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Original Article

Value of Optimizing Atrioventricular Delay in Patients with Dual Chamber Pacemakers Assessed by Three-Dimensional Echocardiography

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ABSTRACT

Background: Cardiac pacing witnessed many advances in the last years, with favorable outcome of saving more lives in different heart diseases associated with conduction abnormalities. Devices usually programmed by manufacturers. However, it did not provide optimal pacing and manual programming was advised.

The aim of work: This study aimed to assess the value of manual optimization of atrioventricular delay [AVD] in dual chamber pacemaker [DDD] patients in comparison of default AVD, using three-dimensional Echocardiography.

Patients and Methods: Fourty patients with DDD were included. They received pacemaker due to high grade of atrioventricular [AV] block. All were submitted full history taking, general and cardiac clinical examination in a systematic pattern. All were subjected to resting 12-leads electrocardio-graphy, and the pacemaker position was confirmed by chest X ray. Dual-chamber pacemakers were interrogated and programmed using St. Jude Medical, Inc. programmer. All patients were checked after 6 weeks and outcome was compared to original values.

Results: Patient's age ranged between 29 and 66 years, and 27 [67.5%] were males. Complete heart block was the principal indication for initial pacing [87.5%] followed by Mobitz type II heart block [12.5%]. Three-dimensional echocardiography revealed that, manual pacing was associated with significant increase of end-systolic volume, end-diastolic volume, ejection fraction and velocity time integral [224.0 ±87, 93.0±34.8, 63.9±3.84 and 63.9±3.84 vs. 187.0±80.6, 75.8±19.4, 60.1±3.09 and 29.2 + 12.7, respectively]. Symptom's improvement revealed that, 21 [77.7%] patients who presented with dyspnea, 15 [83.3%] in dizziness and 20 [90.5%] in the palpitation.

Conclusion: It is recommended to use AVD optimization for all patients of DDD pacemakers. This may be associated with long-term benefit mainly for the systolic functions. Echocardiography is the gold standard of timing optimization through mitral flow Doppler as its waves could mark for atrial contraction which is used for AV timing optimization.

Keywords: Cardiac Pacing; Atrioventricular Delay; Dual Chamber Pacemaker; Three-Dimensional; Echocardiography

INTRODUCTION

Heart pacing had many advances in the last five decades. These advances permit saving of numerous lives by pacing in bradycardia and complete heart block. However, long-term unfavorable effects of the heart were observed with implanted pacemaker. These effects are due to remodeling of the heart muscle due to hemodynamic and electrical effects [1].

During dual chamber pacing, the hemodynamics were influenced by the A-V interval, improperly programmed atrioventricular delay in dual chamber pacemaker can have unfavorable hemodynamics results [2].

The AV delay is defined as the time from the starting of paced or sensed atrial activity to the impulse of ventricle stimulation or sensed ventricular activity. Newly introduced DDD pacemakers permit wide range of programming of AV delay its-related algorithms [3].

The optimal AV synchrony will maximize cardiac output by increasing ventricular preload. Thus, arterial pressure was lowered. In addition, the optimal AV synchrony will also minimize the mitral regurgitation [4].

Echocardiography is the gold standard of timing optimization through mitral flow Doppler as its waves could mark for atrial contraction which is used for AV timing optimization [5].

The standard nominally programmed A-V intervals in DDDR pacemaker; 125 to 175 msec; may not offer the optimal synchrony of atrioventricular delay intervals; however, as long as 250 to 350 msec may be required. Currently, optimization of the atrioventricular delay interval on individual basis is not routinely performed in the clinical practice. This is mainly due to time-consumption in manual optimization and lack of guideline recommendation [4].

THE AIM OF THE WORK

This study aims to evaluate manual optimization of atrioventricular delay in dual chamber pacemaker patients in comparison of default atrioventricular delay regarding hemodynamics using three-dimensional Echocardiography.

PATIENTS AND METHODS

The present study included 40 individuals with permanent dual chamber pacemaker provided by St. Jude Medical, Inc. [St. Paul, MN, USA] received pacemaker due to high grade AV block with the atrial leads positioned in the appendage of the right atrium and the right ventricular leads placed in the apex of the right ventricle.

Patients with poor echocardiographic window [e.g., significant valvular heart disease, patient with ejection fraction less than 50%, and coronary artery disease] were excluded from the study. All patients were studied after giving an informed consent, followed by full history taking [age; gender; symptoms related to low cardiac output that may reflect potential malfunction of the pacemaker. These include palpitations, dizziness, pre-syncope/ syncope, or any symptoms that may look like those found in pre-implantation].

The pacemaker syndrome should be put into consideration as a probable cause for recurrent or new-onset symptoms. Manifestations due to potential infection of the pacemaker include fever, chills, recurrent respiratory disease, or swelling, drainage, or tenderness on the region of the collection.

History taking followed by complete general and local cardiac examination in a systematic view was performed. The examination involves the measurement of vital signs and inspection of the pocket area. Attention had been paid to the existence of localized tenderness, swelling, or redness. All patients were submitted to resting twelve leads electrocardiography. The position of pacemaker and exclusion of lead fractures were confirmed by chest X ray or cinefloroscope postero-anterior view.

Dual-chamber pacemakers were interrogated and programmed using St. Jude Medical, Inc. programmer for DDD and VVI pacing modes in all patients, respectively. The steps of pacemaker interrogation and programming were done for every patient.

Patient was connected to the programmer by five ECG cables, which were put on bony prominences and programmer wand was put above pacemaker. Then we waited until basic programmer screen was displayed [Figure 1].

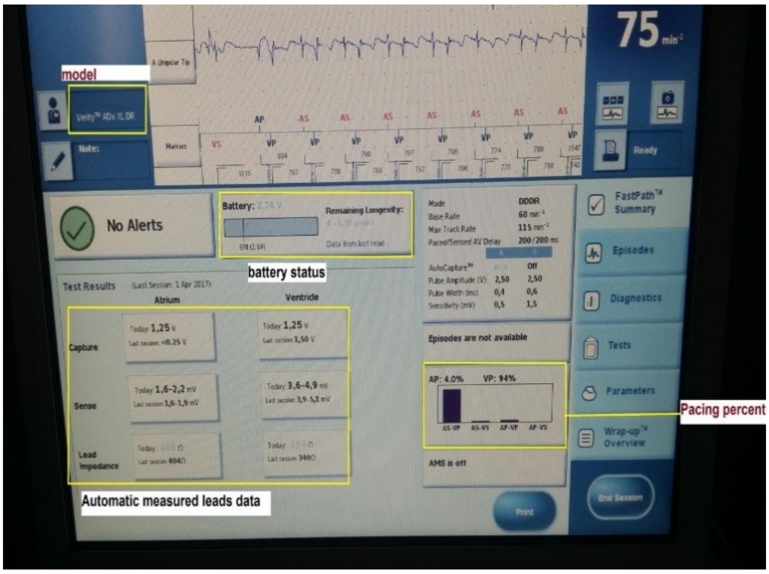

Figure [1]: Basic screen of St. Jude medical programmer

The following basic data and measurements were collected: Pacemaker model, mode and basal rate, battery status [longevity, voltage and impedance], leads status [impedance, polarity, automatic measured capture and sensing threshold, and percent of pacing.

Performing sensing threshold test

Atrial lead

- We programmed pacemaker to DDD mode with lower rate limit [LRL] 20 bpm < sinus rate and with highest atrial output
- We step wisely reduce atrial sensitivity [low to high mV/cm]
- We figured out threshold moment when atrial pacing began
- We adjusted final value to half of measured threshold.

Ventricular lead

- We programmed pacemaker to VVI mode with LRL 20 bpm less than active ventricular rate, longest available AV delay, and highest ventricular output
- We step wisely decreased ventricular sensitivity
- We figured out threshold moment when ventricular pacing artifact was seen at the end of QRS or in ST segment.
- We adjusted final value to half of measured threshold.

Performing capture threshold test

I. With intact AV conduction:

Atrial lead

- We programmed pacemaker to DDD mode with LRL to 20 bpm greater than sinus rate
- We step wisely decreased atrial pulse output
- We figured out threshold moment with appearance of ventricular pacing.
- We adjusted final value to double of measured threshold and not less than 2.5 mv.

Ventricular lead

- We programmed pacemaker to VVI mode with LRL to 20 bpm greater than sinus rate.
- We step wisely decreased ventricular pulse output
- We figured out threshold moment with loss of ventricular capture and appearance of native QRS complexes.
- We adjusted final value to double of measured threshold and not less than 2.5 mv.

II. With second- or third-degree AV block:

Atrial lead

- We programmed pacemaker to DDD mode with LRL to 20 bpm greater than sinus rate
- We step wisely decreased atrial output
- We figured out threshold moment with occurrence of an irregular rhythm [due to mixed AV synchronous and AV sequential pacing].

- We adjusted final value to double of measured threshold and not less than 2.5 mv.

Ventricular lead

- We programmed pacemaker to VVI mode with LRL to 20 bpm greater than native ventricular rate.
- We step wisely decreased ventricular output.
- We figured out threshold moment with loss of ventricular capture and rate slowing.
- We adjusted final value to double of measured threshold and not less than 2.5 mv.

Trans-thoracic echocardiographic examination [performed by the same investigator for all patients]

After pacemaker adjustment using a commercially available echocardiography system [Philips IE 33 Ultrasound, Bothell, WA. 98021 USA] using an X5-1 phased array transducer. Each patient was asked to hold his/her breath during gaining images, which were coupled with an electrocardiographic recording. The images were stored in the hard disk of the system for further analysis with special software [QLAB, version 9; Philips Medical Systems] for the same equipment.

All studies were performed according to the following protocol:

Preparation: We started by proper preparation of the patient and the machine to enhance the acquired images and loops quality which facilitated the analysis later on. This was carried out by ensuring proper connection of the machine-integrated ECG cable to the patient with each lead connected at the recommended position. The study was completed while the patient was in the left lateral decubitus position. Sweep speed was set to 50–100 mm/s for all time interval measurements.

Transthoracic Echocardiographic images were recorded two times, with 6 weeks' interval, with more attention to the following: [a] - Pulsed wave Doppler on mitral valve inflow to assess the peak and shape of both [E and A] waves and severity of the mitral regurgitation [if any]. [b]- Left ventricular ejection fraction [LVEF] using three-dimensional mode [3D] measuring volume of the left ventricle [LV] at end diastole [LVEDD] and at the end systole [LVESD].

The optimum [AVD] identified as the best trans-mitral flow and discrete [E/A] separation in the following steps: [a]- Paced [AVD] were increased successively from [80 to 225] ms at [20 ms] step wise interval [with respect to less value of sensed [AVD] by [30 ms]]. [b] At each value; pulsed Doppler transmitral flow will be recorded and compared with each other.

The optimum AV delay was approved as: Good E-A separation [no fusion of two waves]; No A wave truncation; No or the least mitral regurgitation.

Statistical analysis of data: The data were coded and fed to personal computer, running Microsoft windows [7] and tested for significance by statistical package of social science [SPSS] version 18 [IBM® SPSS ®, Chicago, IL. USA]. Qualitative data expressed by relative frequencies and percentages. Groups compared by independent samples "t" test and Chis square test for parametric quantitative variables and categorical variables, respectively. P value < 0.05 was considered significant.

RESULTS

Study population

The present study included forty individuals with permanent dual chamber pacemaker provided by St. Jude Medical, Inc. [St. Paul, MN, USA] received pacemaker due to high grade AV block with the atrial leads placed in the right atrial appendage and the right ventricular leads placed in the right ventricular apex. The mean age of the study group was ranged from [29] to [66] years old with mean ± SD = [51.7 ± 9.52]. 27 [67.5%] of the study population were males and 13 [32.5%] were females. Complete heart block [CHB] was the main indication for initial dual chamber pacemaker implant [87.5%] and the other indication was Mobitez type II heart block [12.5%]. Hypertension was reported in 17 [42.5%], while 20 [50%] were diabetic. Regarding presentation, 27 [67.5%] of the patients presented with dyspnea, 18 [45%] had dizziness and 22 [55%] with palpitation [Table 1].

Echocardiography assessment

Atrio-ventricular delay [AVD] assessment: After implantation of the dual chamber pacemaker; we considered the patients where the AVD was programmed as default manufacturer values as group [D] or the control group. The second group group [O] the AVD was optimized. Follow up visits and echocardiographic study were done after six weeks to assure optimization and the findings were compared between the two groups. The mean value of ESV in group [D] was ranged from [115] to [403] ml with mean ± SD = [187 ± 80.6]. While in group [O] the value of ESV was ranged from [119] to [476] ml with mean ± SD = [224± 87]. There was significate difference between the two groups. The mean value of EDV in group [D] was ranged from [37] to [124] ml with mean ± SD = [75.8 ± 19.4]. While in group [O] the value of EDV was ranged from [42] to [174] ml with mean ± SD = [93 ± 34.8]. There was significate difference between the two groups. The mean value of EF in group [D] was ranged from [55] to [70] % with mean ± SD = [60.1±3.09]. While in group [O] the value of EF was ranged from [57] to [74] % with mean ± SD = [63.9±3.84]. There was significant difference between the two groups. The mean value of VTI in group [D] was ranged from [12.0] to [58.0] with mean± SD = [29.2 ± 12.7]. While in group [O] the value of VTI was ranged from [15.7] to [73.7] with mean± SD = [36.3 ± 31.9]. There was significate difference between the two groups [Table 2].

There was Improvement in 21 [77.7%] patients who presented with dyspnea, 15 [83.3%] in dizziness and 20 [90.5%] in the palpitation.

Case Presentation

Here we presented, a male patient, 61 years old, Diabetic and hypertensive, with permanent dual chamber pacemaker on complete heart block. Figure [2] showed data of pacemaker programming. The pacemaker was well-positioned as evidenced by chest X-ray [figure 3]. His ejection fraction improved from 59% to 68.0%. Three-D echocardiography and velocity time integral showed significant improvement after manual optimizations [Figures 4-8].

Table [1]: Baseline characteristics of study population

		n = [40]
Age, mean [SD]		[51.7 + 9.52]
Gender	Males, n [%]	27 [67.5%]
	Females, n [%]	13 [32.5%]
Indications	CHB, n [%]	35 [87.5%]
	Mobitez 2, n [%]	5 [12.5%]
Medical History	Hypertension, n [%]	17 [42.5%]
	Diabetes, n [%]	20 [50%]

Table [2]: Echocardiographic findings among studied groups

	Group [D]	Group [O]	P value
ESV [mean + SD] ml	[187 + 80.6]	[224 + 87]	< 0.001 *
EDV [mean + SD] ml	[75.8 + 19.4]	[93.0 + 34.8]	<0.001 *
Ejection fraction [EF] [%]	[60.1 + 3.09]	[63.9 + 3.84]	0.005 *
VTI volume changes	[29.2 + 12.7]	[36.3 + 31.9]	<0.001 *

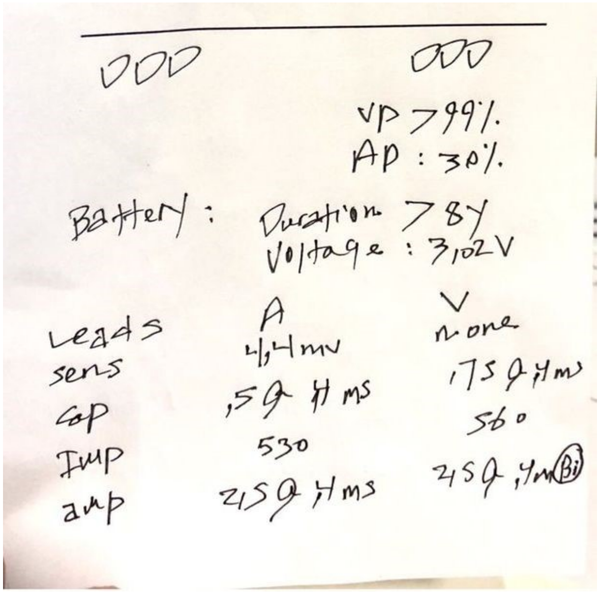

Figure [2]: Data of programming of the case

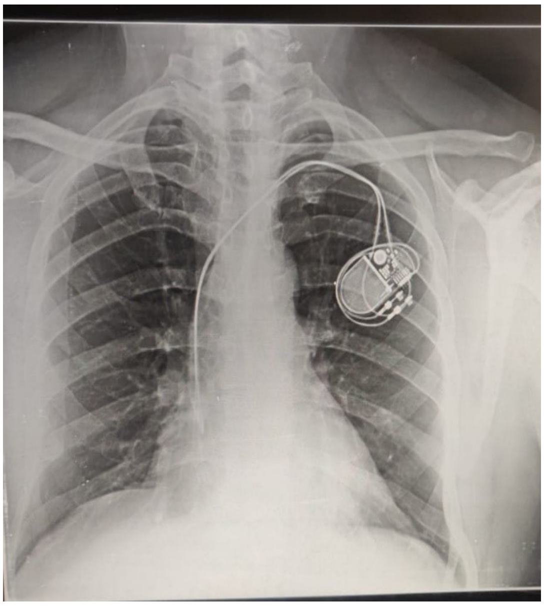

Figure [3]: Chest X-ray, showed well-positioned implanted pacemaker leads

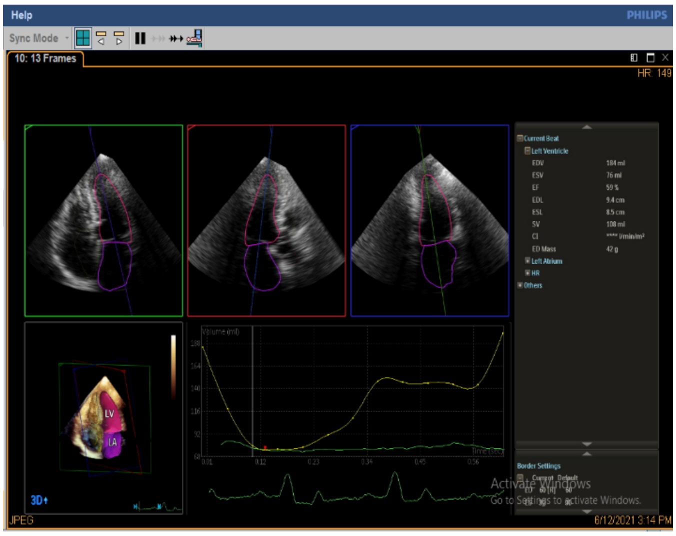

Figure [4]: 3D Echocardiographic default data of case number 1 [before manual optimization].

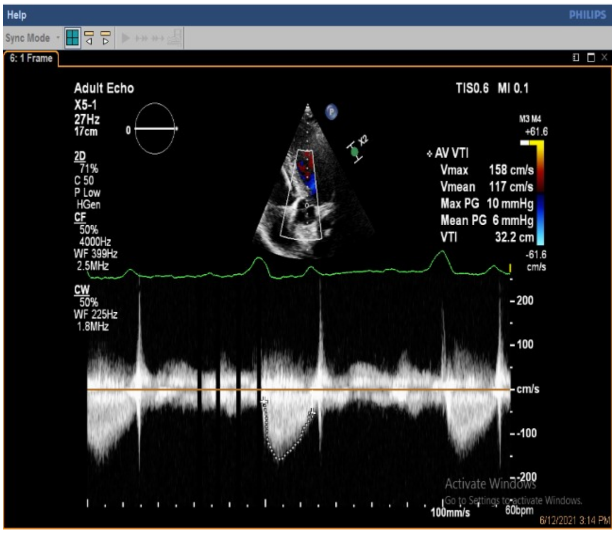

Figure [5]: Default VTI of case number [1] [Before manual optimization].

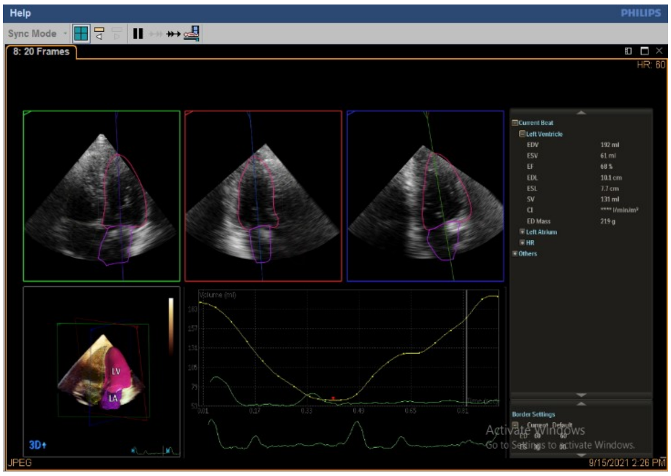

Figure [6]: 3D Echocardiographic Optimized data of case number [1] [After manual optimization].

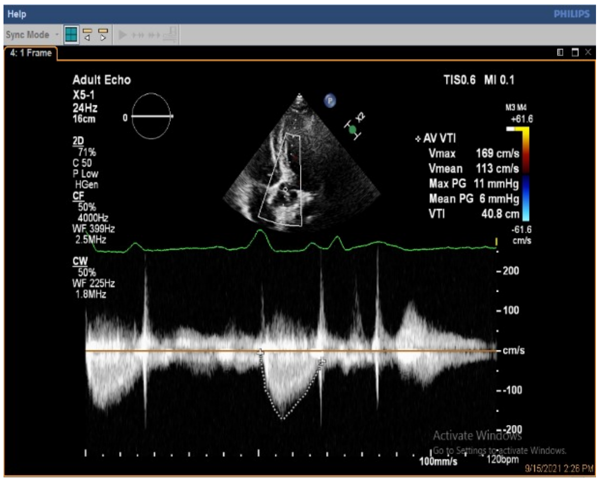

Figure [7]: Optimized VTI of case number [1] [After manual optimization].

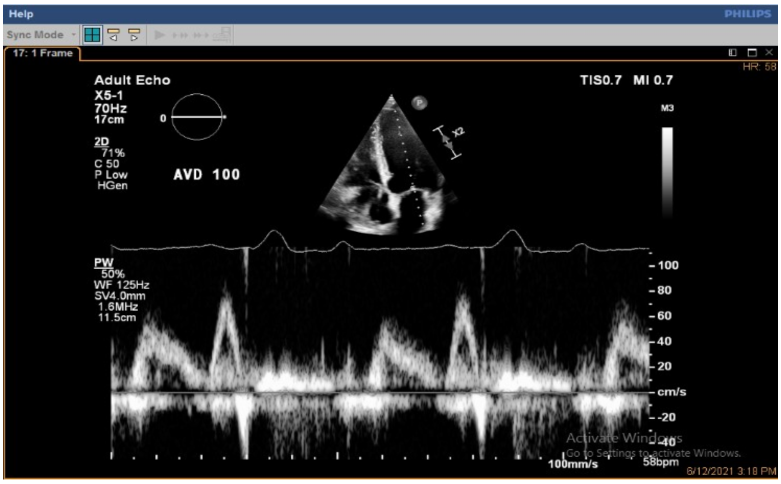

Figure [8]: Pulsed Wave Doppler on mitral valve of optimum AVD of case number

DISCUSSION

In this study we are trying to assess and compare LVEDV, LVESV, and EF by using 3D echocardiography and VTI in forty individuals before and after manual optimization of AVD, this individual presented to cardiology department, Al-Azhar University, Damietta by advanced degree heart block with permanent pacemaker DDD. AVD optimization for all patients who had DDD pacemakers may be associated with long-term benefits especially for the systolic functions. The current work showed a significant LVEF improvement and this is supported by previous studies. For example, Siegrist [6] reported a significant improvement in the LVEF after optimization of CRT devices and this improvement was significantly correlated to the atrio-ventricular synchrony gained by the AVD optimization. In addition, another study from Romania on patients with DDD pacemakers showed a significant LVEF improvement after AVD optimization by an ECG-dependent algorithm [7].

On the other side, Ellenbogen *et al.* [8] reported a non-significant impact between manual or automated optimization on the left ventricle systolic function. Ellenbogen *et al.* had many explanations for their results. 1] They said that, a hemodynamic beneficial effect could be present, but it runs in a small range to yield a significant value. This may be due to the baseline characteristics of the patients sent for a CRT implantation; which is not the situation in the current study. Moreover; Kerlan *et al.* [9] reported AV delay optimization for patients with severe heart failure managed by a CRT device implantation and yields a greater improvement of the systolic function.

Another Chinese study reported a significant LVEF improvement after AVD optimization. It was clear that all of the previously-mentioned studies went after identification of acute results after AVD optimization; except for one which measured the hemodynamic changes for a period of six months after implantation of the CRT device. We followed-up our patients for one year to discover the long-term benefits of optimization and to detect the point of permanent benefits of the dual chamber pace-maker [10]. Furthermore, Koneru *et al.* [11] showed an improvement of the diastolic function and lower atrial filling pressures with AV optimization. Statescu *et al.* [7] suggested a simple approach to optimize AV delay in a DDDR pacemaker by using the programming electrocardiogram [ECG] at follow-up. Compared to the nominal 120-150 msec AV delay, the optimal AV delay achieved was 145-250 msec. Compared to the settings of nominal AV delay, the LVED volume did not changed significantly [112.3±2.3 ml vs 112.9±2.3 ml, before and after optimization respectively, p = 0.54]. However, the LVESV reduced from 59.8±1.7 ml to 50.9 ± 1.3 ml, with significant reduction after the adjusted AV delay. In addition, there was a significant increase of the LVEF [from 61.07± 0.18% to 65.46±0.13%, p <0.001] and isovolumic relaxation time significantly decreased from 102.7 ± 1.9 msec to 97 ± 2 msec. But, E and A wave's velocity and E/A ratio showed non-significant change. In DDD-pacemaker with high degree of AV block, Doppler echocardiography can be used to determine the individual optimal AV delay for the left heart AV synchronization. This method was superior to fixed AVD settings and differential AVD should be programmed for atrially triggered and AV sequential pacing.

Optimization of the AVD by Doppler echo-cardiography produced a significantly higher stroke volume [19%] than with a fixed AVD. There was a wide variability in pace-sense-offsets between-7 and 134 msec, which was reflected by the two optimization methods. It is concluded that echo-cardiography AVO determinations are valid, provided that methodological pitfalls and changes of the disease are identified. Tailoring AVD taking diastolic filling into consideration improves the systolic function and is superior to nominal AVD settings. Fixed differential AVDs as provided by some device manufacturers are far from being physiological in nature. Thus, modern pulse producers should provide a free programmability of wide range AV delays [12].

AV delay is critical in DDD pacemakers. Echo/ Doppler assessment of atrioventricular delay [AVD] provide the highest cardiac output [CO] for AVD optimization. Myocardial performance index [MPI] has been shown to be improved by AVD optimization. Cristina Porciani *et al.* [13] aimed to compare the CO, FT, and MPI derived optimal AVD and to analyze systolic functions at every optimal AVD. Twenty-five patients, 16 men [68±11 years old], ejection fraction ≥ 50%, with a DDD PM for third-degree AV block, submitted to echo/Doppler AVD optimization. CO, FT, and MPI derived optimal AVDs were recognized as the AVDs providing the highest CO, the longest FT, and the minimum MPI, respectively. Isovolumic contraction and relaxation times [ICT, IRT], ejection time [ET], ICT/ET, and IRT/ET ratios were also estimated at every optimal AVD.

Results showed that, CO, FT, and MPI derived optimal AVDs were significantly different [148±36 msec, 116±34 msec, and 127±33 msec, respectively]. ICT/ET was similar at CO, FT, and MPI derived optimal AVD [0.22±0.10, 0.23±0.11, and 0.21± 0.10, respectively]. IRT/ET ratio was comparable at FT and MPI derived optimal AVDs [0.34± 0.15 and 0.33± 0.15, respectively] and significantly shorter than at CO derived optimal AVD [0.40±0.15]. Different techniques indicated different optimal AVDs. However, analysis of systolic and diastolic performance showed that different AVDs result in similar systolic or diastolic performance. At MPI optimized AVD, a high CO combined with the most advantageous situations of both isovolumic contraction and relaxation phases is achieved.

The present study was a self-contrasted and was a single center with a small-sample size. These are the limitations of the current work. In addition, regular follow up of LV systolic function on another visit after longer duration are warranted.

Conclusion: It is highly recommended to implant DDD pacemakers for AVD optimization as this may yield long term benefits mainly on the cardiac systolic functions. Echocardiography is the gold standard to determine timing of optimization through mitral flow Doppler as its waves could mark atrial contraction which was used for AV timing optimization.

Financial and non-financial relationships and activities of interest

None

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