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ORIGINAL RESEARCH

Comparison of QRS Duration Among Right Ventricular Pacing Sites-An Observational Study

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Abstract

Background: Chronic right ventricular apical pacing (RVAP) has been associated with detrimental clinical and hemodynamic outcomes. Theoretically, mid-septum pacing site has been proposed as a more physiological site compared to conventional apical pacing site.

Aim: The present study was designed to assess whether right ventricular (RV) mid-septal pacing could be more favorable compared to the standard RVAP in correlation with pQRSd (paced QRS duration).

Methods: A prospective observational study was conducted at a tertiary care cenre in India between May 2013 and February2015.Total122 patients were enrolled in the study. Of which 102 consecutive patients who underwent pacemaker implantation at mid-septum and apex were compared. Based on pQRSd, patients were dived into two groups. Group I include 73 patients having pQRSd ≤150 msec. Group I was further divided into group Ia (pQRSd ≤ 120 msec) and group Ib (pQRSd= 120-150 msec) including 5 and 68 patients, respectively and group II (pQRSd ≥ 150 msec) comprised 29 patients. Baseline clinical characteristics of all the patients according to pQRSd and pacing site were recorded. pQRSd was calculated using electrocardiogram (ECG).

Results: Mean age was 64.63±8.89 years with male (60.8%) preponderance. Pacemaker was implanted in 102 patients of which, 51 patients were implanted at mid-septum and 51 patients at the apex. Mean pQRSd(<0.001) at apex (147.53±9.81 msec) was significantly higher compared to mid-septum (136.88±11.89 msec). Baseline QRS duration was the independent predictor of pQRSd≤120 msec.

Conclusion: Compared to apical pacing, mid-septal was associated with a considerably shorter pQRSd. Hence, pacing at mid-septum as an alternative to apical site could be beneficial to reduce the associated LV dysfunction.
Keywords: QRS duration; Pacing; Mid-septum; Apex; Right ventricular

Introduction

Permanent pacemaker implantation has been used for more than half a century as a definitive treatment strategy for symptomatic bradyarrhythmia. The right ventricular apex (RVA) has been preferred as the conventional site due to its stable and reliable pacing parameters.(1) Despite of its advantages, long-term RVA pacing is associated with the onset of atrial fibrillation, left ventricular (LV) dysfunction, and heart failure due to pacing induced electrical and mechanical LV dyssynchrony which is defined as pacing-induced cardiomyopathy (PiCM).(2, 3) In recent years, 14.1% of patients suffered with PiCM.(4)

The normal myocardial activation is through the conduction system resulting in synchronic activation of both ventricles. Although myocardial stimulation achieved by pacing outside the conduction axis results in efficient contractions with impressive haemodynamic results, it is not physiological. Such a pacing generates a wave front which propagates gradually through the myocardium resulting in ventricular dyssynchrony(5). This slow conduction through myocardium leads to intraventricular conduction delay, manifested on surface electrocardiogram (ECG) by a prolonged QRS duration. A prolonged QRS duration is an independent risk factor for LV dysfunction and sudden cardiac death. In a recent study by Cho et al., paced QRS duration (>155 msec) was reported as one of the independent predictors of PiCM. (6)Thus, for preventing LV dysfunction it is important that the right ventricular (RV) lead has to be implanted in the position from which QRS duration is shorter.(5, 7)

Among the various sites for right ventricular (RV) pacing, the septal areas, particularly the mid-RV and right ventricular outflow tract (RVOT) septal pacing are hypothetically associated with a more physiological ventricular activation similar to that of normal atrioventricular conduction.(8-10) Experimental and clinical data recommend that RV septal pacing, may prevent or diminish this LV dysfunction related to RVA pacing. Moreover, studies have shown that the mean QRS duration is significantly longer in RVA than mid-septal pacing.(11, 12)The association between paced QRS duration and various sites of RV pacing have not been studied in detail in a large cohort of patients. Therefore, the present study was designed to assess whether RV mid septal pacing could be more favorable compared to the standard RVA pacing in correlation with paced QRS duration.

Materials and methods

Study design and population

This was a prospective observational study conducted between May 2013and February 2015 at a tertiary care center in India including total 122 patients. Patients with standard indication for pacemaker implantation (aged >18 years) were included in the study. Exclusion criteria include patients with persistent atrial fibrillation, patients with unstable angina or an acute coronary syndrome and patients with wide QRS duration on baseline ECG. The study was approved by institutional ethics committee and written informed consent was obtained from all the patients.

Pacemaker implantation

All patients were implanted with dual-chamber or single chamber pacemakers in a sterile manner with a conscious state under local anaesthesia by a skilled operator. A Swan Ganz catheter was placed via subclavian vein and advanced into the pulmonary artery. Electrocardiogram (ECG) was done to calculate QRS duration in the lead which was having

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maximum paced QRS duration.Based on the paced QRS duration, 102 patients were divided into two groups. Group I was further subdivided into two groups (group Ia and group Ib). Group Ia include five patients with QRS ≤ 120 msec while group Ib contains 68 patients with QRS duration 120-150 msec and group II consist of 29 patients with QRS duration >150 msec.

Fluoroscopy was done to look for optimal lead position in antero posterior (AP), left anterior oblique (LAO) 40°, right anterioroblique (RAO) 30° and lateral position. Pacemaker lead tip was divided into two positions based on fluoroscopic findings (i) mid-septal, (ii) apex. Final lead position assessment was done independently by one of the investigators. All patients underwent post procedure echocardiogram. Lateral fluoroscopic view was considered the best view for lead localization.(10)In 20 patients, effect of QRS duration and pacing site on hemodynamic changes was analyzed.

Statistical analysis

Statistical analysis was performed using SPSS Software (version 20., SPSS, Inc., Chicago, IL, USA). Quantitative variables were summarized as mean ± SD and qualitative variables were summarized as frequency counts and percentages. Continuous variables were compared among the group by one way analysis of variance (ANOVA). Categorical variables were analyzed using chi square test or fisher exact t-test. P-value of <0.05 was considered as statistically significant.

Results

A total of 122 consecutive patients who underwent pacemaker implantation during the study period were screened. Association of pacing site with paced QRS duration was examined in 102 patients. Mean age of the patients was 64.63 ± 8.89 years. Males (60.8%) were predominant. The prevalence of complete heart block (CHB), high-grade atrioventricular block (HG AVB) and left bundle branch block (LBBB) was statistically significant between group I and group II. Baseline characteristics of patients according to paced QRS duration are demonstrated in Table 1.

Table 1: Baseline characteristics of patients according to paced QRS duration

		Group-I pQRSd≤ 150 msec		**Group-II**	
Variables	**Total (N=102)**	**≤120 msec (N=5)**	**120-150 msec (N=68)**	**>150 msec (N=29)**	**p-value**
Age, Mean ± SD (years)	64.63±8.89	59.80±10.96	64.62±8.73	65.48±9.0	0.423
Gender					
Male, n (%)	62 (60.8%)	1 (20.0%)	42 (61.8%)	19 (65.5%)	0.150
Female, n (%)	40 (39.2%)	4 (80.0%)	26 (38.2%)	10 (34.5%)	
Diagnosis					
2*AVB, n (%)	8 (7.8%)	0 (0%)	6 (8.8%)	2 (6.9%)	1.000
BiFAVB, n (%)	7 (6.9%)	0 (0%)	4 (5.9%)	3 (10.3%)	0.599
CHB, n (%)	54 (52.9%)	2 (40.0%)	42 (61.8%)	10 (34.5%)	0.040
HG AVB, n (%)	11 (10.8%)	2 (40.0%)	8 (11.8%)	1 (3.4%)	0.047
LBBB, n (%)	9 (8.8%)	0 (0%)	1 (1.5%)	8 (27.6%)	<0.001
SSS, n (%)	13 (12.7%)	1 (20.0%)	7 (10.3%)	5 (17.2%)	0.348
Site of Pacing					
RV Mid Septum, n (%)	51 (50.0%)	5 (100.0%)	39 (57.4%)	7 (24.1%)	0.001

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RV Apex, n (%)	51 (50.0%)	0 (0%)	29 (42.6%)	22 (75.9%)	
Baseline QRS duration, Mean ± SD (msec)	110.19±11.99	94.40±3.58	106.84±9.70	120.76±10.19	<0.001
Paced QRS duration, Mean ± SD (msec)	142.21±12.10	117.40±1.67	137.93±7.60	156.52±4.79	<0.001
Change in QRS duration, Mean ± SD (msec)	31.71±9.41	23.00±4.36	30.94±9.60	35.00±8.36	0.014

pQRSd: Paced QRS duration; 2* AVB: Second degree atrioventricular block; BiFAVB: Atrioventricular block; CHB: Complete heart block; HG AVB: High-grade atrioventricular block; LBBB: Left bundle branch block; SSS: Sick sinus syndrome.

Mean age of the patients with pacing at mid septum was 62.92±8.48 years and the mean age of the patients who underwent pacing at apex was 66.33±9.05 years. Baseline QRS duration at mid septum was 112.71±11.73 msec and at apex was 107.67±11.82 msec. Paced QRS duration was significantly higher at apex compared to mid septum with a mean of 147.53±9.81 msec and 136.88±11.89 msec for apical and mid septum, respectively. Change in the QRS duration (p<0.001) at mid septum and apex was noted as 23.78±3.36 msec and 39.63±6.29 msec, respectively. Baseline characteristics of patients according to pacing site are illustrated in **Table 2**.

Table 2: Baseline characteristics of patients according to pacing site.

Variables	**Mid Septum (N=51)**	**Apex (N=51)**	**p-value**
Age, Mean ± SD(Years)	62.92±8.48	66.33±9.05	0.052
Gender			
Male, n (%)	30 (58.8%)	32 (62.7%)	0.685
Female, n (%)	21 (41.2%)	19 (37.3%)	
Diagnosis			
2*AV Block, n (%)	3 (5.9%)	5 (9.8%)	0.715
BiF AV Block, n (%)	3 (5.9%)	4 (7.8%)	1.000
CHB, n (%)	27 (52.9%)	27 (52.9%)	1.000
HG AV Block, n (%)	6 (11.8%)	5 (9.8%)	0.750
LBBB, n (%)	5 (9.8%)	4 (7.8%)	1.000
SSS, n (%)	7 (13.7%)	6 (11.8%)	0.767
Baseline QRS duration, Mean ± SD (msec)	112.71±11.73	107.67±11.82	0.033
Paced QRS duration, Mean ± SD (msec)	136.88±11.89	147.53±9.81	<0.001
Change in QRS duration, Mean ± SD (msec)	23.78±3.36	39.63±6.29	<0.001
Paced QRS duration (msec)			
≤120 msec	5 (9.8%)	0 (0%)	0.001
121-149 msec	39 (76.5%)	29 (56.9%)	
≥150 msec	7 (13.7%)	22 (43.1%)	

2* AVB: Second degree atrioventricular block; BiFAVB: Atrioventricular block; CHB: Complete heart block; HG AVB: High-grade atrioventricular block; LBBB: Left bundle branch block; SSS: Sick sinus syndrome.

In five patients of group Ia (paced QRS duration ≤120 msec), pacemaker lead tip was implanted at mid septum. Of 68 patients in group Ib (paced QRS duration 121-150 msec), 39 patients had pacemaker lead tip implantation at mid septum and 29 patients had pacemaker lead tip implantation at apex. Among 29 patients of group II (paced QRS duration ≥150

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msec), seven patients were having pacemaker implantation at mid septum and 22 patients were having implantation at apical septum. Different sites of pacing on basis of different paced QRS duration are summarized in **Table 3**.

Table 3: Different sites of pacing on basis of different paced QRS duration.

	Paced QRS duration	Patients (n=102)	Site
Group Ia	≤120 msec	5 (4.9%)	Mid Septum (n=5)
			Apex (n=0)
Group Ib	121-149 msec	68 (66.7%)	Mid Septum (n=39)
			Apex (n=29)
Group II	≥150 msec	29 (28.4%)	Mid Septum (n=7)
			Apex (n=22)

On multivariate analysis, baseline QRS duration [OR 1.14 (1.08-1.21)] predicted paced QRS ≤120 msec. Predictors of paced QRS duration ≤120 msec using multivariate logistic regression model are represented in **Table 4**.

Table 4: Predictors of paced QRS duration ≤120 msec using multivariate logistic regression model

Variables	Odds ratio (95%CI)	p-value
CHB	0.75 (0.25-2.29)	NS
HG AV Block	0.25 (0.04-1.68)	NS
LBBB	9.78 (0.36-266.50)	NS
Baseline QRS duration	1.14 (1.08-1.21)	<0.001

CHB: Complete heart block; HG AVB: High-grade atrioventricular block; LBBB: Left bundle branch block

Among 20 patients, hemodynamic changes due to pacing site was recorded. Systolic blood pressure (SBP) before pacing was 140.65±11.70 mmHg at mid-septum and was 151.15±7.46 mmHg at apex. SBP after pacing at mid septum was 121.45±10.81 mmHg and at apical septum was 129.05±4.75 mmHg. % SBP change in mid-septum was 19.20 ± 1.80% and in apical septum was 22.10 ± 3.23%. Changes of SBP and QRS duration during right ventricular pacing according to site (n=20) are demonstrated in **Table 5**.

Table 5: Changes of systolic blood pressure and QRS duration during right ventricular pacing according to site (n=20)

Parameters	Mid Septum (n=20)	Apex (n=20)	p-value
SBP before pacing, mmHg (Mean ± SD)	140.65±11.70	151.15±7.46	0.002
SBP after pacing, mmHg (Mean ± SD)	121.45±10.81	129.05±4.75	0.007
% SBP change, % (Mean ± SD)	19.20±1.80	22.10±3.23	0.001
QRSd before pacing, msec (Mean ± SD)	62.65±8.13	73.05±6.71	<0.001
QRSd after pacing, msec (Mean ± SD)	137.75±5.18	144.20±11.15	0.024
% QRSd change, % (Mean ± SD)	74.85±4.25	71.15±4.80	0.014

SBP: Systolic Blood Pressure; QRSd: QRS duration

Discussion

In the present study, we thus confirmed that mid-septum right ventricular pacing induced shorter QRS duration, and a significant acute hemodynamic benefit was observed compared to apical pacing. Apical pacing causes increased dyssynchrony and consequently the risk of ventricular dysfunction and atrial fibrillation. However, due to ease of lead implantation and lead stability, apical pacing is the frequently preferred site. Besides, within the RV chamber, it is difficult to position the pacing leads consistently and accurately onto the true septal position in mid-septum because of its posterior orientation. Nevertheless, with the advent of

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screw in leads, alternative pacing sites are an option to routine apical pacing site.(13) The RV mid-septum has been suggested as an alternate pacing site to the RV apical site which results in a more physiological electrical conduction to the LV and thus a more physiological contraction. In a study by Burri H et al., long-term follow-up demonstrated that pacing at the mid-septum is associated with similar sensing and pacing thresholds as RV apical pacing.(14) QRS duration is a characterization of ventricular activation time and has been accepted as a surrogate for evaluating of electrical synchrony. A former study by Cano O et al., reported a positive and statistically significant correlation between paced QRS duration and global dyssynchrony.(11)The myocardial activation sequence is determined by the RV pacing site, hence pacing at various RV sites results in varying paced QRS duration. As prolonged paced QRS duration is correlated with worsening of LV function and elevated risk of heart failure, mid-septum pacing has been proposed as an alternative RV pacing site to preserve LV function.Durrer et al., 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.(15)A former study by Nakamura et al., reported that mid-septal pacing is likely to lead less dyssynchrony than RV apical pacing.(16)

In addition to QRS protraction seen on resting electrocardiograms, increased QRS duration during pacing may be connected to serious cardiac disease. Sumiyoshi et al., studied 114 patients who had undergone pacing for atrioventricular block. The patients were divided into one group with paced QRS duration of>180 msec and a second group with paced QRS duration of <180 msec. The incidence of underlying heart disease (83% vs 32%, $p<0.01$), reduced left ventricular ejection fraction (49±17% vs 68±10%, $p<0.01$) and increased left ventricular end-diastolic dimension (57.1±7.9 mm vs 48.5±5.6 mm, $p<0.01$) were predominant in the patients with paced QRS duration of>180 msec compared to the group with paced QRS duration of <180 msec. Hence, it was concluded that patients with a prolonged paced QRS duration had more serious heart disease, and the paced QRS duration could be valuable in indicating impaired left ventricular function.(17)

In our study, paced QRS duration was significantly higher (p<0.001) in apical pacing (147.53 ± 9.81 msec) compared to mid septal pacing (136.88 ± 11.89 msec). This finding was consistent with a similar study by Gupta et al., where the paced QRS duration (p=0.003) in apical group was 148.9 ± 14.8 msec and the paced QRS duration in mid septum was 139.6 ± 19.9 msec.(10) Similarly, in a study by Cano O et al., RV apical pacing had a significantly longer QRS duration compared to RVSP group (162.2 ± 15.1 msec vs 151.3 ± 18.3 msec; p<0.001). Thus, when compared to traditional RV apical pacing, it was found that selective site pacing from the RV mid-septum causes reduced conduction delay.

In our study, multivariate analysis showed baseline QRS duration as the significant predictor of paced QRS duration ≤ 120 msec. Similarly in a study by Gupta et al., narrower QRS duration (<150 msec) was associated with baseline QRS duration (p=0.001) and female gender (p=0.006).In this study,SBP after pacing was reduced significantly at mid-septum compared to apical pacing. % SBP change (p=0.001) at mid septum was 19.20±1.80% and at apex was 22.10±3.23%. In a study by Hong YJ et al., a significant positive correlation was observed between the paced QRS duration and % SBP change.(18) In the same study, baseline SBP and paced QRS duration was found to be independent predictors of acute hemodynamic deterioration during pacing.

Although alternate site RV pacing results in a narrower paced QRS duration than RV apical pacing, the long-term clinical benefits of non-apical pacing are yet unclear.Hence, long-term follow-up studies randomizing patients to apical versus mid-septal pacing may shed light on the issue of significance of alternate RV pacing site in patients requiring long term RV pacing.

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Study limitations

This study had few limitations. The present study represents a single-centre experience, and the sample was small. Data regarding pacing characteristics such pacing threshold, impedance, and sensitivity were not recorded. Patients having postoperative complete heart block were included in the study cohort since these patients are more likely to have LV dysfunction in the perioperative period and prolonged paced QRS duration. LV ejection fraction over time was not assessed.

Conclusion

Baseline QRS duration was found to be the only predictor for a shorter QRS duration (≤ 120 msec). Compared to apical pacing site, mid-septum was associated with lower paced QRS duration. Hence, RV mid-septal pacing could be used as an alternative to traditional apical pacing site. Mid-septum pacing might reflect a more physiological and synchronous form of ventricular activation.

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