Programming an Optimal Atrioventricular Interval in a Dual Chamber Pacemaker Regional Population

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ABSTRACT

Background: Since the introduction of the dual chamber pacemaker (DDDR) in the early 1980s, researchers have repeatedly discussed and attempted to optimize the atrioventricular (AV) interval, in order to increase the cardiac performance of pacemaker patients. Nominal AV delay in a DDDR is not, by hemodynamics, the best option for the majority of patients with AV conduction disorders. Our research is suggesting a simplified approach to define an optimal AV delay in a DDDR pacemaker population on the use of the programming electrocardiogram (ECG) at follow-up.

Methods: The study enrolled 55 consecutive patients (67.28 ± 1.03 years, 36 male) with an initial dual chamber pacemaker implanted for complete and second degree AV block between 2005-2010. Optimal AV delay was achieved by programming an additional delay of 95 ms, to the medium value of the interval between atrial pacing spike to the end of P wave or to the width of intrinsic P wave, on the ECG of the programming device. At discharge, shortly after the implant procedure, the patients were examined by Doppler echocardiography, during nominal and optimal AV delay pacing measuring systolic and diastolic left ventricular function parameters.

Results: Compared with the nominal AV delay settings, the left ventricular end diastolic volume did not changed (from 112.3 ± 2.3 ml to 112.9 ± 2.3 ml), the end systolic volume decreased (from 59.8 ± 1.7 ml to 50.9 ± 1.3 ml, $p<0.01$) after adjusted the AV delay, followed by an increased left ventricle ejection fraction (from 61.07 ± 0.18 % to 65.46 ± 0.13 %, $p<0.001$) and isovolumic relaxation time decreased (from 102.7 ± 1.9 ms to 97 ± 2 ms, $p<0.05$). E wave velocity, A wave velocity and E/A ratio were not significantly changed.

Conclusion: AV delay adjusted by programmer ECG in a follow-up session of an implantable device is a simple and useful method used in our laboratory as a resource for ventricular pacing optimization and hemodynamic improvement in patients with a dual chamber pacemaker (DDDR).

Keywords: DDDR pacemaker, AV delay, optimization

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INTRODUCTION

Hemodynamics during dual-chamber pacing is influenced by the A-V interval. During dual-chamber pacing at patients with a high-grade AV block, an appropriate electrical A-V interval must be programmed to maintain mechanical synchronization of the cardiac chambers (i.e., mechanical AV synchrony) (1,2). Appropriately timed atrial systole improves the LV performance, reduces mean atrial pressure, and maximizes the LV end-diastolic pressure by coordinating the AV valve closure, facilitating venous return, and the increasing preload (3). The Optimal AV synchrony not only maximizes cardiac output by increasing ventricular preload, thus lowering mean atrial pressure, but also minimizes the diastolic mitral regurgitation (4).

The usual nominally programmed A-V intervals in a DDDR pacemaker, 125 to 175 msec, may not provide the optimal AV synchrony at these patients, and AV delays as long as 250 to 350 msec may be required (5).

A variety of techniques have been used to determine the optimal A-V interval by comparing the calculated stroke volume at different A-V intervals, as measured by continuous-wave cardiac Doppler echocardiography of the aortic valve, right-sided heart catheterization, radionuclide ventriculography, myocardial thallium scintigraphy, or transthoracic impedance cardiography (6). Ritter's method of A-V interval optimization, which uses Doppler echocardiography of the mitral valve inflow profile, is the most widely applied technique (7). This technique is based on the assumption that the AV delay that maximizes cardiac output is the one that provides the longest LV filling time without interruption of the A wave (atrial contraction wave) and allows ventricular systole to begin immediately subsequent to maximum diastolic ventricular filling, thus avoiding cannon A waves and diastolic mitral regurgitation. However, the Ritter's method is time-consuming and being the subject to a significant variability between consecutive measurements, cannot be reliably performed during exercise, and it is not readily available in routine pacemaker follow-up clinics (8).

Our research is a preliminary study, empirical based, suggesting a simplified approach to define an optimal AV delay in a DDDR pacemaker population using the programming ECG at follow-up. ❑

MATERIAL AND METHODS

The study enrolled 55 consecutive patients (67.28 ± 1.03 years, 36 male) with an initial dual chamber pacemaker implanted for complete (49 patients) and second degree (2:1) AV block (6 patients) between 2005-2010 at "Prof. George I.M. Georgescu" Cardiovascular Diseases Institute Iasi. We did not included patients with Wenckebach second degree AV block. Demographic characteristics and clinical data were retrieved from medical records and subsequent clinic visit. The left ventricular ejection fraction (LVEF) at the time of study enrollment was assessed semiquantitatively from routine transthoracic echocardiograms (Simpson, biplane, 4 chambers and 2 chambers) and it was categorized into four groups (normal, slightly reduced, moderately reduced, severly reduced).

All patients received a dual chamber pacemaker (DDDR from Biotronik) with bipolar active fixation atrial leads and bipolar passive fixation right ventricular leads. The right atrial leads were fixed at the high right atrial free wall or placed within the right atrial appendage and the right ventricular leads were implanted at the RV apex. After implantation, the pacemaker remained in the nominal DDDR setting. The nominal setting of the used pulse generator comprises the DDDR mode, a basic pacing rate of 70 bpm, an AV delay after atrial pacing of 150 ms and an AV delay after atrial sensing of 120 ms.

We measured on the programming ECG the intrinsic P wave width (a) and the interval between atrial spike – end of atrial capture (b). The atrioventricular delay for programming was calculated by adding 95 ms to this intervals (AVopt = (a) + 95 ms or AVopt = (b) + 95 ms) (Figure 1).

For programming and ECG measurements we used „ERA 3000" from Biotronik with a setting of 50 mm/sec as a time resolution of the ECG. This was enough to allow P wave width measurement.

Every patient was evaluated by Doppler echocardiography before and after AV delay optimization, at 15 minutes, at rest. All patients were fully paced in the right ventricle during both echocardiographic exams. We measured

following parameters: LVEDV (left ventricle end diastolic volume), LVESV (left ventricle end sistolic volume), LVEF (left ventricle ejection fraction), Simpson, biplane, 4 chambers and 2 chambers mode. We evaluated also the diastolic filling parameters: E wave and A wave velocities, E/A ratio and IRT (isovolumic relaxation time). We noted medium values obtained on three consecutive cardiac cycles.

To eliminate hemodynamic variations of the stroke volume, both Doppler echocardiography exams were performed at the same pacing rates (70 ± 2 bpm). During the first echocardiographic examination we had 3.63% P sensed waves versus 1.81% at the second exam.

Statistical analysis. Categorical variables are reported as absolute numbers and percentages. Continuous variables are presented as means ± standard deviation, as long as they appeared to be normally distributed. Statistical comparisons for continuous data were performed with Student paired t test, whereas comparisons for categorical data were performed with χ^2 test or Fischer exact test, as appropriate. Values were considered significantly different when $p < 0.05$. All statistical analyses were conducted with S.A.V.C. Program and SPSS 16.0 for Windows. ❑

FIGURE 1. AV delay optimization method

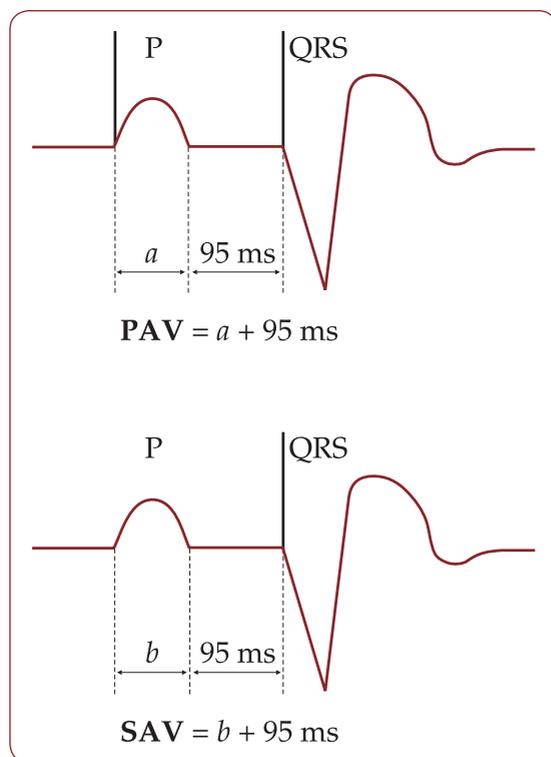PAV – paced AV, SAV – sensed AV, a – atrial capture width, b – sensed P wave width

RESULTS

Compared to the nominal AV delay (120-150 msec), the optimal AV delay, achieved on the programming ECG, was 145-250 msec. Compared to nominal AV delay settings, the left ventricular end diastolic volume did not changed (from 112.3 ± 2.3 ml to 112.9 ± 2.3 ml, $p = 0.54$), the end sistolic volume decreased (from 59.8 ± 1.7 ml to 50.9 ± 1.3 ml), $p < 0.01$ after the adjusted AV delay, followed by an increased left ventricle ejection fraction (from 61.07 ± 0.18 % to 65.46 ± 0.13 %, $p < 0.001$) and isovolumic relaxation time decreased (from 102.7 ± 1.9 ms to 97 ± 2 ms, $p < 0.05$). E wave velocity, A wave velocity and E/A ratio were not significantly changed (Tabel 1).

There was no significant difference in the measurement of LVEF and volumes obtained by the same observer in two different settings (difference 0.001 ± 0.01; $p = 0.9$; intraobserver variability of 2.6%). There was no significant difference in the measurement of LVEF obtained by the two independent observers (difference 0.02 ± 0.02; $p = 0.3$; interobserver variability of 5.3%). In addition, there were close limits of agreement and 95% CIs between both intraobserver and interobserver measurements obtained by 2D echocardiography (Simpson's method). ❑

DISCUSSION

Since the introduction of the DDD pacemaker in the early 1980s, researchers have repeatedly discussed and attempted to optimize the atrioventricular (AV) interval, for increasing cardiac performance of pacemaker patients (9). AV interval comprises spontaneous intra-atrial conduction time of the right and the left atrium and spontaneous inter-atrial conduction time and both are partially reflected in the intracardiac atrial signal or P - wave width on ECG. Additionally, the sensing of atrial signal introduces a delay due to the time it takes the atrial signal to reach the atrial sensing amplifier. Atrial pacing causes another artificial inter- and intra-atrial conduction delay. Thus, the AV interval is a comprehensive electrophysiological parameter (10). While measurement of the AV interval on the right side is simple, direct or indirect its measurements on the left side are complex. However, the importance of left side AV interval has been emphasized, with particu-

lar attention being focused on the harmful effect of short AV interval, since it causes left atrium activation and contraction to occur after left ventricle systole and mitral valve closure (11).

From a hemodynamic point of view the optimal AV interval should allow completion of end-diastolic filling flow prior to ventricular contraction. An appropriately timed atrial systole improves the left ventricle filling and the stroke volume or cardiac output (CO) by means of the Starling law (12). Since the main function of the heart is to maintain adequate CO to meet the metabolic requirements of tissues, it is reasonable that the AV interval optimization based on CO measurements is considered to be the "gold standard." In fact, most of researchers use CO for evaluation AV interval (13). Recently, it was demonstrated that CO significantly correlated with inter-atrial conduction time. Because inter-atrial and intra-atrial conduction, especially intra-left atrial conduction time varies over a wide range among pacemaker patients, the duration of the optimal AV interval is individual (14). Moreover, inter- and intra-atrial conduction times and consequently the optimal AV interval depends on many variables: the patient's metabolic demands, body posture, heart rate, anatomic and functional cardiac parameters and finally on pacing/sensing mode (15). Excessively short or too long AV interval both should be prevented because the former interrupt atrial kick may induce cannon waves and pacemaker syndrome and the latter may induce diastolic mitral regurgitation (16). The contribution of the optimal AV interval is significant and varies from 13 to 40% of CO, thus providing a hemodynamic advantage in both hearts with normal and decreased contractility (17).

At many patients, the atrial contribution to CO can be so substantially reduced with an inappropriate AV interval so as to result in an impairment equivalent to that seen during VVI pacing (18). The long-term loss of AV synchrony, i.e., inappropriately programmed AV interval, is associated with electrical and mechanical atrial remodeling, which may be reversible after the reestablishment of AV synchrony, or the optimization of the AV interval. This electrical and mechanical remodeling may lead to atrial fibrillation and other atrial arrhythmias (19).

Study limitations are represented by the small number of patients enrolled. We did not measure other echocardiographic parameters like diastolic filling time, or A wave duration. We are proposing to develop our study using more detailed echocardiographic findings. ❏

CONCLUSION

In practice many physicians do not use any method to optimize AV delay because it is a time-consuming procedure and because the optimal AV interval assessed one time per several months during follow-up visits is ineffective, because AV interval is dependent on many of the afore mentioned factors and accordingly should be adjusted constantly and appropriately.

This is a preliminary study that is proposing a method, used in our laboratory, of AV delay optimization by programmer ECG in a follow-up sesion of an implantable device as a simple and useful resource for ventricular pacing optimization and hemodynamic improvement in patients with a dual chamber pacemaker (DDDR).

Echocardiographic parameters	Nominal AV Delay	Optimal AV Delay	p
Left ventricle			
LVEDV (ml)	112.3 ± 2.3	112.9 ± 2.3	0.54
LVESV (ml)	**59.8 ± 1.7**	**50.9 ± 1.3**	**<0.01**
LVEF (%)	**61.07 ± 0.18**	**65.46 ± 0.13**	**<0.001**
LVEF (%)	61.07 ± 0.18	65.46 ± 0.13	< 0.001
E wave velocity (m/s)	0.78 ± 0.24	0.79 ± 0.26	0.58
A wave velocity (m/s)	0.84 ± 0.27	0.84 ± 0.29	0.83
E/A ratio	0.94 ± 0.64	0.95 ± 0.65	0.81
IRT (ms)	**102.7 ± 1.9**	**97 ± 2**	**<0.05**

TABLE 1. Results – echocardiographic evaluation at optimal versus nominal AV delay

LVEDV – left ventricle end diastolic volume, LVESV – left ventricle end systolic volume, LVEF – left ventricle ejection fraction, IRT – isovolumic relaxation time

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