Matthias Heinke*, Gudrun Dannberg, Tobias Heinke, Johannes Hörth and Helmut Kühnert

Electrical interventricular delay and left ventricular delay in right ventricular pacemaker pacing before upgrading to cardiac resynchronization therapy

Abstract: Cardiac resynchronization therapy with biventricular pacing is an established therapy for heart failure patients with sinus rhythm, reduced left ventricular ejection fraction and electrical ventricular desynchronization. The aim of the study was to evaluate electrical interventricular delay and left ventricular delay in right ventricular pacemaker pacing before upgrading to cardiac resynchronization therapy. Heart failure patients with right ventricular pacing, DDD pacemaker, DDD defibrillator and 24.5 ± 4.9 % left ventricular ejection fraction were measured by surface ECG and transesophageal bipolar left ventricular ECG before upgrading to cardiac resynchronization therapy. Interventricular and intraventricular desynchronization in right ventricular pacemaker pacing were 228.2 ± 44.8ms QRS duration, 86.5 ± 32.8ms interventricular delay and 94.4 ± 23.8ms left ventricular delay. Cardiac resynchronization therapy was optimized by impedance cardiography. Transesophageal electrical interventricular delay and left ventricular delay in right ventricular pacemaker pacing may be additional useful ventricular desynchronization parameters to improve patient selection for upgrading right ventricular pacemaker pacing to cardiac resynchronization therapy.

Keywords: Cardiac resynchronization therapy, left ventricular ECG, right ventricular pacing, interventricular delay, left ventricular delay, biventricular pacing, transesophageal ECG, ventricular desynchronization

https://doi.org/10.1515/cdbme-2017-0051

1 Introduction

Cardiac resynchronization therapy with biventricular pacing is an established therapy for heart failure patients with sinus rhythm, reduced left ventricular ejection fraction and electrical interventricular and intraventricular desynchronization [1, 2]. Transesophageal focused ECG allow the non-invasive evaluation of electrical interventricular delay [3-5].

The aim of the study was to evaluate electrical interventricular delay, left ventricular delay and the ratio between QRS duration and interventricular delay in right ventricular pacemaker and defibrillator pacing before upgrading to cardiac resynchronization therapy with biventricular pacing.

2 Methods

Eleven heart failure patients with dual chamber DDD pacemaker in ten patients, dual chamber DDD defibrillator in one patient, right ventricular pacing, New York Heart Association class 3.0 ± 0.2 and 24.5 ± 4.9 % left ventricular ejection fraction were measured by surface ECG and transesophageal bipolar left ventricular ECG before upgrading to cardiac resynchronization therapy defibrillator in eight patients and cardiac resynchronization therapy pacemaker in three patients. The mean age of one female and ten males was 69.0 ± 7.9 years.

***Corresponding author: Matthias Heinke** Biomedical Engineering Department of University of Applied Sciences Offenburg, Badstrasse 24, D-77652 Offenburg, Germany, e-mail: matthias.heinke@hs-offenburg.de
Helmut Kühnert, Gudrun Dannberg: Department of Internal Medicine I, Cardiology Division, University of Jena, Erlanger Allee 101, D-07743 Jena, Germany, e-mail: helmkue@gmail.com, Gudrun.Dannberg@med.uni-jena.de
Tobias Heinke: Siemens Healthineers GmbH, Röntgenstrasse 2, D-07407 Rudolstadt, Germany, e-mail: tobias.heinke@siemens.com
Johannes Hörth: Biomedical Engineering Department of University of Applied Sciences Offenburg, Badstrasse 24, D-77652 Offenburg, Germany, e-mail: johannes.hoerth@hs-offenburg.de

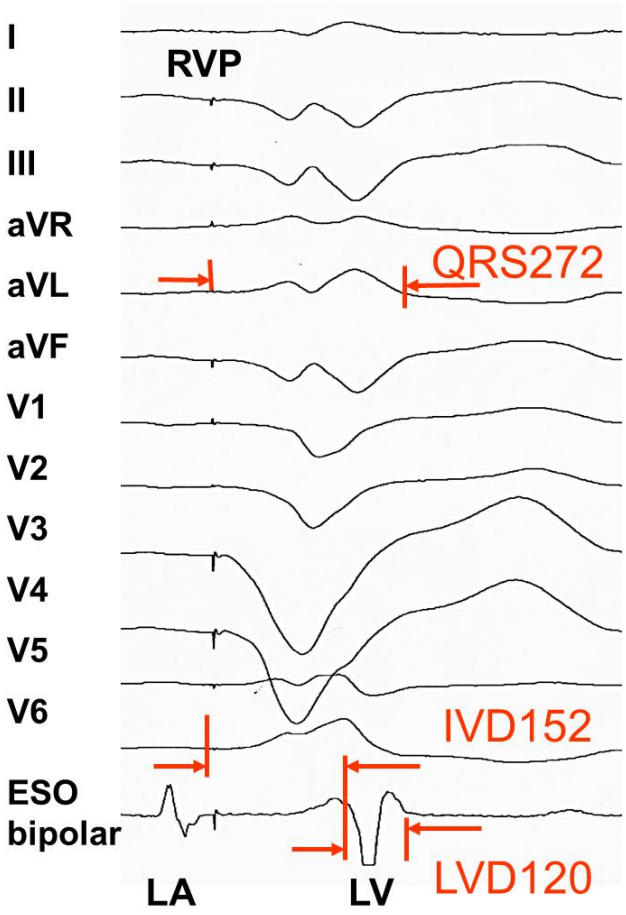

Figure 1: Right ventricular pacing with transesophageal interventricular delay of 152ms, surface ECG I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5, V6, transesophageal focused bipolar left atrial and left ventricular ECG ESO bipolar with sinus rhythm, dilated cardiomyopathy and atrioventricular block III before upgrading of cardiac resynchronization therapy defibrillator with posterolateral left ventricular electrode in a cardiac resynchronization therapy responder. LA – left atrial signal, LV left ventricular signal, IVD – interventricular delay, LVD – left ventricular delay, QRS – QRS duration, ESO bipolar – transesophageal bipolar ECG, RVP – right ventricular pacing.

Electrical interventricular delay was measured between onset of QRS in the surface ECG and onset of left ventricular signal in the transesophageal ECG. Electrical left ventricular delay was measured between onset and offset of left ventricular signal in the transesophageal ECG (see Figure 1). Cardiac resynchronization therapy atrioventricular delay after atrial sensing and atrial pacing were optimized by transthoracic impedance cardiography.

Statistical analysis was performed by Origin® 2017 software (OriginLab Corporation, Northampon, MA, USA) using paired and unpaired t-tests, as appropriate, with a statistical significance of $p<0.05$ and with Pearson correlation coefficients.

Electromagnetic simulation was performed with CST STUDIO SUITE® (CST – Computer Simulation Technology, Darmstadt).

3 Results

Evaluation of electrical interventricular delay and left ventricular delay was possible in eleven heart failure patients with right ventricular pacemaker or defibrillator pacing. Transesophageal posterior left atrial and left ventricular ECG was recorded in ten patients with dual chamber DDD pacemaker and in one patient with dual chamber DDD defibrillator.

3.1 Electrical interventricular desynchronization

Electrical interventricular and left ventricular desynchronization in right ventricular pacemaker pacing were 228.2 ± 44.8ms QRS duration, 86.5 ± 32.8ms interventricular delay, 94.4 ± 23.8ms left ventricular delay, 2.6 ± 0.8 QRS-duration to interventricular delay ratio with correlation between interventricular delay and QRS duration to interventricular delay ratio (r=-0.668 P=0.0248) and 2.3 ± 0.7 QRS duration to left ventricular delay ratio (see Figure 2).

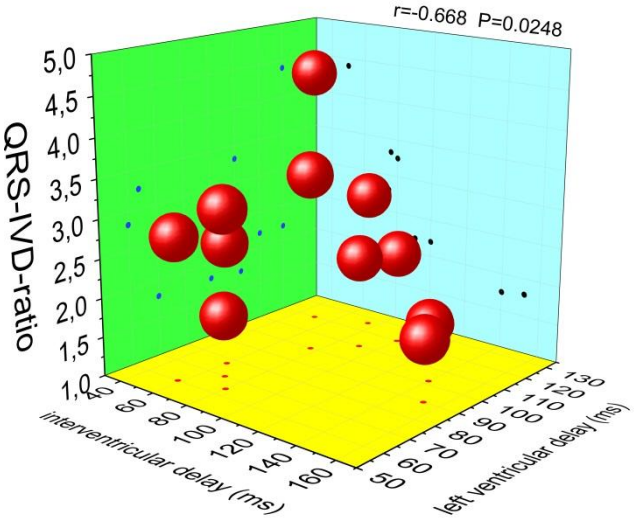

Figure 2: Electrical interventricular and left ventricular desynchronization in right ventricular pacemaker pacing with transesophageal electrical interventricular delay, left ventricular delay and QRS duration to interventricular delay ratio. QRSD-IVD-ratio - QRS duration to interventricular delay ratio, r, P – Pearson correlation coefficients.

3.2 Left ventricular ejection fraction

The left ventricular ejection fraction to electrical interventricular delay ratio was 0.3 ± 0.1 with correlation between electrical interventricular delay and left ventricular ejection fraction to electrical interventricular delay ratio (r=-0.8063 P=0.00272) and with correlation between QRS duration and left ventricular ejection fraction to electrical interventricular delay (r=-0.7251 P=0.01157) (see Figure 3).

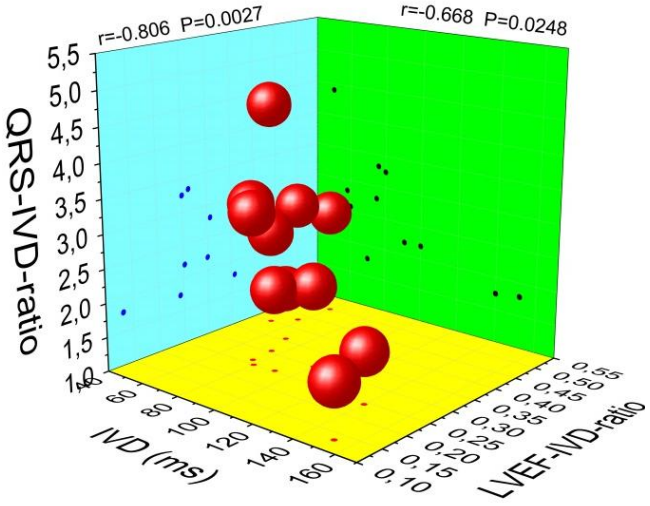

Figure 3: Left ventricular ejection fraction and electrical interventricular desynchronization in right ventricular pacemaker pacing with transesophageal electrical interventricular delay, QRS duration to interventricular delay ratio and left ventricular ejection fraction to interventricular delay ratio. QRSD-IVD-ratio - QRS duration to interventricular delay ratio, IVD – interventricular delay, LVEF-IVD-ratio - left ventricular ejection fraction to interventricular delay ratio r, P – Pearson correlation coefficients.

3.3 Cardiac resynchronization therapy

Optimal atrioventricular delay after atrial sensing and atrial pacing were 128.3 ± 24.8ms atrioventricular delay after atrial sensing in six patients and 173.3 ± 40.4ms atrioventricular delay after atrial pacing in three patients (see Figure 4). During 30.4 ± 29.6 month cardiac resynchronization therapy follow-up, the New York Heart Association class improved from 3.1 ± 0.2 to 2.2 ± 0.3 (see Figure 5).

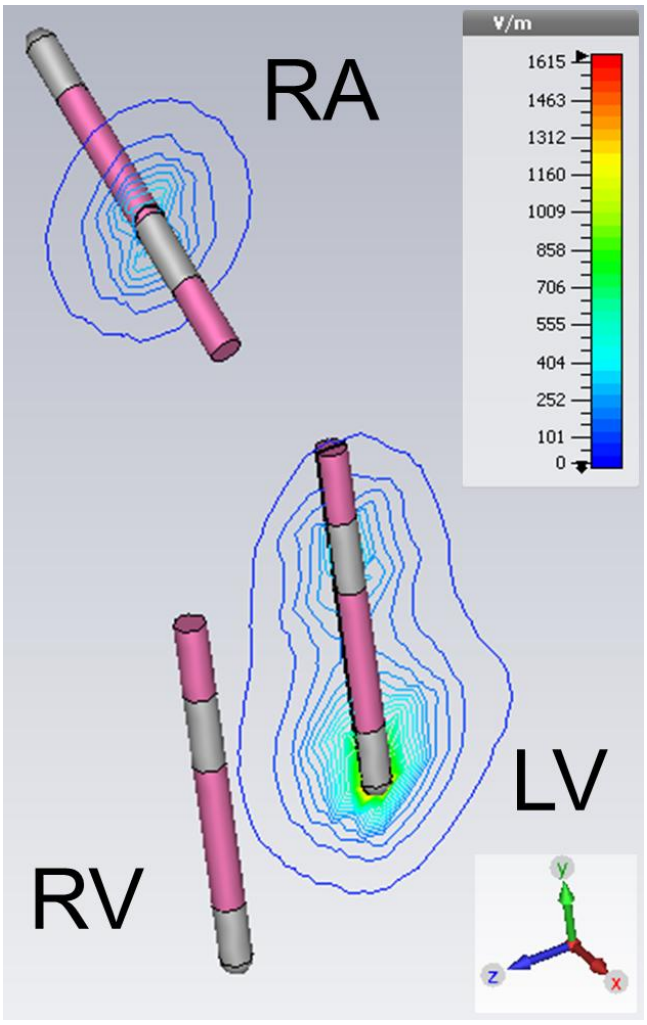

Figure 4: Simulation of cardiac resynchronization therapy with right atrial, right ventricular and left ventricular bipolar electrodes and higher bipolar left ventricular electrical pacing field. RA – bipolar right atrial electrode, RV – bipolar right ventricular electrode, LV – bipolar left ventricular electrode, V/m – electrical pacing field.

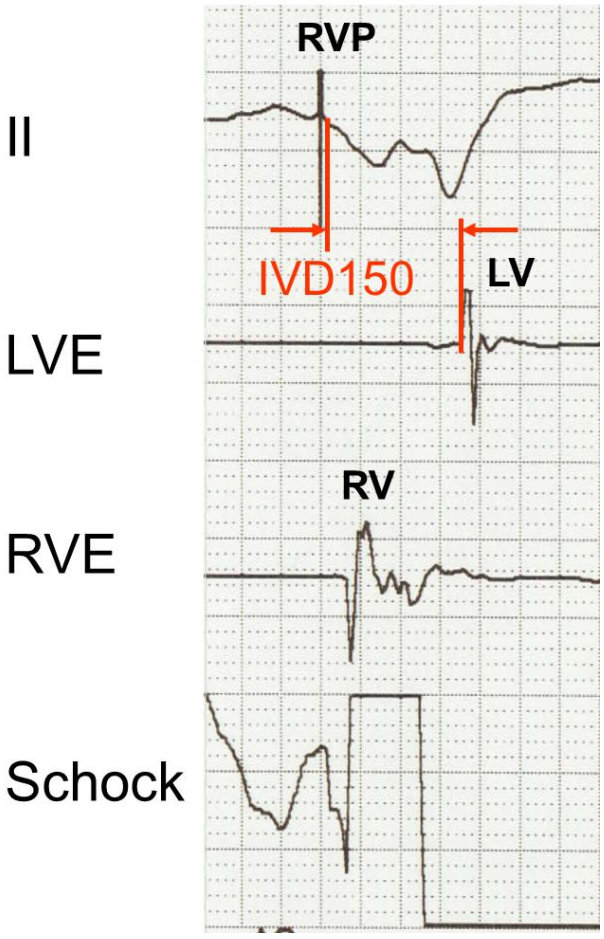

Figure 5: Right ventricular pacing with interventricular delay of 150ms, surface ECG II, left ventricular ECG, right ventricular ECG and defibrillation electrode ECG, sinus rhythm, dilated cardiomyopathy and atrioventricular block III° after upgrading of cardiac resynchronization therapy defibrillator Boston Renewal 4 with posterolateral left ventricular electrode in a cardiac resynchronization therapy responder. RV – right ventricular signal, LV - left ventricular signal, IVD – interventricular delay, RVP – right ventricular pacing, II – surface ECG, LVE – left ventricular ECG, RVE – right ventricular ECG, Schock – defibrillation electrode ECG.

4 Discussion

Stipdonk and co-workers evaluated the electrical ventricular delay between onset of QRS complex and left ventricular lateral wall activation in patients with non-specific intraventricular conduction delay with EnSite NavX electro-anatomical mapping [6]. Electrical interventricular delay with telemetric left ventricular ECG was a good predictor for the evaluation of cardiac resynchronization therapy responder and non-responder in heart failure patients with sinus rhythm [1]. The evaluation of transesophageal interventricular delay was possible with focused transesophageal left ventricular ECG in heart failure patients with sinus rhythm [3].

Transesophageal electrical interventricular delay and left ventricular delay in right ventricular pacemaker pacing may be additional useful ventricular desynchronization parameters to improve patient selection for upgrading right ventricular pacemaker pacing to cardiac resynchronization therapy.

Author's Statement

Research funding: The authors state no funding involved.
Conflict of interest: Authors state no conflict of interest.
Informed consent: Informed consent has been obtained from all individuals included in this study.
Ethical approval: The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

References

[1] Gold MR, Birgersdotter-Green U, Singh JP, et al. (2011): The relationship between ventricular electrical delay and left ventricular remodeling with cardiac resynchronization therapy. European Heart Journal 32, 2516-2524, DOI: 10.1093/eurheartj/ehr329.
[2] Ellenbogen KA, Gold MR, Meyer TE, et al (2010): Primary results from the SmartDelay determined AV optimization: A comparison to other AV delay methods used in cardiac resynchronization therapy (SMART-AV) trail. Circulation. 122:1-9, DOI: 10.1161/CIRCULATIONAHA.110.992552.
[3] Heinke M, Ismer B, Kühnert H et al (2011): Transesophageal left ventricular electrogramm-recording and temporary pacing to improve patient selection for cardiac resynchronization. Med Biol Eng Comput 49: 851-858.
[4] Heinke M, Surber R, Kühnert H et al (2007): Transesophageal left ventricular posterior wall potential in heart failure patients with biventricular pacing. Biomed. Techn. 52: 173-179.
[5] Heinke M, Kühnert H, Heinke T et al (2016): Left cardiac atrioventricular delay and interventricular delay in cardiac resynchronization therapy responder and non-responder. Current Directions in Biomedical Engineering. 2(1): 247-250, DOI 10.1515/cdbme-2016-0055.
[6] Stipdonk van AMW, Mafi Rad M, Luermans JGLM et al (2016) Identifying delayed left ventricular lateral wall activation in patients with non-specific intraventricular conduction delay using coronary venous electroanatomical mapping. Neth Heart J 24:58-65.