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Impact of Different Right Ventricular Lead Positions on QRS Complex Duration Post Cardiac Resynchronization Therapy Device Implantation

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ABSTRACT

Background: Undoubtedly one of the most successful recent developments in the treatment of heart failure (HF) is cardiac resynchronization therapy (CRT). CRT aims to provide the failing heart with a mechanical advantage that can significantly reduce symptoms and mortality by treating ventricular dyssynchrony, a problem that affects up to one-third of patients with highly symptomatic systolic HF. **Objectives:** The aim of the current study was to evaluate the effect of different right ventricular (RV) lead positions on QRS complex duration post CRT device implantation in patients indicated for CRT as a treatment of chronic heart failure. **Patients and methods:** This clinical trial included 100 patients who underwent CRT device implantation as a treatment for heart failure, divided into 2 groups according to the site of RV lead implantation after confirmation of the RV lead position; 54 patients had the RV lead implanted in the RV Apex (RVA n=54) and 46 patients had the RV lead implanted in the RV Septum (RVS n=46).
Results: There was no significant difference between the two groups regarding clinical response (NYHA Class) (P-value = 0.583), left ventricular ejection fraction (LVEF) (Δ EF 6.26 ± 1.64 in RVS group vs. 6.07 ± 1.43 in RVA group, P-value = 0.575) LVES diameter (47.70 ± 8.03 in RVS group vs. 45.39 ± 7.48 in RVA group, P-value = 0.141) or QRS complex narrowing (Δ QRS 60.93 ± 14.68 in RVS group vs. 54.07 ± 13.12 in RVA group, P-value = 0.182). **Conclusion:** Our results demonstrate that septal RV pacing in CRT is non-inferior to apical RV pacing regarding the primary objective of the study regarding clinical outcome, narrowing of QRS complex (Δ QRS) or LV reverse remodeling.
Keywords: RV pacing, Heart failure, Non responders, CRT, Pacemaker, QRS complex.

INTRODUCTION

Patients with symptomatic heart failure (HF), reduced left ventricular ejection fraction (LVEF), and broad QRS are advised to undergo cardiac resynchronization therapy (CRT) [(1)]. Pacing the right and left ventricles simultaneously or sequentially results in cardiac resynchronization treatment. Even though such implantation is technically successful in 90% of patients [(2)] only 2/3 of individuals have clinical improvement or reverse remodeling of the left ventricle (LV). Several factors could account for this insufficient response: inadequate patient selection [(1,3)].Poor programming and insufficient left ventricular (LV) lead position [(4,5)]. There is disagreement about whether the right ventricular (RV) lead position can enhance the response to CRT. Although the apical position is customary, particularly for patients receiving a CRT-defibrillator (CRT-D), long-term RV apical pacing may negatively impact cardiac function in intracardiac cardioverter defibrillator (ICD) receivers [(6)].

Recent proposals for alternative RV pacing sites in CRT patients, suggest primarily the RV septum. With the limitations of either retrospective analysis of large prospective trials [(7)], prospective non-randomized trials, or single-Centre randomized studies, no discernible effect of these various RV pacing sites was shown [(8,9)].

The aim of present study was to evaluate the effect of different RV lead positions on QRS complex duration and morphology post CRT device implantation in patients indicated for CRT based on ESC guidelines of heart failure published in 2016.

PATIENTS AND METHODS

A total of 100 patients at least 3 months post CRT device implantation were enrolled in this study and classified into two group, the first group included 46 patients having the RV lead positioned in RV apex and the second group included 54 patients having the RV lead positioned in RV septum, the outcomes regarding QRS complex duration, Echocardiography and clinical response were compared between the two groups.

The study protocol was approved by Ain Shams University Faculty of Medicine Scientific and Ethical Committee.

Inclusion criteria: Patients underwent CRT device implantation as a treatment for HF with reduced ejection fraction after at least 3 months post implantation based on ESC guidelines of Heart failure published in 2016 with biventricular pacing >95%.

Exclusion Criteria: (1) Patients with multiple co morbidities that may underestimate the clinical improvement including patients with COPD, interstitial pulmonary fibrosis, bronchial asthma, cerebrovascular disease, skeletomuscular abnormalities or sever CKD. (2) Patients with heart block. (3) Documented AF within 1month prior enrolment.

Methods:

All patients after written informed consent were subjected to the following at baseline:

1. Full history taking including: Age and sex, risk factors, etiology of chronic heart failure (ischemic vs dilated non-ischemic cardiomyopathy), co-morbid conditions including COPD, bronchial asthma, interstitial pulmonary disease, cerebrovascular disease, Skeletomuscular diseases, or (CKD), symptoms including New York Heart Association (NYHA) classification.
2. Resting 12 leads surface electrocardiogram: Prior to CRT, surface ECGs were retrospectively examined. The following measurements were taken from a

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fresh 12-lead surface ECG at the time of enrollment: unpaced QRS, complex duration, QRS complex duration during active biventricular pacing, and ΔQRS duration (difference between QRS duration during inactive pacing and QRS duration during active pacing). R in V1 is given extra attention in the ECG post-procedure since it is virtually always present in effective CRT and exceptional in RV apical pacing [(10)].

3. Device programing was done with assessment of leads impedance, sensitivity, output, threshold, paced AV delay, and interventricular delay (VV delay)
4. A fluoroscope was done to confirm LV lead position, RV lead position In RAO and LAO views.
5. Echocardiography was done for each patient and compared to pre implantation Echocardiography regarding: Left ventricular ejection fraction (LVEF) by 2D eye balling. Assessment of LVEF by M-Mode wasn`t the method of choice to avoid overestimation of LV systolic functions as the study enrolled patient with ischemic cardiomyopathy with pre-implantation echocardiography showing regional segmental wall motion abnormalities. Although modified Simpson's method is more accurate for assessing LVEF it was averted due to lack of standardization as the majority of the enrolled patients were not assessed by this method.

- LV end diastolic diameter (LVED) and LV end systolic diameter (LVED).

- The degree of improvement of mitral regurgitation.

Ethical consent:

An approval of the study was obtained from Ain Shams University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

Data were gathered, edited, coded, and entered into IBM SPSS version 23 of the Statistical Package for Social Sciences. When the quantitative data were parametric, they were displayed as means, standard deviations, and ranges; when they were non-parametric, they were displayed as medians and interquartile ranges (IQR). Qualitative variables were also shown as percentages and numbers. When the predicted count in a particular cell was less than 5, the groups were compared using the Chi-square test and/or Fisher exact test. Independent t-tests were used to compare two groups' quantitative data with parametric distribution, while Mann-Whitney tests were used with non-parametric distribution. The comparison between two paired groups regarding quantitative data non parametric distribution was done by using Wilcoxon test. Spearman correlation coefficients were used to assess the correlation between two quantitative parameters in the same group. Receiver operating characteristic curve (ROC) was used to assess the best cut off point with its sensitivity, specificity, positive predictive value, negative predictive value and area under curve (AUC) of the studied marker. The confidence interval was set to 95% and the margin of error accepted was set to 5%. P value $\leq$0.05 was considered significant.

RESULT

The study included 100 patients their age ranged from 40 to 70 years the mean was 60.02 (SD 7.18), the majority of them were males 82 (82%) while there were only 18 females (18%). Of the included subjects 81 patients (81%) were hypertensive, according to the definition of hypertension in ESC guidelines for the management of arterial hypertension published in 2018 defining hypertension as office systolic blood pressure (SBP) $\geq$140 mmHg and/or diastolic blood pressure (DBP) $\geq$ 80 mmHg confirmed by either another office blood pressure measurement, ambulatory blood pressure measurement, or home blood pressure measurement [(11)], and 19 patients (19%) were not hypertensive. Regarding diabetic status 71 patients (71%) were diabetic (HbA1C more than 6.5% according to definition of Diabetes Mellitus by American Diabetes Association) [(12)] and 29 patients (29%) were not diabetic. Regarding smoking, of the study patients 60 (60%) were smokers and 40 patients (40%) were non-smokers.

1. Comparison between RV septal and RV apical group regarding age, sex, risk factors and aetiology of chronic heart failure.

There was no significant difference between the two groups regarding age (mean value of 61.11 ± 7.20 in RVS group vs. 59.09 ± 7.10 in RVA group, P value 0.163), sex (37 males and 9 females in RVS group vs. 45 males and 9 females in RVA group, P value 0.707), HTN (37 patients in RVS group vs. 44 patients in RVA group, P value 0.894), DM (35 patients in RVS group vs 36 patients in RVA group, P value 0.301), or smoking (26 smokers in RVS group vs 34 smokers in RVA group, P value = 0.512), and there was no significant difference between the two groups regarding the etiology of chronic heart failure (ICM patients no = 28 and DCM patients no =18 in RVS group vs. ICM patients no = 32 and DCM patients no = 22 in RVA group, P value 0.870).

2. Comparison between RV septal and RV apical group regarding pre-implantation clinical response, ECG and Echocardiography.

There were no significant difference between the two group regarding the preimplantation clinical response (p value 0.881), QRS complex duration (P value 0.894), QRS complex morphology (p value 0.219), LVEF (p value = 0.779), LVED diameter (p value 0.288), LVES diameter (p value 0.167) or the degree of mitral regurgitation (p value 0.240) as shown in **table 1** and **table 2**.

Table (1): Comparison between RV septal and RV apical group regarding preimplantation parameters clinical response, ECG, echocardiography.

Variable		RV lead position		P-value
		Septal group	Apical group	
		No. = 46	No. = 54	
New York Heart Association (NYHA)	II	1 (2.2%)	1 (1.9%)	0.881
	III	26 (56.5%)	28 (51.9%)	
	IV	19 (41.3%)	25 (46.3%)	
QRS Duration (msec)	Mean ± SD	166.52 ± 16.76	167.04 ± 20.98	0.894
	Range	140 – 200	140 – 240	
QRS Morphology	LBBB	38 (82.6%)	39 (72.2%)	0.219
	NLBBB	8 (17.4%)	15 (27.8%)	
Ejection fraction (EF)	Mean ± SD Range	29.80 ± 4.30 20 – 35	30.04 ± 3.96 20 – 35	0.779
LVED	Mean ± SD Range	62.96 ± 7.08 48 – 81	61.37 ± 7.65 45 – 81	0.288
LVES	Mean ± SD Range	52.17 ± 8.28 36 – 69	49.87 ± 8.22 34 – 70	0.167
MR	Mild MR Moderate MR Sever MR	22 (47.8%) 23 (50.0%) 1 (2.2%)	28 (51.9%) 21 (38.9%) 5 (9.3%)	0.240

3. Comparison between preimplantation and post-implantation clinical response, Electrocardiograph, and Echocardiography in RV septal group (RVS).

Regarding the clinical response (NYHA class) there were a highly significant increase in NHYA class l patients (pre-implantation n = 0, Post-implantation n = 28, P value 0.000), significant increase in NYHA class II patients (pre-implantation no =1, post-implantation no = 8, P value 0.014), a highly significant reduction in NYHA class III patients (pre-implantation n=26, post-implantation n= 10, P value 0.001), and a highly significant reduction in NYHA class IV patients (pre-implantation n = 19, post-implantation n =0, P value 0.000) as shown in **table 2**.

Regarding QRS complex duration there was highly significant reduction in QRS complex duration (mean pre-implantation QRS duration value was166.52 ± 16.76 msecs vs post-implantation 105.37 ± 26.11 msec, P value 0.000) as shown in **table 2**.

Regarding Echocardiographic parameters there were a highly significant improvement of LV ejection fraction (LVEF) (mean pre-implantation EF value was 29.80 ± 4.30 % vs post-implantation 35.87 ± 3.82 %, P value 0.000), a highly significant reduction in LV end diastolic diameter (LVED diameter) (mean pre-implantation diameter value was 62.96 ± 7.08 mm vs post-implantation 58.24 ± 7.28 mm, p value 0.000), a highly significant reduction in LV end systolic diameter (LVES diameter) (mean pre-implantation diameter value was 52.17 ± 8.28 mm vs. post-implantation 44.63 ± 7.31 mm, p value 0.000) as shown in **table 2**.

Table (2): Comparison between preimplantation and post-implantation clinical response, Electrocardiograph, and Echocardiography in RV septal group (RVS).

RVS (Septal group)		Pre implantation	Post implantation	P-value
		No. = 46	No. = 46	
NYHA	I	0 (0.0%)	28 (60.9%)	0.000
	II	1 (2.2%)	8 (17.4%)	0.014
	III	26 (56.5%)	10 (21.70%)	0.001
	IV	19 (41.3%)	0 (0.0%)	0.000
EF	Mean ± SD	29.80 ± 4.30	35.87 ± 3.82	0.000
	Range	20 – 35	27 – 41	
LVED	Mean ± SD	62.96 ± 7.08	58.24 ± 7.28	0.000
	Range	48 – 81	43 – 78	
LVES	Mean ± SD	52.17 ± 8.28	44.63 ± 7.31	0.000
	Range	36 – 69	30 – 65	
QRS D (msec)	Mean ± SD	166.52 ± 16.76	105.37 ± 26.11	0.000
	Range	140 – 200	80 – 185	

4. Comparison between preimplantation and post-implantation clinical response, Electrocardiograph, and Echocardiography in RV apex group (RVA).

Regarding the clinical response (NYHA class) there were a highly significant increase in NHYA class l patients (pre implantation n = 0, Post-implantation n = 27, P value 0.000), highly significant increase in NYHA class II patients (pre implantation no=1, post-implantation no = 15, P value 0.000), a highly significant reduction in NYHA class III patients (pre implantation no=28, post-implantation no= 12, P value 0.001), and a highly significant reduction in NYHA class IV patients (preimplantation no = 25, post-implantation no=0, P value 0.000) as shown in **table 3**.

Regarding QRS complex duration there was highly significant reduction in QRS complex duration (mean pre-implantation QRS duration value was 167.04 ± 20.98 msec vs 112.96 ± 27.18 msec post-implantation msec, P value 0.000) as shown in **table 3**.

Regarding Echocardiographic parameters there were a highly significant improvement of LV ejection fraction (LVEF) (mean pre-implantation EF value was 30.04 ± 3.96 % vs post-implantation 35.96 ± 3.85%, P value 0.000), a highly significant reduction in LV end diastolic diameter (LVED diameter) (mean pre implantation diameter value was 61.37 ± 7.65 mm vs post implantation 56.24 ± 7.46 mm, p value 0.000), a highly significant reduction in LV end systolic diameter (LVES diameter) (mean pre-implantation diameter value was 49.87 ± 8.22 mm vs. post-implantation 42.41 ± 7.45 mm, p value 0.000) as shown in **table 3**.

Table (3): Comparison between preimplantation and post-implantation clinical response, Electrocardiograph, and Echocardiography in RV apex group (RVA).

RVA (Apical group)		Pre implantation	Post implantation	P-value
		No. = 54	No. = 54	
NYHA	I	0 (0.0%)	27 (50.0%)	0.000
	II	1 (1.9%)	15 (27.8%)	0.000
	III	28 (51.9%)	12 (22.2%)	0.001
	IV	25 (46.3%)	0 (0.0%)	0.000
EF	Mean ± SD	30.04 ± 3.96	35.96 ± 3.85	0.000
	Range	20 – 35	26 – 43	
LVED	Mean ± SD	61.37 ± 7.65	56.24 ± 7.46	0.000
	Range	45 – 81	40 – 78	
LVES	Mean ± SD	49.87 ± 8.22	42.41 ± 7.45	0.000
	Range	34 – 70	28 - 68	
QRSD (msec)	Mean ± SD	167.04 ± 20.98	112.96 ± 27.18	0.000
	Range	140 – 240	80 – 185	

5. Comparison between RV septal group (RVS) and RV apex (RVA) group regarding post implantation clinical response (NYHA class), regarding post implantation narrowing of the QRS complex duration (ΔQRS) and post implantation Echocardiographic parameters:

There was no a significant difference between the two groups regarding the clinical response (NYHA I no = 28 in RVS vs. no = 27 in RVA, NYHA II no = 8 in RVS vs. no = 15 in RVA, NYHA III no = 10 in RVS vs. no = 12 in RVA, P value = 0.427) as shown in **table 4**.

There was no significant difference regarding QRS complex duration between the two groups post implantation (mean QRS duration value was 105.37 ± 26.11 msec in RVS vs. 112.96 ± 27.18 msec in RVA group, p value 0.190, mean ΔQRS duration value was 60.93 ± 14.68 msec in RVS vs. 54.07 ± 13.12 msec in RVA group, P value 0.182) as shown in **table 4**.

There was no significant difference between the two groups regarding LVEF (mean EF value was 35.87 ± 3.82 % in RVS vs. 35.96 ± 3.85 % in RVA, P value 0.904). No significant difference regarding ΔEF, EF post CRT implantation minus EF pre-CRT implantation, (mean ΔEF value was 6.07 ± 1.43 % in RVS vs. 5.93 ± 1.32 % in RVA, P value 0.701) as shown in table 4.

No significant difference regarding LVED (mean LVED diameter value was 58.24 ± 7.28 mm in RVS vs. 56.24 ± 7.46 mm in RVA, p value 0.180) as shown in table 7. No significant difference regarding LVES diameter (mean LVES diameter value was 44.63 ± 7.31 mm in RVS vs. 42.41 ± 7.45 mm in RVA, P value 0.137) as shown in table 7, No significant difference regarding the degree of mitral regurgitation improvement (mild MR no = 38 patients in RVS vs. no = 39 patients in RVA, moderate MR no = 8 patients in RVS vs. no = 14 in RVA, sever MR no = 0.00 in RVS vs no = 1 in RVA, p value 0.364) as shown in **table 4**.

Table (4): Comparison between RV septal group (RVS) and RV apex (RVA) group regarding post implantation clinical response (NYHA class), regarding post implantation narrowing of the QRS complex duration (ΔQRS) and post implantation Echocardiographic parameters.

Variable		RV lead position		P-value
		Septal group	Apical group	
		No. = 46	No. = 54	
QRSDpost (msec)	Mean ± SD Range	105.37 ± 26.11 80 – 185	112.96 ± 27.18 80 – 185	0.190
deltaQRS (msec)	Mean ± SD Range	60.93 ± 14.68 10 – 100	54.07 ± 13.12 10 - 100	0.182
EF post	Mean ± SD Range	35.87 ± 3.82 27 – 41	35.96 ± 3.85 26 – 43	0.904
Delta EF	Mean ± SD Range	6.07 ± 1.43 3 – 10	5.93 ± 1.32 3 – 9	0.701
LVED post	Mean ± SD Range	58.24 ± 7.28 43 – 78	56.24 ± 7.46 40 – 78	0.180
LVES post	Mean ± SD Range	44.63 ± 7.31 30 – 65	42.41 ± 7.45 28 - 68	0.137
MR	Mild MR Moderate MR Severe MR	38 (82.6%) 8 (17.4%) 0 (0.0%)	39 (72.2%) 14 (25.9%) 1 (1.9%)	0.364

6. Responders vs non-responders

Based on the response criteria used in our study of the 100 patients enrolled for the study 30 patients (30%) were non-Echo responder, 19 patients (19%) were not clinical responders, and 15 patients (15%) were non-ECG responders as shown in **table 5**.

Table (5): Responder vs non-responders.

Variable		Total
		No. = 100
Clinical improvement	Improved Not improved	81 (81.0%) 19 (19.0%)
Echo improvement	Improved Not improved	70 (70.0%) 30 (30.0%)
QRS improvement	Improved Not improved	85 (85.0%) 15 (15.0%)

7. Comparison between RVS and RVA groups regarding non-responders.

There was non-significant difference between the two groups regarding non-echo responder patients (no = 13 patients in RVS group vs no = 17 patients in RVA group, P value 0.705) as shown in table 12.

No significant difference between the two groups regarding the clinical non-responder patients (no = 8 patients in RVS group vs no = 11 patients in RVA group, P value 0.726) as shown in table 12. No significant difference between the two groups regarding ECG non-responder patients (no = 6 patients in RVS group vs no = 9 patients in RVA group, P value 0.613) as shown in **table 6**.

Table (6): Comparison between RVS and RVA groups regarding non-responders.

Variable		Total No. = 100	Septal group No. = 46	Apical group No. = 54	P-value
Clinical	Improved	81 (81.0%)	38 (82.6%)	43 (79.6%)	0.705
	Not improved	19 (19.0%)	8 (17.4%)	11 (20.4%)	
Echo	Improved	70 (70.0%)	33 (71.7%)	37 (68.5%)	0.726
	Not improved	30 (30.0%)	13 (28.3%)	17 (31.5%)	
QRS	Improved	85 (85.0%)	40 (87.0%)	45 (83.3%)	0.613
	Not improved	15 (15.0%)	6 (13.0%)	9 (16.7%)	

DISCUSSION

Contingent on the criterion used, it is thought that HF affects 1-2% of the population, reaching over 10% in those over the age of 70 [9]. Undoubtedly one of the most successful recent developments in the treatment of HF is CRT. CRT aims to provide the failing heart with a mechanical advantage that can significantly reduce symptoms and mortality by treating ventricular dyssynchrony, a problem that affects up to one-third of patients with highly symptomatic systolic HF [10].

Despite the fact that such implantation is technically successful in 90% of patients, only 2/3 of patients have clinical improvement or LV reversal remodeling. Such an incomplete response could be explained by a number of factors, including poor patient selection [10,11], insufficient LV lead positioning, and poor programming [12].

It is debatable whether RV lead position might enhance the response to CRT. Although the apical position is customary, particularly for patients receiving a CRT-defibrillator (CRT-D), long-term RV apical pacing has been shown to have negative effects on cardiac function in intracardiac cardioverter defibrillator (ICD) receivers [12,13,14]. Recent proposals for alternative RV pacing sites in CRT patients, suggest primarily the RV septum. Our study canvassed the impact of different RV lead positions (RV apex vs. RV septum) on QRS complex duration, clinical response, LVEF and dimensions as indicators for LV reverse remodeling, and the degree of mitral regurgitation. The results shed lighted that there were no a significant difference between the two groups RVA and RV septum regarding the clinical response (NYHA class) post CRT device implantation (P value 0.427), no significant difference regarding QRS duration between the two groups (mean QRS duration value was 105.37 ± 26.11 msec in RVS vs. 112.96 ± 27.18 msec in RVA group, p value 0.190, mean ΔQRS duration value was 60.93 ± 14.68 msec in RVS vs. 54.07 ± 13.12 msec in RVA group, P value 0.182), no significant difference between the two groups regarding LVEF (mean EF value was 35.87 ± 3.82 % in RVS vs. 35.96 ± 3.85 % in RVA, P value 0.904), no significant difference regarding ΔEF (mean ΔEF value was 6.07 ± 1.43 % in RVS vs. 5.93 ± 1.32 % in RVA, P value 0.701), no significant difference regarding LVED diameter (mean LVED diameter value was 58.24 ± 7.28 mm in RVS vs. 56.24 ± 7.46 mm in RVA, p value 0.180), no significant difference regarding LVES diameter (mean LVES diameter value was 44.63 ± 7.31 mm in RVS vs. 42.41 ± 7.45 mm in RVA, P value 0.137), and no significant difference regarding the degree of mitral regurgitation improvement (p value 0.364).

These outcomes are consistent with the Septal-CRT trial's findings, which involved 263 patients who were randomly randomized in a 1:1 ratio to receive RVS pacing (n = 131) or RVA pacing (n = 132) [15]. Between baseline and six months, there was no difference in the two groups' reductions in left ventricular end-systolic volume (LVESV) (225.3+39.4 mL in the RVS group vs. 229.3+44.5 mL). This study thus reveals that, with a comparable decrease in the LVESV at 6 months, RVS pacing in CRT is not inferior to RVA pacing for LV reverse remodeling. Additionally, there was no difference in the clinical result. The composite endpoint, which included total mortality and the interval between the first HF hospitalizations, was comparable in both groups.

The findings of our study did not agree with those of a **Weizong *et al.*** [16] meta-analysis of 20 RCTs that included 1114 patients, 568 of whom underwent RV non-apical pacing (RVNA), and 546 of whom received RV apical pacing. High-degree AV block, sick sinus syndrome, and AV node ablation for persistent AF were reasons for pacemaker placement. The RVOT, para-His bundle, and mid/lower or high RVS were among the RVNA pacing sites. RVNA (primarily right ventricular septum (RVS)) pacing demonstrated superior pacing threshold and R-wave amplitude as well as higher impedance as compared to RVA pacing. At the end of the follow-up period, left ventricular ejection fraction (LVEF) increased significantly as a result of

RVNA pacing (weighted mean difference = 3.58, 95% confidence interval = 1.80-5.35), and the effects were seen in the subgroups of baseline LVEF 45%, baseline LVEF > 45%, and 6-month follow-up. RVS and RVA pacing significantly improved LVEF in different ways (weighted mean difference: 4.82; 95% CI: 2.78–6.87). A shorter QRS duration, a smaller left ventricular end-systolic volume, and a lower New York Heart Association functional class were other effects of RVNA pacing.

These differences are attributed to the fact that the vast majority of the patients included in this meta-analysis had permanent pacing indications (sick sinus syndrome or AV node block) rather than treatment of electro-mechanical dyssynchrony in chronic heart failure, hence wide QRS complex duration was not an inclusion criteria for the patients in the twenty RCTs included in the meta-analysis so it is not surprising that the QRS duration was narrower in both acute and long-term RVNA pacing, indicating that RVNA pacing get close to the physiological state of the ventricular activation sequence **(16)**.

While in our study all the included patients had been scheduled for CRT device implantation seeking for regaining the electrical synchronization between right and left ventricles through biventricular pacing in which clinical improvement, and the degree of LV reverse remodeling depends multiple factors including age, sex, the etiology of chronic heart failure, the pre implantation width of QRS complex, the position of LV lead and the position of RV lead in relation to LV lead that achieve the maximal electrical separation.

Of note, no previous studies had demonstrated the impact of different RV lead positions apical vs. septal post-CRT device implantation on narrowing of QRS complex duration and delta QRS in the context of electric remodeling.

In conclusion, there is no difference between septal RV pacing in CRT and apical pacing regarding the primary objective of the study regarding clinical outcome, narrowing of QRS complex(ΔQRS) or LV reverse remodeling, thus no recommendation for optimal RV lead position can hence be drawn from this study.

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