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Dependency of Cardiac Resynchronization Therapy on Myocardial Viability at the LV Lead Position

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OBJECTIVES This study sought to analyze the effectiveness of cardiac resynchronization therapy (CRT) related to the viability in the segment of left ventricular (LV) lead position defined by myocardial deformation imaging.

BACKGROUND Echocardiographic myocardial deformation analysis allows determination of LV lead position as well as extent of myocardial viability.

METHODS Myocardial deformation imaging based on tracking of acoustic markers within 2-dimensional echo images (GE Ultrasound, GE Healthcare, Horton, Norway) was performed in 65 heart failure patients (54 $\pm$ 6 years of age, 41 men) before and 12 months after CRT implantation. In a 16-segment model, the LV lead position was defined based on the segmental strain curve with earliest peak strain, whereas the CRT system was programmed to pure LV pacing. Nonviability of a segment (transmural scar formation) was assumed if the peak systolic circumferential strain was $>$–11.1%.

RESULTS In 47 patients, the LV lead was placed in a viable segment, and in 18 patients, it was placed in a nonviable segment. At 12-month follow-up there was greater decrease of LV end-diastolic volumes (58 $\pm$ 13 ml vs. 44 $\pm$ 12 ml, $p = 0.0388$) and greater increase of LV ejection fraction (11 $\pm$ 4% vs. 5 $\pm$ 4%, $p = 0.0343$) and peak oxygen consumption (2.5 $\pm$ 0.9 ml/kg/min vs. 1.7 $\pm$ 1.1 ml/kg/min, $p = 0.0465$) in the viable compared with the nonviable group. The change in LV ejection fraction and the reduction in LV end-diastolic volumes at follow-up correlated to an increasing peak systolic circumferential strain in the segment of the LV pacing lead ($r = 0.61$, $p = 0.0274$ and $r = 0.64$, $p = 0.0412$, respectively). Considering only patients with ischemic heart disease, differences between viable and nonviable LV lead position group were even greater.

CONCLUSIONS Preserved viability in the segment of the CRT LV lead position results in greater LV reverse remodeling and functional benefit at 12-month follow-up. Deformation imaging allows analysis of viability in the LV lead segment. (J Am Coll Cardiol Img 2011;4:366–74) © 2011 by the American College of Cardiology Foundation

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Cardiac resynchronization therapy (CRT) is used for the treatment of advanced drug-refractory heart failure of ischemic and nonischemic origin (1–5). However, up to one-third of patients do not respond to CRT using standard clinical selection criteria (5,6). Factors influencing the patient's response to CRT are not completely understood. Echocardiographic parameters suggested to evaluate mechanical dyssynchrony and predict CRT success have not been confirmed in a large multicenter study (7–9). Technical and procedural factors such as optimal left ventricular (LV) lead placement seem to have an important impact. Butter et al. (10) demonstrated in an experimental analysis that the LV lead should be placed in the area of greatest delay in mechanical contraction and electrical activation to achieve the optimal resynchronization effect. Clinical studies confirmed that concurrence of the LV lead position and the LV segment with latest contraction before CRT results in significantly better effectiveness of CRT on LV function and clinical outcome (11,12). Ischemic etiology of heart failure has been identified as a predictor of impaired responsiveness (13). The extent of scar tissue has been shown to define the response to CRT (14–17). The response to CRT may thus be directly related to the extent of myocardial viability in the area of the LV lead and nonresponse in ischemic heart failure may be the consequence of the LV lead being positioned in a scarred segment without functional capacity.

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Myocardial deformation imaging can be used to define CRT LV lead position and determine myocardial viability. Temporal analysis of segmental myocardial deformation curves has been shown to allow definition of LV lead position (11,18). The magnitude of peak segmental myocardial strain closely relates to segmental viability (19,20).

This study sought to determine CRT effectiveness related to the viability of the segment with the LV lead position as well as the area surrounding the LV lead segment. Viability was defined by analysis of myocardial deformation.

METHODS

Patients. We included in this study 65 consecutive patients (mean age 55 ± 4 years, 39 men) with end-stage heart failure severe LV systolic dysfunction (ejection fraction [EF] <35%), scheduled for new implantation of a biventricular pacemaker. Patients had to be in New York Heart Association functional class III (n = 48) or IV (n = 17) despite optimal pharmacologic therapy and show sinus rhythm with a QRS interval duration >120 ms. Etiology of heart failure was ischemic in 46 patients and nonischemic in 19 patients based on coronary angiography. No studies to assess myocardial viability were performed before CRT implantation. This study was approved by the local ethical committee and all subjects gave written informed consent.

Biventricular device implantation. The LV pacing lead was inserted by a transvenous approach through the coronary sinus into a cardiac vein of the free wall. An average of 2.1 veins were tried intraoperatively to achieve an optimal LV lead position. Optimal LV lead position was considered to be when the width of the QRS complex was minimized and the arterial systolic pressure increased. No information about presence of myocardial viability or area of latest activation was provided intraoperatively. The right atrial and ventricular leads were positioned conventionally. All patients received a biventricular cardioverter-defibrillator (Attain-System with InSync Marquis, Medtronic, Minneapolis, Minnesota [n = 40] or Aesula-System with Epic HF V-339, St. Jude Medical, St. Paul, Minnesota [n = 25]).

Post-operatively the optimal atrioventricular time was determined by Doppler echocardiography and set between 100 and 150 ms (mean time 122 ± 10 ms) in 61 patients and between 70 and 85 ms (mean time 75 ± 8 ms) in 4 patients. The ventriculo-ventricular time was set to 0 in all patients. Thresholds for sensing and pacing of the LV lead at the final position were documented.

To exclude LV lead dislocation and change of AV time, the device was controlled at 6- and 12-month follow-up. Seven days after implantation of the CRT system, transient programming of the device to pure LV pacing was performed during an echocardiographic examination to determine the LV lead position.

Echocardiography. All studies were performed before CRT, one day after implantation, and at 12 (± 3)-month follow-up using a Vivid Seven digital ultrasound scanner (General Electric, Horton, Norway). Using apical 4- and 2-chamber views, LVEF and left ventricular end-diastolic volume (LVEDV) were determined employing biplane Simpson method. The physician performing the echocardio-

ABBREVIATIONS AND ACRONYMS

CRT = cardiac resynchronization therapy

EF = ejection fraction

LV = left ventricle/ventricular

LVEDV = LV end-diastolic volume

ROC = receiver-operator characteristic

VO_2max = peak oxygen consumption

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