

Left Ventricular Strain Analysis Reveals Better Synchrony and Diastolic Function for Septal Versus Apical Right Ventricular Permanent Pacing

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ABSTRACT

Objectives: Left ventricular function and synchrony may be altered by right ventricular (RV) apical pacing. Septal pacing might be a better alternative. We compared effects on cardiac synchrony and function, between the 2 pacing sites, in chronically implanted patients.

Material and methods: 40 pacing-dependent patients (74±9 years, 21 men), 20 paced at the apex, were studied 11±4 months after implantation (baseline); 32 of them were re-examined after 1 year. Systolic function was assessed from ejection fraction (EF), cardiac index (CI), mean longitudinal systolic strain (MLSS), and strain rate (MLSR); diastolic function from E/A, E/E', and E/Vp ratios. Intraventricular dyssynchrony from standard deviation (SSD) and maximal difference (MAXS) of the 12 LV myocardial systolic timings, and sum of all times from the aortic valve closure to peak strain (SUMTAVC) for those segments with post-systolic shortening; interventricular synchrony from the aorto-pulmonary delay (APD).

Outcomes: Four patients died, all of them from the apical group. NYHA functional class was not different. Cardiac synchrony was not significantly different between the two pacing sites at baseline, and after 1 year follow-up. Although at baseline there was a greater dyssynchrony for the septal site, this did not progress at follow-up, whereas this increased for the apical site. Meanwhile, there was a higher LV filling pressure (E/E' ratio) for the apical site at 1 year (13±6 vs. 18±6; p=0.04).

Conclusions: Both septal and apical pacing sites affect negatively LV mechanical activation timings and synchrony. Apical, but not septal site, affects LV synchrony at 1 year, associated with increased filling pressure.

Keywords: septal pacing, dyssynchrony, left ventricular function

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INTRODUCTION

Permanent ventricular pacing for symptomatic bradycardia is one of those rare treatments proved to change the lives of numerous patients faced with a disease with high morbidity and mortality. Because of the important benefits of cardiac pacing in these patients, possible disadvantageous effects on cardiac function have only recently been recognized as clinically significant, although 85 years ago they were showed firstly by Wiggers (1-3).

Among different possible ventricular pacing sites, RV apex (RVA) has been selected as the conventional site for lead positioning because is easily accessible, and allows safe and stable long-term pacing using endocardial pacing leads. Recent studies have shown that up to 50% of pacemaker patients have LV dysfunction, and RV apical pacing may result in a higher risk of morbidity and mortality at long-term follow up (2,4-6).

To prevent these unpredictable side effects of long-term RVA pacing, alternative pacing sites have been studied. Pacing from the septum is associated with shorter QRS duration, and was suggested to improved outcome, acutely (7-9) and during medium-term follow up (10-12). However, long-term follow up data are limited to nonrandomized studies, including relatively few patients, and did not show convincing data about the superiority of septal over RVA pacing (13-15). Moreover, extensive data looking in more details to the subtle mechanisms of LV dysfunction in patients with septal vs. RVA pacing are lacking.

The purpose of our study was to compare long-term effects on cardiac synchrony and function, by conventional and TDI strain and strain rate measurements, between the two pacing sites, in chronically implanted patients.

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MATERIAL AND METHODS

Study design. Our study was a prospective, observational study. Patients were recruited at 12 months after pacemaker implantation, on the basis of having a permanent uni/dual-chamber pacemaker, implanted for symptomatic bradycardia. All patients were pacing dependent, with a cumulative percent ventricular pacing $\geq 90\%$. Exclusion criteria were age < 18 years or > 90 years, recent acute coronary syn-

drome < 3 months, important medical condition with life expectancy < 1 year, and inappropriate quality of echocardiographic images. Study was approved by the local Ethics Committee, and all patients provided written informed consent.

Clinical status. Patients were examined at baseline, and after 12 months from the baseline visit, in order to record demographic characteristics, cardiovascular medication, signs and symptoms of HF, and 12 lead ECG. NYHA functional class was assessed. For patients missing the 12 months visit, a telephonic follow up was performed, and, if appropriate, date of death was obtained from the relatives. A pre-stimulation ECG was obtained for all patients from the discharged letters or hospitalization reports. For measurement of the paced/non-paced QRS duration, a standard 12 lead surface ECG at 25 mm/s was accepted. The paced QRS duration was defined as the length of time from the beginning of the pacing artifact to the end of the QRS complex.

Echocardiographic protocol. A detailed echocardiographic evaluation was performed at 12 months after pacemaker implantation (baseline), and after 12 months from the baseline visit. The examination was done with the patients in the left lateral decubitus position, using a commercially available system Vivid 7 (GE Vingmed Ultrasound AS N-3190 Horten, Norway), equipped with a 3.5 MHz transducer. To minimize variability, all examinations were performed by one investigator (RRC), who was blinded to the pacing status. All images were stored digitally in cine-loop format and analyzed offline. Each parameter was measured and averaged over 3 consecutive beats.

A standard transthoracic study was performed to define anatomy, valvular, and ventricular function. LVEDD, LVESD, and LA diameters were measured from the parasternal long-axis view. RA and RV diameters were measured from the apical 4-chamber view. LVEF was calculated, using the Simpson's rule (16). Mitral (MR) and tricuspid regurgitation (TR) were graded by the width of the vena contracta from mild-to-severe in three degrees, according to the American Society of Echocardiography guidelines (17).

For TDI (Tissue Doppler Imaging), color Doppler frame rates varied between 100 and 130 frames/s, depending on the sector width, while aliasing velocities varied between 16 and 32 cm/s. Longitudinal myocardial strain and

strain rate curves were derived from the digitally stored images. Sample volume was placed in the center of the 12 basal- and mid-segments of the following LV walls: septal, lateral (in the apical 4C view), anterior, inferior (in the apical 2C view), and posterior and antero-septal (in the apical 3C view). Peak systolic strain (%), strain rate (1/s), and time-to-peak systolic strain (TTPS) during ejection phase were measured (Figure 1) (18). We also measured, for segments with post-systolic shortening, the time from the aortic valve closure to peak systolic strain (TAVC).

The following variables were assessed:

Systolic Function:

1. Cardiac index, determined by the LV outflow method, and divided by body surface area (CI);
2. LVEF;
3. Mean longitudinal systolic strain (MLSS), as a mean of all longitudinal TDI systolic strains;
4. Mean longitudinal systolic strain rate (MLSR), as a mean of all longitudinal TDI systolic strain rates.

Diastolic function:

1. E/A as the ratio between peak early filling (E-wave) and peak late diastolic filling (A-wave) velocities, obtained by placing the sample volume between the mitral leaflet

tips in the apical 4-chambers view, only for the patients in sinus rhythm;

2. E/Vp as the ratio between E-wave from the mitral inflow profile and flow propagation velocity (Vp). Vp was measured in the apical 4-chamber view, using color M-mode, with the scan line placed in the center of the LV inflow from the mitral valve to the apex. Vp was measured as the slope of the first aliasing velocity during early filling, measured from the mitral valve plane to 4 cm distally into the LV cavity;
3. E/E' as the ratio between E-wave and mean from septal and lateral annular early diastolic velocity (E') (19).

Intraventricular dyssynchrony:

1. Maximal systolic temporal difference (MAXS) was defined as the delay between the shortest and the longest myocardial timings (TTPS), for all 12 LV segments. A maximal temporal difference of >130 msec between any LV walls was considered to be pathological, in accordance with the published data (Figure 2) (20,21).
2. Systolic standard deviation (SSD) of all 12 LV myocardial timings, as a measurement of electromechanical delay dispersion;
3. Sum of all times of delayed longitudinal contraction (SUMTAVC), calculated using TDI strain. A segment was considered to have post-systolic shortening if the strain analysis demonstrated that the end of the segmental contraction occurred after the aortic valve closure (Figure 2).

Interventricular dyssynchrony was assessed from aorto-pulmonary delay (APD), as the difference between aortic and pulmonary pre-ejection delays using conventional PW Doppler. The PW Doppler was placed in the LV outflow tract just under the aortic valve from the apical 5-chamber view for the aortic ejection signal, and in the RV outflow tract just under the pulmonary valve from the parasternal short-axis view for the pulmonary ejection signal. Measurements were performed by placing the first caliper at the QRS onset and the second caliper at the onset of the aortic ejection signal and pulmonary ejection signal. A difference of more than 40 msec demonstrated interventricular dyssynchrony.

Pacemaker data

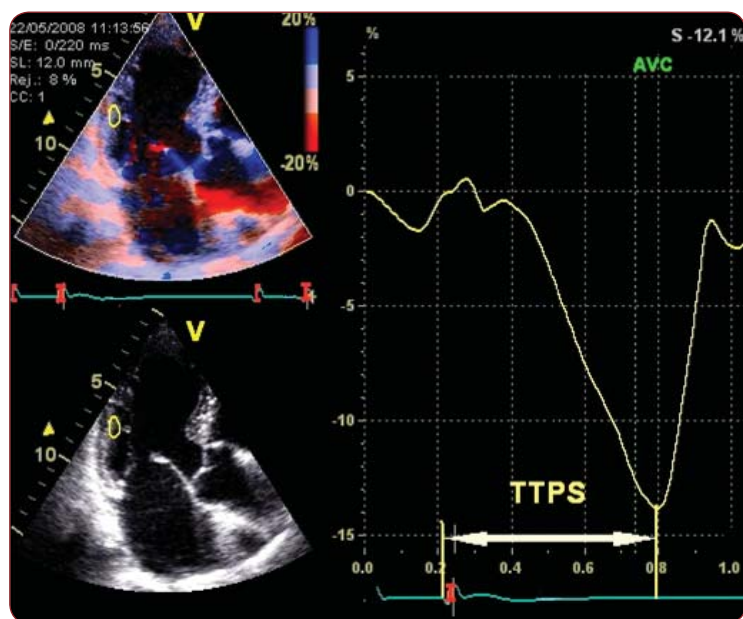


FIGURE 1. Representative longitudinal strain trace from a patient paced at the apical site. Peak systolic strain is negative (%). Dashed line indicates aortic valve closure (AVC). Time to peak systolic strain is defined as time from the beginning of paced QRS to the first and well defined peak strain (TTPS).

All patients were implanted in the same institution and the follow up visits were performed at 6, and respectively 12 months for the control of pacemaker parameters. RVA pacing was achieved with a passive fixation lead. High and mid-septal pacing was achieved with an active fixation lead. Appropriate positioning of the electrode was confirmed fluoroscopically at the time of the pacemaker implantation, before the baseline visit. Documentation of lead position was acquired in each patient using 3 standard projections: anterior-posterior, 40° left anterior oblique (LAO 40°), and 40° right anterior oblique (RAO 40°) views. The LAO fluoroscopic view appears to be the most desirable method to determine RV septal positioning (22). Stimulation modes were VVIR or DDDR (rate-responsive) for uni- or dual-chamber pacing. Percent of ventricular paced beats and the parameters of the pacemaker were determined from stored pacemaker data obtained at each visit. Capture threshold, lead impedance, and sensing were measured.

Statistical Analysis

All continuous variables had normal distribution. All statistics for these variables are expressed as mean value $\pm$ 1 SD. Categorical data are summarized as frequencies and percentages. The statistical methods used were Student's *t* test for normally distributed paired and unpaired data, and Mann-Whitney *U* test for ordinal variable, using commercial software (SPSS Inc, release 16). A 'p' value of <0.05 was considered to be significant. The intraobserver reproducibility was assessed in 10 patients, for longitudinal systolic strain, strain rate, and time-to-peak systolic strain; coefficient of variation was 4.75% for longitudinal systolic strain, 5.50% for strain rate, and 4.54% for time-to-peak systolic strain. $\square$

OUTCOMES

The authors had full access to the data and take full responsibility for its integrity. All authors had read and agree to the manuscript. We screened 60 consecutive patients. 5 patients declined participation and 15 were not pacing dependent. We studied 40 pacing dependent patients; 20 paced at the apex and 20 at the septal level. Pacing modes were VVIR for 21 patients (8 from the septal group) and DDDR for 19 of them (12 from the septal

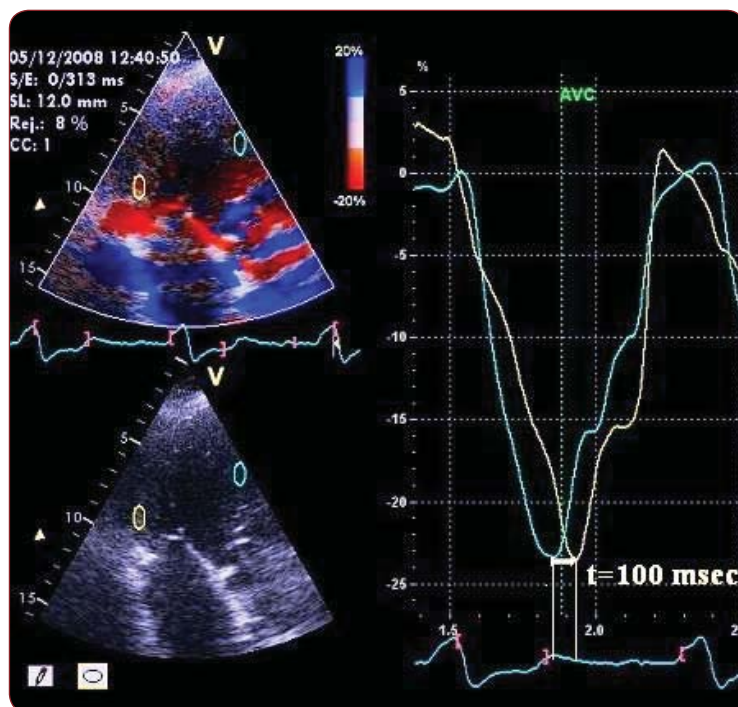


FIGURE 2. An illustrative example of intraventricular systolic dyssynchrony of 100 msec. Strain tracings show simultaneous longitudinal strain of basal posterior and basal anterior septal wall from the apical three-chamber view, from an apical paced patient. Dashed line represents aortic valve closure (AVC). A delayed longitudinal contraction (post systolic shortening) is also illustrated in basal posterior segment.

group). Table 1 shows clinical and demographic data of the overall population and separately, for the septal and apical pacing groups. There were no significant differences between the 2 groups at baseline, apart from more men in the apical group ($p=0.03$). After 12 months there were also no differences between pacing sites regarding pacing mode, atrial rhythm, NYHA functional class, associated diseases and cardiovascular treatment.

For the overall population, we recorded an important increase of the QRS duration from pre-stimulation to baseline ($p<0.001$) (Table 1), without further differences from baseline to the follow-up visit (165 ± 21 vs. 169 ± 23 , $p=0.6$). There were also no differences between septal and apical site, either for pre-stimulation and baseline QRS duration, or at follow up visit (167 ± 27 vs. 171 ± 22 , $p=0.6$).

Four patients died during follow up, all from the apical group (2 from myocardial infarction, 1 from hemorrhagic stroke, and 1 from sudden death); 32 patients (16 from the apical group) had a 1 year follow up visit. Two of them (1 from each group) had inappropriate quality of the echocardiographic images for strain analy-

Parameters	All patients (n=40)	Septal pacing (n=20)	Apical pacing (n=20)	P value
Age (mean±SD)	74±8	73±9	74±8	0.89
Months post-implantation	11±4	10±4	12±5	0.23
Male, n (%)	21 (52)	8 (40)	13 (65)	0.03
Sinus rhythm, n (%)	34 (85)	18 (90)	16 (80)	0.63
Atrial fibrillation, n (%)	6 (15)	2 (10)	4 (20)	0.38
VVI mode, n (%)	21 (52)	8 (38)	13 (62)	0.48
Hypertension, n (%)	37 (93)	18 (90)	19 (95)	0.15
LVH, n (%)	17(43)	8(40)	9(45)	0.46
Diabetes mellitus, n (%)	11 (28)	6 (30)	5 (25)	0.43
Obesity, n (%)	13 (33)	6 (30)	7 (35)	0.68
Prior MI, n (%)	4 (20)	2 (10)	2 (10)	0.57
EF<45%, n (%)	7(17)	5(25)	2(10)	0.07
QRS pre-stimulation	130±23	129±22	131±26	0.8
QRS baseline	165±21	163±21	163±21	0.6
Pharmacological therapy	29 (73)	15 (75)	14 (70)	0.32
ACE inhibitor, n (%)	13 (33)	4 (20)	9 (45)	0.46
Beta-blocker, n (%)	20 (50)	9 (45)	11 (55)	0.48
Loop diuretic, n (%)	15 (38)	7 (35)	8 (40)	0.70
Calcium-blocker, n (%)	3 (8)	1 (5)	2 (10)	0.33
Spironolactone, n (%)	30(75)	14 (70)	16 (80)	1.00
Aspirin, n (%)				

TABLE 1. Baseline clinical and demographic data.

LVH, left ventricular hypertrophy; MI, myocardial infarction; EF, ejection fraction.

sis.

Conventional parameters. There were no significant differences between groups, at baseline and follow up visit, for diameters, volumes, MR and TR severity (Table 2). There were also no statistically significant changes between visits for both pacing sites, apart from an improved RVEDD from baseline to 12 months follow up for the septal group ($p=0.03$).

Systolic Function. There were no significant differences between groups, at baseline and follow up visit, for global (Table 2) or regional (Table 3) LV systolic functions. There

were also no significant changes between visits, and in variation of changes, for both pacing sites.

Diastolic function. At baseline, there were no significant differences between septal and apical pacing sites for E/A, E/E', and E/Vp ratios. However, at 12 months diastolic dysfunction progressed only for the apical pacing site, with higher estimated end-diastolic LV pressure (Table 2).

Dyssynchrony. At baseline there was a trend of greater dyssynchrony for the septal site (SSD and MAXS) (Table 3). Separately, at each visit, there were no significant differences between the 2 sites for all intra- and inter-ventricular systolic dyssynchrony parameters. However, between visits, there was an increase in myocardial timings dispersion and dyssynchrony, expressed by MAXS ($p=0.013$) and SSD ($p=0.022$), only for the apical pacing site (Table 3).

Correlations. For septal pacing, at baseline, we recorded a significant correlation between MLSS and RVED ($r=0.6$, $p=0.016$), MLSS and LVEDV ($r=0.8$, $p<0.001$), and MLSR and LVEDV ($r=0.6$, $p=0.015$). We also found a significant linear correlation between MLSS at baseline and E/E' ratio at follow up ($r=0.60$, $p=0.016$) (Figure 3A). Meanwhile, E/E' ratio at 12 months correlated with the difference between pre-stimulation and baseline QRS duration ($r=0.53$, $p=0.04$). Furthermore, E/E' ratio correlated with changes between visits for sum of times of delayed longitudinal contraction ($\Delta\text{SUMTAVC}$), as an expression of intraventricular dyssynchrony ($r=0.50$, $p=0.04$) (Figure 3B).

For apical pacing, there was a positive cor-

Parameter mean±SD	Baseline			12 months			Changes from baseline to 12 months		
	Septal	Apical	P	Septal	Apical	P	Septal	Apical	P for changes
LA mm	40±7	44±8	0.17	43±7	42±10	0.87	4±12	-0.2±7	0.38
RA mm	38±7	39±6	0.36	39±10	40±8	0.56	0.1±10	-1.1±8	0.65
LVEDD mm	49±9	47±7	0.76	48±8	45±9	0.60	2±12	-2±8	0.96
LVEDV ml	37±9	35±7	0.62	36±9	35±9	0.81	2±8	-1±5	0.93
LVEDV ml	108±33	100±25	0.91	121±36	106±33	0.42	11±23	2±24	0.30
LVESV ml	53±27	47±16	0.85	64±32	53±19	0.27	13±25	3±19	0.24
LVEF %	53±11	54±8	0.65	51±14	54±8	0.10	-10±18	1±12	0.12
CI l/min/m ²	2.9±2.2	2.3±1	0.45	2.6±1	2.2±0.8	0.31	-0.4±1.4	-0.2±0.8	0.34
RVEDDmm	36±7	36±7	0.56	32±8	34±7	0.45	-4±8 *	-3±10	0.85
E/A	1.3±1.2	1.6±1	0.39	0.8±0.3	1.9±1.6	0.03	-0.4±1.2	0.2±1.2	0.18
E/Vp	2.6±2.5	2.3±1	0.70	1.7±0.6	2.1±0.7	0.05	-1±2.5	-0.1±1.3	0.35
E/E'	12±9	15±6	0.29	12±6	18±6	0.04	1±9	2±7	0.76

TABLE 2. Comparison between standard echocardiographic data for septal versus apical site, at baseline and 12 months follow up visit.

SD, standard deviation; CI, cardiac index; * $p<0.05$.

Parameter mean±SD	Baseline			12 months			Changes from baseline to 12 months		
	Septal	Apical	P	Septal	Apical	P	Septal	Apical	P for changes
MLSS (%)	-11±4	-13±5	0.08	-12±4	-11±3	0.80	-1±4	2±5	0.11
MLSR (1/s)	-1±0.5	-1±0.5	0.65	-1±0.5	-1±0.5	0.96	-0.03±0.6	0.07±0.7	0.70
SSD (msec)	79±32	57±26	0.07	92±49	90±54	0.90	13±53	33±49*	0.30
MAXS (msec)	276±134	195±101	0.08	280±153	274±122	0.89	4±84	79±107*	0.63
SUMTAVC (msec)	439±425	324±283	0.39	507±456	438±461	0.69	67±637	115±451	0.82
APD (msec)	41±21	40±34	0.26	42±20	41±25	0.87	1±26	10±32	0.41

TABLE 3. Comparison between echo parameters of cardiac dyssynchrony and regional function for septal versus apical site, at baseline and 12 months follow up visit.

MLSS, mean longitudinal systolic strain; MLSR, mean longitudinal systolic strain rate; SSD, systolic standard deviation of the 12 LV myocardial timings; MAXS, systolic maximal difference of the 12 LV myocardial timings; SUMTAVC, sum of all timings from the aortic valve closure to peak systolic strain; APD, aorto-pulmonary delay; *, $p < 0.05$.

relation between longitudinal dysfunction (MLSS) at baseline and the degree of changes in intraventricular dyssynchrony (Δ MAXS) ($r=0.66$, $p=0.007$) (Figure 4) and in interventricular dyssynchrony (Δ APD) ($r=0.63$, $p=0.016$). An increase in longitudinal dysfunction between visits (Δ MLSS) generated a higher LV filling pressure (E/E') at 12 months ($r=0.60$, $p=0.019$). As for the septal site, E/E' ratio correlated with changes from pre-stimulation to baseline in QRS duration ($r=0.62$, $p=0.014$).

For the whole group, at baseline we found a significant correlation between MLSS and pre-stimulation QRS duration ($r=0.47$, $p=0.023$), and MLSR and LVEDV ($r=0.52$, $p=0.023$). We also recorded a positive linear correlation between QRS duration and E/E' ratio ($r=0.45$, $p=0.026$). As for the septal site, E/E' ratio correlated with changes from pre-stimulation to baseline in QRS duration ($r=0.56$, $p=0.001$). By multiple regression analysis, best predictors of increased filling pressure at 12 months (E/E' ratio) were pre-stimulation and baseline QRS duration, MLSS, and MLSR at baseline ($r=0.70$, $r^2=0.51$, $p=0.003$). $\square$

DISCUSSION

There are many evidences showing that RV pacing induces LV dyssynchrony in a substantial number of patients who received permanent ventricular pacing (23-25). This results in abnormal late activation of LV walls, LV remodeling (26,27), mitral regurgitation (28), and reduced myocardial perfusion and EF (29,30). These adverse effects explain increased risks of HF and death (31-33). The decrease in LV systolic function and NYHA functional class is directly related to the presence of LV dyssynchrony (29,34,35). After a mean of 3.8 years of

follow up, in patients with normal LV function and no evidence of intraventricular or interventricular dyssynchrony at baseline, Tops et al. showed that up to 50% of these patients has developed new-onset echocardiographic evidences of dyssynchrony (36).

Our study showed that there were no significant differences between septal and apical pacing, in terms of LVEF, CI, NYHA class, both after 11+/4 months from the pacemaker implantation, and after 12 months from the first evaluation. However, by using new parameters to prove dyssynchrony, we demonstrated that after 1 year after the first evaluation, synchrony is negatively affected by apical pacing but not by septal pacing, with increased LV filling pressure. The best predictors for increased filing pressure were initial longitudinal LV function, pre-stimulation, and also initial post-implant QRS duration.

Despite the theoretical advantage of the septal pacing, numerous clinical reports did not show convincing data about the superiority of septal over RVA pacing in terms of clinical events (37,38). In CRT patients, there is no benefit of nonapical RV lead location in clinical outcome or echocardiographic response. Moreover, nonapical RV lead location is associated with an increased risk of ventricular tachyarrhythmias, particularly in the first year after device implantation (38).

Cate et al., in an acute study, showed that both RVA and septal pacing increased electromechanical delay, both affecting similarly regional longitudinal LV strain and timings (39). Liu et al. revealed an acute increase of LV systolic dyssynchrony index, assessed by real-time 3D echocardiography, during RVA pacing (40).

Reports on long-term results are, however,

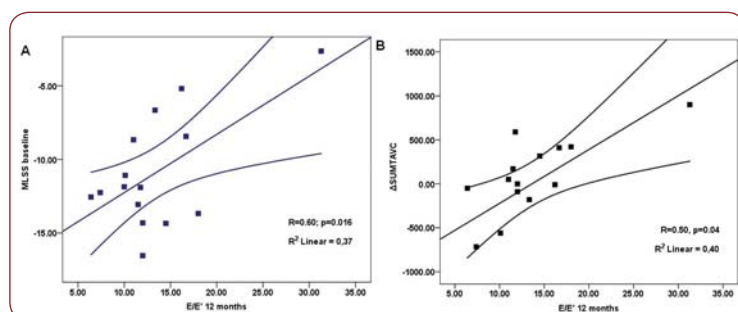


FIGURE 3. Correlation between mean longitudinal systolic strain (MLSS) at baseline and E/E' ratio at follow up (panel A), and correlation between E/E' ratio at follow up and the degree of changes in intraventricular dyssynchrony, expressed by sum of times of delayed longitudinal contraction (Δ SUMTAVC), for septal pacing (panel B).

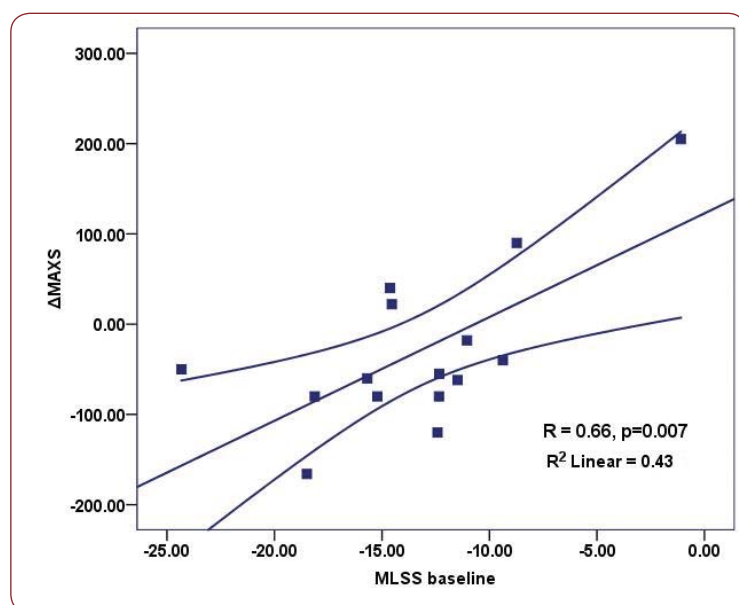


FIGURE 4. Correlation between longitudinal dysfunction (MLSS) at baseline and the degree of changes in intraventricular dyssynchrony (Δ MAXS), for apical pacing.

still limited and more controversial. Thus, Ng et al., in a long-term study, demonstrated more impaired circumferential strain and worse LV dyssynchrony with the septal than with the apical pacing (41). Kypta et al. analyzed 98 pacing dependent patients by measuring LVEF, BNP levels, and exercise capacity. All changes from baseline to 18 months were statistically not different between the two sites (42). In a retrospective analysis of 150 consecutive patients, with permanent pacing, it was showed that IVS pacing improves medium- and long-term survival (43). On contrary, by analyzing 11,246 patients with apical pacing, Freudenberger et al. showed a significant higher hospital admission rates and cardiac death, by comparison to a control group (44).

Similarly, in our study, four patients died (10%), all of them from the apical group ($p=0.036$). However, based on our limited group and since survival after pacing depends on many variables such as age, structural heart disease, etc., we cannot speculate about the superiority of the septal pacing in terms of survival.

Another important issue is the position of the septal lead. Vlay found, in a 9 year experience of 460 consecutive implants, an overall success rate of 84% in the IVS group, with excellent lead performance (14). Lieberman et al. suggested that the different positions of the septal lead could explain the different results reported in the literature (45).

In our study, stimulation sites in the high and mid septal area were both considered in the septal group. However, these might have a different influence on function and synchrony. RVA pacing bypasses the His-Purkinje system resulting in a left bundle branch block like pattern on the surface ECG (46). The resulting electrical asynchrony determines a prolonged QRS duration due to slow myocardial conduction (47). Septal site generates different activation pattern, not as good as intrinsic conduction but theoretically shorter than the apical site. On contrary, we found a similar QRS duration at baseline and 12 months, without differences between sites and visits. Both pacing sites increased QRS duration similarly. This was probably generated because of preexisting intrinsic conduction disturbances, and also because of the heterogeneity of the septal group regarding the lead position into the septum. The confirmation of the septal position was done fluoroscopic at the time of the pacemaker implantation, prior the first clinic and echocardiographic visit.

Currently, this is the standard method for lead positioning, but its accuracy is moderate (60%). There are some studies using 3D echocardiography or electroanatomic mapping, suggesting that the radiological criteria might be inaccurate (48-51). $\square$

STUDY LIMITATIONS

We had no data about the EF before the pacemaker implantation. There was also a large range of the ejection fraction at baseline (11 ± 4 months after pacemaker implantation). Because our group was relatively small, we

could not analyze separately the effect of different pacing sites, for patients with normal or reduced EF. We also could not analyze separately the impact on cardiac function of different stimulation modes. However, our study group reflects a real world scenario for pacing dependent patients. LV diastolic filling pattern at follow-up was more impaired in patients with RV apical pacing. The small study population and the presence of the VVI mode in a high number of patients prevents from drawing meaningful conclusions in regard of clinical implications of this finding.

We used fluoroscopy as gold standard for lead position, but as mentioned before, the accuracy of this method for lead positioning is still controversial. $\square$

CONCLUSIONS

Both septal and apical pacing sites negatively affect LV synchrony, in pacing dependent patients. These subtle changes can be detected by TDI strain echocardiography. Apical, but not septal site, affects LV synchrony at 1 year. This can explain an increased filling pressure and worse diastolic profile. Our data, similar with other studies, are proving that septal site has some potential advantages over the apical pacing. This might be an argument for the indication of using this pacing site. However, larger studies with longer follow up are needed to reveal more clear differences between the two pacing sites.

Abbreviations and Acronyms

RV = right ventricular/ventricle
 LV = left ventricular/ventricle
 RVA = right ventricular apex/apical
 IVS = interventricular septum
 DDD = dual-chamber pacing
 VVI = single chamber ventricular pacing
 RA= right atrial diameter in systole
 LA= left atrial diameter in systole
 LVEDD= left ventricular end-diastolic diameter
 LVESD= left ventricular end-systolic diameter
 LVEDV= left ventricular end-diastolic volume
 LVESV= left ventricular end-systolic volume
 RVED= right ventricular end-diastolic diameter
 LVEF= left ventricular ejection fraction
 HF = heart failure

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