Short Term Evaluation of Left Ventricular Function Following Dual Chamber Pacemaker: a Speckle Tracking Study

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Abstract:
Background: In 2012 the consensus issued by both the American College of Cardiology & Foundation Heart Rhythm Society recommend the use of Dual Chamber Pacemaker instead of Single chamber pacemaker for patients with Sinus Node dysfunction. Restoration of atrioventricular synchrony in patient with sinus node dysfunction or Atrioventricular block representing a new era in electrical therapy. The focus on normal physiology led to the nearly universal application of dual-chamber pacing to restore atrioventricular (AV) synchrony in patients with sinus rhythm.

Objective: To evaluate Speckle Tracking Echocardiography in detection of early ventricular changes toward Heart failure after implantation of dual chamber pacemaker.

Patients & Methods: Speckle tracking was used to evaluate the percent of ventricular deformation before and 3 months follow up after dual chamber implantation, this study included 28 patients with Sinus node dysfunction or Heart Failure-LBBB. This prospective observational study was carried out on patients of medical city, Baghdad Teaching Hospital, cardiology & Echocardiography Higher Education (Diploma) center from November 2016 to July 2017.

Results: No statistical difference was noted between both gender groups in regard to main risk factors. Four methods were used to evaluate ventricular function synchrony (Ejection Fraction %, Global longitudinal stain, intraventricular synchrony using septal to posterior wall motion delay, interventricular Mechanical delay by Pulse wave). Global EF evaluated by Simpson biplane method remained the same in all patients after 3-month follow-up (P = NS). Global longitudinal strain (GLS) significantly decreased in all patients. Inter-ventricular dyssynchrony evaluation revealed no significant change after 3 months.

Conclusion: Global longitudinal strain and Left Ventricular desynchrony assessment enables us to detect early signs of LV dysfunction in Subjects with dual chamber pacemaker.

Keywords: Left ventricle, desynchrony, global longitudinal, sinus node dysfunction, dual chamber pacemaker

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Introduction:
Restoration of atrioventricular synchrony in patient with sinus node dysfunction or Atrioventricular block representing a new era in electrical therapy. The focus on normal physiology led to the nearly universal application of dual-chamber pacing to restore atrioventricular (AV) synchrony in patients with sinus rhythm. A properly timed atrial systole improves stroke volume through the Frank-Starling mechanism, by providing greater left ventricular end-diastolic fiber stretch, and, consequently, enhanced end-systolic fiber shortening, all of this without an increase in average pulmonary venous pressure. Higher left ventricular end, but not average, diastolic pressures and volumes; higher systolic and mean blood pressures; and lower right atrial and pulmonary capillary wedge pressures have been reported with AV synchronous pacing compared with ventricular pacing. In 2012, the consensus issued by both the American College of Cardiology & Foundation Heart Rhythm Society recommend the use of Dual chamber Pacemaker.
maker instead of Single chamber pace maker for patients with Sinus Node dysfunction or AV Block.

Since superiority of dual chamber pacemaker over single chamber have been demonstrated in many studies. Although most of the studies & data showed that patients with pacemaker implanted for improving the Sick sinus node or Atrioventricular Block develop dyssynchronization of ventricular activation & contraction, after right ventricular pacing worsen long-term cardiac morbidity and mortality.

The aim of this study: to evaluate the use of Speckle Tracking Echocardiography in detection of early ventricular changes toward Heart failure after implantation of dual chamber pacemaker.

Patients and Methods:

This prospective observational study was carried out on patients of medical city, Baghdad Teaching Hospital, cardiology & Echocardiography Higher Education (Diploma) center from November 2016 to July 2017. Total 28 adult subjects (both male and females) of aged ≥ 18 years were enrolled in this study.

The study population consists of 28 subjects planned to undergo cardiac pacing therapy in accordance with the American College of Cardiology (ACC), the American Heart Association (AHA), and the Heart Rhythm Society (HRS) jointly published guidelines. Patients suffered from Sinus node dysfunction or acquired atrioventricular block. All patients were on maximally tolerated appropriate medical therapy. Within this group the following risk factors were considered in such a way that: 18 subjects (68 %) were hypertensive, 14 Subjects (50%) were diabetics, 16 Subjects (57 %) were with high lipid Profile, 18 Subjects (64%) were with History of IHD, no one of them was with history of Heart failure, Chronic Renal Failure, Asthma, COPD.

After written informed consent was obtained, a well-designed questionnaire was used to collect the data of the recruited patients retrospectively; physical examination, Electrocardiography & pre-operative Echocardiography were done.

Resynchronization forms the primary data set for this study. Detailed echocardiography was therefore performed according to a comprehensive protocol for image acquisition. Baseline echocardiography was performed in all patients by a single operator using a Philips CX50 Compact Xtreme System echocardiography machine with a S5-1 [1-5MHZ] probe for standard 2D imaging, color flow mapping, pulsed wave (PW) and continuous wave (CW) Doppler and tissue Doppler imaging (TDI). Conventional ECG electrodes (right arm, left arm, and left leg) were connected to the patient providing standard axial ECG limb leads I, II and III. The patient was positioned semi-recumbent in the left lateral position for parasternal and apical imaging, and in a supine position for subcostal imaging. The appropriate ECG lead to record during image acquisition was chosen in order to most clearly define the onset of the QRS complex, and therefore aid accuracy of subsequent measurements. Three cardiac cycles of each imaging plane and modality were acquired. Doppler measurements were recorded in static respiration to minimize any respiratory effect on Doppler parameters. Respiratory maneuvers were used as necessary to optimize 2D imaging. The baseline and scale of Doppler recordings were optimized to maximize the size of the velocity envelope without aliasing. Images were acquired according to a standardized protocol.

Statistical Analysis:

Data were transferred from the clinical data sheets and echocardiographic analysis worksheets to Microsoft Excel spreadsheets for initial data storage and processing. Spreadsheets were then imported into Statistical Package for Social Sciences (SPSS 22, SPSS Inc., Chicago) for statistical analysis. Results are presented as mean ± standard deviation (SD) unless otherwise stated. A probability value of <0.05 was considered statistically significant.

Results:

General Baseline Characteristics:

28 subjects’ studied before and 3 months after dual chamber implantation, Table (1) illustrates the Baseline characteristics of the studied subjects including the mean of height, weight, the mean of Body Mass Index with all Risk factors in patients History.
Table 1: Baseline characteristics for Dual chamber pacemaker group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Male</th>
<th>Female</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subjects</td>
<td>20 (71%)</td>
<td>8 (29%)</td>
<td>-</td>
</tr>
<tr>
<td>Age (years)</td>
<td>59.30 (10.37)</td>
<td>53.25 (8.27)</td>
<td>0.154</td>
</tr>
<tr>
<td>Height (meter)</td>
<td>1.75 (0.05)</td>
<td>1.60 (0.05)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>86.15 (12.30)</td>
<td>72.80 (14.4)</td>
<td>0.026</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.9 (4.46)</td>
<td>28.85 (4.67)</td>
<td>0.63</td>
</tr>
<tr>
<td>Hypertension</td>
<td>70%</td>
<td>50%</td>
<td>0.33</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>60%</td>
<td>25%</td>
<td>0.10</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>60%</td>
<td>50%</td>
<td>0.64</td>
</tr>
<tr>
<td>IHD</td>
<td>65%</td>
<td>62%</td>
<td>0.95</td>
</tr>
<tr>
<td>HF</td>
<td>0%</td>
<td>0%</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Data were expressed as the mean and standard deviation (SD) except for the risk factors which were expressed as percent.

*A P value less than or equal to 0.05 was considered as statistically significant
NS= Non-Significant
IHD= Ischemic Heart Disease
HF= Heart Failure

In relation to the history of main risk factors as hypertension, Diabetes mellitus Type 2 & dyslipidemia, Figure (1) illustrate the numbers of patients presented with these risk factors for each gender Group with no statistical difference between two groups.
Figure 1: Distribution of HT, DM and Dyslipidemia among Dual Chamber pacemaker Group

NS= Non-Significant
HT= Hypertension
DM = Diabetes Mellitus

For history of ischemic heart disease and Heart failure, Figure (2) illustrate the number of subjects in each gender group with history of thesees cardiovascular disease.

Figure 2 Distribution of ischemic Heart Disease & heart Failure among Subjects

NS= Non-Significant
IHD = Ischemic Heart Disease
HF = Heart Failure

Four methods were used to evaluate ventricular function synchrony (Ejection Fraction %, Global longitudinal stain, intraventricular synchrony using septal to posterior wall motion delay, interventricular Mechanical delay by Pulse wave). The main echocardiographic parameters are presented in Table (2), figure (3),(4). Global EF evaluated by Simpson biplane method remained the same in all patients after 3-month follow-up (P = NS). global longitudinal strain (GLS) significantly decreased in all patients from -15.02(0.56) to -13.61(0.432) (P < 0.001).
Table 2: Echocardiographic Parameter before & after Dual chamber pacemaker implantation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Pacemaker Implantation</th>
<th>3 Months after Pacemaker Implantation</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF, %</td>
<td>49.60(4.7)</td>
<td>50.25(4.88)</td>
<td>NS</td>
</tr>
<tr>
<td>GLS, %</td>
<td>-15.02(0.56)</td>
<td>-13.61(0.432)</td>
<td>0.001</td>
</tr>
<tr>
<td>SPWMD, ms</td>
<td>100.25(24.64)</td>
<td>114.67(26.88)</td>
<td>NS</td>
</tr>
<tr>
<td>IVMD, ms</td>
<td>23.07(6.64)</td>
<td>27.21(7.81)</td>
<td>NS</td>
</tr>
</tbody>
</table>

All parametric data were expressed as the mean and standard deviation (SD).

*A P value less than or equal to 0.05 was considered as statistically significant.

GLS = Global Longitudinal Strain by Speckle Tracking Imaging Technique.
SPWMD = Septal to posterior Wall Motion Delay by M-Mode
IVMD = Inter-Ventricular Mechanical Delay by pulsed wave Doppler

Figure 3: Main Echocardiographic Parameters in Dual Chamber Pacemaker patients
These data show that LV dysfunction usually is underestimated in standard clinical practice. Intervertricular dyssynchrony evaluation revealed no significant change after 3 months. But all patients developed various degree of intra-ventricular dyssynchrony, yet; in all patients – intraventricular dyssynchrony remained between physiological normal limits.

From this Each Echo graphic method used above is eligible to evaluate global longitudinal function, but Speckle tracking imaging (STI) techniques gives opportunity to assess not only global but also precise local myocardium segment not in qualitative but in quantitative values.

Discussion:

Development and advances in heart pacing over the last nearly half a century allowed to save numerous lives by providing pacing support in bradycardia and complete heart block. Nevertheless, long-term follow up of patients with implanted pacemaker showed unfavorable remodeling of the heart, both from hemodynamic as well as electrical standpoint. The optimal programmed pacemaker setting, apart from the optimal place for ventricular stimulation, is essential to obtain the best hemodynamic after-effects of the stimulation of the heart and to minimize potential unfavorable effects. In patients with dual-chamber pacemaker the correct function of the left ventricle of the heart depends mainly on the electric delays between the stimulated chambers. Atrioventricular delay during dual-chamber pacing influences left ventricle contraction function through preload modulation. Research data in Subjects with pacemakers for Sinus Node dysfunction or Atrioventricular block provide increasing evidence showing that desynchronization of ventricular electrical activation and contraction, induced by right ventricular pacing (RV) worsens long-term cardiac morbidity and mortality. The risk of heart failure is increased even in hearts with initially normal pump function and in case of part-time ventricular pacing. These epidemiologic data fit with knowledge from decades of pathophysiological research, indicating that RV pacing creates abnormal contraction, reduced pump function, causes hypertrophy and ultrastructural abnormalities. It is known that large randomized clinical trials in sinus node disease or atrioventricular block have reached a consensus that despite maintenance of AV synchrony, Dual Chamber Pacemaker does not reduce death, and has surprisingly modest or even negative benefits for progression of heart failure and atrial fibrillation, that emerge only after many years of follow-up. The Canadian Trial of Physiological Pacing (CTOPP) was reported in 2000. In this trial 2568 Subjects (mean age 73 years) with symptomatic bradycardia requiring permanent pacing, were randomized to atrial or ventricular pacing groups and monitored for an average of 3 years. There were no differences in the incidence of heart failure hospitalization. The DAVID (The Dual Chamber) trial tested the hypothesis that dual Chamber pacing at rate of 70 bpm would enable optimal heart failure management and reduce heart failure hospitalization and death risk compared with ventricular-only backup pacing. The study was terminated prematurely and unexpectedly because of an excess of heart failure and deaths in the dual chamber pacing group.
Because of data mentioned above, Dual Chamber pacemaker with large percentage of ventricular pacing (more than 90%) was accepted as a simple clinical model for myocardial remodeling. Dual Chamber pacemaker creates the same ECG pattern as left bundle branch block (LBBB). Electrical activation and contraction geometry in LBBB are close to right ventricle pacing model with unchanged atrioventricular synchrony. Despite these provocative observations, clinical experience indicates that the majority of pacemaker Subjects tolerate chronic right ventricle pacing. In the MOST (The Mode Selection Trial) study, only about 10% of Subjects had new heart failure onset during follow-up and were more likely to have a lower ejection fraction, myocardial infarction, and a worse New York Heart Association functional class compared with Subjects who did not experience heart failure. But also it means that from 1000 Subjects who have conventional indications for dual Chamber pacemaker and normal ejection fraction, one hundred of them are at risk of heart failure due to right ventricle pacing.

The main question is the mechanism of LV dysfunction. Animal studies have shown that the mechanical effect of asynchronous electrical activation is important, because the various LV segments differ not only in time of onset of contraction, but also in quality of contraction. Contraction disturbances due to right ventricular pacing have been proven not only in animal studies, but also in Subjects – perfusion defects and wall motion abnormalities have been shown in up to 65% of the Subjects with angiographically normal coronary arteries, exposed to chronic RVA pacing. Modern echocardiographic techniques such as strain, strain rate and single speckle tracking have the same value for research of new criteria to evaluate risk factors of heart failure progression. Our research showed several criteria for early dyssynchrony evaluation which can be followed by subsequent dual Chamber Pacemaker system optimization.

In our study, we included only patients with preserved Ejection Fraction as baseline LV function is a potentially important determinant of the LV response to pacing. In a previous acute pacing study, Dual Chamber Pacemaker in normal LV function produced little in the way of dyssynchrony but as baseline LV function worsened, the amount of dyssynchrony was greater. This would suggest that baseline LV function is important in the response to Dual Chamber pacing.

Our study showed, no statistical significant change in Ejection fraction before and after dual chamber pacemaker implantation after three months, Septal to posterior wall motion delay and interventricular mechanical delay also showed no statistical significant difference between baseline and three months after implantation from (15.02(0.56) to 13.61(0.43) (p = 0.001)), global longitudinal strain and LV dyssynchrony assessment enables us to detect early signs of LV dysfunction in Subjects with dual chamber pacemaker.

Our finding of reduced Global Longitudinal Strain after Dual Chamber Pacemaker is consistent with previous studies. However, these studies have often been limited by focusing on individual measurements (e.g. Global Longitudinal Strain or left ventricle ejection fraction, rather than evaluating both parameters in the same patients), single time-point follow-up, or highly selected populations making no allowance for variations in pacing burden (e.g. pacing-dependent patients only, or following AV nodal ablation). For example, Delgado et al. examined the acute effects of dual chamber pacemaker pacing in patients with preserved left ventricle function and reported a significant decline in both Global Longitudinal Strain & left ventricle ejection fraction, but the long term impact and risk of Pacemaker induced ventricular dysfunction progression or pacemaker induced cardiomyopathy was not described. In a sub-study of the Protection of Left Ventricular Function During Right Ventricular Pacing (Protect-PACE) trial, there was no significant difference in baseline Global Longitudinal Strain between the dual chamber pacing group and controls. Notably, however, Global Longitudinal Strain was not evaluated prior to pacing, with the baseline measurement being obtained after pacemaker implantation. After 2-years, Global Longitudinal Strain was reported to be significantly reduced in the dual chamber pacemaker group compared to controls, but this study does not yield information regarding the tempo of changes from baseline to 2 years, nor if there was an earlier time point for possible therapeutic intervention. Similarly, evaluated the effects of RV apical pacing on left ventricular ejection fraction at 2 years. In a retrospective study, predictors of a decline of LVEF >5% were examined among
patients undergoing AV node ablation for atrial fibrillation and pacemaker implantation. GLS performed a median of 4-months after initiation of pacing was significantly reduced in patients who had a decline in LVEF >5% at 2-years compared to those who did not. 

The Pacing and Cardiac Enlargement (PACE) study was a prospective study that compared measured LVEF in patients randomized to dual chamber pacemaker or biventricular pacing. In dual chamber pacemaker subjects with pacemaker induced ventricular dysfunction at 1 year, further significant reductions in LVEF were observed when follow-up was extended to 2 years (7% vs. 9.9% reduction in LVEF at 1 and 2 years respectively). Thus, relatively small reductions in LVEF at 12 months, may progress to result in more clinically significant reductions in LVEF with extended follow-up, emphasizing the importance of global longitudinal strain in identifying this patient group at an early stage of the disease process. Moreover, in the present study, a significant decline in GLS was observed. Therefore, we demonstrate the utility of three month GLS not only to risk stratify patients following pacemaker implantation, but also to predict the decline in LVEF.

Conclusion: Global longitudinal strain and Left Ventricular desynchrony assessment enables us to detect early signs of LV dysfunction in Subjects with dual chamber pacemaker.

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The authors state no conflict of interest.

References:


