Optimal programming in cardiac resynchronization therapy

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ABSTRACT

Cardiac resynchronization therapy (CRT) has been shown to improve cardiac function, diminish hospitalization frequency, and enhance quality of life in selected heart failure patients. This benefit is mostly due to improved synchronization of ventricular contraction in the diseased heart. Since heart failure patients represent a heterogeneous group, cardiac resynchronization therapy must be tailored to each patient. Thus the best performance can be achieved by optimal programming of the device for each individual. This communication discusses different methods used for optimal programming for individuals who undergo CRT device implantations. *(Anadolu Kardiyol Derg 2007; 7 Suppl 1; 50-2)*

Key words: cardiac resynchronization therapy, artificial cardiac pacing, heart failure

Introduction

In patients with severe left ventricular (LV) dysfunction and intraventricular conduction disease, who are already being administered maximally tolerated pharmacological treatment for heart failure, biventricular stimulation (i.e., cardiac resynchronization therapy [CRT]) has been shown to improve cardiac function, diminish heart failure hospitalization frequency, and enhance quality of life presumably due to improved synchronization of ventricular contraction in the diseased heart (1-11).

Clinical experience

Clinical experience with biventricular and/or LV-based pacing dates from the initial case report by Cazeau et al (12). Subsequently, Blanc et al (1, 13) indicated that in acute studies both left ventricular and biventricular pacing were comparable hemodynamically, and far better than right ventricular (RV) pacing alone in patients with left ventricular dysfunction. Kass et al (14) used careful evaluation of ventricular pressure-volume loops to provide further important insight supporting this latter observation. Subsequently several controlled trials have demonstrated improvements in exercise tolerance and quality of life, and reduced hospitalization frequency associated with introduction of a biventricular pacing strategy (4, 6, 7, 15). By way of example, Abraham et al (7) concluded that biventricular pacing resulted in significant clinical improvement in patients who had both moderate-to-severe heart failure and an intraventricular conduction delay.

Mechanisms

Cardiac resynchronization therapy improves cardiac hemodynamics in heart failure patients with one or more of the following actions (7); i) increased LV filling time, ii) decreased septal dyskinesis, increased LV dp/dt, iii) reduced mitral regurgitation.

Increased LV Filling Time

Left ventricular filling time is the diastolic filling period which starts with the beginning of the E wave (mitral flow velocity during early filling) and ends with the end of A wave (mitral flow velocity during atrial contraction). In the presence of an interventricular conduction delay LV activation is delayed whereas atrial activation is not. So, the passive filling and atrial kick occur simultaneously, resulting in shortened LV filling time and decreased preloading of LV. The related echocardiographic finding is the fusion of E and A waves. With the initiation of the biventricular pacing both ventricles activate simultaneously, thus LV becomes able to complete the contraction and begin relaxation earlier, which causes an increase in ventricular filling time. The resultant echo effect is the re-separation of the E and A waves on Doppler transmitral flow measurement.

Decreased septal dyskinesis, increased LV dp/dt

Interventricular conduction delays also disturb the normal activation contraction sequence between the septum and free wall. Free wall contracts in a time distance after the septal contraction and the resulting time mismatch causes the septum to move away from the free wall during ventricular systole diminishing the septum's contribution to LV stroke volume.

Biventricular pacing causes the septal and free walls to activate synchronously. This allows ventricular ejection to occur prior to relaxation of septum improving the stroke volume and other systolic indices like LV dp/dt.

Reduced mitral regurgitation

Normal mitral valve opening and closure depends on an appropriately timed atrial and ventricular contraction. In the

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presence of an interventricular (VV) and atrioventricular (AV) conduction delays, mitral valve closure may not be complete. If the time lag is long enough ventriculo-atrial pressure gradient may cause diastolic mitral regurgitation. By resynchronizing atrioventricular and interventricular activation mitral regurgitation is reduced or eliminated.

Optimal programming

Since heart failure patients represent a heterogeneous group, cardiac resynchronization therapy must be tailored to each patient. Thus the best performance can be achieved by optimal programming of the device for each individual. Three main components of the optimal programming are; i) pacing both the right and left ventricles, ii) optimizing the AV delay, iii) optimizing the VV delay.

Pacing both the right and the left ventricles

Selecting a left ventricular pacing site that best corrects the electromechanical delay within the LV is the first step and the key to provide effective biventricular pacing. Early studies have shown that pacing at sites of latest activation of the LV provides the greatest improvement in pulse pressure and LV dp/dt (1, 4, 7). When the LV lead tip is at the latest site of activation, the LV electrogram signal will intersect the latter part of QRS on surface electrocardiogram (ECG).

The position of the right ventricular lead relevant to LV lead is another important consideration. Optimally the RV lead is positioned as far away from the LV lead as possible. Maximizing this distance not only reduces the risk of far-field sensing but also improves effectiveness of biventricular pacing. In this regard, the position of the LV lead in the lateral (marginal) and posterolateral veins have shown to provide the most effective biventricular pacing.

Optimizing the AV delay

Achieving an optimized AV delay adjusts the contraction sequence between the left atrium and the left ventricle to optimize left ventricular filling without truncating atrial contribution. Optimal AV delay optimizes stroke volume and minimizes mitral regurgitation. There are several methods to determine optimal AV delay.

The first one is empirical calculation where the optimal AV time is calculated as the half of the sensed PR interval minus 20.

One more complicated formulation is the Ritter technique (17). In this technique, one obtains a pulsed wave Doppler view of trans-mitral flow via a 4-chamber view. As the ECG, E-wave and A-wave recordings are visualized, a short sensed AV interval (AVShort) is programmed, and the corresponding QA (QAShort) is measured. Next, the long sensed AV interval (AVLong) is programmed and the corresponding QA (QALong) is measured. The optimal AV is then calculated as follows;

$$AVopt=AVshort + [(AVlong+QAlong)-(AVshort+QAshort)].$$

The third method is the iterative method where the operator starts with an AV delay programming that causes ventricular pre-excitation. Then the programmed AV delay is decreased until the A-wave begins to truncate. Subsequently the AV delay is increased until the completion of the A-wave contribution is seen. That specific time frame is then taken as the optimal AV delay.

The fourth and last method is the pulse pressure method where an arterial line is utilized to measure the central aortic pressure accurately. The AV delay programming starts at a lower value and then delay is increased progressively to get an optimal value that provides maximal difference between systolic and diastolic blood pressures.

Optimizing the VV delay

Optimizing the pacing timing between two ventricles helps to adjust contraction sequence between the left and right ventricles, ideally optimizing the left to produce the largest stroke volume in certain patients. The optimal Velocity Time Integral (VTI), which is a surrogate for stroke volume, is used to determine an optimal VV delay setting.

In this technique, Doppler velocities across the aortic valve are obtained using the apical long axis view. Either a continuous or pulse wave Doppler velocity can be used hence both have advantages and disadvantages. Then the VTI values, as the area under velocity time curve, are calculated. The multiplication of the VTI with the LV outflow tract area gives the stroke volume, thus a larger VTI represents a greater stroke volume.

For different VV settings all VTI values are calculated next, without moving the sample volume on Doppler echocardiogram. Two to three VTI values are measured for each VV setting and an average value is taken. The greatest VTI with maximal stroke volume is determined and the associated setting is accepted as the optimal VV delay for that given patient.

Conclusion

Cardiac resynchronization therapy offers a significant morbidity and mortality benefit for patients suffering from severe congestive heart failure. However, there are some issues still waiting to be resolved like, prediction of responders vs. nonresponders. We believe that the achievements in tailoring of the therapy to different individuals may help to shed light on these issues and undoubtedly, an optimal programming of these devices may be the key for this purpose.

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