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# High-resolution semi-invasive left heart electrocardiography in cardiac pacing and cardiac resynchronization therapy

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## Abstract

Responder-rate in cardiac resynchronization therapy (CRT) of patients in sinus rhythm (SR) or atrial fibrillation (AF) mainly depends on accurat selection, optimal position of the left ventricular electrode and individualization of hemodynamical parameters of the implanted biventricular pacing system during follow-up. High resolution esophageal left heart electrocardiography offers a quick and semi-invasive approach to the electrical activity of left atrium and left ventricle. It was used in 62 heart failure patients in sinus rhythm and 11 in atrial fibrillation after implantation of CRT systems to compare the semi-invasive interventricular conduction delay (IVCD**E**) with QRS width. In all of the patients, guideline decision for CRT was linked with IVCD**E** of about 40ms and up. From logical point of view, IVCD**E** provides the minimal target interval for the left ventricular electrode placement in order to exclude non-responders. Esophageal measurement of interatrial conduction intervals in VDD and DDD pacing was utilized to individualize the AV delay and to exclude adverse hemodynamic effects.

## Introduction

Three main reasons exist to seek for alternative methods in the field of cardiac resynchronization therapy. Accurate selection of eligible patients for this therapy can increase the responder-rate as well as optimal specification of their individual left ventricular electrode position and optimal programming of hemodynamic pacing parameters. The three requirements could be fulfilled preoperatively by selecting patients characterized by a distinct interventricular conduction delay, intraoperatively by placing the LV electrode within a desynchronized but not scarred left ventricular region and postoperatively replacing empirical hemodynamic optimization by a logical way to determine the individually optimal AV delay /1/.

High resolution filtered esophageal left heart electrogram (LHE) seems to be an alternative in the field of CRT. Preoperativeley, in symptomatic heart failure patients in sinus rhythm and in atrial fibrillation. It offers a semi-invasive measurement of the interventricular conduction delay /2, 3/. The measured value can intraoperativley provide the minimal target interval for left ventricular electrode placement (figure 1). In the postoperative stage, the left atrial electrogram enables measurement of implant-related interatrial conduction intervals.

## Methods

Esophageal left heart electrograms were recorded in 62 patients in sinus rhythm and in 11 patients in atrial fibrillation after implantation of CRT systems CRT (59m, 14f, age: 66.7 ± 9.8yrs.) using the TOslim (Osypka, Rheinfelden, Germany) esophageal electrode in combination with esophageal electrogram feature of the Biotronic ICS 3000 standard programmer (Biotronik, Berlin, Germany) /3/. Placing the electrode in position of maximal left ventricular deflection high-resolution esophageal left ventricular electrogram was recorded in both patient groups, sinus rhythm and atrial fibrillation, to measure the esophageal interventricular conduction delay $IVCD_E$ between onset of QRS in surface ECG and onset of the left atrial deflection in the esophageal left heart electrogram as an additional parameter to characterize the ventricular desynchronization /4/.

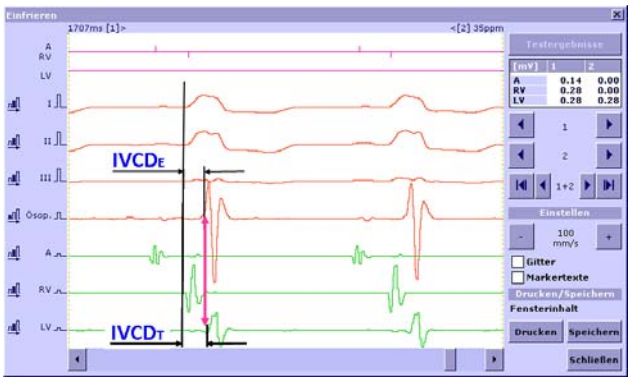


**Figure 1:** Comparison of esophageal (IVCD**E**) and telemetric interventricular conduction delay (IVCD**T**) in heart failure patient with Biotronic CRT system.

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In the esophageal electrode position of maximal left atrial deflection, high-resolution esophageal left atrial electrogram was used in the sinus rhythm group to determine the interatrial conduction, which is a fundamental determinant of the hemodynamically optimal AV delay.
They were determined in VDD operation as interval between atrial sense event or atrial stimulus in DDD operation and the onset of left atrial deflection in the esophageal left atrial electrogram, respectively. We previously reported that the hemodynamically optimal AV delays for VDD and DDD operation can be approximated based on these measurement by adding the mean optimal electromechanical interval which was echocardiographically determined in a comparable CRT patient group to be about 50ms /5/.

## Results

Esophageal left heart electrogram was recorded without any problems in all of the 73 patients.

In the 62 heart failure patients of the sinus rhythm group, the mean QRS width of 174 ± 22ms (118-215ms) was linked with esophageal interventricular conduction delay IVCD**E** of 72 ± 24ms ranging between 40 and 124ms.

In the 11 patients of the atrial fibrillation group, mean QRS of 162 ± 27ms (120-206ms) resulted in IVCD**E** of 62ms ± 27ms ranging between 37 and 98ms. In both groups, the guideline decision for CRT was linked with esophageal interventricular conduction delays of about 40ms and up.

In all patients of the sinus rhythm group, the hemodynamically optimal AV delays in VDD and DDD operation were approximated based on the individually measured interatrial conduction intervalls (IACT) of 36 ± 27ms in VDD and 93 ± 25ms in DDD operation, respectively, by adding about 50ms /5/.


**Figure 2:** Demonstration of adverse programming of the AV delay in symptomatic heart failure patient with CRT system. The esophageal left atrial deflection disappears within the paced QRS complex indicating truncation of the left atrial contribution.

In these patients, measurement of the individual interatrial conduction delays uncovered adverse hemodynamic effects. In 11 patients during VDD and even 13 patients during DDD operation, the left atrial deflection was either truncated by the ventricular stimulus or disappeared within the ventricular deflection if factory settings of the AVD delay were programmed (figure 2).
Thus, a special advantage of the esophageal electrogram is that this method clearly indicates if the left atrial contribution to the left ventricular filling is either restricted or even completely excluded. In other words, the esophageal left atrial electrogram indicates if AV delays are obviously programmed too short.

## Conclusions

One of the main results of this study is that guideline decision to CRT in both, sinus rhythm and atrial fibrillation is linked with IVCD**E** of about 40ms and up. Thus, measurement of the esophageal interventricular conduction delay could be additionally used to justify implantation of CRT systems in sinus rhythm, atrial fibrillation or even patients with borderline values of QRS width or standard desynchronization parameters.
From logical point of view, the esophageal interventricular conduction delay provides a new semi-invasive parameter indicating the minimal target interval for the left ventricular electrode placement. Missing this target interval should encourage further attempts to find a better position in order to increase CRT responder rate /6/.
Esophageal left atrial electrogram recording clearly indicates individually too short AV delays preventing a hemodynamic effect of the left atrial activity. As a general rule, durations of the optimal AV delays in VDD and DDD pacing exceed the duration of the appropriate interatrial conduction intervals. If echo optimization is not possible, simplified AV delay calculation can be performed by accurately measuring the individual interatrial conduction interval and adding about 50ms for both modes in CRT patients but 70ms in AV block patients with unimpaired left ventricular function /1, 5/.
As an additional advantage, the chronology of left atrial deflection in esophageal left atrial electrogram during VDD and DDD pacing can also be utilized in CRT patients with bradycardia changing between sinus rhythm and atrial pacing:
- In these patients, AV delay optimization can be reduced to one of the two modes, VDD or DDD, solely. Optimal AV delay for the other mode can easily by calculated using the difference of the interatrial conduction intervals.
- Moreover, different durations of the interval between left atrial deflection and ventricular stimulus during sinus rhythm and atrial stimulation indicates imperfect AV delay programming.
Larger and follow-up studies have to performed to demonstrate the value of this alternative method for CRT.

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