Can the Optimal Atrioventricular Delay Be Predicted Intraoperatively by a Beat-to-Beat Recording of the Peak Endocardial Acceleration?

B. ISMER, W. VOSS, J. PLACKE, T. KÖRBER, G.H. VON KNORRE, C.A. NIENABER
University of Rostock, Clinic for Internal Medicine, Department of Cardiology, Rostock, Germany

G. GAGGINI
Sorin Biomedica Cardio, Saluggia, Italy

Summary

During a pilot study, special ventricular leads were implanted in patients with atrioventricular (AV) block to measure the beat-to-beat recordings of the peak endocardial acceleration (PEA) sensor signal. These measurements were performed in order to assess the possibility of rapidly predicting the optimal intraoperative AV delay in individual patients. By manually increasing or decreasing the AV delay in a stepwise fashion in both the VDD and DDD modes, the PEA and left atrial esophageal electrogram were simultaneously recorded. These recordings were used to compare the PEA results with the approximate electrocardiographic results for the optimal AV delay. During pre-discharge tests, the results were also compared to the optimal AV delay using Doppler echocardiography. The PEA method yields comparable values to those of the other methods.

Key Words

Pacing, atrioventicular delay optimization, Peak Endocardial Acceleration (PEA)

Introduction

In patients with atrioventricular (AV) block, AV synchrony can be restored by implanting biventricular DDD pacing systems if an individual optimization of the pacemaker AV delay is performed. If optimization is not performed, the remaining AV delay (AVD) is left at nominal settings and adverse hemodynamic effects may develop. Several methods have been proposed to calculate or estimate the individual hemodynamic optimal length of the AV interval. Depending on the available technology, two principles can generally be applied:

- An estimation of the optimal AV delay, which requires serial measurement of a hemodynamic parameter at feasible AV delay steps.
- A calculation of the optimal AV delay, which is based on the exact individual measurement of only a few parameters related to time. It is preferred if higher accuracy is required.

Independent of the particular optimization method, the results provide either an approximate or exact length of the individual optimal AV delay at any heart rate. Generally, this hemodynamically optimal AV delay varies considerably and is based on the interindividual variation of the actual heart rate. Since automatic AV delay optimization is still under development and the methods discussed are time consuming and require additional procedures, a routine, individualized optimal AV coordination is usually neglected and AV delay is left at nominal settings that depend on the particular pacing system. Since biventricular pacing systems were found to be useful in cardiac resynchronization therapy of patients with chronic heart failure, an increased importance of AV delay optimization has been perceived. Thus, further simplification of the AV delay optimization remains a real and unsolved problem.

To avoid the expense of a pre-discharge AV delay optimization procedure, the aim of our study was to search

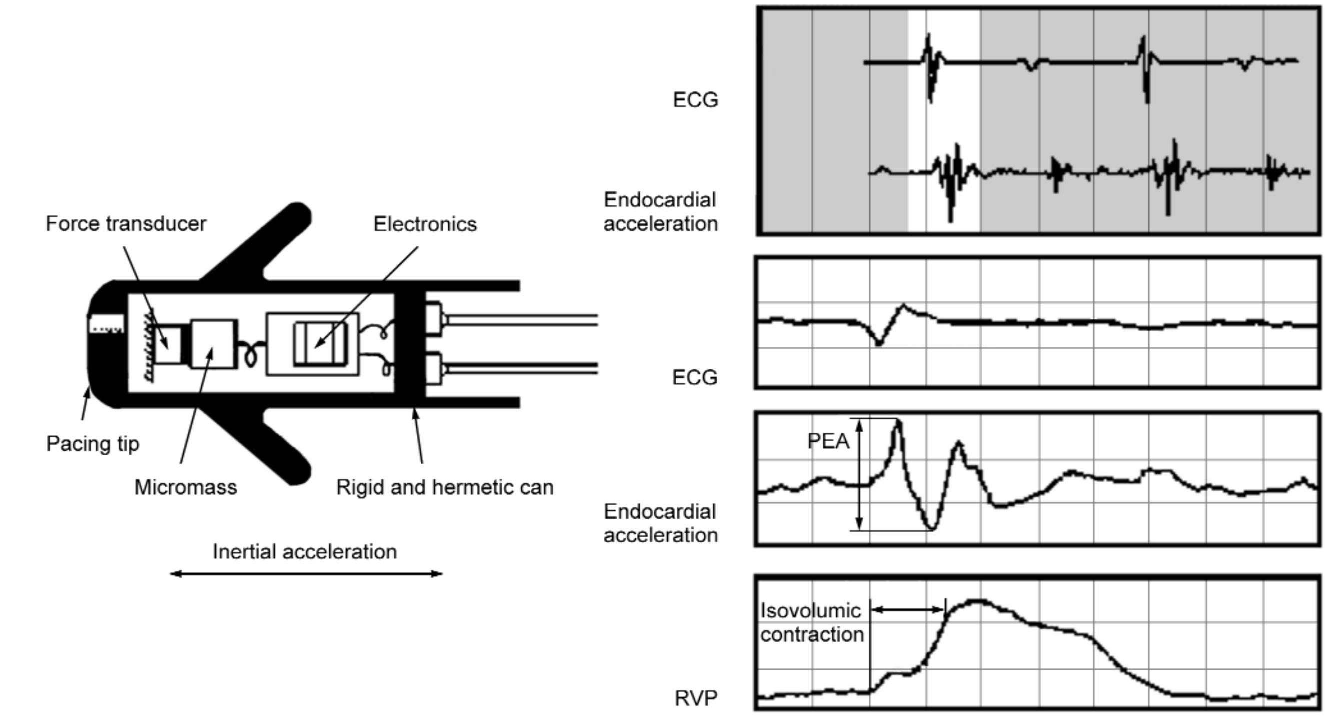

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Figure 1. Principle of the peak endocardial acceleration (PEA) sensor (panel a) within the ventricular lead of the Mini-Living/MiniBest pacing system (Sorin, Italy) and the relationship between the ECG, right ventricular pressure (RVP), and the endocardial acceleration (panel b).

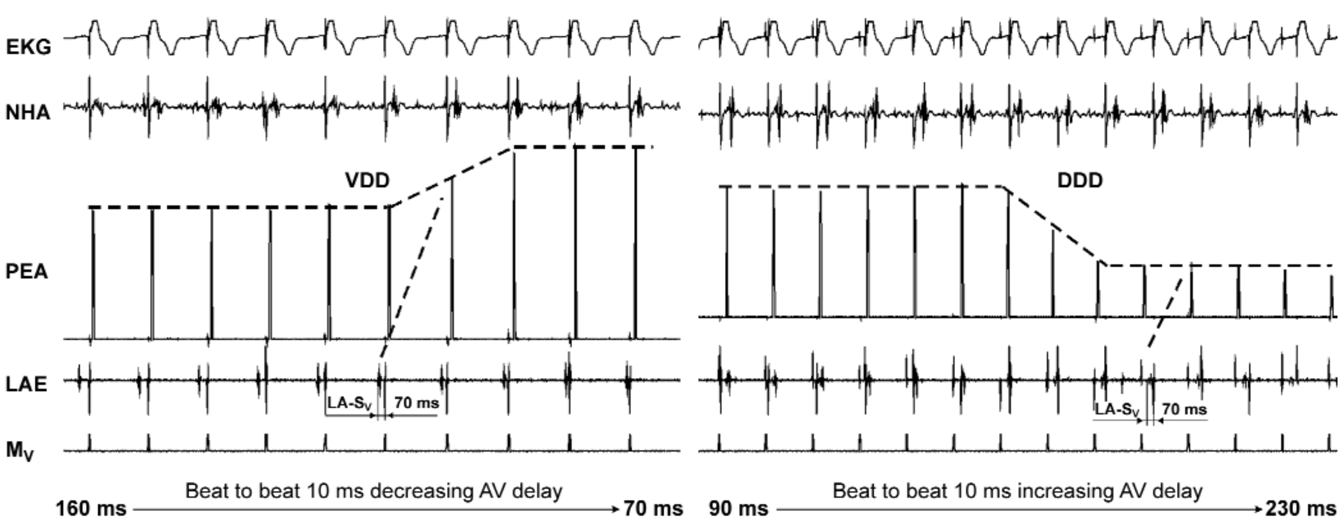

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Figure 3. Recording of the native Natural Heart Acceleration (NHA) signal and Peak Endocardial Acceleration (PEA) signals of the MiniBest electrode (Sorin) during a beat-to-beat 10 ms stepwise decreasing (VDD, panel a) and increasing (DDD, panel b) AV delay. Additionally, the PEA trigger (M_V), ECG, and a filtered bipolar esophageal left atrlal electrogram (LAE) were simultaneously recorded. Optimal AV delay by left atrial electrocardiography can be approximated by a mean interval of 70 ms between the left atrial deflection (LA) and ventricular stimulus (S_V).

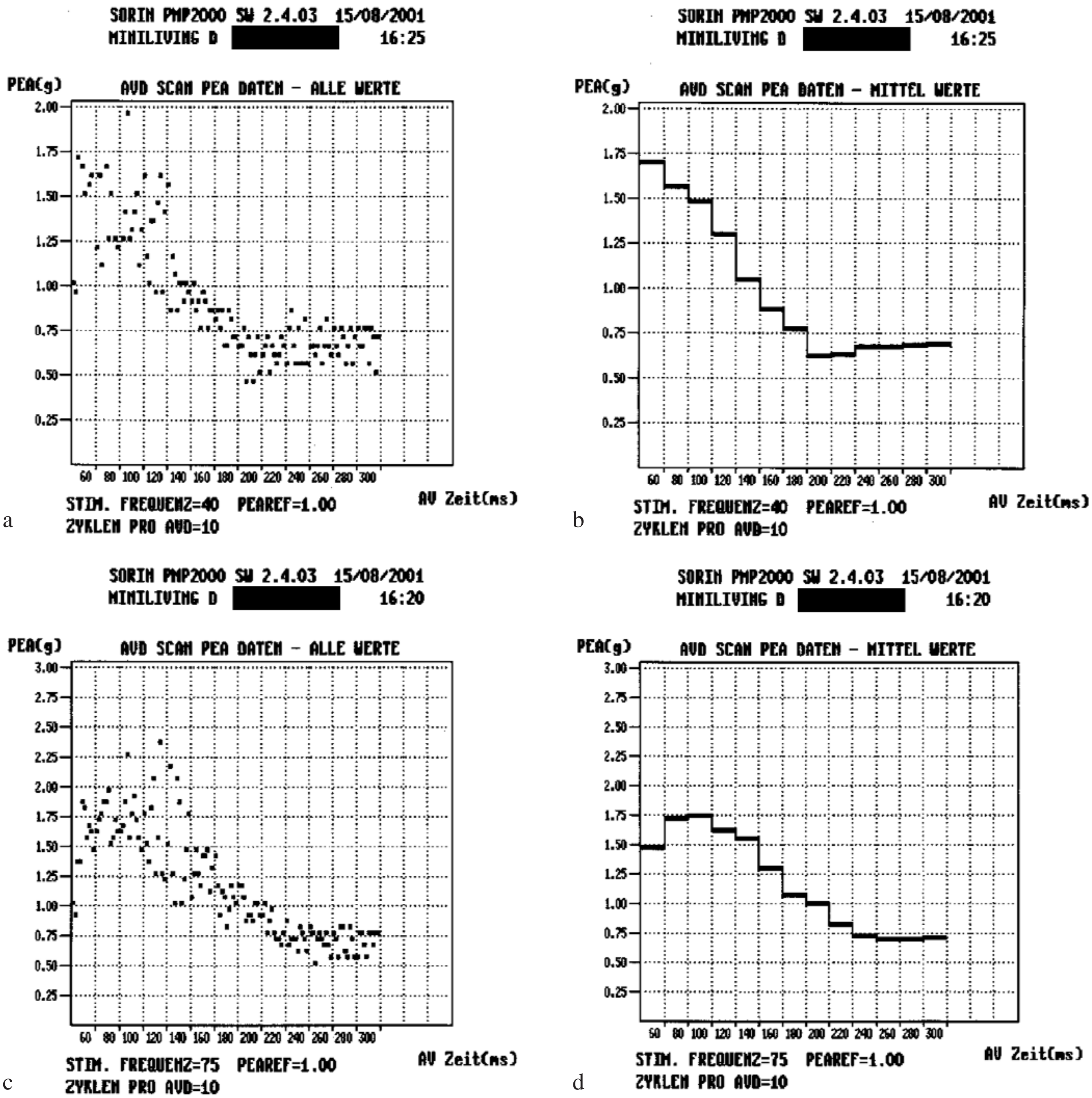

Figure 2. Example of a postoperative atrioventricular delay (AVD) scan using the Mini-Living/MiniBest pacing system (Sorin). A minimum of 10 Peak Endocardial Acceleration (PEA) values on each AVD step is needed to plot a PEA (in arbitrary units) versus an AVD (in ms) curve. The beginning of the low PEA plateau values indicates the region of the optimal AVD. Pacing rate = 40 beats/min (all data, panel a; mean values, panel b). Pacing rate = 75 beats/min (all data, panel c; mean values, panel d).

for a new method that would provide a practicable intraoperative estimation of the individual optimal AV delay in patients with complete AV block.

Materials and Methods

The peak endocardial acceleration (PEA) sensor (Figure 1) in rate adaptive pacing systems (the Mini-Living pacemaker and Mini-Best ventricular lead,

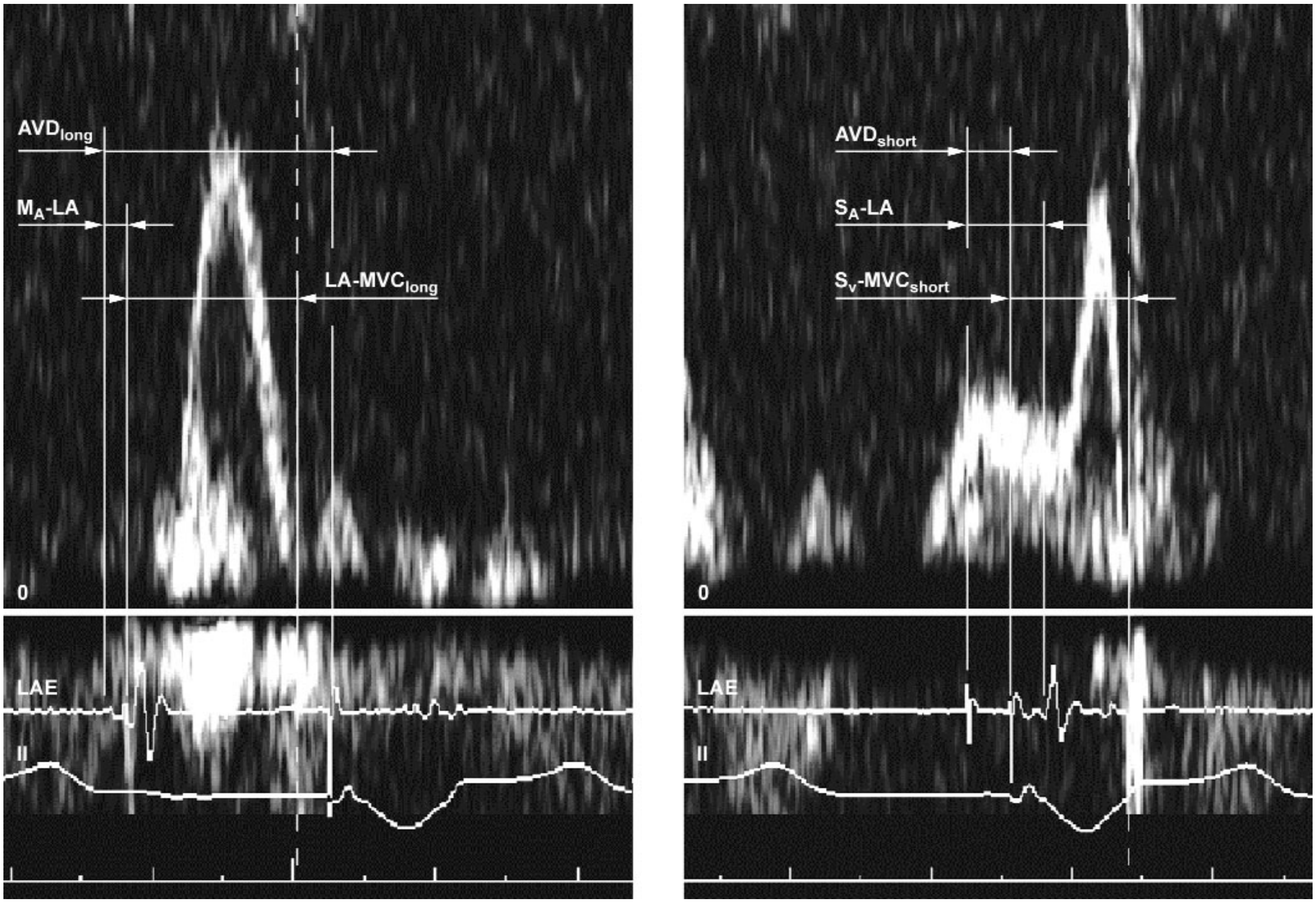

Figure 4. Principle of the Electro-Doppler-Echocardiographic atrioventricular delay (AVD) optimization in the same patient from Figure 2. Simultaneous recording of the transmitral flow, filtered bipolar esophageal left atrial electrogram, and ECG by echo Doppler pattern. The method offers the possibility of separately studying the conduction component (M_A-LA in VDD, S_A-LA in DDD pacemaker mode), the electromechanical component (difference between electromechanical action LA-MVC_{long}, and the latency of induced mitral valve closure S_V-MVC_{short}) of the AVD. Only two echo screen images are necessary to measure all AVD components and to calculate the individual optimal AVD in both the VDD and DDD operation.

Sorin, Italy) has been reported to be useful in performing a semiautomatic determination of the hemodynamically optimal AV delay in patients with AV block [1]. An AVD scan is performed by automatically increasing the AVD in a programmable stepwise fashion of at least 10ms increments between 60 to 300 ms. For each increment, a minimum of 10 and a maximum of 100 PEA values is measured on a beat-to-beat basis. By generating an average curve, the beginning of the plateau of low PEA values can be determined, indicating the region of the optimal AV delay (Figure 2). In order to perform a complete analysis the software needs to be operating for at least 6 min and is therefore not suitable for beat-to-beat measurements. Therefore, the PEA measurements must be performed intraoperatively using not the pacemaker but a special PEA interface.

In order to predict the optimal AV delay during intraoperative VDD and DDD modes, we tested an AV delay scan that is ten times faster, based on the beat-to-beat PEA measurement. An external DDD pacemaker (Pace203H, Osypka, USA) was manually adjusted to perform the beat-to-beat AV delay using a stepwise increasing and decreasing delay of 10 ms per step. During implantation of the MiniBest pacing lead in six patients (mean age 65.8 years, 3 male) with complete AV block, the NHA94 heart acceleration sensor interface (Sorin) was used to measure the natural heart acceleration (NHA) and to calculate the beat-to-beat

Method		PEA	LAE	Doppler
VDD	Mean ± SD	112.5 ± 12.6	102.5 ± 12.6	113 ± 18.7
VDD	Range	100 – 130	90 – 120	87 – 128
DDD	Mean ± SD	185 ± 12.9	170 ± 8.2	181 ± 22.5
DDD	Range	170 – 200	160 – 180	165 – 214

Table 1. Results in arbitrary units (mean, SD = standard deviation, and range) of the intraoperative prediction of the optimal AV delay (ms) in VDD and DDD mode using the beat-to-beat Peak Endocardial Acceleration (PEA) scan in comparison with the intraoperative results of the esophageal left atrial electrocardiographic (LAE) method and the postoperative echocardiographic method in four patients with complete AV block.

PEA values, which were similar to the MiniLiving algorithm. Finally, NHA and PEA signals were stored using an electrophysiology laboratory (The EP Laboratory, Bard Electrophysiology, Lowell, MA, USA).

Additional results from our group have shown an excellent correlation of the optimal AVD with a mean interval of about 70 ms using the left atrial deflection and the ventricular stimulus during both VDD and DDD pacing [2,3]. Therefore, we simultaneously recorded the filtered bipolar left atrial esophageal electrogram (LAE) in four of the six patients (Figure 3). Thus, we were able to develop an intraoperative approximation of the optimal AV delay using a reference method, too.

As a third AV delay optimization method, the Electro-Doppler-Echocardiographic [4,5] method (Figure 4) was applied during pre-discharge tests to compare the intraoperative results.

Results

As a result of these recordings within the region of the expected optimal AV delay by left atrial elctrocardiography, continuous beat-to-beat variations between the PEA and the AVD were observed in all six patients. In four patients, (Table 1) all three measurements were performed. The LAE method yields comparable values to those of the other methods. Standard variations were similar for the PEA and the LAE, whereas variations in the Doppler method were twice as great.

Discussion

The results of this pilot study can only be considered a first step in assessing the potential of intraoperative AV delay optimization using the PEA sensor. Nevertheless, the results of the comparison with two other methods support further investigations in order to seek quick and automatic methods for performing an individual AV delay optimization.

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Contact
Dr. Bruno Ismer
Department of Cardiology
Clinic for Internal Medicine
University of Rostock
PSF 100888
D-18055 Rostock
Germany
Phone: +49 381 4947 708
Fax: +49 381 4947 708
E-mail: bruno.ismer@med.uni-rostock.de