

Research Article

Cardiac Pacemaker and the Effect on Hemodynamics of the Tricuspid Valve

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Abstract

Placement of ICDs, permanent pacemakers and biventricular devices is performed under fluoroscopic guidance. Implantable device leads can cause Tricuspid Regurgitation (TR) when they interfere with leaflet motion. In our clinical experience, we had two cases where patients with endocardial right ventricle leads developed severe TR. One patient was treated by having his leads repositioned and the other required surgery. This study analyzed the grade of tricuspid regurgitation before and after implantation of lead pacemaker in Right Ventricle.

Aim: Evaluation of tricuspid regurgitation after right ventricular permanent lead implantation to check if echocardiographic guidance is needed for adequate lead positioning.

Methods: 76 patients had trans-thoracic Doppler echocardiographic studies before and after implantation of permanent right ventricular leads.

Results: Before Right Ventricular (RV) lead implantation, 96% of patients had Tricuspid Regurgitation (TR). Patients were stratified by grade of regurgitation. 57 patients were grade 1 (75%), 12 (16%) were grade 2 and 4 were grade 3 or 4 (5%). After RV lead implantation, 44 patients with grade 1 TR remained with the same degree (77%) while in 2 (3.5%) TR progressed to grade 2 and in the remainder the TR disappeared.

Most of the patients with grade 2 TR before RV lead implantation (75%) remained in grade 2 while 25% the grade decreased to grade 1.

In all the patients with grade 3 and 4 TR pre-implantation, the severity of TR decreased by one grade.

In 56 patients with non-CRT device implantations, 39 (70%) had grade 1 TR before procedure. After implantation, 28 (72%) of them did not change grade and 11 (28%) progressed to grade 2.

Regarding grade 2 TR before implantation in 8 patients (14%) - the TR grade decreased in 3 (37.5%) and did not change in the others. In 3 (5.4%) patients with grade 3 and 4 TR before the procedure, the TR decreased after procedure.

Conclusion: Implantation of permanent RV leads did not worsen TR grade.

Keywords: Cardiac Pacemaker; Right Ventricular; Tricuspid Regurgitation; Implantable Cardiac Defibrillators

Introduction

For the last few years, there have been a significant increase in the number of implantable cardiac devices such as Permanent Pacemakers (PPM), Implantable Cardiac Defibrillators (ICD) and Biventricular pacemakers (BiV) worldwide [1-3]. Implantation of these devices significantly reduced cardiac morbidity and mortality [4-5]. However, these interventions are not without complications. Interactions between Right Ventricular (RV) electrodes and valve structures are associated with exacerbation of Tricuspid Regurgitation (TR).

This may be due to a mechanical cause such as the formation of scar tissue or thrombus on the leads that impair the closing of the valve leaves. For example, a perforation or rupture of the valve leaflets may trigger the development TR. Another mechanism for the formation of TR is asynchrony, which results from abnormal activation of the RV by a cardiac pacemaker. It's important to note that it may resolve if the patient returns to his internal sinus rhythm [7,8]. Kim, et al., demonstrated that TR after ICD or Permanent Pacemaker (PPM) implantation is not associated with an increase in pulmonary arterial pressure (Fig. 1) [9].

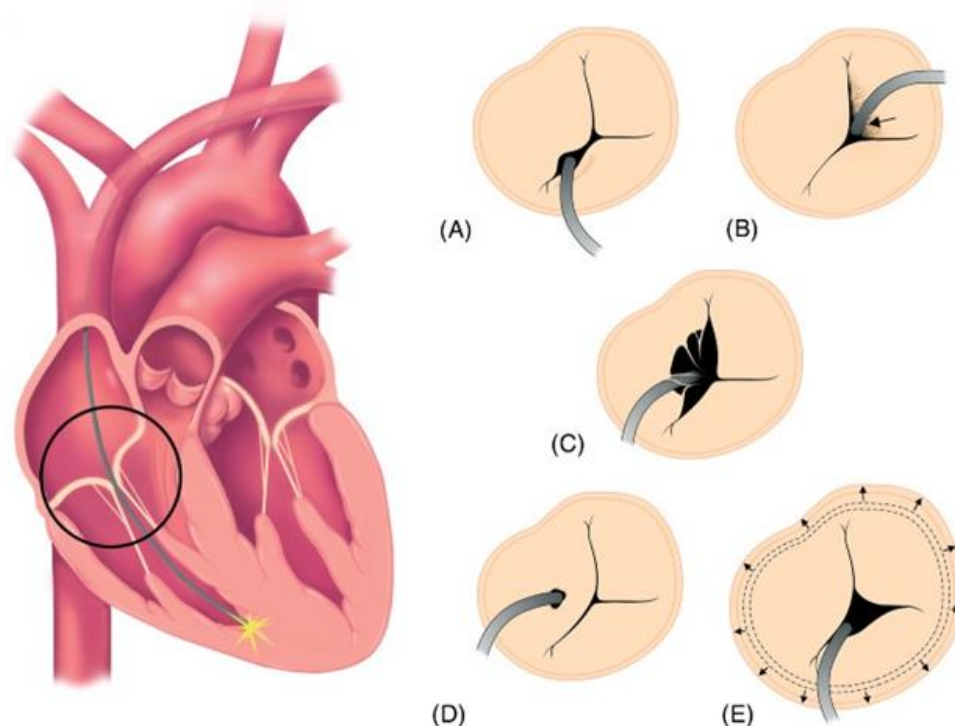


Figure 1: Mechanisms of mechanical tricuspid regurgitation in the setting of permanent pacemaker or implantable cardioverter-defibrillator leads. (a) Valve obstruction caused by lead placed in between leaflets; (b) Lead adherence due to fibrosis and scar formation to valve causing incomplete closure; (c) Lead entrapment in the tricuspid valve apparatus; (d) Valve perforation or laceration; (e) Annular dilatation.

Previous studies and postmortems in the 1970s demonstrated that the leads for pacemakers may attach to the leaflets of the tricuspid valve and even more frequently to the papillary muscles. Over time, holes or tears usually developed on the back leaflet. Regarding TR that develops years after PPM implantation – Iskandar, et al., claim that adhesion of the Tricuspid Valve (TV) leaflets to the pacemaker electrodes obstructs leaflet movement and thereby causes an unsynchronized motion of the posterior leaflet with the septal and anterior leaflets. It is further claimed that already 12 hours after the procedure, the formation of a neo-endocardium is observed, with the development of fibrous sheaths around the leads, resulting in multiple endocardial connections. Fibrosis tissue and adhesions that are subsequently formed may affect valve function. A thin layer of fibrin begins to develop around the pacemaker wiring shortly after electrode implantation has been observed.

A study by Huang, et al., found that lead thrombosis often occurs within 4-5 days after cardiac lead implantation, which may result in acute TR [28]. As previously described, the frequency of acute TR varies in many published studies [40]. While several small studies (mostly retrospective), case reports and reviews have suggested that permanent endocardial electrode implantation can lead to Tricuspid valve disorder (TR) [15-16], other studies have not demonstrated any relationship between the implantation of the device and the development of TR [17].

In addition, the effect of CRT therapy on the development of TR after device implantation has not been defined. Furthermore, patients undergoing ablation for atrial and ventricular arrhythmias routinely undergo temporary pacemaker lead insertion, often using multiple leads that cross the tricuspid valve [18-19]. However, very little is known about the effects of temporary electrode insertion on TR severity in these patients [20]. Left Bundle Branch Block (LBBB) is a common finding in heart failure situations with decreased left ventricular function and is accompanied by increased morbidity and mortality [21]. One third of patients

with heart failure have LBBB which may cause desynchronization of left ventricular contraction and thus worsening of the heart failure [22,23]. At the same time, the effect of LBBB on right ventricular function is not sufficiently known and there is a debate regarding the extent of the effect of resynchronization therapy on improving right ventricular function [24-28]. It is known that right ventricular function is an independent predictor for the response to treatment by CRT, which can indicate that there is an interaction between CRT and right ventricular function [29]. The function of the left ventricle may affect the function of the right ventricle through the pulmonary circulation and also through the interventricular interaction [30-31]. In the presence of LBBB, there is a disturbance in the contraction of the interventricular septum with early systole shortening and movement to the left [32-33] and then lengthening and movement to the right of the septum will appear [34-35]. This mobility of the septum may affect the function of the right ventricle [36-37]. The traditional grading of tricuspid regurgitation severity focuses on color Doppler ultrasound imaging. Reliance on jet size and Right Atrial (RA) dilation depends on several technical and hemodynamic factors.

1. Vena contracta width is the recommended parameter in TR severity grading, where ≥ 7 mm is indicative of severe TR.
2. Quantitative Proximal Iso-Velocity Surface Area (PISA) method (also known as flow convergence method) is possible, but less often used, where severe TR is defined as an Effective Regurgitant Orifice (EROA) ≥ 40 mm² with a regurgitant volume of ≥ 45 ml.

Tricuspid regurgitation defined as EROA with a cut-off ≥ 40 mm² was found to be associated with increased mortality and morbidity for 10 years according to previous works (Fig. 2) [48].

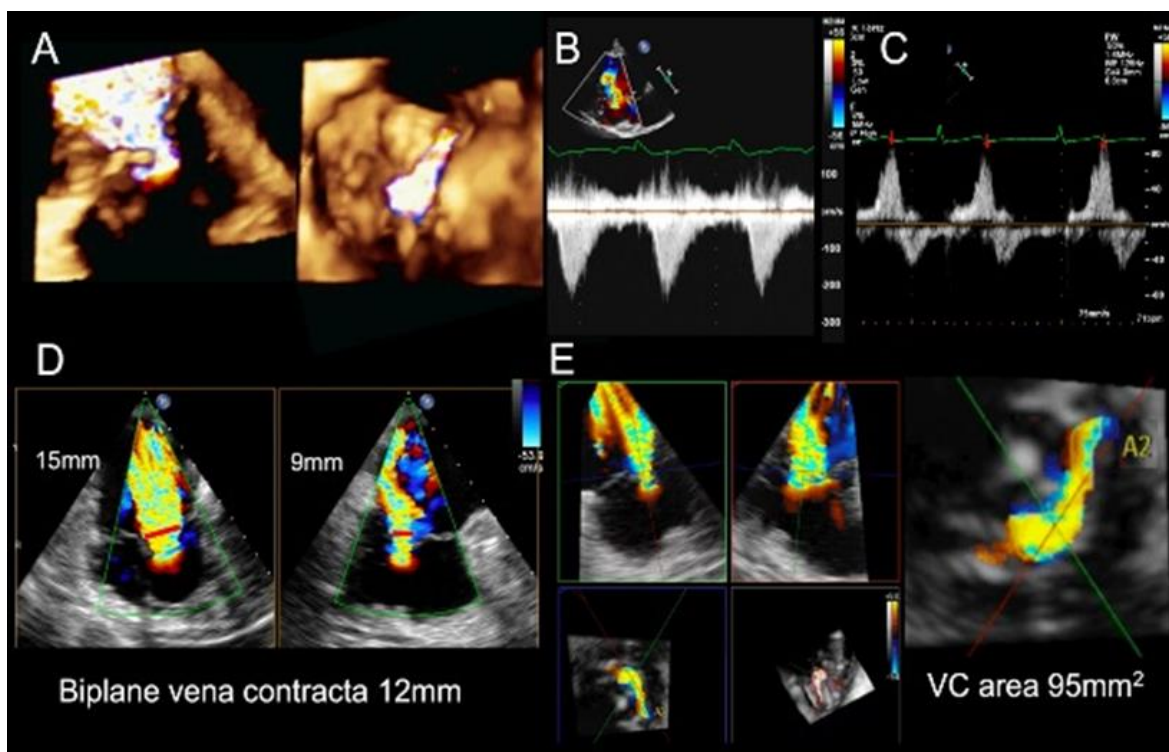


Figure 2: Selection of tricuspid valve regurgitation parameters. (A) Is a 3D colour flow full-volume acquisition of severe TR and demonstrates the flow convergence, vena contracta and jet expansion upwards into the RA (left image) and the en face view of the flow convergence viewed from the RV aspect (right image). The regurgitant orifice is an irregular elliptical shape; (B) Continuous wave Doppler profile of severe tricuspid regurgitation, demonstrating a triangular low velocity jet. In this setting, estimation of RV systolic pressures will be underestimated due to rapid pressure equalization between RA and RV; (C) Depicts systolic flow reversal, seen in severe tricuspid regurgitation, during hepatic vein flow interrogation; (D) 3D echo format, X-plane, where orthogonal planes in 2D are imaged simultaneously. The vena contracta (red arrows) is longer in the left view and highlights an elliptical regurgitant orifice, confirming the findings in image A; (E) Shows multiplane reconstruction format of the 3D vena contracta and measurement of the vena contracta area and demonstrates massive TR VC area 95 mm². VC, vena contracta.

Research Hypothesis

Since RV function and the severity of TR are predictors of morbidity and mortality, it is very important to evaluate the effect of the different types of pacing on RV function and TR severity in order to choose the optimal pacing method for a patient.

Method and Materials

Research Setup

This study is a retrospective analytical study. Data about each of the subjects in this study was collected from the medical files of the patient population, including the echocardiographic indices before and after the implantation of the cardiac device. We checked the data of 76 patients in an anonymous form and coded according to serial number (the coding list was then eliminated). A comparison was made of the echocardiography and Doppler data before and after pacing, as well as a comparison between the different types of pacing.

Statistical Methods

The continuous measures were presented as mean and standard deviation. Discontinuous values were presented as numbers and/or percentages. Student-t-test (?) was used to compare the continuous values and chi-square test was used between the non-continuous parameters. An ANOVA statistical calculation of the indices was also performed. The correlation coefficients R between the different parameters were calculated. A value of $P < 0.05$ is considered statistically significant.

Ethical Aspects

In addition to the approval of the ethics committee at the hospital, the operations and tests performed on patients were non-invasive, routine, without side effects, without radiation and performed regardless of this current study for all patients.

Ethical Statement

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore, was exempt.

The Study Population and Patients' Data (Fig. 3, Table 1)

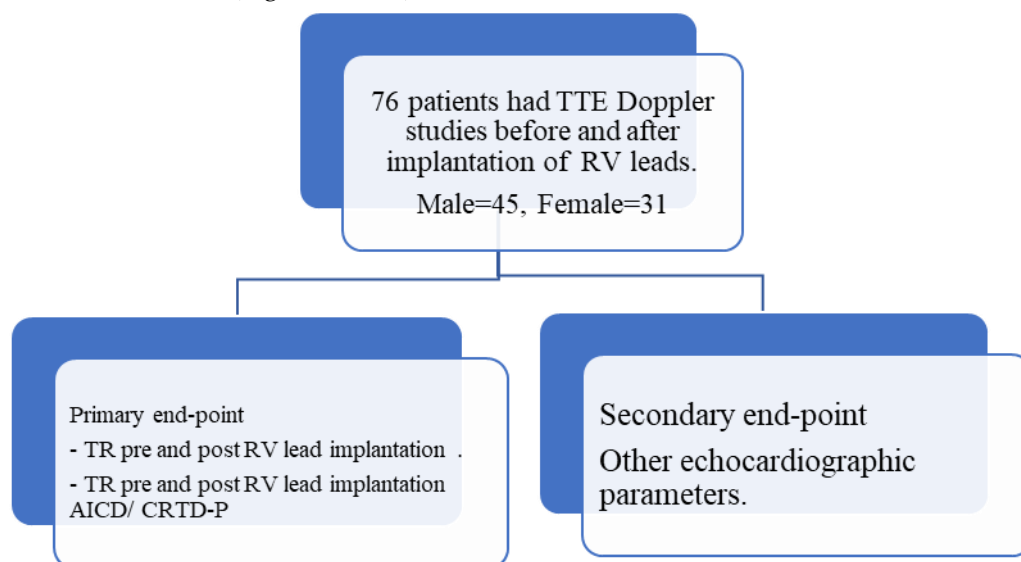


Figure 3: Study population and patients' data.

Characteristic	
Age	74±11
Sex	M=45, F=31
Smoker	20 (29%)
DM	31 (46.78%)

HTN	58 (76.31%)
HLP	63 (82.8%)
COPD/Asthma	18 (23.68%)
CVA	11 (14.47%)
PVD	22 (28.94%)
IHD	53 (69.73%)
AFIB	36 (47.36%)
Renal Failure	33 (43.42%)
AFIB: Atrial Fibrillation, CVA: Cerebrovascular Accident, DM: Diabetes Mellitus, HLP: Hyperlipidemia, HTN: Hypertension, IHD: Ischemic Heart Disease	

Table 1: Characteristics of the patients.

Variables

Independent Variables

The type of implanted device, the type of pacing (Table 2).

CHARACTERISTIC	
CRTD/P	20 (26.31%)
ICD	14 (18.42%)
DR	25(32.89%)
VVI	11 (14.47)
VDD	6 (7.89%)

Table 2: Independent variables.

Dependent Variables

Dimensions and function of the right ventricle.

Severity of tricuspid regurgitation.

Dimensions and function of the left ventricle.

Evaluation of MR, TR, AR severity, TAPSE and the change in data after pacing.

Primary End Point

Results:

- Before RV lead implantation 96% of patients had TR, grade 1 in 57 patients (75%), grade 2 in 12 (16%), grade 3 and 4 in 4 (5%)
- After RV lead implantation, 44 patients with grade 1 TR remained with the same degree (77%) while in 2 (3.5%) TR progressed to grade 2 and in the remainder the TR disappeared
- Most of the patients with grade 2 TR before RV lead implantation (75%) remained in grade 2, while in 25% the grade decreased to grade 1
- In all patients with grade 3 and 4 TR pre-implantation, the severity of TR decreased by one grade (Fig. 4-6)

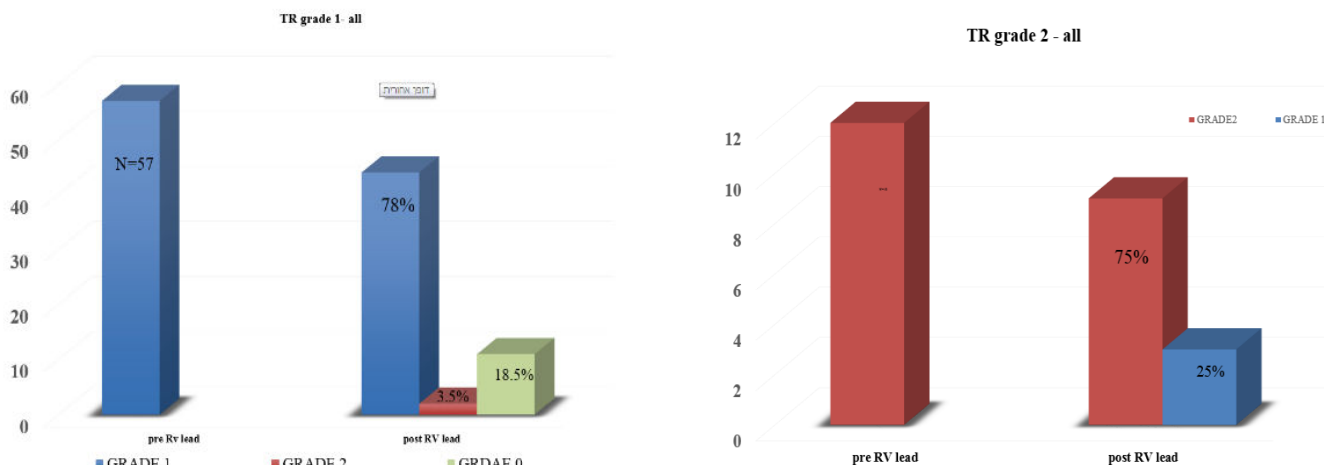


Figure 4: TR grade progression.

- In 56 patients with non-CRT device implantations, 39 (70%) had grade 1 TR before procedure and 28 (72%) of them TR grade did not change and in 11 (28%) TR grade progressed to grade 2 after implantation
- Grade 2 TR before implantation was observed in 8 patients (14%) and after the implantation the TR grade decreased in 3 (37.5%) of them and did not change in the others
- In 3 (5.4%) patients with grade 3 and 4 TR before procedure, the TR decreased after the procedure

non-CRT device implantations , N=56

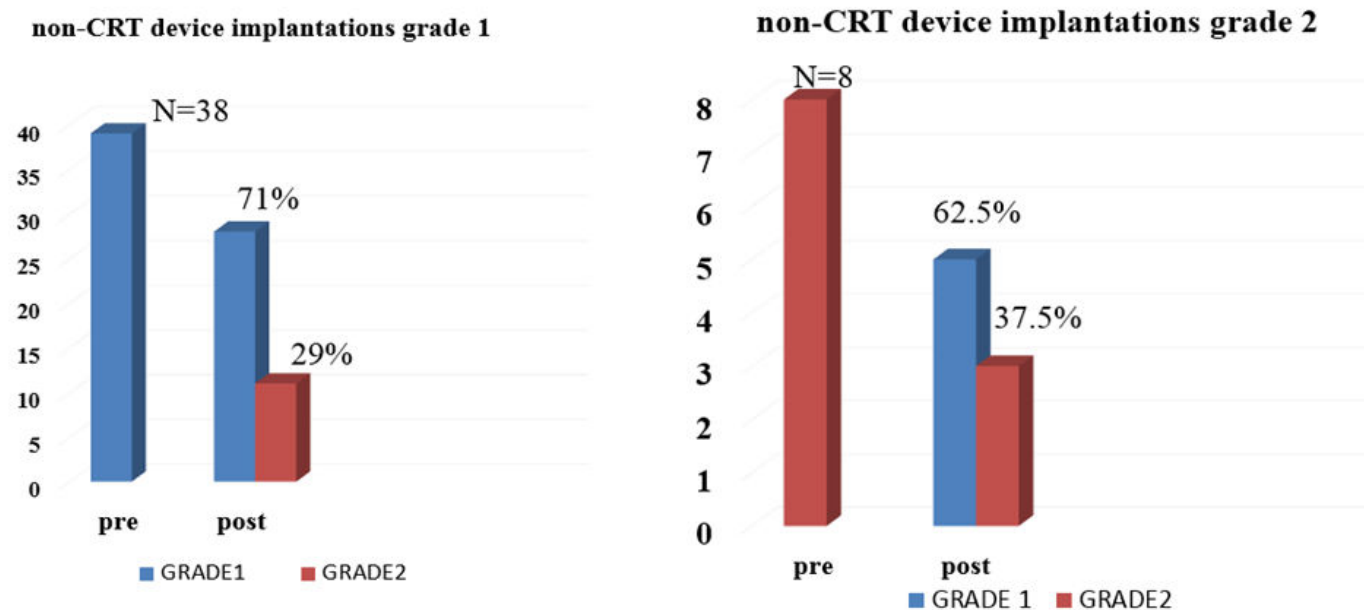


Figure 5: Non-CRT device implantation progression.

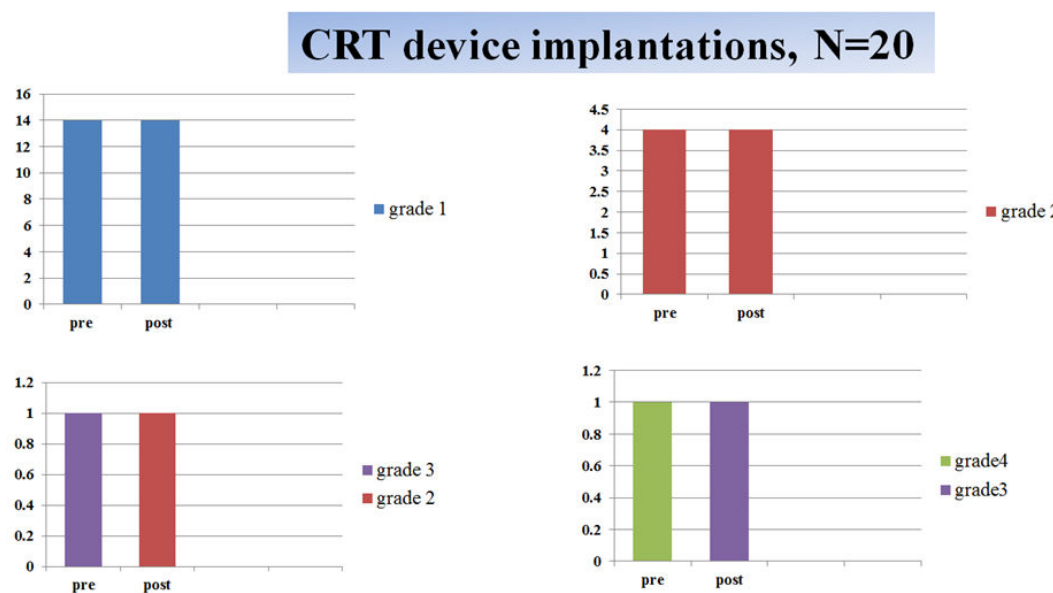


Figure 6: CRT device implantation.

Secondary End Point (Fig. 7)

	EF	LVEDD	LVESD	IVS-D	LPW-D	A.ROOT	LA-AP	E	A	EA
Pre	44±15	5.7±1	3.62±1	1.27±0.1	1.22±1	3.39±0.3	4.22±0.9	92.7±34	80.7±29	8.2±2.4
Post	42±15	5.8±1	3.76±1	1.28±0.2	1.19±0.1	3.35±0.3	4.32±0.9	85.1±33	79.1±29	5.4±2
P-value	ns	ns	ns	ns	ns	ns	Ns	ns	ns	Ns

	MR GRADE	P. Velocity Aortic	AR	P.V Pulmonic	ACC Time Pulmonic	PG-T	TAPSE
Pre	27±16	148.9±87	12±3	84.4±27	105.3±27	36.4±12	21.8±4
Post	33±15	156.3±70	10±1	205.9±1034	108.2±23	38.8±13	20.1±4
P-value	ns	ns	ns	ns	ns	Ns	ns

Figure 7: A: mitral A wave late diastolic velocity, E: mitral E wave early diastolic velocity, Ea: mitral annulus wave early diastolic tissue Doppler velocity, EDT: E wave deceleration time, E/A: E to A ratio, E/Ea: E to Ea ratio, LA: left atrium, LA-A: left atrium area, LVEED: left ventricle diastolic diameter, LVEF: left ventricle ejection fraction, LVESD: left ventricle systolic diameter, LPW-D: left posterior wall diameter.

Summary

Cardiac device-related TR is usually due to mechanical injury such as perforation of the valve leaflets, entrapment of leads resulting in scar tissue formation or impaired valve growth. It may also cause physiological alterations like unsynchronized activation of the right ventricle from apex to base.

In this study, we came to the conclusion that implantation of an electrode through the tricuspid valve does not involve worsening of right ventricular function or tricuspid regurgitation. This is demonstrated by the maintenance or reduction in TR grading in all the patients of this study.

However, larger, prospective and well-controlled studies are needed to optimally assess the incidence and timing of TR after endocardial lead implantation.

Conflict of Interests

The authors declare no conflict of interest regarding authorship roles or publication of article.

Consent

Not applicable because this study is based exclusively on published literature.

Disclosure

The authors report no conflicts of interest.

Acknowledgement

None

Financial Disclosure

No funding was not involved in the manuscript writing, editing, approval or decision to publish.

Authors Contribution

All the authors have equal contribution and all the authors have read and agreed to the published version of the manuscript.

Data Availability

Not applicable

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