Section: Cardiology

Original Research Article

COMPARISON OF THE EFFECTS OF ALTERNATIVE RIGHT VENTRICULAR PACING SITES (RV APICAL VS MID- SEPTAL) ON ACUTE HEMODYNAMICS

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ABSTRACT

Background: Cardiac pacing no doubt, is effective in the treatment of various cardiac conditions but conventional RV apical pacing has detrimental effects on cardiac structure and function. The aim of the study was to study the comparison of effect on alternative RV pacing sites (apical vs mid-septal) on acute hemodynamic (Systolic BP, Diastolic BP and MAP).

Materials and Methods: 22 stable patients undergoing EPS ±RFA for PSVT were included in the study. In each patient, the QRS width and axis were measured and the difference between the sinus QRS width at Mid-septum and Apex were compared. Similarly, SBP, DBP and MAP was recorded and compared. QRS width was plotted against ΔSBP for each data.

Results: Among the 20 patients taken for the study, the different indications for undergoing cardiac catheterisation were AVRT (35%), AVNRT (50%) and AT (15%). The mean baseline QRS from surface ECG was 62.9±8.6. The mean QRS at Mid-septum after pacing was 138±5.6 and mean QRS at Apex was 154±9.3 respectively. The average increase in QRS after pacing was 74.8±4.3 unit more at apex compared to mid-septum and the difference was statistically significant (P<0.001). The mean baseline SBP, DBP and MAP was 140.7±11.7, 80.4±7.3 and 100.4±8.2 respectively. The mean SBP after pacing at mid-septum was 121.5±10.8 and at apex was 117.9±10.1 respectively and the difference was not statistically significant (p=0.290). The mean DBP after pacing at mid-septum was 76.8±7.3 and at apex was 73.6±7.2 respectively and the difference was also not statistically significant (p=0.163). The mean MAP after pacing at mid-septum was 91.8±8.1 and at apex was 88.3±7.7 respectively and the difference again was not statistically significant (p=0.167). The average baseline PA saturation was 74.4□2.4 unit. The mean of PA saturation after pacing at mid-septum was 71.1 ± 2.4 and at apex was 67.7 ± 2.1 respectively, the difference was not statistically significant (p=0.051). A significant affirmative correlation (r=-0.67; p=0.001) was found in the QRS duration during pacing in relation to SBP change. However, no significant correlation was established between the pacing site and the SBP change.

Conclusion: We therefore conclude that Right Ventricular Pacing at Apex causes significant increase in QRS duration as compared to pacing at Mid-septum but there was no significant effect on SBP, DBP and MAP between the two sites of pacing. However, the study was limited owing to small numbers of patients and only two pacing sites were compared. Besides, the results were limited for acute hemodynamic events only and may not apply to more long term conditions in which adaptive mechanisms may be of help. Despite the

shortcomings, we recommend that the ventricular pacing lead should be placed at the site where the paced QRS duration is minimum during permanent pacemaker implantation. This should preferably be at a level of less than 140 ms.
Keywords: Right Ventricular Pacing, RV Apical Pacing, Mid-Septal Pacing, Acute Hemodynamics

INTRODUCTION

Pacemaker implantation is the most reliable long-term treatment option for patients with significant bradyarrhythmias. Most pacing systems employ one lead in the right ventricle (RV) usually implanted into the apical region.

However, RV apical pacing prolongs QRS complex duration,[1] induces mechanical asynchrony, [2,3] promotes atrial fibrillation (AF) and heart failure. [4-6] Detrimental effect of RV apical pacing could be potentially diminished by the use of alternative RV pacing sites. Several studies demonstrated that septal pacing or pacing from RV outflow tract shows better results than apical pacing. [3,7-11]

In cardiac pacing, the endocardial pacing lead is typically positioned at the right ventricular (RV) apex. However, with the energy normally used for pacing purposes, the electric pulse directly excites just a small portion of the ventricular myocardium, restricted to about 1 mm in case of point stimulation by a very small electrode. Starting from the edge of this area, the activation front spreads through the myocardial cell network until Purkinje fibres are depolarized and can eventually contribute to the latest part of the conduction process. Focal pacing thus entails heterogeneous activation delays in different regions and ventricular electromechanical dyssynchrony. [12,13] Right ventricular apical pacing can induce both interventricular dyssynchrony (between the RV and the LV), as well as intraventricular dyssynchrony (within the LV).[14] Intraventricular conduction defects, which are manifested as increased QRS duration, are seen frequently in patients with left ventricular dysfunction and have an adverse effect on left ventricular systolic and diastolic function.

At the same time, there is increasing indirect evidence derived from large pacing mode selection trials and observational studies, that conventional RV apical pacing may have detrimental effects on cardiac structure and left ventricular function, which are associated with alterations in systolic and diastolic function associated with chronic apical pacing which could explain the increased incidence of atrial fibrillation and heart failure in long-term paced patients.[12,13,14] These detrimental effects can be overcome by alternative site pacing.

Evidence in favor of alternative site pacing is mostly based on the electrocardiographic and echocardiographic evaluation of RV stimulation side-effects, while a significant influence of the pacing site on functional capacity, quality of life and survival has not been demonstrated by randomized controlled trials.[15] Both the abnormal electrical and mechanical activation pattern of the ventricles can result in changes in cardiac metabolism and perfusion, remodelling, hemodynamics, and mechanical function.[16]

Alternative RV pacing sites Pacing at the RV outflow tract, septal pacing and direct His bundle pacing have been suggested as alternatives to the RV apex when pacing is inevitable.[17,18] Because of the closer proximity to the normal conduction system, these sites may result in less electrical activation delay (represented by a shorter QRS duration) and less mechanical dyssynchrony and the deterioration of LV function .Several clinical studies have determined that correction of conduction defects by multisite ventricular pacing has caused marked improvement in left ventricular function and in overall hemodynamic performance.[12,13,19,20] The present study was therefore conducted to study the effect of RV pacing at apex and mid-septum on QRS width and hemodynamic changes.

MATERIALS AND METHODS

The present study was conducted between 2013 to 2015 at the Department of Cardiology, Batra Hospital and Medical Research Centre, New Delhi. The study was approved by the local ethics committee and informed consent was obtained from the enrolled patients. A total of 20 patients were taken for study at BHMRC New Delhi. All the patients taken for the study were stable and were scheduled to undergo EPS ± RFA for Paroxysmal Supraventricular Tachycardia.

Patients with persistent atrial fibrillation, unstable angina or an acute coronary syndrome, valvular heart disease and a wide QRS on baseline ECG were excluded from the study.

2.1 Study Design

Patients were studied in a fasting state and all procedures were performed taking aseptic precautions with the patient in a conscious state under local anaesthesia. A short, 5 Fr. sheath was placed into the left femoral artery and connected to standard blood pressure transducer. RV pacing was carried out at RV Apex and RV septum at cycle lengths of 600 ms and 500 ms using a 6-7F deflectable quadripolar electrode catheter (Livewire, St. Jude Medical, Minneapolis, MN, USA) under Fluoroscopy. This was done subsequent to successful radio frequency catheter ablation for paroxysmal supraventricular tachycardia. RV pacing was sustained for about 15 seconds after the stabilization of femoral arterial

pressure during pacing. Paced QRS duration was measured after stabilization of blood pressure during pacing, as were systolic, diastolic, and mean blood pressures. Hemodynamic change was then compared at RV Apex and RV Septum during RV pacing.

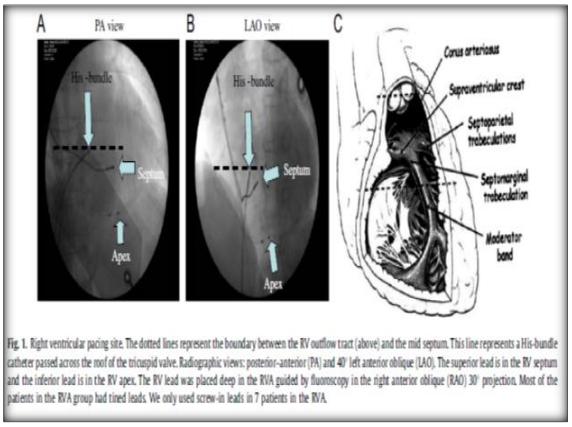

Fig. 1. Right ventricular pacing site. The dotted lines represent the boundary between the RV outflow tract (above) and the mid septum. This line represents a His-bundle catheter passed across the roof of the tricuspid valve. Radiographic views: posterior-anterior (PA) and 40° left anterior oblique (LAO). The superior lead is in the RV septum and the inferior lead is in the RV apex. The RV lead was placed deep in the RVA guided by fluoroscopy in the right anterior oblique (RAO) 30° projection. Most of the patients in the RVA group had tined leads. We only used screw-in leads in 7 patients in the RVA.

2.2 Data Analysis

QRS width and axis were measured and the difference between the pacing QRS width at Mid-septum and Apex were compared. Similarly, SBP, DBP and MAP was recorded and compared. QRS width was plotted against ΔS BP for each data.

2.3 Statistics

Data contained both continuous and categorical variables. Therefore, mean with SD for continuous and frequency with proportions were used for their presentation. Student 'T'test for the quantitative variables with two independent groups and Chi-square/Fisher's test was used for statistical significance between qualitative variables. The correlation between the scale variables was assessed by scatter plots and Pearson's coefficient. Further, the multivariate regression analysis was used to find the independent predictors of decrease in SBP. The p value less than 0.05 was considered as statistical significant. The statistical software IBM PASW (Version 22.0) was used for entire analysis.

RESULTS

All patients who had either undergone cardiac catheterisation or EPS ± RFA were identified during May 2013 to Feb 2015. After screening for almost 6 months, 20 patients were taken for the study and their outcome analysis was done.

The age of the study group ranged from 27-62 years for males with mean 43.6±10.9 years and 28-62 years for females 39.5±10.9 years. [Table1]

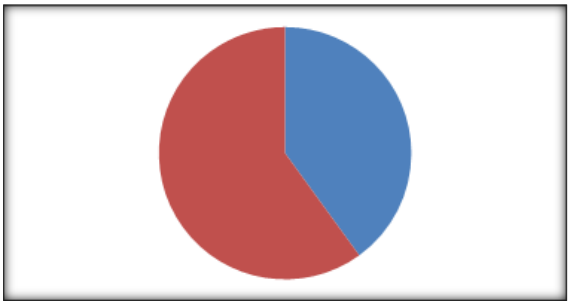

Figure 1

The different indications for undergoing cardiac catheterisation were AVRT (35%), AVNRT (50%) and AT (15%) (Table 2).

The mean baseline QRSd from surface ECG was 62.9±8.6. The mean QRSd at Midseptum after pacing was 138±5.6 and mean QRSd at Apex was 154±9.3 respectively. The average increase in QRSd after pacing was 74.8±4.3 units more at apex compared to midseptum and the difference was stastically significant (P<0.001)(Table3 and figure 2)

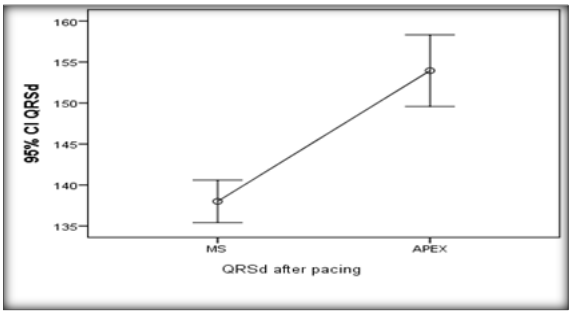

Figure 2

The mean baseline SBP, DBP and MAP was 140.7±11.7, 80.4±7.3 and 100.4±8.2 respectively. The mean SBP after pacing at midseptum was 121.5±10.8 and at apex was 117.9±10.1 respectively and the difference was not statistically significant (p=0.290). The mean DBP after pacing at midseptum was 76.8±7.3 and at apex was 73.6±7.2 respectively and the difference was also not statistically significant (p=0.163). The mean MAP after pacing at midseptum was 91.8±8.1 and at apex was 88.3±7.7 respectively and the difference again was not statistically significant (p=0.167) (Table 4 and Figure 3a, 3b, 3c).

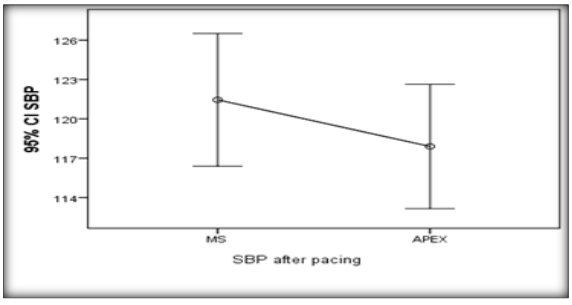

Figure 3a

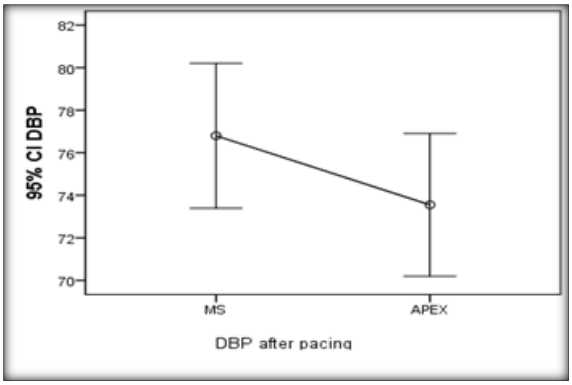

Figure 3b

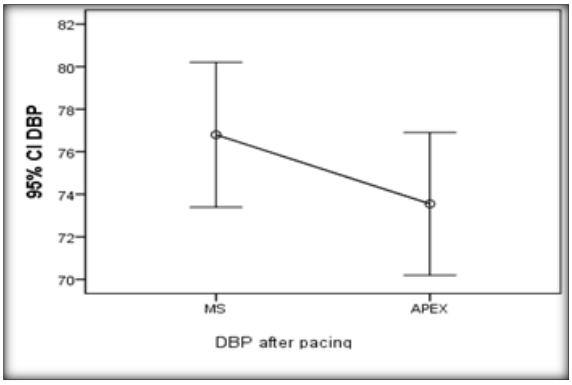

Figure 3c

The relation between QRS and change in SBP according to pacing site is represented in Table 6. The significant affirmative correlation (r=-0.67; p=0.001) was found in the QRS duration during pacing in relation to SBP change. No significant correlation, however, was established between the pacing site and the SBP change. (Fig.4a, 4b)

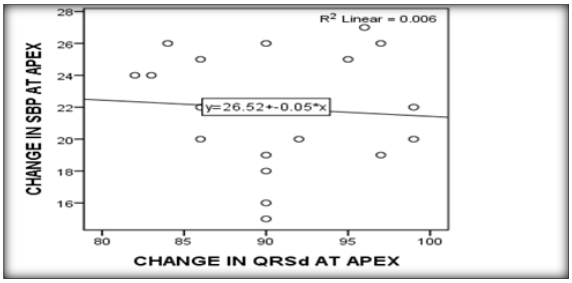

Figure 4a

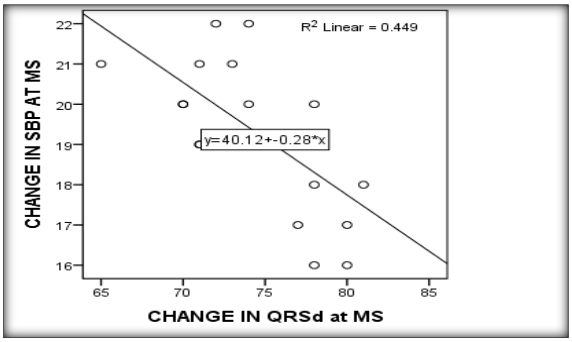

Figure 4b: LI

The multivariate linear regression analysis was carried out to predict the decrease in SBP during RV pacing. The overall fitting of the model for MS procedure was 58.4% and for Apex was 56%. The baseline SBP was significantly related with the change in QRSd at MS. However, none of the variables were found statistically significant at APEX procedure. (Table 7)The overall prediction was presented by the residuals plots in Figure 5a and 5b.

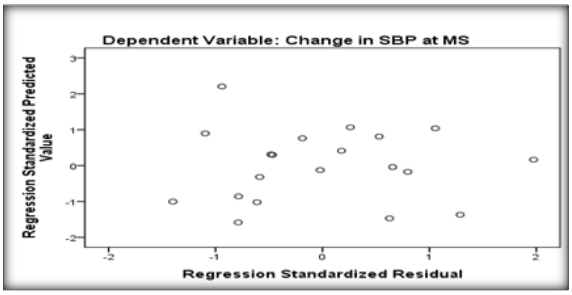

Figure 5a:

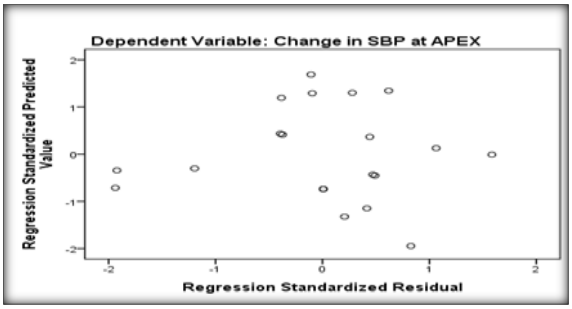

Figure 5b

Table 1

	Sex	N	Mean	SD
Age (years)	Female	8	39.5	10.9
	Male	12	43.6	10.9

Table 2

Type of syndrome	Number (n=20)	%
AVRT	7	35
AVNRT	10	50
AT	3	15

Table 3

Variables after pacing	Group	N	Mean	SD	P value
QRSd	MS	20	138.0	5.6	**p<0.001**
	APEX	20	154.0	9.3	

Table 4

Variables after pacing	Group	N	Mean	SD	P value
SBP	MS	20	121.5	10.8	0.290
	APEX	20	117.9	10.1	
DBP	MS	20	76.8	7.3	0.163
	APEX	20	73.6	7.2	
MAP	MS	20	91.8	8.1	0.167
	APEX	20	88.3	7.7	

Table 5

	CHANGE IN SBPAT MS		CHANGE IN SBP AT APEX	
	Pearson Correlation	p value	Pearson Correlation	p value
CHANGE IN QRSd at MS	-0.67	**0.001**		
CHANGE IN QRSd AT APEX			-0.077	0.748

Table 6: Linear regression analysis to predict decrease in SBP

Variables in the model	Regression coefficient	SE	t value	P value	95.0% C.I.	
					LB	UB
At MS						
Change in QRSd	-0.32	0.11	-2.96	0.010	-0.54	-0.09
DBP after pacing	0.19	0.12	1.55	0.141	-0.07	0.44
MAP after pacing	-0.14	0.13	-1.09	0.292	-0.42	0.14
PA SAT after pacing	-0.20	0.14	-1.43	0.172	-0.48	0.10
AT APEX						
Change in QRSd	0.02	0.12	0.13	0.901	-0.25	0.28
DBP after pacing	-0.63	0.29	-2.21	0.043	-1.24	-0.02
MAP after pacing	0.81	0.26	3.13	0.007	0.26	1.37
PA SAT after pacing	0.34	0.31	1.09	0.295	-0.32	1.00

DISCUSSION

In the present study, we thus confirmed that mid-septum right ventricular pacing induced shorter QRSd and modest but insignificant acute hemodynamic benefits compared to apical pacing. Previous reports have suggested that prolongation of the QRS interval results in decreased LVEF and a higher risk of CHF. [28,29] Thus, there has been increasing interest in RV pacing sites that are associated with more favorable physiologic function. Some studies suggest that pacing from a septal stimulation site may produce such favorable physiologic atrioventricular conduction. [21,27] However, the absence of definitive data showing the superiority of RVS-pacing over RVA-pacing has limited the adoption of this strategy.

Durrer et al,[30] reported that ventricular depolarization begins in the LV septum, which suggests that initiating pacing from regions close to this area (e.g., RV septum) may produce a physiologic contraction pattern. In contrast, the free wall of the RV is the last zone to be depolarized. Thus, it is important to distinguish septal positioning from other RV sites. The pacing of this site produces a narrower QRS than the pacing of the right ventricular apex. These findings suggest that right ventricular septal site may be more optimal than the right ventricular apex in patients who need continuous ventricular pacing. Moreover, the difference in QRS interval between the 2 groups became significant after pacing in this study. The negative remodeling effects of RVA-pacing may take years to manifest.[31]

Miwa Kikuchi, MD, Kaoru Tanno, MD,[27] investigated 149 consecutive patients who underwent implantation of a dual chamber pacemaker for atrioventricular block with either RVS-pacing between July 2007 and June 2010 or RVA-pacing between January 2003 and June 2007.The endpoint was defined as death and hospitalization due to heart failure(HF).The rates of mortality and hospitalization due to HF were significant lower in the RVS-pacing group than that in the RVA-pacing group(event free RVS:1year, 98% and 2 years,98%;RVA:1year,85%and 2 years,81%; $p<0.05$). None of the patients died from HF in the RVS-pacing group, while 4 patients died from HF in the RVA-pacing group within 2 years after pacemaker implantation. The paced QRS interval was significantly shorter with RVS pacing than with RVA pacing at different times after pacemaker implantation (RVS: immediately 157.8 ± 24.0 ms, after 3 months 157.3 ± 17.5 ms, after 6 months 153.6 ± 21.7 ms, after 12 months 153.6 ± 19.4 ms, after 24 months 149.3± 24.0 ms vs. RVA: immediately 168.3 ± 23.7 ms, after 3 months 168.7± 26.0 ms, after 6 months168.0± 22.8 ms, after 12 months171.2 ± 22.3 ms, after 24 months176.1 ± 25.5 ms; $p< 0.05$). They Concluded that RVS pacing is feasible and safe with more favorable clinical benefits than RVA pacing.

Similarly, Silvet et al,[22] tested the hypothesis that increased QRS duration seen in patients with moderate or severe left ventricular dysfunction resulted in higher mortality. They separated the patients into two groups; those with normal (<110ms) QRS duration and those with prolonged (≥110 ms) QRS duration. Patients with increased QRS duration tended to be older, had lower ejection fractions, lower heart rates, larger left ventricular cavities, larger left

atrial sizes, and longer QT intervals. They also had 6-year survival rates of 40%, as compared to 60% for patients exhibiting normal QRS duration. This allowed them to conclude that QRS protraction is associated to an increase in mortality. This is independent of the levels of ejection fraction, rhythm, and age.

Prolonged QRS duration is also closely associated to the poor prognosis of patients with acute myocardial infarction. Brilakis et al,[23] established that QRS duration of more than 100 ms in the absence of a bundle branch block can independently predict increased mortality in patients with non-ST elevation myocardial infarction. The lower survival rate in patients with myocardial infarction can be explained, in part, with the following mechanisms. First, increased QRS duration is powerfully correlated with heart failure, both upon admission (as evidenced by worse Killip class) and upon dismissal (as evidenced by the decreased pre dismissal ejection fraction). Second, QRS protraction is associated with ischemia and multivessel coronary artery disease. In patients with normal coronary arteries, QRS duration diminishes with exercise, probably due to an increase in the sympathetic tone. In contrast, in patients with coronary artery disease, QRS duration actually increases during exercise testing.

Michaelides et al,[24] reported that exercise-induced QRS prolongation was proportional to the number of coronary arteries with stenosis. This is seen at levels of more than 70%. Mean QRS prolongation was 4.8±7.5 ms in patients with 1-vessel disease, 7.8±11.8 ms in patients with 2-vessel disease, and 13.3±12.1 ms in patients with 3-vessel disease. Third, QRS protraction is associated with development of ventricular tachycardia or fibrillation. In the 743 patients of the placebo arm of the Cardiac Arrhythmia Suppression Trial 25 with stable coronary artery disease and exhibiting QRS duration of more than 100 ms, the risk ratio was 1.4 for new or aggravated congestive heart failure, 1.5 for arrhythmic death or cardiac arrest, and 1.4 for all-cause mortality. In post-acute myocardial infarction patients, QRS protraction was significantly correlated with arrhythmic events.25 Therefore, QRS prolongation may be seen as a marker of increased vulnerability to re-entrant ventricular dysrhythmias and arrhythmic death.

In addition to QRS prolongation seen on resting electrocardiograms, increased QRS duration during pacing may be connected to serious cardiac disease. Sumiyoshi et al,[26] studied 114 patients who had increased QRS duration and suggest QRS prolongation could be valuable in indicating impaired left ventricular function. Our finding was in favor of acute hemodynamic effects as observed by Young Joon Hoong M.D Bo Ra. Yang15 in 14 patients Who underwent EPS study and found that during RV pacing, blood pressures (systolic/diastolic/mean) decreased. The change of post-pacing QRS duration and pre-pacing systolic blood pressure (SBP) were greater in the group with paced QRS duration. The differences overall were greater than 140 ms. The SBP decrease during pacing was larger in the group exhibiting paced QRS duration of greater than 140 ms. The SBP decrease during pacing showed relation to QRS duration during pacing (r=0.500, p=0.001), the change of QRS duration post-pacing (r=0.426, p=0.001), and SBP during sinus rhythm (r=0.342, p=0.001) on linear correlation analysis. The pacing site, on the other hand, did not affect acute hemodynamic changes during pacing. We therefore conclude Right Ventricular Pacing at Apex causes significant increase in QRS duration as compared to pacing at Mid-septum but there was no significant effect on SBP, DBP, MAP and PA saturation between the two sites of pacing. However, the study was limited owing to small numbers of patients in our study and only two pacing sites were compared. Besides since the results were limited for acute hemodynamic events, they may not apply to more long term conditions in which adaptive mechanisms may reduce these effects. Despite the shortcomings, we recommend that the ventricular pacing lead should be placed at the site where the paced QRS duration is minimum during permanent pacemaker implantation. This should preferably be at a level of less than 140 ms.

CONCLUSION

To conclude, this study demonstrated that right ventricular (RV) pacing at the apex significantly increases the QRS duration compared to pacing at the mid-septum, though both sites showed no significant differences in acute hemodynamic parameters like systolic, diastolic, and mean arterial pressures. These findings support the hypothesis that RV mid-septal pacing, which produces a shorter QRS duration, may offer a less disruptive electrical activation pattern. However, given the study's limitations—including a small sample size, focus on acute hemodynamic responses, and examination of only two pacing sites—the implications for long-term outcomes remain uncertain. Further studies are necessary to explore whether pacing site selection can improve long-term cardiac function and patient prognosis. Nonetheless, it is recommended that pacemaker leads be positioned at sites where paced QRS duration is minimized, ideally under 140 ms, during permanent pacemaker implantation.

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