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Regional Left Ventricular Electrical Activation and Peak Contraction Are Closely Related in Candidates for Cardiac Resynchronization Therapy

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ABSTRACT

OBJECTIVES This study determined the relationship between the timing of left ventricular (LV) electrical activation and peak contraction at potential LV pacing locations in candidates for cardiac resynchronization therapy (CRT).

BACKGROUND Targeting the LV lead to the region of latest electrical activation or the segment of latest peak contraction has both been shown to improve CRT response. Whether these regions correspond within CRT patients is uncertain.

METHODS Twenty-eight consecutive CRT candidates underwent intraprocedural coronary venous electroanatomic mapping using EnSite NavX. Peak contraction time of the mapped LV regions was determined using longitudinal strain derived from speckle tracking echocardiography. Electrical activation and peak contraction times were correlated on a per patient basis, and the regions of latest electrical activation and latest peak contraction were compared.

RESULTS Successful measurements by both techniques allowed analysis in 23 of 28 patients. There was a strong positive correlation between electrical activation and peak contraction times within each patient ($R^2 = 0.85 \pm 0.09$). However, the magnitude of the electrical activation-peak contraction relationship varied greatly among patients (slope of regression line: 4.05 ± 3.23). The regions of latest electrical activation and latest peak contraction corresponded in 19 of 23 (83%) patients and were adjacent in 4 patients.

CONCLUSIONS There is a close relationship between the timing of LV electrical activation and peak contraction in CRT candidates. This finding suggests that a strategy of determining the latest activated LV region based on speckle tracking echocardiography corresponds to that based on intracardiac measurements of electrical activation. (J Am Coll Cardiol EP 2017;■:■–■) © 2017 by the American College of Cardiology Foundation.

Cardiac resynchronization therapy (CRT) has become an important treatment for heart failure patients with left ventricular (LV) systolic dysfunction and evidence of LV conduction delay. CRT aims to resynchronize the electrical ventricular activation by paced pre-excitation of the delayed LV lateral wall. CRT restores coordinated ventricular contraction, improves LV systolic function, and reverses ventricular remodeling (1). The position of the LV lead with respect to the region of latest activation has been shown to be an important determinant of CRT response. Studies that focus on

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ABBREVIATIONS AND ACRONYMS

CRT = cardiac resynchronization therapy

CS = coronary sinus

EAM = electroanatomic mapping

LAO = left anterior oblique

LBBB = left bundle branch block

LV = left ventricular

MUMC = Maastricht University Medical Center

RAO = right anterior oblique

electrical activation have demonstrated that a greater delay in time from onset of the QRS complex to the locally sensed LV lead electrogram is associated with a greater likelihood of benefit from CRT (2). Other studies have used speckle tracking–based strain measures of mechanical activation and have suggested better CRT outcome when the LV lead position coincides with the segment of latest peak contraction (3). Whether the region of latest electrical activation corresponds with the segment of latest peak contraction is uncertain. On the one hand, pre-clinical studies in nonfailing canine hearts have previously shown that electrical and mechanical activation of the heart are closely coupled (4-6). On the other hand, the results of 2 recent small-scale studies on this subject in CRT patients have been conflicting (7,8). Therefore, it remains unclear whether the pre-clinical results can be extrapolated to the dyssynchronous failing human heart. The purpose of the present study was to perform a within-patient comparison of the timing of LV electrical activation and peak contraction at potential LV pacing locations that are accessible via the coronary veins in patients undergoing CRT.

METHODS

STUDY POPULATION. This study was conducted in 28 consecutive patients enrolled for CRT with LV ejection fractions of <35%, who were in New York Heart Association functional classes II, III, or ambulatory IV, and who had left bundle branch block (LBBB) according to specific criteria (9) or non-LBBB with a QRS duration of >150 ms. The study protocol was approved by the Maastricht University Medical Center (MUMC) Institutional Review Board.

CORONARY VENOUS ELECTROANATOMIC MAPPING. All patients underwent intraprocedural coronary venous electroanatomic mapping (EAM) at the MUMC as described previously (10). In brief, before LV lead placement, a 0.014-inch guidewire (Vision Wire, Biotronik SE&Co. KG, Berlin, Germany), which permits unipolar sensing and pacing, was inserted into the coronary sinus (CS) and connected to EnSite NavX (St Jude Medical, St. Paul, Minnesota). The guidewire was manipulated to various CS branches, creating an anatomic map, along with determining local electrical activation time during intrinsic ventricular activation. The coronary venous anatomy was classified using the segmental approach (11) by detailed evaluation of biplane coronary venograms. In the left anterior oblique (LAO) image, the CS was divided into anterior, lateral, and posterior areas, and the distribution of the branches was described similarly. The right anterior oblique (RAO) image was used to divide CS branches into basal, mid-ventricular, and apical segments. In each patient, the electrical activation time of a myocardial segment was calculated as the average of all electrical activation times measured within that segment during mapping. After the mapping procedure, the LV lead was positioned in a lateral or posterolateral vein according to routine clinical practice.

ECHOCARDIOGRAPHY. Standard 2-dimensional echocardiography was performed within 2 weeks before CRT implantation at the MUMC using a commercial machine (Philips IE 33, Philips Medical Systems, Andover, Massachusetts). Routine gray-scale cine loop images were acquired in standard apical views with a frame rate of at least 50 Hz and digitally stored for post-processing offline (Xcelera software R3.3L1; Philips, Eindhoven, the Netherlands). LV end-diastolic volume, LV end-systolic volume, and LV ejection fraction were calculated using Simpson's biplane method. Speckle tracking 2-dimensional longitudinal strain analysis was performed at the University Medical Center Utrecht by an experienced observer blinded to the electrical data using Cardiac Performance Analysis software version 1.2 (Tomtec Imaging Systems, Unterschleissheim, Germany). The endocardial border was manually traced in end systole. Subsequently, the speckle tracking software automatically analyzed frame-by-frame movement of the stable patterns of acoustic markers (speckles) to generate time–strain curves over the cardiac cycle of the myocardial segments. Because the area of the LV that can be approached for EAM via the CS is limited to the LV free wall, the assessment of segmental time-to-peak contraction was also limited to the LV free wall segments. The time-to-peak contraction of each mapped myocardial segment was measured in milliseconds from QRS onset to peak longitudinal strain. If segmental time–strain curves showed >1 peak, the first peak was assessed. Echocardiographic images that were of insufficient quality for speckle tracking strain analysis and myocardial segments with likely scar (low amplitude longitudinal strain curves <5.3%, thin wall ≤0.5 cm, abnormal increase in acoustic reflectance, and akinetic wall motion) (12,13) were handled as missing data.

COMPARISON OF ELECTRICAL ACTIVATION AND PEAK CONTRACTION TIMES. For each patient, the electrical activation and peak contraction times of each myocardial segment were compared separately.