Directed Transesophageal Left Atrial and Left Ventricular Electrocardiography in Evaluation of Interatrial and Interventricular Delay in Patients with Heart Failure

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Abstract— **Cardiac resynchronisation therapy (CRT) by biventricular (BV) pacing is an established therapy for heart failure (HF) patients with ventricular desynchronisation, but not all patients improved clinically. The aim of the study was to assess directed transesophageal electrocardiography (ECG) of left atrial (LA) potential and left ventricular (LV) potential in evaluation of interatrial delay (IAD) and interventricular delay (IVD) in patients with HF.**

Methods: 45 HF patients (age 61 ± 12 years; 9 females, 36 males) in NYHA class 2.9 ± 0.4, 26 ± 9 % LV ejection fraction and 157 ± 40 ms QRS duration (QRSD) were analyzed IAD and IVD using directed transesophageal bipolar recording of the posterior LA and LV wall potentials with hemispherical electrodes. IAD was the right atrial – LA - interval between onset of P-wave in the surface ECG and onset of LA potential in the transesophageal ECG. IVD was the right ventricular – LV - interval between onset of QRS complex in the surface ECG and onset of LV potential in the transesophageal ECG.

Results: Transesophageal IVD was smaller than transesophageal IAD (66 ± 32 ms vs. 82 ± 39 ms, P = 0.036) in HF patients with impaired LV function. Transesophageal IAD was smaller than QRSD (P < 0.001) and transesophageal IVD was also smaller than QRSD (P < 0.001). Enlarged left atria were smaller than enlarged left ventricles (48 ± 9 mm vs. 61 ± 9 mm, P < 0.001) in HF patients. Finite element simulation of electrical pacing field evaluated transesophageal directed electrical field electrodes.

Conclusion: Directed transesophageal LA and LV ECG may detect IAD and IVD in symptomatic HF patients before implantation of BV pacing device. Transesophageal LA and LV ECG recording may be a useful non-invasive technique to detect atrial and ventricular desynchronisation in HF patients.

Keywords— **transesophageal electrocardiography, interatrial delay, interventricular delay, heart failure, biventricular pacing.**

I. Introduction

Cardiac resynchronisation therapy by biventricular pacing is an established therapy for heart failure patients with ventricular desynchronisation, but not all patients improved clinically. Previous studies of biventricular pacing for heart failure patients evaluated electrical components of ventricular dyssynchronisation with the right ventricular and left ventricular pacemaker electrocardiograms [1]. A mean transesophageal interventricular delay > 30 ms divided responders to biventricular pacing from non-responders in long-term biventricular pacing [2, 3].

The aim of the study was to assess transesophageal electrocardiography of left atrial potential and left ventricular potential in evaluation of interatrial delay and interventricular delay in patients with heart failure.

II. Methods

Forty five heart failure patients with New York Heart Association (NYHA) class 2.9 ± 0.4, 26 ± 9 % left ventricular ejection fraction and 157 ± 40 ms QRS duration were analysed with transesophageal left atrial and left ventricular ECG recording. The mean age of the patients was 61 ± 12 years (9 females, 36 males). The criteria of left atrial ECG recording was the existence of left atrial posterior wall potential in the transesophageal bipolar ECG. The criteria of left ventricular ECG recording was the existence of left ventricular posterior wall potential in the transesophageal bipolar ECG.

The transesophageal interatrial delay was analysed on the basis of recording the time interval between the onset of P-wave in the 12-lead ECG and the onset of the left atrial potential in the transesophageal ECG. The transesophageal interventricular delay was analysed on the basis of recording the time interval between the onset of QRS complex in the 12-lead ECG and the onset of left ventricular potential in the transesophageal ECG (CardioLab® Prucka Engineering, Inc., El Rio, Houston, USA; LabDuo® C. R. Bard, Inc., Murray Hill, USA). Transesophageal left atrial and left ventricular posterior wall potential were analysed in

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the bipolar transesophageal electrocardiogram. High-resolution bipolar left atrial and left ventricular ECG were recorded with an esophageal lead of 10.5 mm in diameter (TO, Dr. Osypka GmbH, Reinfelden, Germany) with one cylindrical electrode of 10 mm length and seven (TO8) or three hemispherical electrodes (TO4) of 6 mm length and with an inter-electrode distance of 15 mm. Esophageal electrodes were located on the left atrial posterior wall and on the left ventricular posterior wall orthogonal to the coronary sinus (Fig. 1).

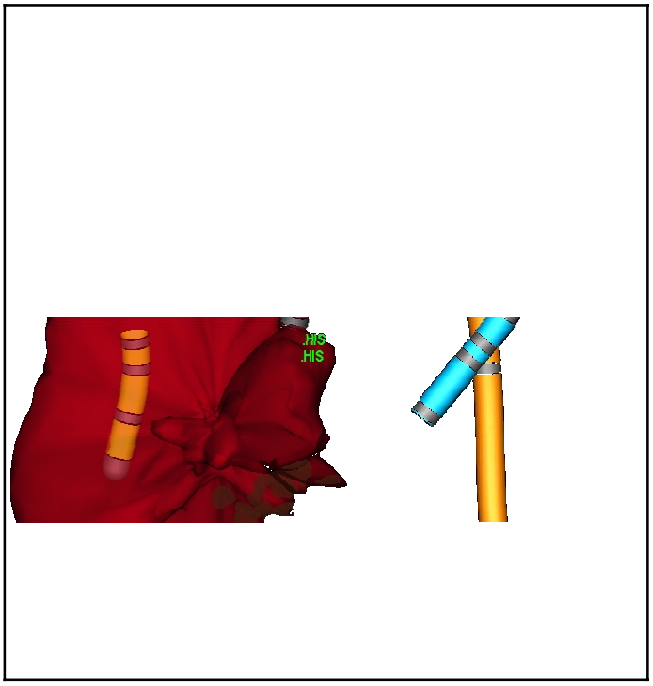

Fig. 1 3-dimensional view (front side of the patient) of transesophageal left atrial electrodes and transesophageal left ventricular electrodes on posterior position of the left heart orthogonal to the coronary sinus electrode catheter (right side) and the right atrium with right atrial electrode catheter and His bundle electrode catheter (left side) with EnSite 3000® 3-dimensional Mapping-System (Endocardial Solution, Inc, St.Paul, MN,USA). HIS – His bundle, SVC – superior vena cava.

Finite element simulation of the transesophageal electrical pacing field was performed using Ansoft Maxwell® electrical field simulation software [4] (Fig. 2) (Fig. 3).

The positioning of the esophageal TO4/8 leads were from 42 cm (158 cm height) to 50 cm (183 cm height) between mouth and distal cylindrical electrode 1 for recording of transesophageal left ventricular ECG with maximum of left ventricular potential amplitude and from 35 cm (158 cm height) to 42 cm (183 cm height) between mouth and atrial electrode for recording of transesophageal left atrial ECG with maximum of left atrial potential amplitude.

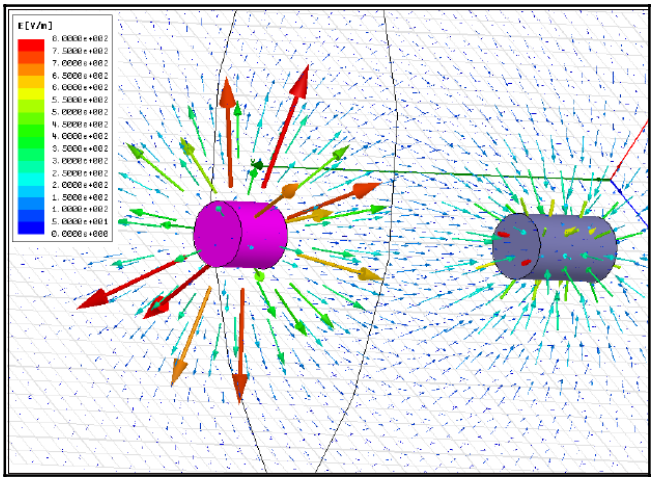

Fig. 2 Finite element simulation of bipolar transesophageal undirected electrical pacing field of esophageal cylindrical electrodes using Ansoft Maxwell® 3-dimendional simulation software. E indicates the amplitude of the electrical pacing field. Red electrode (left side) is the different pacing electrode and blue electrode (right side) is the indifferent pacing electrode.

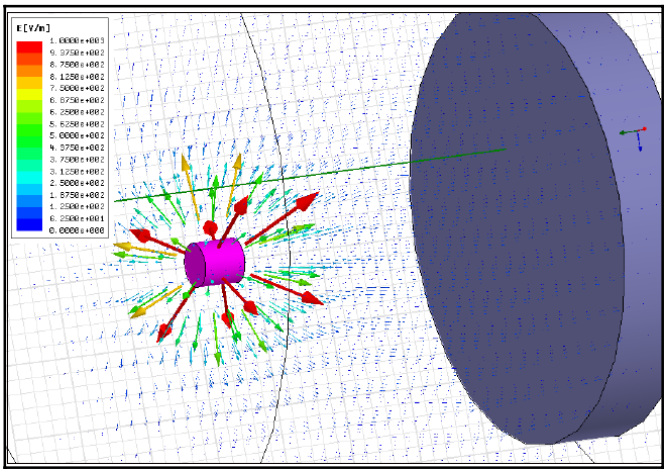

Fig. 3 Finite element simulation of unipolar transesophageal undirected electrical pacing field of esophageal cylindrical electrode using Ansoft Maxwell® 3-dimendional simulation software. E indicates the amplitude of the electrical pacing field. Red electrode (left side) is the different pacing electrode and blue electrode (right side) is the indifferent pacing electrode.

Left ventricular ejection fraction was quantified by two-dimensional echocardiography using the Simpson method [5]. Statistical analysis was performed with Origin® 7.5 (OriginLab Corporation, Northampton, MA, USA) using paired and unpaired t-tests, as appropriate, with a statistical significance of $p<0.05$.

III. Results

Transesophageal 66 ± 32 ms interventricular delay was smaller than transesophageal 82 ± 39 ms interatrial delay (P = 0.036) in heart failure patients with impaired left ventricular function. Transesophageal interatrial delay and transesophageal interventricular delay were smaller than 157 ± 40 ms QRS duration (P < 0.001) (Fig. 4).

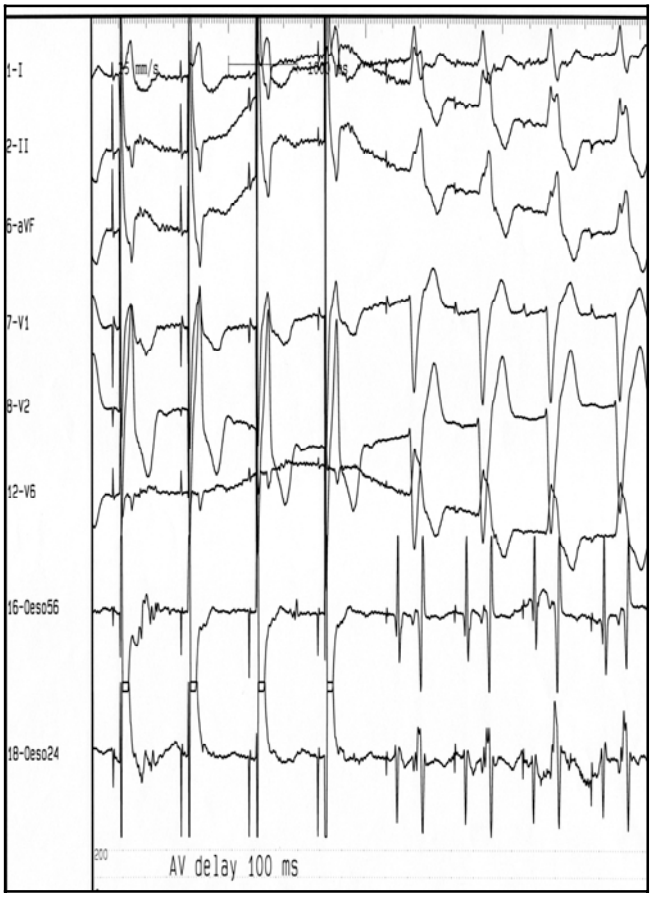

Fig. 4 Transesophageal left atrial and left ventricular ECG recording in right atrial pacing with spontaneous atrioventricular conduction, left bundle branch block pattern, 140 ms interatrial delay between right atrial stimulus and onset of left atrial potential, and 140 ms interventricular delay between QRS onset and left ventricular potential (4 beats on the right side). Transesophageal atrial sensed left ventricular pacing with 100 ms AV delay in a patient with heart failure and right atrial pacing at 60/min (4 beats on the left side).Oeso56 – bipolar filtered transesophageal ECG between left atrial electrodes 5 and 6, Oeso24 – bipolar filtered transesophageal ECG between left ventricular electrodes 2 and 4; I, II, aVF, V1, V2, V6 – surface ECG leads.

Enlarged left atrium with 48 ± 9 mm was smaller than enlarged left ventricle with 61 ± 9 mm (P < 0.001, n=9) in heart failure patients. Electrical field simulation of transesophageal pacing to the heart evaluated transesophageal directed electrical field electrodes for bipolar directed ECG recording (Fig. 5).

Fig. 5 New esophageal lead of 10.5 mm in diameter (TO4, Dr. Osypka GmbH, Reinfelden, Germany) with three proximal hemispherical electrodes with 6 mm length, one distal cylindrical electrode with 10 mm length and with an inter-electrode distance of 15 mm for directed bipolar transesophageal pacing and bipolar ECG recording. Hemispherical esophageal electrodes are on the heart side of the esophageal lead. The positioning of the esophageal lead were from 42 cm (158 cm height) to 50 cm (183 cm height) between mouth and distal cylindrical electrode 1 for recording of transesophageal left ventricular ECG with maximum of left ventricular potential amplitude and from 35 cm (158 cm height) to 42 cm (183 cm height) between mouth and atrial electrode for recording of transesophageal left atrial ECG with maximum of left atrial potential amplitude.

IV. Conclusions

Previous studies of cardiac resynchronization therapy have demonstrated clinical and hemodynamic response to biventricular pacing in approximately two-thirds of symptomatic heart failure patients with QRS-duration ≥ 130 ms and low left ventricular ejection fraction [6].

This study investigated directed transesophageal left atrial and left ventricular electrocardiogram recording in evaluation of electrical interatrial and interventricular delay in patients with heart failure. Directed transesophageal left atrial and left ventricular ECG may detect interatrial delay and interventricular delay in symptomatic heart failure patients with enlarged left atrium and enlarged left ventricle before implantation of biventricular pacing device.

Our study shows that directed transesophageal left atrial and left ventricular ECG recording may be a simple and useful non-invasive technique to detect atrial and ventricular desynchronisation in heart failure patients.

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