A Simplified Hemodynamic Study to Evaluate the Effects of Biventricular and Left Ventricular Pacing Prior to a Pacemaker Upgrade

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

Summary

If patients with previously implanted pacemakers develop chronic heart failure, biventricular pacing is an option to improve their hemodynamics. A pre-implantation hemodynamic study should be performed to test the value of upgrading to biventricular pacing. The study can be simplified by applying a single percutaneous coronary intervention guidewire via the coronary sinus into a suitable posterolateral vein and an arterial pressure line for monitoring purposes. By connecting the guidewire to an external DDD pacemaker, left ventricular pacing can by generated in addition to right ventricular pacing. Thereby, left ventricular pacing can be synchronized either by telemetric atrial real-time markers, or by directly sensing the right ventricular pacing stimuli of the implanted system. Using telemetric synchronization, the hemodynamic effects of pure left ventricular, as well as biventricular stimulation using different atrioventricular and interventricular delays can be easily tested without any restrictions.

Key Words

Biventricular pacing, telemetry, atrioventricular delay, interventricular delay

Introduction

In patients with chronic heart failure and left bundle branch block, biventricular pacing can improve the hemodynamics and, therefore, the quality of life [1-4]. Right ventricular- (RV) based stimulation (VVI, DDD) produces an artificial delay in the left ventricular (LV) posterolateral region; therefore, upgrading to biventricular pacing must be considered if chronic heart failure develops. Since the effects of biventricular pacing therapy depend on several factors, a pre-implantation hemodynamic study will usually be performed to test its effectiveness prior to implantation of a biventricular pacing system. Therefore, at least two leads have to be applied for right atrial sensing or pacing and LV pacing. This conventional method can be simplified by inserting a percutaneous coronary intervention (PCI) guidewire for LV pacing and an arterial line for cardiac monitoring, only.

The aim of this study is to simplify hemodynamic study procedures prior to upgrading previously implanted pacemaker patients to biventricular pacing.

Materials and Methods

Via the coronary sinus, a single PCI guidewire was introduced into a suitable posterolateral vein while the femoral or LV pressure was recorded. The PCI guidewire was then connected to an external DDD pacemaker to perform LV sensing and pacing. Synchronization of the LV pacing stimuli was performed either by telemetric atrial sense-event markers or directly by RV pacing stimuli of the implanted pacemaker.

Biventricular Pacing by using Telemetric Atrial Sense-Event Markers for Triggering LV Stimuli

In patients with DDD systems providing real-time telemetry and an analog real-time marker programmer output, the atrial marker signal of the implanted pacemaker was connected either directly to a programmer (PMS 1000, Biotronik, Germany), or via an interface (2090AB and 9790AB, Medtronic, USA) to the atrial inputs of the external LV pacemaker (Pace 203H, Osypka, Germany) which was operating in the VAT mode. By connecting the ventricular output of the

external pacemaker to the PCI guidewire with a femoral Seldinger wire as a reference, pure LV as well as biventricular pacing with the following impulse configurations was performed:

- biventricular pacing with simultaneous RV and LV impulses and adjustable atrioventricular (AV) delay, and;
- biventricular pacing with both, adjustable AV delay and interventricular (VV) delay with different sequencing of the RV and LV pacing stimuli.

Biventricular Pacing by using RV Stimuli for Triggering LV Stimuli

A simplified procedure was used if the internal pacing system did not provide real-time telemetry and analog marker output signals.

- To perform the VDD operation with adjustable AV delay and simultaneous RV and LV stimuli in patients with implanted DDD pacemakers, the external pacemaker in VVT mode was directly connected to the PCI guidewire to sense the internal RV pacing stimuli and to trigger LV pacing with a negligible delay. Afterwards AV delay was adjusted by programming the implanted device.
- To perform the VDD operation with adjustable AV and VV delay in patients with implanted DDD pacemakers, the LV PCI guidewire was connected to the external pacemaker while it was in VAT mode, along with a short-circuited atrial input and ventricular output. Afterwards VV delay was adjusted by changing the AV delay of the external pacemaker. One disadvantage of this method is that the biventricular VV delay adjustment during VDD operation is exclusively limited to the preceding RV stimuli.
- To perform a DDD operation with adjustable AV and VV delay (without limitations) in patients with implanted DDD pacemakers, the implanted device has to be programmed to DOO mode.
- To perform pure LV DDD stimulation with adjustable AV delay in patients with implanted DDD pacemakers, the latter has to be programmed to AAI with the external pacemaker set to VAT mode.
- To perform biventricular stimulation with simultaneous RV and LV stimuli in patients with implanted VVI systems (in atrial fibrillation), the external pacemaker in the VVT mode was programmed similar to the testing of the biventricular VDD operation.

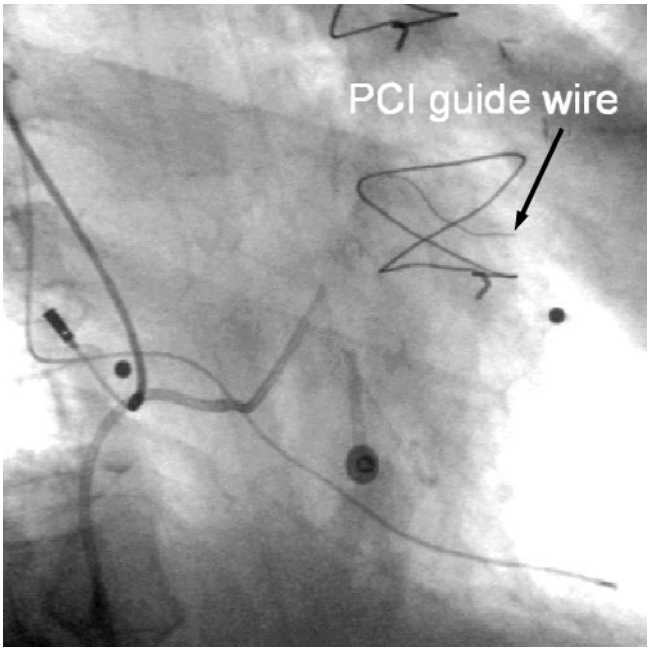

Figure 1. Positions of the previously implanted right ventricular pacemaker leads and the single percutaneous coronary intervention (PCI) guidewire to test the hemodynamic effects of biventricular and left ventricular pacing prior to upgrading.

Patient	Pacemaker	Pacing Mode	Age (years)	Disease
1	Physios (Biotronik, Berlin)	DDD	67	CHF, AV-block
2	Thera (Medtronic, USA)	DDD	68	CHF, SSS
3	Sigma SR (Medtronic, USA)	VVI	59	CHF, AF, bradycardia

Table 1. Patient characteristics. CHF = congestive heart failure; SSS = sick sinus syndrome; AF = atrial fibrillation.

- To perform biventricular stimulation with adjustable VV delay in patients with implanted VVI systems (in atrial fibrillation), the LV PCI guidewire was connected to the external pacemaker which was in the VAT mode, with a short-circuited atrial input and ventricular output. However, it is unfortunate that left to right VV delays cannot be attained.

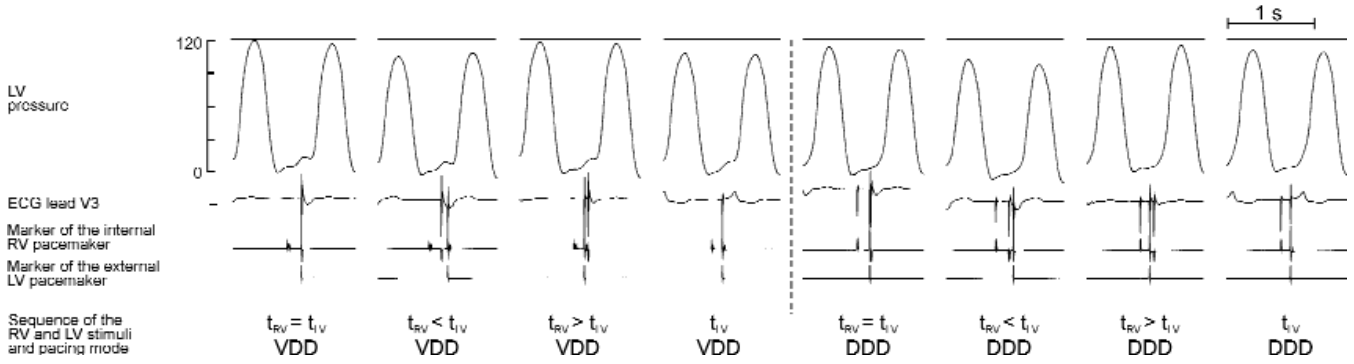

Figure 2. Pre-implantation hemodynamic study in patient 1 (see Table 1) with a previously implanted RV DDD pacemaker and external LV pacemaker to test the effects of biventricular pacing. The external LV pacemaker was triggered by the telemetric right atrial sense-event markers of the implanted RV pacemaker in different pacing modes to perform biventricular and pure LV VDD and DDD stimulation. Adjusting the AV delays of both the internal and external systems, the possibilities of a technologically advanced biventricular pacemaker with separate RV and LV outputs and adjustable AV and VV delay can be tested prior to upgrading. The benefits of the different pacing methods where analyzed by measuring LV pressure.

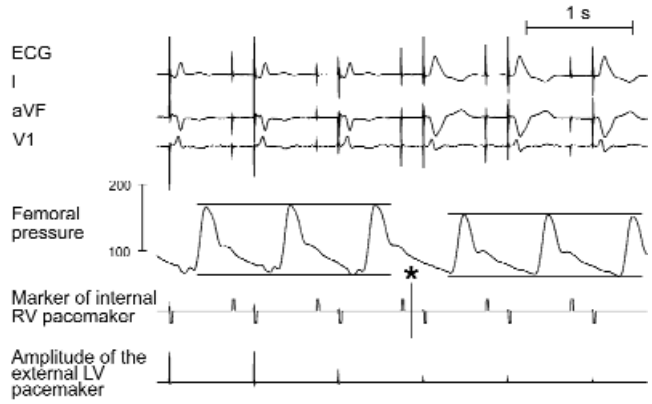

*Figure 3. Left ventricular threshold testing in patient 2 (see Table 1) with a previously implanted DDD pacemaker system using telemetric triggering of the LV pacemaker. * = transition from biventricular to RV capture.*

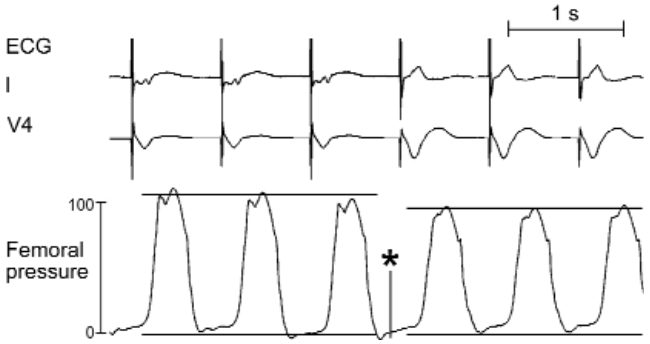

*Figure 5. Example of a LV threshold test in patient 3 (see Table 1) with atrial fibrillation and an implanted VVI pacemaker. To perform biventricular pacing, the external LV pacemaker was triggered directly by RV stimuli which were sensed via the PCI guidewire. * = transition from biventricular to RV capture.*

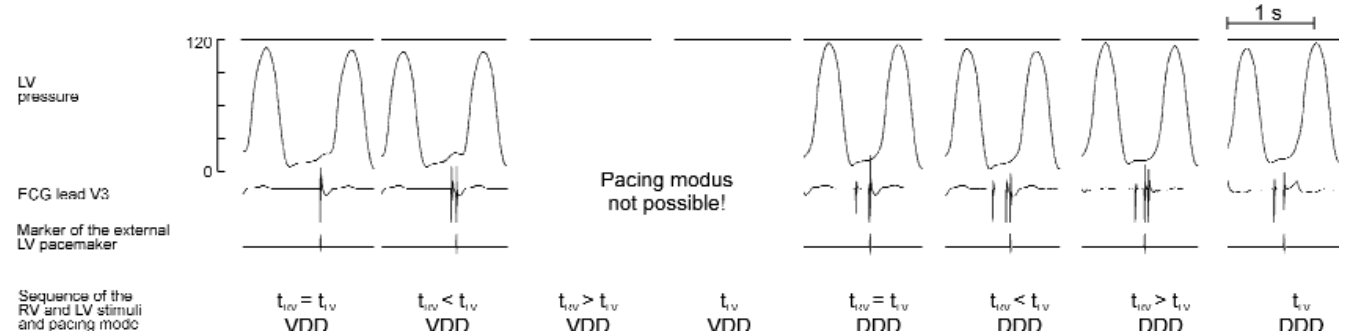

Figure 4. An alternative hemodynamic study for patient 1 (see Table 1), with a previously implanted RV DDD pacemaker and external LV pacemaker, to test the effectiveness of biventricular pacing. The external LV pacemaker was triggered in the VVT or VAT To perform biventricular pacing, external LV pacemaker was triggered directly by RV stimuli which were sensed via the PCI guidewire to perform biventricular VDD and DDD pacing with adjustable AV and VV delay. In contrast to the telemetric method, pure LV VDD pacing as well as interventricular delay with the earlier LV pacing in the biventricular VDD operation cannot be studied using this simplified method.

Results

Both methods for triggering an external pacemaker with the already implanted RV system were successfully performed, enabling us to effectively study the hemodynamic effects of biventricular pacing (Figure 1).

Biventricular Pacing by using Telemetric Atrial Sense-Event Markers for Triggering LV Stimuli

This method was performed in two patients with implanted DDD pacemakers (see Table 1). Figure 2 demonstrates both pure LV and biventricular pacing with different RV and LV stimuli, as well as different VV delays in the VDD and DDD modes. Figure 3 demonstrates biventricular pacing with simultaneous RV and LV stimuli during an LV threshold test.

Biventricular Pacing by using RV Stimuli for Triggering LV Stimuli

In contrast to the previous method, Figure 4 documents our inability to study pure LV VDD stimulation and VV delays with the preceding LV stimulus in the VDD mode. The method was also performed in a pacemaker in the VVI mode (Figure 5).

Discussion and Conclusion

To upgrade previously implanted pacemaker patients to biventricular pacing, hemodynamic pre-implantation studies can be simplified by applying a single PCI guidewire via the coronary sinus along with a monitoring arterial pressure line. To generate LV and RV pacing in the implanted system, the wire has to be connected to an external DDD pacemaker which can be synchronized in different ways:

- If telemetric synchronization of the external LV pacemaker is possible, the hemodynamic effect of biventricular pacing with separate RV and LV outputs and adjustable AV and VV delays without any limitations can be studied prior to the implantation of a biventricular system. Thus, before upgrading, all modes in modern biventricular pacing systems can be tested.
- If telemetric synchronization of the external LV pacer is not possible, the hemodynamic effects of biventricular pacing with adjustable AV delay along with the reduced possibilities for VV delay can be performed by synchronizing the external pacemaker to the internal pacing stimuli.

References

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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