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ORIGINAL ARTICLE

Left Ventricular Speckle Tracking Guidance in DDD Pacemaker Optimization

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ABSTRACT

Background: Different strategies have been investigated for optimizing atrioventricular (AV) synchrony in patients with dual chamber pacemakers (DDD), which has a crucial role in preserving an effective cardiac output. To utilize the Left ventricular 2D speckle tracking strain parameters as a new tool guiding atrioventricular delay (AVD) synchronization in patients with DDD pacemaker to achieve the best LV systolic performance.

Method: This interventional cross-over study involved 255 patients with DDD pacemakers, with mean age 50.62 ± 7.03 years, 175 of them were males 68.6% and 80 were females 31.4%. Each device was programmed to 4 different AV intervals, at one-week interval each; (AV pacing /AV sensing):120/100,150/130,180/160, 200/180 msec). Conventional echocardiographic parameters & left ventricular (LV) 2D speckle tracking (ST) strain were interrogated.

Results: At relatively prolonged AVD (180/160 msec), both LV longitudinal strain and left ventricular outflow tract velocity time integral (LVOT VTI) were significantly improved (18.11±1.35 & 27.19 ± 3.16 respectively with P <0.001). Also, E/e` showed the lowest values (8.5 ±2.9) and exercise time reached the best between (150/130 and 180/160 msec AVD;309±119 & 320±124, p <0.001 respectively).

Conclusions: The benefit of LV speckle tracking based AV optimization looks to result from achieving the best LV systolic performance, this is a very important concern during AV synchronization in DDD pacemakers.

Key words: Dual chamber pacemaker: AV interval optimization; LV longitudinal strain; Speckle tracking.

INTRODUCTION

Dual chamber pacemaker systems are used for second and third-degree heart block to imitate the physiological AV sequential pacing, so they provide a profound hemodynamic benefit rather than VVI pacemaker systems which have a deleterious impact on ventricular filling. However, dyssynchronization induced by right ventricular (RV) pacing is still an obstacle in DDD pacemakers which necessarily worsens cardiac performance [1,2]. Since Global Longitudinal Strain (GLS) and LV dyssynchrony evaluation empowers the early detection of LV dysfunction. So, Speckle strain based AVD programing in DDD pacemaker can be built in arrange to avoid further dyssynchronisation [3].

In line with our proposal, many previous studies handled LV speckle tracking-based AVD optimization showed significant improvement of the systolic performance and outcome in cardiac resynchronization therapy defibrillator (CRT-D) non-responders [4,5].

METHODS

Written informed consent was obtained from all participants. The study was approved by the research ethical committee of Faculty of Medicine, Zagazig University. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Study population

Among patients with implanted DDD pacemakers for second- or third-degree AV block, eligible patients (255; 175 males and 80 females) with more than 90 % ventricular pacing, with good LV systolic function (EF >50 %) were selected from the pacemaker follow-up clinic. Patients with moderate or severe valvular heart disease, atrial flutter or atrial fibrillation, sick sinus syndrome involving the SA node, patients with severe organ failure, and those with suboptimal echocardiographic images were all excluded from the study.

A standard 12-lead surface electrocardiogram (ECG) was done for every patient to verify the performance of the pacemaker along with device routine programming to insure more than 90% capture. All devices were programmed to DDD mode with no adaptive AV delay and sensors were turned off. Then, AVD was programmed at five different intervals, each maintained for one week before switching. The AVD was programmed as (paced/sensed respectively) at 120/100, 150/130, 180/160, and 200/180 msec. intervals. Programming was not done in an ascending manner, instead, randomly to avoid bias.

Echocardiography:

At the end of each week, patients were examined by Transthoracic echocardiography (TTE) at left lateral decubitus using GE Vivid E95, model GA 091568 (Norway) with a 5 MHz transducer. Three consecutive cardiac cycles of each view were recorded during quiet breathing at frame rates of 50-80 frames /sec. The operators were blinded to the AV interval. All echocardiographic measurements were taken in accordance with the recommendations of the American Society of Echocardiography (ASE) [6]. Left ventricular ejection fraction (LV EF) was recorded using biplane method. Doppler measurements included LVOT VTI (cm), mitral inflow velocities (the peak early (E) and late (A) transmitral flow velocities), E velocity deceleration time (DT) and the ratio of early-to-late peak velocities (E/A). Tissue Doppler imaging was performed to measure the early diastolic (E') myocardial peak velocity at the lateral and septal annular base of the mitral valve and averaged from both positions, E/e' ratio & isovolumic relaxation time (IVRT) were calculated [7].

2D Speckle tracking

The software automatically traced the contour of the LV endocardium at apical four, three & two chamber views, borders were manually adjusted when required. 2D Systolic global longitudinal strain was automatically analyzed by the software (Normal GLS range assessed by ST is (-18 to -20%) [8].

Patients who were able to exercise (198 patients), were submitted to a 6-minute walking test (6MWT). It is a simple test that assesses exercise capacity. The patient was asked to walk the longest distance possible in a set interval of 6 min, through a corridor 30-m long. The patient can stop or slow down and then resume walking, depending on the degree of fatigue [9].

Statistical Analysis:

All data were collected, tabulated, and statistically analyzed using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as the mean ± SD & median (range), and qualitative data were expressed as absolute frequencies (number) & relative frequencies (percentage). Continuous data were checked for normality by using Kolmogorov-Smirnov test. Repeated measures ANOVA test was used to compare the results with different programmed AV intervals. Post hoc analysis was done by LSD test to compare two dependent groups of normally distributed data. All tests were two-sided). P value was set at <0.05 for significant results & <0.001 for high significant results.

RESULTS

Our study enrolled 255 patients with DDD pacemakers for second or third-degree AV block, their ages ranged from 33 to 65 years with a mean ± SD (50.62 ± 7.03) years. 175 (68.6%) were males and 80 (31.4%) were females. 45.1% of our cohort were hypertensive, 7.8% were Diabetics and 56.9% were smokers. Regarding LV systolic parameters; LV EF% measured by the volumetric method did not show significant changes among different AV interval groups (P value =0.72). while systolic performance assessed by GLS % analysis showed progressive improvement with an incremental increase of AV interval, and peak values presented at (180/160 msec) 18.11± 1.35 p <0.001. Also, LVOT VTI (cm) showed maximum values observed at (180/160 & 200/180 msec; ± 3.36 & 27.18 ± 3.36 respectively, p value <0.001). While exercise capacity measured in meters at 6MWT(m)reached the peak at (150/130 & 180/160 msec; 315±119 & 320±124, p <0.001 respectively) (Table 1). At the level of diastolic parameters, only E/e' showed significant improvement between 180/160 and 200/180 msec, (p<0.00) while other conventional parameters (E/e`m/s, E/A, DT msec & IVRT msec) did not show any significant improvement between different AVD intervals (Table 1).

Upon comparing exercise capacity between groups, exercise distance improved progressively while increasing the AVD, where the best values were obtained at 150/130 and 180/160 msec (315± 119 & 320±124 m) respectively (p<0.001) (Table 1). Post Hoc analysis proved the significant changes among different programmed intervals (Table 2).

Table 1: LV systolic and diastolic parameters with different AV intervals

	AV interval (msec)				Wilks's Test (F)	P value
	120/100	150/130	180/160	200/180		
E/A	0.75 ± 0.33	0.74 ± 0.32	0.74 ± 0.34	0.74 ± 0.30	1.833	0.142
E/e` average	12 ±2.77	12.3± 3.2	8.5 ±2.9	9 ± 4.84	9.86	0.035
E DT msec	170.5±16.9	168.9±18.9	170±21.3	169±20	7.85	0.587
IVRT msec	90.11 ± 6.04	91± 4.92	90.9 ± 5.25	91.1 ± 4.84	1.964	0.122
LAVI mL/m2	36.8 ± 5.6	37.1±4.9	36.5 ±3.9	37.5±6.1	6.8	0.367
LVOT VTI (cm)	23.41 ± 2.92	24.53 ± 2.80	27.19 ± 3.16	27.18 ± 3.36	187.31	<0.001
EF %	57.97± 3.23	58.94 ±3.02	62.94 ±2.96	61.90 ±3.00	0.44	0.723
PGLS %	-15.05 0.88	-15.7±1.06	-18.11±1.35	-17.95±1.41	88.755	<0.001
6-minute walk test m	290±112	315±119	320±124	297± 130	56.54	<0.001

E/e`, peak early transmitral /early diastolic myocardial velocities; E DT, E wave deceleration time; IVRT, isovolumetric relaxation time; EF, ejection fraction; GLS, global longitudinal strain, LVOT VTI, left ventricular outflow tract velocity time integral; AV, atrioventricular.

Table 2: Post Hoc test for significant parameters

Parameter	120/100 Vs 150/130 msec	120/100 Vs 180/160 msec	120/100 Vs 200/180 msec	150/130 Vs 180/160 msec	150/130 Vs 200/180 msec	180/160 Vs 200/180 msec
PGLS LSD test	**-0.65 <0.001**	**-2.06 <0.001**	**-1.9 <0.001**	**-1.41 <0.001**	**-1.42 <0.001**	**0.16 0.061**
E/e` LSD	**0.158 <0.136**	**0.738 0.001**	**0.511 0.059**	**-0.620 0.005**	**-0.048 0.855**	**-0.672 0.006**
LVOT VTI LSD	**-1.125 <0.001**	**-3.784 <0.001**	**-3.773 <0.001**	**-2.659 <0.001**	**-2.647 <0.001**	**0.012 0.897**

LSD least significant test

DISCUSSION

Simulating the normal cardiac physiology and preservation of atrioventricular (AV) synchrony is the mainstay for maximizing cardiac performance in patients with DDD pacemaker. LV 2D speckle tracking strain has been interrogated in many studies to detect early signs of LV dysfunction resulting from RV pacing and interventricular dyssynchrony [10]. Currently, secondary to time consumption and lack of guideline standardization, routine AVD optimization on an individual base is not clinically practiced, but instead, devices are empirically programmed to a fixed AVD interval [11]. So, in our research, we utilized LV GLS at speckle tracking as a relatively new modality to guide AVD optimization in DDD pacemaker and detect the best interval achieving robust systolic performance.

We observed upon the incremental increase of AVD interval, LV GLS achieved the best value at (180/160 and 200/180 msec; 18.11 ± 1.35 and 17.95± 1.41 respectively) than the nominal default setting (120/100 & 150/130 msec) with p <0.001. Our result was in line with Sipula et al. [4] who proved better outcome in CRT-D non-responders upon optimization of AVD based on speckle tracking strain analysis.

The potentially longer AV delay than the usual default in our study has been observed in previous studies and succeeded to achieve a better systolic performance either detected at the level of LV GLS analysis as observed by Arık et al. [12] or by conventional EF methods as reported by Statescu et al. [13] who utilized ECG dependent programming algorithm. Our results come in contrast to many studies which showed improved CO &3D derived systolic function at lower AVD intervals (127±33 msec) [14] while others compared electrogram-based algorithm, echocardiographically optimized AV interval and fixed AVD, reported that routine AVD optimization by is neither inferior nor superior to nominal settings in CRT outcome [11].

In another study invasively evaluated LV pressure-volume relationship during different AV intervals (from 80 msec to 300 msec) in patients with DDD pacemaker, Eberhardt et al. [15] found the best relation was achieved around 152 ± 39 msec, which included 180/160 msec interval used in our study. However, systolic function based on LVOT VTI showed progressive improvement with increasing AV delay time, peaking at 180/160 & 200/180 msec. This comes in line with findings of Arik et al. [12] who observed significantly higher LVOT–VTI values at higher AVD, 200 msec compared to 100 msec intervals.

Regarding the diastolic parameters, E/e` showed significant improvement at both 180/160 msec and 200/180 msec than lower AVD intervals. This may indicate more improvement of LA filling pressure with prolongation of AV time. The same was demonstrated by Leonelli et al. [16] who found significant improvement in E/e' when the AV delay time increased to 220 msec. Meanwhile discordant results reported by Styliadis et al. [17] that E/e` improved with prolongation of AV delay time up to 150 msec only and worsened with further prolongation up to 200 mse.

We did not find any significant difference among different AVD intervals at E and A velocities, E/A, E wave DT, and IVRT. This is similar to that shown by Arik et al. [12], Wu et al. [18]

We studied the exercise tolerance and measured the exercise distance at 6MWT where the highest was achieved at (180/160 & 150/130 msec AVD). It seems that progressive improvement of GLS & LVOT VTI in Transthoracic echocardiography was translated to an increase in exercise tolerance.

At GLS speckle based AVD optimization, a high systolic performance combined with the most advantageous improvement of LVOT VTI, E/e` & exercise tolerance was achieved. So, the relatively longer AVD (180/160 msec) maintains the full booster atrial contraction without interruption so, ventricular preload and sarcomeric length were optimized prior to contraction, which increases LV cardiac output.

Limitations:

-Regular follow up of LV systolic function either by Simpson-derived EF or speckle strain analysis on other visits after longer duration was not performed.

-All the patients recruited in the study had preserved LV systolic function & so, the effect of speckle-based AVD optimization on myopathic myocardium was not studied.

-LV diastology was assessed by conventional echocardiographic parameters, we think that evaluating LA speckle tracking strain may provide more accurate judgment on diastolic function.

- Inter and intra observer variability

CONCLUSION

AV optimization based on speckle strain analysis is a very promising strategy potentially leading to significant refinement of LV systolic performance in DDD pacemaker patients. Increasing AV delay time within the physiological limits has favorable effects on LV systolic and diastolic performance as well as the exercise capacity than lower default settings.

Declaration of interest

The authors report no conflicts of interest. The authors along are responsible for the content and writing of the paper.

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