Left Ventricular Resynchronization in H.F.: Comparison of Alternative Optimization Methods

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Abstract

This paper compares the results of two different procedures, Doppler Ultrasound and Transthoracic Impedance, to monitor the left ventricular stroke volume on a group of heart failure patients submitted to electrical resynchronization therapy. The two procedures have been applied in parallel on 9 patients by changing the stimulation delays between the septal and posterior ventricular walls and the results have been compared to evaluate the correlation between the two choices, and their sensitivity to detect the optimal stimulation condition. The results demonstrated a good agreement between the data obtained with the two procedures (R=0.82), but a very limited change of the target parameter (Stroke Volume) by changing the stimulation delay. This suggests doubts on the choice of stroke volume as the best parameter to be observed for the optimization process and on the adequate sensitivity of the two procedures to highligt the process.

1. Introduction

Left ventricular resynchronization is a widely diffused therapeutic approach in patients with heart failure (HF) showing an increased delay between the left ventricular septal and posterior wall electrical depolarization. This increased delay, which in some cases may produce QRS duration higher than 120ms, is associated with a mechanical dissinchrony which impairs the just limited ventricular function, with a very negative effect on the emodynamic parameters.

To compensate this negative condition, few years ago the producers of cardiac electric stimulators developed special devices for anticipating the electrical stimulation of the left ventricular postero-lateral wall by an electrode lead inserted through the coronary venous system. Nowadays this approach is widely used and a positive result is obtained in about two thirds of the patients, depending on the optimization of stimulation delay between the septal and the posterior ventricular wall (VV delay). The assumption is that the electrical resynchronization produces a more efficient mechanical contraction, with immediate benefits on the stroke volume and long term positive effects on ventricular volumes and ejection fraction [1].

At the moment the standard optimization approach is based on the non invasive stroke volume (SV) measurement by Doppler Ultrasound at different stimulation delays, which requires repetitive attempts, ending in a very time consuming procedure [2].

Recently the procedure for monitoring the stroke volume SV developed by Kubicek in the seventies [3] based on transthoracic electrical impedance, has been revised and optimized by some authors [4-7], and this method is now proposed as an efficient and time saving solution for the optimization of the left ventricular resynchronization procedure [8,9]. In clinical practice the possibility to manage the electrophysiologic procedure independently from the echocardiographyc one is a real advantage, but a validation process is mandatory, because the two alternative solutions have different inherent errors and the their equivalence must be demonstrated.

This paper compares the SV data obtained with standard echocardiographyc and proposed transthoracic Impedance procedures, on a court of HF patients treated with electrical resynchronization at different VV delays, to verify both the sensitivity of the SV parameter to optimize the electrical delay and the equivalence of the two different approaches.

2. Methods

We measured the stroke volumes SV at different stimulation delays between the septal and latero-posterior wall of the left ventricle, in 9 Heart Failure patients (6 males and 3 females, mean age 70±7 years, mean left ventricular ejection fraction FE=28.2±6.7 %, NYHA class II-III, QRS>120ms) with left ventricular enlargement and a recently implanted biventricular pacing system BIV.

The cardiac output measurement protocol consisted of two steps:

1. The stroke volume was measured on each patient by pulsed Doppler Echocardiographyc technique (Philips 5500) as time integral of aortic flow velocity IVT in the ejection phase [2], at step changes in atrio-ventricular AV delay from 60 to 180ms, and then varying ventricular-ventricular delay VV from -80ms to 80ms.

Each different stimulation condition was set up and after a stabilization interval of 10 beats the Doppler Aortic flow velocity signal was recorded. Due to the time shortage a single beat aortic flow profile was manually outlined on the instrument screen and the IVT value was calculated. For a single patient a total of 15 different stimulation conditions were settled, requiring about one hour of time;

2. Simultaneously, for each stimulation condition the SV was measured by monitoring the changes of transthoracic impedance by Task Force Monitor System (CNSystems Medizintechnik GmbH, Graz, Austria), according to Kubiceck's algorithm

$$SV = \rho \left(\frac{L}{Z_0} \right)^2 T \left(\frac{dZ}{dt} \right)_{\min}$$

L = Distance between the thoracic electrodes

Z_0 = Mean value of the electrical thoracic impedance

Z = Instantaneous value of the electrical thoracic impedance

T = Ventricular ejection time

ρ = Blood density

The impedance signals storage was set immediately after the ending of the Echocardiographyc measurement and the SV was obtained as mean value of 10 beats (minimum).

The evaluation of the results was addressed to two different objectives.

First, for all the patients the two parameters (IVT and SV) obtained at the different VV time delays, have been put in comparison and the linear correlation coefficient R has been calculated (Fig. 1).

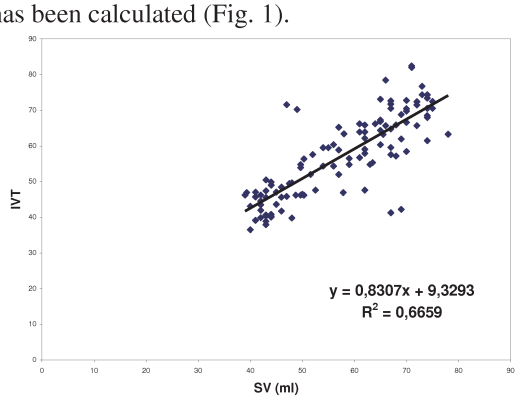

Fig. 1 . Whole population IVT and SV values

For this, the mean IVT value for each patient was normalized to the mean SV of the same patient.

Second, for each patient the IVT and SV values have been graphically displayed with respect to the VV stimulation delays, in order to evaluate the sensitivity of two procedures to support the optimization process.

3. Results

The comparison of the stroke volumes values obtained on the whole population is shown on Fig.1. The correlation coefficient was 0,82.

An example of changes of IVT and SV with respect to VV time delays is shown on Fig 2.

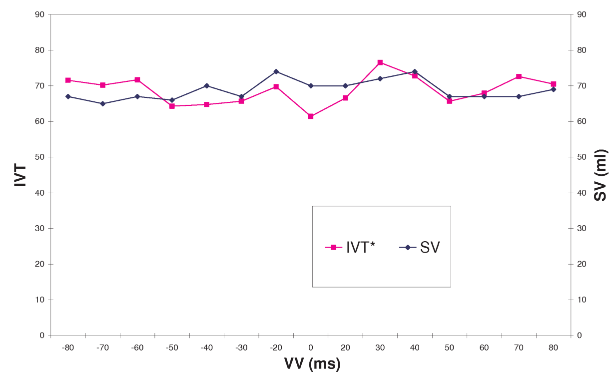

Fig.2: IVt and SV for a single patient, obtained by changing the VV stimulation delay.

4. Discussion and conclusions

The left ventricular resynchronization on HF patients with reduced ejection fraction and a QRS duration higher than 120 mS has demonstrated a clear positive effect on about two thirds of the patients. The reasons of an inadequate response are referred to the anatomo-physiologic conditions of the patient and to a non optimal resynchronization approach, mainly for the choice of the VV stimulation delay. For this reason, considering also the high cost of the dedicated device, procedures to monitor the resynchronization optimization have been developed. The mandatory requirements of the procedures were to be noninvasive, suitable and effective, and the Doppler Ultrasound measurement of the stroke volume was proposed as the standard choice.

The limitations of the Doppler Ultrasound solution are the complexity of the measurement process, which requires the outlining of the aortic blood velocity profile, the operator dependence and the long time required to test multiple VV stimulation delays. These limitations are further amplified considering the need to follow each patient to adequate the stimulation conditions each month, for some years! Recently an alternative SV non invasive monitoring procedure has been reintroduced in the clinical practice after some years of sleep: the Kubiceck's thoracic Impedance method, optimized by a different electrodes positioning and a better algorithm. Nowadays this choice is proposed, with the advantage of a simpler technical approach and a complete operator independence, being the error associated to each measurement similar to that of Doppler ultrasound solution (about 10%).

In this paper we used the two procedures in parallel on a court of 9 HF patients, to verify the agreement of the results and the sensitivity to the stimulation delay changes. For the agreement evaluation all the data, obtained on the whole patients population at the different VV stimulation delays have been graphically shown (fig.1). The linear correlation coefficient was R=0.82, quite good!

A different evaluation descends from the graphical description of both IVT and SV values obtained on a single patient by changing the VV stimulation delays: the behaviour is completely different from what we expected! On the graphs it is very difficult to detect a value corresponding to the optimal delay and the oscillatory shape seems to highlight an error associated to the single measurement which overcomes the physiological change of the parameter itself.

The result is a doubt both on the choice of the stroke volume as the optimal parameter to drive the optimization process, and on the adequacy of inherent technical performance of the two procedures (the error is about 10%!) to support the optimization process. Further observations are necessary to improve the measurements quality and to increase the population; at this moment the judgment is very critical!

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