The new criterion for cardiac resynchronization therapy treatment assessed by two channels impedance cardiography

K Peczalski¹,², T Palko¹, D Wojciechowski²,³, Z Dunajski¹, M Kowalewski².
¹Institute of Metrology and Biomedical Engineering Warsaw Technical University, Warsaw
²Stopczyk Centre of Cardiology Wolski Hospital, Warsaw
³IBIB PAS Warsaw

E-mail: k.peczalski@mchtr.pw.edu.pl

Abstract. The cardiac resynchronization therapy is an effective treatment for systolic failure patients. Independent electrical stimulation of left and right ventricle corrects mechanical ventricular dyssynchrony. About 30-40% treated patients do not respond to therapy. In order to improve clinical outcome authors propose the two channels impedance cardiography for assessment of ventricular dyssynchrony. The proposed method is intended for validation of patients diagnosis and optimization of pacemaker settings for cardiac resynchronization therapy. The preliminary study has showed that bichannel impedance cardiography is a promising tool for assessment of ventricular dyssynchrony.

1. Introduction
The cardiac resynchronization therapy (CRT) is a common treatment for systolic heart failure patients. The method is based on resynchronization of improper timing of the heart conductive system by multipoints pacing. The independent electrical stimulation of left ventricle (LV) and right ventricle (RV) corrects the mechanical dyssynchrony (MD) and increases stroke volume of the heart.

The common accepted criteria for CRT are: ejection fraction (EF) less than 35%, New York Heart Association (NYHA) class III or IV and QRS complex duration (QRSd) longer than 120 msec [1, 2]. One can see that the only criterion related to MD is QRSd which describes sum of depolarization potentials of LV and RV. The delay between systole of right and left side of the heart, triggered by depolarization potentials, is indicated by extended duration of QRS. Two above mentioned criteria confirm the symptoms of heart failure in the patient.

The clinical outcome of CRT is limited by fact that about 30% of treated patients do not respond to therapy [1]. No response to CRT seems to be caused by improper selection of patients for resynchronization pacing. Echocardiography-guided methods (USG) have been most commonly employed for measurement of MD. According to published data and authors clinical results the echo indices of MD are difficult to collect, appear to be discordant, and fail to predict clinical outcomes [3, 4]. There are two possible explanations for the poor accuracy of USG. The first explanation is related to how the blood flow velocity is detected with Doppler sonography. Doppler sonography is used to measure blood flow velocity by the Doppler frequency shift of echoes from red blood cells. The angle between the ultrasound beam and the blood flow seems to be a significant source of measurement uncertainty since the Doppler shift for given velocity of blood is proportional to the cosine of the angle \( \alpha \). Maximum Doppler frequency shift occurs when blood is flowing directly
towards or away from the ultrasound beam. Thus, scanning as close as possible to 0° will increase sensitivity and minimize ambiguity in the flow direction. The crucial limitation of the cardiosonography technique is the dependence of the measurements on the angle between the ultrasound beam and the direction of blood flow. The resulting error in blood flow velocity measurements is unavoidable and varies from one procedure to another. The second explanation is related to the technique of estimation of MD by means of USG.

The measurement procedure consists of three steps:

1. Measurement of the pre ejection period (PEP) between the Q wave of QRS complex in the reference ECG record and the onset of ejection through pulmonary valve for RV.
2. Measurement of PEP between Q wave of QRS complex in reference ECG record and onset of the ejection through the aortal valve for LV.
3. The MD is calculated by PEP(LV) minus PEP(RV).

The global uncertainty of the measurement method of MD depends on following components:

- the uncertainty due to the indirect mode of measurement (subtraction of two separate measurements gives bigger error),
- the uncertainty caused by possible changes of the patient’s heart rhythm due to time differences between consecutive measurements,
- the uncertainty of the blood velocity measurement due to the inconsistency of the angle between the ultrasound beam and the blood stream direction and consequently poor repeatability of the results (as described above).

These arguments indicate inaccuracies of the USG methods in the assessment of the MD in systolic heart failure patients. Therefore the new more accurate method is desirable for improving the clinical outcomes of CRT.

2. The proposed measurement method
We propose to apply two channel impedance cardiography (IC) for the assessment of MD in order to improve the fidelity of selection of systolic heart failure patients for the CRT treatment [5].

This method has following advantages to USG:

- measurements for LV and RV are simultaneously executed on the same beat of the heart,
- direct measurement of MD avoids uncertainty related to subtraction of two measurements carried out at different times,
- absence of the error due to inconsistent angle of the probe application (the angle between beam and blood flow).

In addition the measurement procedure is simple, less time consuming and does not require a highly trained operator.

The system consists of two channels for current tetrapolar impedance measurement method. Different frequencies of alternating application current (AC) current are applied for each channel in order to avoid interference between them. The parameters of AC are: first channel 1 mA, 63 kHz and second channel 1 mA, 95 kHz. The terapolar method was applied to reduce influence of contact impedance (electrode – skin of patients) on the measured signal.

The lead system was dedicated to collecting flow data in the right pulmonary artery and aorta. The flow in the right pulmonary artery was assessed by two pairs of leads located to the right of the sternum in the second intercostals area. The distance between signal electrodes was in the range of 6-8 cm depending on the patient. The flow in upper aorta was assessed also by two pair of leads located longitudinally to the sternum (higher in first intercostals area and second on the level of xiphisternum). In this case the distance between signal electrodes was in range of 12 – 18 cm.
The MD interval was calculated directly from the distance between the onset of aortic flow and the onset of pulmonary flow.

3. Preliminary clinical study
The preliminary clinical study was performed upon approval of the Ethical Committee.

1. The 60 years old volunteer in I class of NYHA with a QRS duration of less than 120 milliseconds and an EF higher than 35%, underwent two channels IC examination. The MD was found to be zero (fig. 2). No additional echo study was done,

2. Five patients treated by CRT were examined by IC and cardiosonography for MD assessment. The criteria for resynchronization pacing were fulfilled for all of them. The differences (in ms) between results achieved for DDD and CRT pacing for IC and USG are as follows:

- first patient CRT – 10, DDD – 20,
- second patient CRT – 0, DDD – 20,
- third patient CRT – 0, DDD – 80,
- fourth patient CRT – 30, DDD – 50,
- fifth patient CRT – 70, DDD – 30 (unstable rhythm).

The goal of further optimization of MD was to get the delay between pulmonary and aortic onsets close to zero. The result of adjustment of MD in range 0 – 20 ms was terminated the optimization procedure in all examined patients. The tailoring of MD for each patient by USG was postponed due to the time needed for achieving sufficient results. However, exactly the same results for both methods were observed in two patients. The switch from the CRT pacing mode (after optimization) to DDD (pacing mode supporting right atrium and right ventricle of the heart) caused the significant increase of MD in four of five patients.

Figure 1. proposed biIC lead system

Figure 2. MD in healthy volunteer
4. Conclusions

1. Preliminary clinical studies have showed that this new technique has potential for more accurate diagnosis using parallel measurements of pulmonary and aortal flow with two channels Impedance Cardiography.

2. The proposed new method needs to be tested in a larger group of patients in order to statistically validate its accuracy for mechanical dyssynchrony measurements.

5. References

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