Opportunities for Optimization of Biventricular Pacing Using an Implanted Hemodynamic Monitor

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Abstract

PURPOSE: Optimization of pacing parameters such as AV delay is important in heart failure (HF) patients treated with cardiac resynchronization therapy (CRT). We hypothesized, that an implantable hemodynamic monitor (IHM) might be helpful in identifying the optimal AV-delay. METHODS:10 patients with HF, successfully treated by CRT were also implanted with an IHM that continuously records heart rate, activity, RV pressures and an estimation of the pulmonary artery diastolic pressure (ePAD). First, AV delays were optimized by echo, then different AV-delays (50-190 ms) were randomly programmed using steps of 20 ms. RESULTS: Using the IHM, a U-shaped curve was obtained with an optimal AV delay slightly longer as compared with echo. Shortening the AV interval resulted in increased ePAD values. CONCLUSIONS: In future, CRT optimization may be guided by hemodynamic sensors recording basic cardiovascular measures during daily activities of living.

1. Introduction

Cardiac resynchronization therapy (CRT) has been proven to improve quality of life, functional status and survival in patients with drug refractory chronic heart failure and cardiac dyssynchrony (1;2). Optimization of pacing parameters such as atrio-ventricular (AV) or inter-ventricular (VV) delay is important in heart failure (HF) patients treated with cardiac resynchronization therapy (CRT) (3-5). Commonly these optimization procedures are performed using echocardiographic techniques. The clinical value of these echo techniques is still under investigations and only reflects a single point in time with a patient condition not reflecting daily living conditions. Beyond this, echo-guided CRT optimization underlies general limitations (i.e. high inter- and intra- observer variability, limited image quality in some patients). An implanted hemodynamic monitor (IHM) has been shown to be a reliable method for the continuous measurement and recording of cardiac filling pressures in HF patients (6-8). We hypothesized, that beyond single case observations (9) the IHM can be helpful in identifying the optimal AV-delay.

2. Methods

10 patients with heart failure, successfully treated by CRT (InSync III®), (LVEF 24±9%, LVEDD 64±11mm) were also implanted with an IHM (Chronicle®, Medtronic Inc.). All patients were on optimal pharmacological heart failure treatment, receiving all the maximum tolerated dose of beta blockers and ACE inhibitors. The IHM continuously records heart rate, patients' activity, RV systolic/diastolic pressures and an estimation of the pulmonary artery diastolic pressure (ePAD), reflecting left atrial filling pressures. The Chronicle® IHM consists of a memory device and a RV lead with a pressure sensor, Figure 1.

Figure 1: Chonicle® implantable hemodynamic monitor (Medtronic Inc.) The system consists of a memory device, a pressure lead and an external pressure reference.

Patients enrolled in the study were provided with a combined implant of CRT and Chronicle system. The pressure sensor was placed in the right ventricular high septum or right ventricular outflow tract, Figure 2.

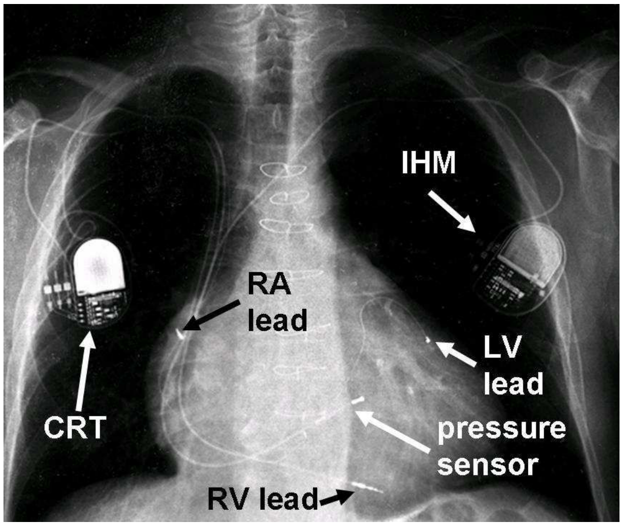

Figure 2: Chest x-ray of a study patient showing double implant of a cardiac resynchronization therapy (CRT) system including right atrial (RA), right ventricular (RV) and left ventricular (LV) lead in combination with an implantable hemodynamic monitor (IHM) system consisting of memory device and pressure sensor lead.

The study consisted of acute and ambulatory phases to test the hemodynamic impact of CRT. CRT was provided for at least three months before acute testing of AV delays. Tests were performed with the patient at rest and in supine position. In the acute testing procedures AV delays were optimized first by echo using an evaluation of the mitral inflow pattern (Ritter method). The aim is to maximize the diastolic filling time without truncation of the active left ventricular filling by the left atrium. Then, different AV-delays (50-190 ms) were randomly programmed using steps of 20 ms. The ePAD was calculated as a 20s median, 40-60s after programming was changed, Figure 3. A low ePAD value in the sequence of different AV delays was considered optimal. Measurements were repeated 1 week later under the same conditions.

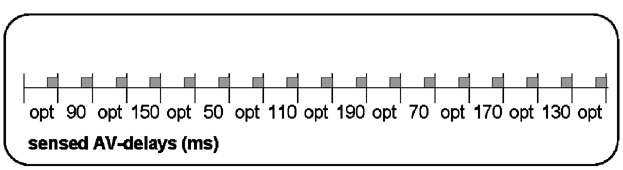

Figure 3: Example of a measurement scheme for randomized AV optimization. Every setting is at least programmed for one minute followed by a minute of optimal setting (opt) as pre-defined by echocardiography, Ritter method. Data from the last 20 s of each 1 minute recording was used for analysis.

Data from acute tests were acquired using a programmer system that continuously recorded and stored real-time pressure waveforms, device marker channel and Chronicle lead unipolar EGM. The pressure sensor inserted into the right ventricle continuously measures absolute cavity pressures. To correct for changes in atmospheric pressure, an external pressure reference is used to correct for barometric alterations in pressures and to allow a reliable measurement of absolute cardiac pressures. The resulting data contains a variety of pressure waveform characteristics that were validated in previous studies(6). The concept to measure the estimated pulmonary artery diastolic (ePAD) pressure has been evaluated and found to be a good estimate for left ventricular filling, Figure 4. The ePAD is measured as the pressure at time of pulmonary valve opening defined by maximum positive dp/dt of the RV pressure curve. For the individual patient a low left ventricular filling was considered to be a hemodynamically optimized condition for a heart failure patient.

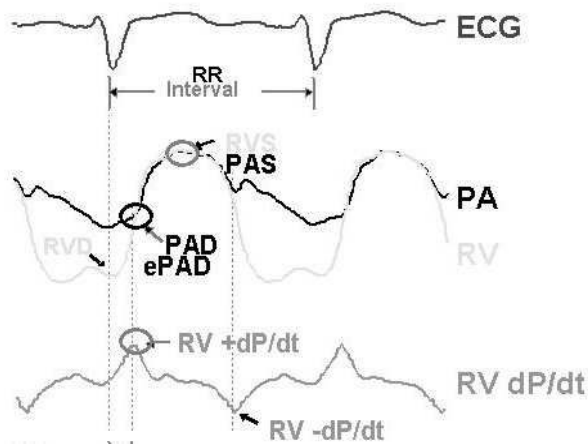

Figure 4: Concept of measuring the estimated pulmonary artery diastolic (ePAD) pressure using the maximum first derivative of the RV pressure curve (+dp/dt).

For statistical test, SPSS 12.0 for Windows, SPSS Inc. was used. The non-parametric Mann-Whitney U test was applied to compare differences within the groups and a p-level of 0.05 was considered statistically significant.

3. Results

Dual device implant was well tolerated by the patients and no adverse events occurred during acute AV optimization procedures. One patient was excluded due to development of chronic atrial fibrillation and could thus not complete the AV optimization procedure, since no AV delays can be assigned in patients with AF due to irregular, unsynchronized and chaotic electrical activation of the atrial chambers.

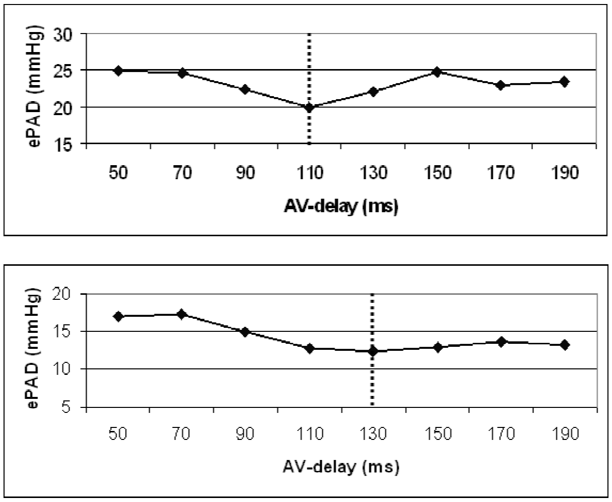

Figure 5: Examples of AV optimization results from two patients studied. Top graph shows a patient with echo-defined optimal AV delay of 110 ms that was confirmed by a low ePAD pressure. Bottom graph indicates that short AV delays should be avoided. It shows a less pronounced optimal setting at 130 ms sensed AV delay.

Using the IHM, a U-shaped curve was obtained, indicating an optimal AV delay slightly longer (+20 ms) as compared with echo (-0.7± 1.4 mm Hg, p<0.01). Shortening the AV interval resulted in increased ePAD (+2.3 ± 2.3 mmHg, p<0.001).

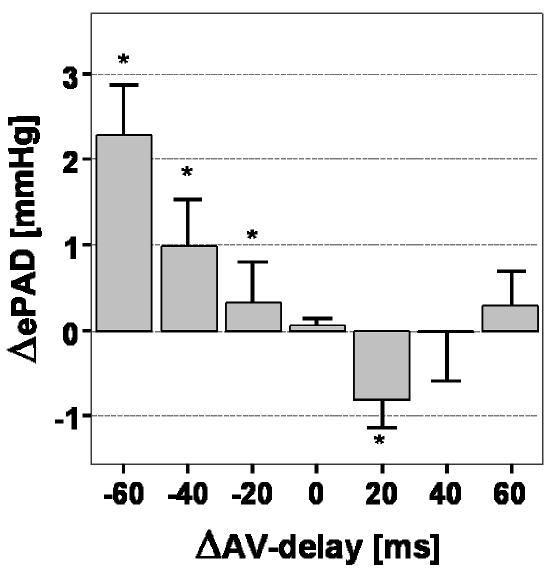

Figure 6: Overall results of nine patients analyzed. Graph indicates the change in ePAD compared to optimal setting definded by echo procedure. Bars give the change in pressure for shortened (-20, -40, -60 ms) and prolonged (+20, +40, +60 ms) AV intervals, *p<0.05 vs. echo-optimized AV delay.

The relatively low ePAD at +60 ms may be associated with fusion beats at longer AV-delays. These observations were consistent in the repeated tests.

4. Discussion and conclusions

In this study the IHM was used to assess the hemodynamic response to different AV delays during resting condition. During these acute tests significant changes of RV hemodynamics were observed resulting from different AV intervals programmed to CRT devices. Using RV pressures for device optimization, the optimal AV delay identified by the IHM was similar to standard echo optimization according to the Ritter method, which is also demonstrated by the U-shaped ePAD curves compared to echo optimized AV delay. The analysis of right ventricular hemodynamics suggest to avoid short AV delays in clinical practice and to perhaps chose slightly longer AV delays than those suggested by echo methods. The IHM, therefore can be considered to be a helpful tool for the identification of the optimal AV-delay in HF patients treated with CRT. However, further studies need to be performed to confirm this. Furthermore, the Chronicle device allows monitoring RV pressures continuously and therefore has the potential to measure hemodynamic alterations that reflect daily living conditions like exercise or different body positions. Automated closed-loop procedures would allow repeated device optimizations based on the hemodynamic status of the individual patient. In the future, a hemodynamic sensor may be incorporated in CRT devices for long-term recording of filling pressures and to allow for hemodynamic device optimization during daily activities of living.

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References

(1) Cleland JG, Daubert JC, Erdmann E, Freemantle N, Gras D, Kappenberger L et al. The effect of cardiac resynchronization on morbidity and mortality in heart failure. N Engl J Med 2005; 352:1539-1549.

(2) Salukhe TV, Dimopoulos K, Francis D. Cardiac resynchronisation may reduce all-cause mortality: meta-analysis of preliminary COMPANION data with CONTAK-CD, InSync ICD, MIRACLE and

MUSTIC. Int J Cardiol 2004; 93:101-103.
(3) Fox DJ, Fitzpatrick AP, Davidson NC. Optimisation of cardiac resynchronisation therapy: addressing the problem of "non-responders". Heart 2005; 91:1000-1002.
(4) Burri H, Sunthorn H, Somsen A, Zaza S, Fleury E, Shah D et al. Optimizing sequential biventricular pacing using radionuclide ventriculography. Heart Rhythm 2005; 2:960-965.
(5) Lane RE, Chow AW, Chin D, Mayet J. Selection and optimisation of biventricular pacing: the role of echocardiography. Heart 2004; 90 Suppl 6:vi10-vi16.
(6) Magalski A, Adamson P, Gadler F, Boehm M, Steinhaus D, Reynolds D et al. Continuous ambulatory right heart pressure measurements with an implantable hemodynamic monitor: a multicenter, 12-month follow-up study of patients with chronic heart failure. J Card Fail 2002; 8:63-70.
(7) Adamson PB, Magalski A, Braunschweig F, Bohm M, Reynolds D, Steinhaus D et al. Ongoing right ventricular hemodynamics in heart failure: clinical value of measurements derived from an implantable monitoring system. J Am Coll Cardiol 2003; 41:565-571.
(8) Steinhaus D, Reynolds DW, Gadler F, Kay GN, Hess MF, Bennett T. Implant experience with an implantable hemodynamic monitor for the management of symptomatic heart failure. Pacing Clin Electrophysiol 2005; 28:747-753.
(9) Braunschweig F, Kjellstrom B, Gadler F, Linde C. Optimization of cardiac resynchronization therapy by continuous hemodynamic monitoring. J Cardiovasc Electrophysiol 2004; 15:94-96.

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