB(n=33), mobitz type II heart block (n=2), and high grade AV block (n=5). There were no intraprocedural complications during CIED placement.

Follow-up and Recovery of Conduction

Average time of follow-up was 17.1±8.1 months, during which 50% of the patients (20/40) had durable recovery of AV node conduction. There was one patient with a device related complication over the follow-up period. This patient had an RV lead fracture that was replaced without further sequela.

The recovery of AV node conduction over the follow-up period is displayed in Figure 2. About half of the patients who recovered AV conduction did so within 1 month (11/20 patients), with an average recovery time of 2.8±4.0 months. The longest time to recovery of conduction was 15 months.

Patients who underwent CIED placement at the time of TAVR and those who underwent CIED placement later in their hospitalization had similar rates of long term conduction recovery (47% vs 52%, P=0.75). Time between TAVR and CIED placement had no effect on long-term recovery rates (P>0.05). There were no demographic differences between patients who underwent CIED placement at the time of TAVR (n=17) and those who underwent

placement later in their hospitalization (n=23) including age, sex, STS, EF, pre-existing conduction abnormalities, or history of atrial fibrillation/flutter (P>0.05 for all).

Patient characteristics for those with and without recovery of AV node conduction are displayed in Table 2. Univariate predictors for lack of AV node recovery that were then included in the multivariate analysis included a history of prior cardiac surgery (OR 0.12 [0.0.01-0.83]), LVIDd (0.37[0.13-0.91]/mm), aortic valve annular size (OR 0.50[0.29-0.75]/mm), and atrial fibrillation or flutter (0.27[0.06-1.0]) (Table 3). On multivariate analysis, only aortic annular size (0.53 [0.28 - 0.86]/mm significantly predicted a lack of conduction recovery (P=0.02).

Recovery and Later Loss of Conduction

Among the 20 patients who remained pacemaker dependent, four patients (20%) had intermittent recovery of AV conduction but were pacemaker dependent by the end of the follow-up period (Table 4). The average time to recovery of conduction was 2.2±0.2 months with recurrent loss of conduction diagnosed at 8.2±0.9 months and the latest recurrent loss of conduction occurring at 14 months. There were no significant procedural or demographic differences between this group and the group which recovered conduction permanently (P>0.05 for all). Three patients displayed bundle branch blocks after initial recovery of conduction; these abnormalities were already present in two patients post-TAVR, one patient had progression from IVCD to a LBBB and took the longest to eventually lose conduction (14 months) All four patients had return to their pre-TAVR AV conduction after initial recovery of conduction (2/4 with return to 1st degree AV block, 1/4 with persistent atrial fibrillation and normal ventricular rates, 1/4 with sinus rhythm and normal AV conduction that developed AF with normal ventricular rates).

Device Settings and Follow-up EKG

Device settings and EKG characteristics at the time of last follow up among patients who had recovery of conduction are shown in Table 5. Most patient's had near normalization of their EKGs compared to their pre-TAVR assessment. All patients with return of conduction had normal AV conduction (n=7) or 1st degree AV block (n=13). In 19/20 patients the mean PR prolongation between pre TAVR implant and follow up was 32.2±45.5ms, one patient had 2nd degree AV type I block pre-TAVR and had no AV block at follow up. Most patients (n=15) (75%) had abnormal QRS morphologies (LBBB n=6; RBBB n=6; IVCD n=3) at follow up, 73% (n=11) patients had preexisting abnormal QRS morphologies and 27% (n=4) patients developed new abnormal QRS morphologies. The mean QRS prolongation at the time of follow-up was 13.8±22.8ms.

The median ventricular pacing burden in patients who had recovered AV nodal conduction was 0[0-1.5]%; there was a minority of patients (n=3) who had 1st degree AV block and

pacing burdens>50%. This may have been minimized by programming changes to minimize ventricular pacing.

DISCUSSION

In this study, we reported on the natural history of conduction abnormalities in patients who received CIED implant for conduction abnormalities following self-expandable TAVR. We demonstrated that 50% of patients who received a CIED for new AV-block had recovery of conduction on long term follow-up. Those that underwent CIED placement at the time of TAVR had a similar rate of conduction recovery as those who had them placed later in the hospitalization stay. While the majority of patients who recovered conduction did so within several months, some patients will continue to display recovery up to 15 months after their procedure. Clinical factors associated with long-term conduction status included aortic annulus diameter.

Our baseline TAVR population and incidence of CIED placement reflect real-world practices [13]. Our mean time-to-CIED-implant (2.4 days) was similar to previously reported large cohort studies[6]. Similar to prior studies, older age and pre-existing conduction abnormalities were associated with the need for CIED placement post-TAVR [14, 15]. In addition, in our study population a history of diabetes was also found to be associated with CIED placement following TAVR.

Incidence and Timing of Conduction Recovery

We reported on detailed conduction and device data over an extended follow-up period and found that 20/40 (50%) of patients recovered AV nodal conduction. Furthermore, these patients experienced only mild PR prolongation and QRS changes compared to pre-TAVR assessment. The majority of patients that recovered conduction did so within several months and maintained conduction over a follow-up period over one year.

Acute conduction abnormalities post-TAVR are caused by mechanical compression of adjacent structures by the prosthesis leading to ischemic and inflammatory changes in the peri-nodal tissue[16]. Sinha et al reported on an autopsy performed in a patient with new AV block after TAVR who died on post-operative day 10 of an unrelated cause[17]. Pathology showed necrosis and ischemic injury of the perinodal tissue, with sparing of the AV node and subendocardial septal issue. Intramyocardial hemorrhage and hematoma formation have also been described[18] which can exert further local compressive forces. Resolution of these changes over time leads to recovery of conduction. The self-expanding valve exerts a persistent radial force and extends deeper in the LVOT[16, 19]. These device-specific factors may help explain the delayed conduction recovery seen months later though the exact mechanisms are unknown. A comparison between self-expanding and balloon expandable valves should be the focus of future studies.

Factors Associated with Conduction Recovery

Several clinical factors were associated with conduction recovery. Using a multivariate analysis, the only significant predictor was aortic annulus size where patients with a larger aortic annulus were less likely to recover conduction (OR 0.53, 95% CI 0.28-0.86, p=0.02). The cause of this association is not clear but may be related to abnormal aortic and LVOT geometry resulting in increased radial forces being delivered to conductive tissue by the valve prosthesis. This observation is supported by procedural factors associated with new heart block, such as device implantation depth, angle of deployment and prosthesis to LVOT diameter ratios[7, 20].

Patients who received a CIED at the time of TAVR had similar rates of conduction recovery as those who had them placed later in the hospitalization. Presumably a longer duration of heart block prior to CIED implant would be more specific in identifying those who will have long-term conduction abnormalities. Waiting periods are broadly recommended though the optimal timing of CIED implantation is unknown[21]. Implant timing in our study was based on operator judgment. Prospective clinical trials are needed to better understand the effect of immediate versus delayed CIED implantation.

Recovery and Subsequent Loss of Conduction

In 16% of patients who recovered conduction early on, a subsequent loss of conduction was observed. Most patients' ultimate loss of conduction occurred within 8 months of TAVR, although one patient experienced a late loss of conduction at 14 months. No clinical factors were associated with later loss of AV conduction, though the patient who lost conduction at 14 months was notable for the development of a new LBBB after initial recovery of conduction. This ability for late recurrent loss of conduction can have important implications for device programming and management.

Prior Studies

These results contribute to a growing body of evidence that recovery of conduction is common in patients who undergo CIED implantation after TAVR. There is substantial heterogeneity in follow-up periods, methodology of conduction assessment (resting EKGs versus device interrogation), and definition of conduction recovery; however, reports show that most patients will experience partial, if not complete conduction recovery over long term follow up[3, 22-26]. Reported rates of long-term recovery are approximately 50-60%, consistent with this study. Clinical factors associated with recovery are less reliably demonstrated. A recent study by Kaplan et al followed 67 patients with high-grade or complete AV block following balloon-expandable and SEV TAVR placement and reported that only 21.9% remained pacemaker dependent after one year[25]. The use of SEV as well as post-balloon

dilation was associated with a higher rates of pacemaker dependency. In contrast, Raelson et al performed a similar analysis on patients undergoing both balloon-expandable and SEV and were unable to find predictors of recovery[23]. Our study expands on these findings by detailing the patterns of conduction recovery in patients who underwent device implantation following balloon expandable valves and highlights the risk of late loss of conduction and the subsequent implications for device management.

Implications for Patient Management

We demonstrate that TAVR induced heart block is transient in about half of the patients receiving a CIED following TAVR. Device programming in these patients should incorporate strategies to identify this recovery early and utilize device programming to limit unnecessary RV pacing.[27] The use of cardiac resynchronization therapy or His bundle pacing as opposed to traditional right ventricular pacing is influenced in part by the anticipated pacing burden and cardiac function[28]. In select patients, a trial of single-chamber pacing with later upgrade based on long-term pacing needs may be pursued; however, device therapy must ultimately be tailored to an individual patient's needs based on multiple factors.

The observation of durable as well as transient recovery of AV conduction in these patients may have implications for device explantation. Elective explantation in patients who experience recovery of conduction is not standard of care but could reduce exposure to the long-term risks of implantable devices. This issue has added relevance given the expanding indications for TAVR and the use of these valves in lower risk and younger patients[29]. Patients who undergo device extraction for traditional indications (infection, device malfunction, vascular stenosis, et cetera) may likewise face an uncertain need for device reimplantation. Prior to explantation, one must keep in mind that despite apparent recovery in conduction, patients may still have intermittent AV conduction block requiring rare ventricular pacing. Device diagnostics (which are available through select CIED vendors) revealing if any ventricular paced beats were present over a period of time would have to be analyzed.

LIMITATIONS

This was a single-center, retrospective study with limited patient numbers and the results of this study should be confirmed with larger, multi-center studies. We focused our analysis on self-expandable valves and future studies should compare these findings to balloon expandable values. Our analysis was limited to patients who survived greater than one-year post-TAVR and had adequate follow up. This was done to focus the results on long term conduction assessment which will provide clinically meaningful implications on device management. We reported on all available EKG and device interrogation reports over the follow-up period; however, these events occurred months apart and we cannot account for conduction patterns between device interrogations. Patients with recovery of AV conduction had minimal or unchanged EKGs and minimal or no ventricular pacing burden at follow up

but this does not preclude transient high-grade block, rate dependent conduction abnormalities or sinus node dysfunction. Future studies will incorporate standardized device programming and follow up to better assess clinical pacing requirements.

CONCLUSIONS

Factors associated with an increased risk of requiring a CIED in all patients undergoing TAVR were age, pre-existing conduction block, the use of self-expandable valves, and diabetes. Despite a higher need for CIEDs in patients with heart block following self-expandable TAVR, half of these patients will recover conduction over long term follow-up and this recovery can occur months after TAVR deployment. A larger aortic annulus was the lone clinical predictor showing less chance of conduction recovery. Highlighted in this study were a group of patients with transient recovery of conduction with subsequent return of heart block.

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Figure 1) Study Population Selection. Included were 40 patients who underwent CIED placement for AV conduction abnormalities following self-expandable TAVR with a follow-up period at the time of this study of at least one year. TAVR - transcutaneous aortic valve replacement, ICD - implantable cardiac defibrillator, CIED - cardiac implantable electronic device, AV - atrioventricular.

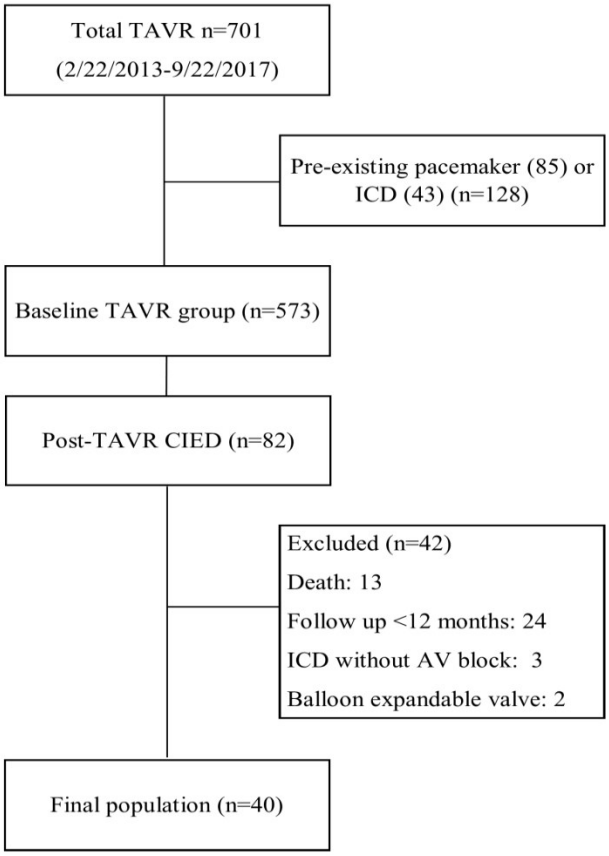
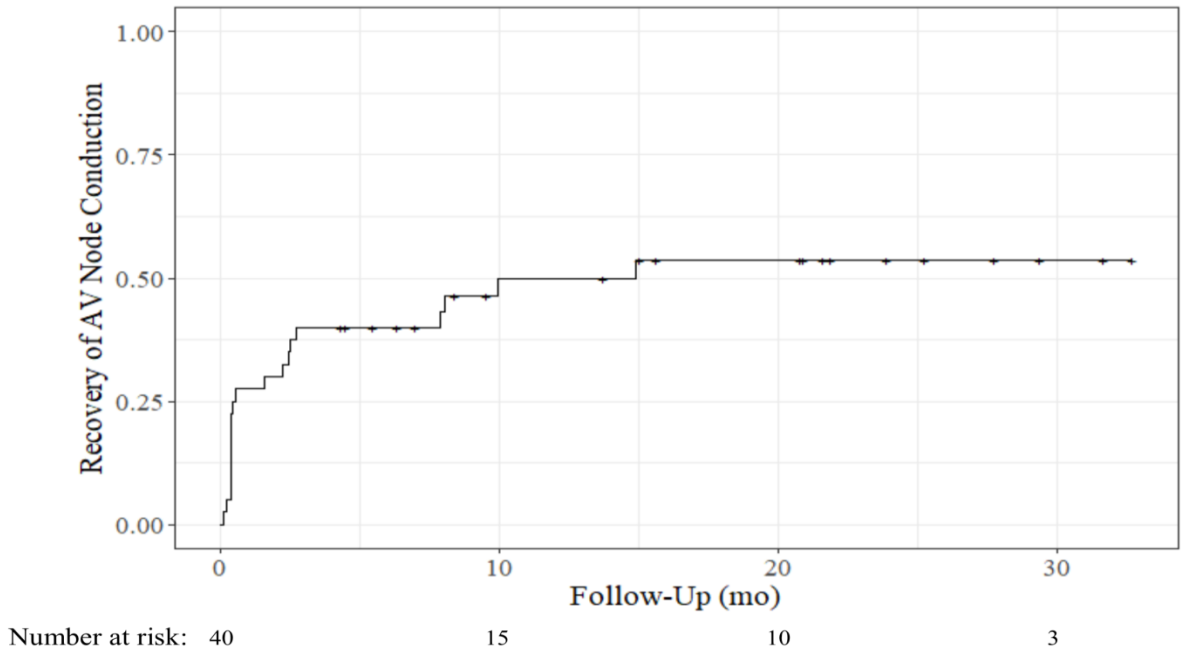


Figure 2) Recovery of AV node conduction was seen in 50% of patients following self-expandable transcutaneous aortic valve replacement. Among these patients, more than half recovered conduction within the first month. AV - atrioventricular; mo - months.



	No Post TAVR CIED (n=491)	Post TAVR CIED (n=82)	OR	P
Age	78.75±12.17	80.9±8.6	1.03 [1.01-1.05]/yr	0.02
Male Sex (%)	57%(283)	62%(51)		0.44
White Race (%)	93%(459)	94%(77)		0.88
Pre-Existing Conduction Abnormality	42%(205)	62%(51)	2.3 [1.4 - 3.7]	<0.001
LVEF	57.9±15.4	56.4±14.6		0.39
STS Risk Score	6.27±5.07	6.61±4.14		0.57
CoreValve	71%(348)	90%(74)	3.81 [1.89 - 8.73]	<0.001
Stroke	10%(51)	11%(9)		0.83
Smoker	46%(226)	45%(37)		0.88
HTN	70%(398)	80%(65)		0.7
DM	35%(176)	50%(41)	1.79 [1.11 - 2.87]	0.02
Prior MI	20%(96)	20%(16)		0.79
Prior CABG	22%(107)	22%(18)		0.97
Prior PCI	34%(169)	31%(26)		0.68
PAD	46%(226)	45%(37)		0.88
AF/Flutter	34%(167)	40%(33)		0.26

Table 1) Comparison of demographic and clinical data among patients with and without cardiac implantable electronic devices for AV block after TAVR placement. TAVR - transcutaneous aortic valve replacement; CIED - cardiac implantable electronic device; CI - confidence interval; OR - odds ratio; LVEF - left ventricular ejection fraction; STS - Society of Thoracic Surgeons; HTN - hypertension; DM - diabetes mellitus; MI - myocardial infarction; CABG - coronary artery bypass graft; PCI - percutaneous coronary intervention; PAD - peripheral artery disease; AF - atrial fibrillation.

	Recovery (n=20)	No Recovery (n=20)	P	OR [95% CI]
Demographics				
Age (yrs)	80.5±10.0	75.9±9.5	0.14	
Sex(male)	40%(8)	65%(13)	0.12	
Race(white)	90%(18)	100%(20)	0.15	
STS Risk Score	5.3±2.6	6.1±3.8	0.42	
Pre-Existing Conduction abnormality	70%(14)	65%(13)	0.75	
Smoker	5%(1)	10%(2)	0.56	
HTN	70%(14)	70%(14)	1	
DM	40%(8)	45%(9)	0.75	
Prior MI	15%(3)	5%(1)	0.3	
Prior PCI	20%(4)	30%(6)	0.48	
PAD	40%(8)	35%(7)	0.75	
AF/Flutter	25%(5)	55%(11)	0.05	0.27 [0.06 - 1.00]
CAD (# of diseased vessels)	0.85±1.22	1.1±1.25	0.53	
Prior CABG	5%(1)	15%(3)	0.3	
Prior Cardiac Surgery (yes)	5%(1)	30%(6)	0.06	0.12 [0.01 - 0.83]
Procedural Characteristics				
Time to implant (days)	2.4±2.1	2.4±2.8	1	
Intraprocedural placement	40%(8)	45%(9)	0.54	
Implant depth (mm)	4.1±1.2	4.1±0.9	0.74	
TAVR size (mm)	29.6±2.6	30.1±2.0	0.49	
TAVR/LVOT	1.41±0.12	1.35±0.12	0.14	

TAVR to Aortic Annulus oversize (%)	16.85±7.15	18.5±9.86	0.65	
Pre Lab				
Creatinine (mg/dl)	1.26±0.48	1.54±1.75	0.48	
Hemoglobin (g/dl)	12.06±1.9	12.05±2.1	0.98	
Albumin (g/dl)	3.89±0.37	3.91±0.32	0.85	
Platelet (103 /µL)	251±115	202±57	0.09	
Echo/Imaging				
Left Ventricular EF (%)	59.0±11.6%	55.4±16.2	0.42	
RV systolic pressure (mmHg)	45.6±13.5	50.5±9.3	0.25	
LVIDd (cm)	4.58±0.75	5.12±0.75	0.04	0.37 [0.13 - 0.91]
LVIDs (cm)	3.12±0.81	3.54±1.02	0.27	
Septal Wall Thickness (cm)	1.2±0.25	1.2±0.22	0.63	
Aortic Valve Annulus (mm)	23.5±1.5	25.9±2.15	<0.01	0.50 [0.29 - 0.75]/mm
LVOT (mm)	21.1±2.4	22.3±2.3	0.12	
Aortic Valve Area (cm2)	0.76±0.19	0.73±0.17	0.57	
Aortic Valve Peak Velocity (m/s)	3.90±0.91	3.94±0.85	0.89	
Pre EKG				
PR (ms)	187.6±69.7	176.9±31.4	0.63	
QRS (ms)	121.6±23.1	116.5±28.31	0.56	
QTc (ms)	467±38.5	458.1±34	0.44	
RBBB	35%(7)	30%(6)	0.74	
LBBB	5%(1)	5%(1)	1	
IVCD	15%(3)	10%(2)	0.64	

Fascicular Block	10%(2)	15%(3)	0.64	

Table 2) Comparison of demographic, clinical, and procedural data among patients with and without recovery of AV nodal conduction following cardiac implantable electronic device placement. OR - odds ratio; CI - confidence interval; STS - Society of Thoracic Surgeons; TAVR - transcatheter aortic valve replacement; HTN - hypertension; DM - diabetes mellitus; MI - myocardial infarction; PCI - percutaneous coronary intervention; PAD - peripheral arterial disease; AF - atrial fibrillation; CAD - coronary artery disease; CABG - coronary artery bypass grafting; Cr - creatinine; Hgb - hemoglobin; LVEF - left ventricular ejection fraction; LVOT - left ventricular outflow tract; RV - right ventricle; LVIDd - left ventricular intraventricular dimension diastole; LVIDs - left ventricular intraventricular dimension systole; AV - atrioventricular; RBBB - right bundle branch block; LBBB - left bundle branch block; IVCD - intraventricular conduction delay.

	OR [95% CI]	P
AF/flutter	0.15 [0.01-1.03]	0.07
Prior Cardiac Surgery	0.13 [0.04-1.52]	0.14
LVIDd	0.56 [0.13 - 2.15]/mm	0.39
Aortic Annulus	0.53 [0.28 0.86]/mm	0.02

Table 3) Multivariate analysis for predictors of conduction recovery. OR - odds ratio; CI - confidence interval; AF - atrial fibrillation; LVIDd - left ventricular intercavitary dimension diastole.

Patient (#)	Age	Sex	STS Risk Score	EF (%)	Atrial rhythm	PR duration (ms)	QRS width (ms)	QTc (ms)	QRS morphology	Time to Recovery (mo)	Time to Loss (mo)
1	83.0	Male	3.5	60	A flutter	NA	156	528	LBBB	2.0	3.9
2	69.8	Male	0.9	65	AF	NA	82	457	Normal	2.2	14.4
3	91.7	Female	6.8	60	NSR	214	126	460	RBBB, LAFB	2.3	9.7
4	72.0	Female	8.1	30	NSR	224	172	452	LBBB	2.3	4.6

Table 4) Characteristics of patients with transient recovery of conduction. EKG data shown are from the last EKG prior to the development of heart block. TAVR - transcatheter aortic valve replacement; STS - Society of Thoracic Surgeons; EF - ejection fraction; NSR - normal sinus rhythm; IVCD - intraventricular conduction delay; RBBB - right bundle branch block; LAFB - left anterior fascicular block; AF - atrial fibrillation; ms - milliseconds; mo - months.

Time to follow up EKG (days)	Atrial Rhythm	AV Conduction	Native Ventricular Rate (bpm)	PR (ms)	QRS (ms)	QTc (ms)	QRS (ms)	Fascicular Block
414±197	NSR: 12, SB:4, AP: 4	Normal: 7 1stºAV Block: 13	70.3±13.5	225±54	128±25	456±36	Normal: 5 LBBB:6 RBBB:6 IVCD: 3	LAFB: 4
Time to follow up Device Interrogation(days)	Device Mode	%A pace	%V pace	Pace AV	Sense AV	LR		
521±226	AAI(R)->DDD: 13 DDD(R):7 DDI(R):1	25.6±28.5	0[0-1.5]	220.0±61.4	205.2±61.4	59.3±2.4		

Table 5) EKG and device characteristics at final follow up in patients with recovery of conduction. Values are mean±standard deviation or median[1st quartile – 3rd quartile]. AV - atrioventricular; bpm - beats per minute; NSR - normal sinus rhythm; SB – sinus bradycardia; AP – atrial pacing; LBBB - left bundle branch block; RBBB - right bundle branch block; IVCD - intraventricular conduction delay; LAFB - left anterior fascicular block; LR - lower rate