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**Title:** Left ventricular mechanics in advanced heart failure patients  
**Issue Date:** 2015-11-03
CHAPTER 5

Effect of cardiac resynchronization therapy on subendocardial and subepicardial left ventricular twist mechanics and relation to favorable outcome.

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The analysis of left ventricular (LV) mechanics provides novel insights into the effects of cardiac resynchronization therapy (CRT) on LV performance. Currently, advances in speckle-tracking echocardiography analysis have permitted to characterize subendo- and subepicardial LV twist. This study investigated the role of the acute changes in subendo- and subepicardial LV twist for the prediction of mid-term beneficial effects of CRT.

A total of 84 heart failure patients scheduled for CRT were recruited. All patients underwent echocardiography prior to, within 48 hours after CRT implantation, and at 6 months follow-up. The assessment of LV volumes, ejection fraction (EF) and mechanical dyssynchrony (SDI) was performed with real-time 3D echocardiography. The assessment of subendo- and subepicardial LV twist was performed with 2D speckle-tracking echocardiography. Favorable outcome was defined by the occurrence of reduction ≥15% in LV end-systolic volume associated to improvement ≥1 in NYHA functional class at 6 months follow-up. At 6 months follow-up, 53% of the patients showed a favorable outcome. Ischemic etiology for heart failure, baseline SDI, immediate improvement in LVEF, immediate improvement in SDI, and immediate improvement in subendo- and subepicardial LV twist were significantly related to favorable outcome. However, at multivariable logistic regression analysis, only the immediate improvement of subepicardial LV twist was independently related to favorable outcome (odds ratio=2.31, 95%CI=1.29-4.15, p=0.005). Furthermore, the immediate improvement of subepicardial LV twist had incremental value over established parameters. In conclusion, the immediate improvement in subepicardial LV twist (but not subendocardial LV twist) is independently related to favorable outcome after CRT.
INTRODUCTION

Recent advances in speckle-tracking echocardiography analysis have permitted to characterize subendo- and subepicardial left ventricular (LV) twist. The aim of the present study was to investigate the changes induced by cardiac resynchronization therapy (CRT) on the rotational mechanics detected with speckle-tracking echocardiography. Specifically, the role of the acute changes in subendo- and subepicardial LV twist for the prediction of mid-term beneficial effects of CRT (LV reverse remodeling associated with clinical improvement at 6 months follow-up), was explored over the classical parameters including mechanical LV dyssynchrony and LV ejection fraction (EF).

METHODS

A total of 106 consecutive heart failure patients scheduled for CRT were included. According to current guidelines, the inclusion criteria were: New York Heart Association (NYHA) functional class III-IV, sinus rhythm, LVEF ≤35% and QRS duration ≥120 ms. Etiology of heart failure was considered ischemic in the presence of significant coronary artery disease (>50% stenosis in ≥1 major epicardial coronary artery) on coronary angiography and/or a history of myocardial infarction or revascularization.

All patients underwent complete baseline clinical evaluation, 12-lead surface electrocardiogram and transthoracic echocardiography prior to and within 48 hours after CRT device implantation. Global measures of LV performance were evaluated with real-time 3-dimensional (3D) echocardiography and 2-dimensional (2D) speckle tracking. The assessment of LV volumes, ejection fraction and mechanical dyssynchrony was performed with real-time 3D echocardiography. The assessment of subendo- and subepicardial LV twist was performed with 2D speckle-tracking. In addition, the clinical and echocardiographic evaluation was repeated 6 months after CRT implantation. Favorable outcome was defined by the occurrence of LV reverse remodeling (reduction ≥15% in LV end-systolic volume) associated with clinical improvement (≥1 NYHA functional class) at 6 months follow-up. Finally, the variables related to favorable outcome were investigated and the role of the newest rotational parameters over the established parameters was explored.

All patients were imaged in left lateral decubitus position using a commercially available system (iE33, Philips Medical Systems, Bothell, Washington) equipped with an X3, fully sampled matrix transducer. Apical full-volume data sets were obtained at a frame rate of 20-35 frames/sec and quantitative analysis was performed off-
line using a semiautomated contour tracing algorithm (Q-Lab, version 6.0, Philips Medical Systems), as previously described.\textsuperscript{10-12} LV volumes and ejection fraction were measured. In addition, the systolic dyssynchrony index (SDI) was obtained as marker of global LV dyssynchrony, as previously reported.\textsuperscript{10-12}

Two-dimensional gray-scale harmonic images were obtained in the left lateral decubitus position using a commercially available ultrasound system (iE33, Philips Medical Systems, Bothell, Washington) equipped with a broadband S5-1 transducer. Parasternal short-axis images were acquired at 2 different levels: 1) basal level, identified by the mitral valve; 2) apical level, defined as the smallest cavity achievable distally to the papillary muscles (just proximal to the level with end-systolic luminal obliteration), moving the probe down and slightly laterally. Patients without appropriate apical level were excluded from the study. Frame rate ranged from 55 to 90 frame/s and 3 cardiac cycles for each parasternal short-axis level were stored in cine-loop format for the off-line analysis (Q-Lab, version 6.0, Philips Medical Systems).

In the current study, 2D speckle-tracking analysis (Q-Lab, version 6.0, Philips Medical Systems) was performed by placing manually several small kernel regions in the subendo- and subepicardial border on an end-diastolic frame. Then, the software tracked the 2 borders frame by frame and the tracking could be adjusted manually, if needed.\textsuperscript{4}

The 2D speckle-tracking software calculates LV rotation from the apical and basal short-axis images as the average angular displacement of the 6 standard segments referring to the ventricular centroid, frame by frame. Counterclockwise rotation was marked as positive value and clockwise rotation as negative value when viewed from the LV apex. LV twist was defined as the net difference (in degrees) of apical and basal rotation at isochronal time points. For the calculation of LV twist, averaged apical and basal rotation data were exported to a spreadsheet program (Excel 2003; Microsoft Corporation, Redmond, Washington). The following measurements were derived both for subendo- and subepicardial layers: peak apical and basal rotation, peak LV twist.

All patients received a biventricular pacemaker with cardioverter-defibrillator function (Contak Renewal 4RF, Boston Scientific St. Paul, Minnesota; or InSync Sentry, Medtronic Inc, Minneapolis, Minnesota; Lumax 340 HF-T, Biotronik, Berlin). The right atrial and ventricular leads were positioned conventionally. All LV leads were implanted transvenously, and positioned preferably in a (postero-)lateral vein. A coronary sinus venogram was obtained using a balloon catheter, followed by the insertion of the LV pacing lead. An 8-F guiding catheter was used to place the LV lead (Easytrak, Boston Scientific, or Attain-SD, Medtronic, or Corox OTW Biotronik) in the coronary sinus.
All continuous variables are presented as mean ± SD. Categorical data are presented as numbers and percentages. Unpaired T-test was used to compare baseline, immediately after CRT and 6 months follow-up parameters between patients with vs. without favorable outcome. Chi-squared test was used to compare categorical variables between patients with and without favorable outcome. Paired T-test was used to compare baseline and 6 months follow-up data in each group of patients. In order to identify variables related to favorable outcome at 6 months follow-up, uni- and multivariable logistic regression analysis were performed including clinical and echocardiographic characteristics of the patients at baseline and immediately after CRT. Only significant (p < 0.05) univariable factors were entered as covariates in the multivariable analysis using backward selection model. Finally, the incremental value of the newest rotational parameters (subendo- and subepicardial LV twist) over other variables was assessed by calculating the global chi-square test for each model. All statistical tests were 2-sided, and a p value < 0.05 was considered significant. A statistical software program SPSS 16.0 (SPSS Inc, Chicago, IL, USA) was used for statistical analysis.

RESULTS

A total of 22 of 106 (21%) patients were excluded because the image quality did not allow reliable analysis. Therefore, the overall patient population consisted of 84 patients. Of the 84 heart failure patients enrolled, 4 did not complete the 6 months follow-up; 1 patients died of worsening heart failure, 1 had LV pacing switched off due to intolerable phrenic stimulation, and 2 were lost to follow-up.

Baseline characteristics of the overall patient population are listed in Table 1. The mean age was 65 ± 9 years, and all the patients had dilated LV with poor LV function (mean LVEF 26 ± 5%). In addition, the LV rotational parameters were severely reduced in the subendo- and subepicardial layers (peak subendo- and subepicardial LV twist were 4.2 ± 2.9° and 2.3 ± 1.8°, respectively).

At 6 months follow-up, 42 of 80 (53%) patients showed a favorable outcome (LV reverse remodeling associated to clinical improvement at 6 months follow-up).

The baseline parameters of the patients with and without favorable outcome (LV reverse remodeling associated with clinical improvement at 6 months follow-up) are reported in Table 2. The patients with favorable outcome had less frequently ischemic etiology of heart failure (p = 0.025). Both groups of patients showed comparable LV volumes and ejection fraction. However, the baseline SDI was significantly larger in the group of patients with favorable outcome (8.1 ± 2.3% vs. 6.4
± 1.4%, p <0.001). In addition, no differences in baseline subendocardial LV twist (4.0 ± 3.1° vs. 4.5 ± 2.7°, p = 0.45) or subepicardial LV twist (1.9 ± 1.8° vs. 2.6 ± 1.8°, p = 0.10) were observed.

Immediately after CRT, the group of patients with favorable outcome showed a significantly larger improvement in LVEF and SDI than patients without favorable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Heart failure patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
<td><strong>Heart failure patients</strong></td>
</tr>
<tr>
<td><strong>Variable</strong></td>
<td><strong>Heart failure patients</strong></td>
</tr>
<tr>
<td>Age (years)</td>
<td>65 ± 9</td>
</tr>
<tr>
<td>Male/female</td>
<td>55/29</td>
</tr>
<tr>
<td><strong>Medication</strong></td>
<td></td>
</tr>
<tr>
<td>ACE Inhibitors</td>
<td>76 (91%)</td>
</tr>
<tr>
<td>β-blockers</td>
<td>71 (85%)</td>
</tr>
<tr>
<td>Diuretics and/or spironolactone</td>
<td>71 (85%)</td>
</tr>
<tr>
<td><strong>Etiology of the heart failure</strong></td>
<td></td>
</tr>
<tr>
<td>Ischemic</td>
<td>44 (52%)</td>
</tr>
<tr>
<td>Non-ischemic</td>
<td>40 (48%)</td>
</tr>
<tr>
<td><strong>NYHA functional class III/IV, n</strong></td>
<td>81/3</td>
</tr>
<tr>
<td>QRS duration (ms)</td>
<td>151 ± 29</td>
</tr>
<tr>
<td>LV end-diastolic volume (ml)</td>
<td>200 ± 61</td>
</tr>
<tr>
<td>LV lead positioned in postero-lateral vein</td>
<td>80 (95%)</td>
</tr>
<tr>
<td>LV end-systolic volume (ml)</td>
<td>147 ± 50</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>26 ± 5</td>
</tr>
<tr>
<td>Systolic Dyssynchrony Index (%)</td>
<td>7.3 ± 2.1</td>
</tr>
<tr>
<td>Peak subendocardial apical rotation (°)</td>
<td>2.5 ± 2.1</td>
</tr>
<tr>
<td>Peak subendocardial basal rotation (°)</td>
<td>-2.5 ± 2.1</td>
</tr>
<tr>
<td>Peak subendocardial LV twist (°)</td>
<td>4.2 ± 2.9</td>
</tr>
<tr>
<td>Peak subepicardial apical (°)</td>
<td>1.5 ± 1.4</td>
</tr>
<tr>
<td>Peak subepicardial basal rotation (°)</td>
<td>-1.7 ± 1.4</td>
</tr>
<tr>
<td>Peak subepicardial LV twist (°)</td>
<td>2.3 ± 1.8</td>
</tr>
</tbody>
</table>

ACE: angiotensin-converting enzyme; LV: left ventricular; NYHA: New York Heart Association
Effect of cardiac resynchronization therapy on subendo- and subepicardial left ventricular twist mechanics

Outcome (delta [Δ]) LVEF was 8 ± 6% vs. 3 ± 4%, p <0.001 and Δ SDI was -2.6 ± 2.8% vs. -0.3 ± 2.1%, p <0.001; Figure 1 A, B). Similarly, the improvement in subendo- and subepicardial LV twist immediately after CRT was more pronounced in patients with favorable outcome (Δ subendocardial LV twist was 1.9 ± 2.8° vs. 0.3 ± 2.9°, p = 0.012 and 2.1 ± 2.1° vs. -0.2 ± 1.7°, p <0.001; Figure 1 C, D).

Table 2. Patients with vs. without favorable outcome (left ventricular reverse remodeling associated to clinical improvement at 6 months follow-up)

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Patients with favorable outcome (n = 42)</th>
<th>Patients without favorable outcome (n = 38)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic etiology, n (%)</td>
<td>16 (38)</td>
<td>24 (63)</td>
<td>0.025</td>
</tr>
<tr>
<td>QRS duration (ms)</td>
<td>152 ± 27</td>
<td>151 ± 31</td>
<td>0.87</td>
</tr>
<tr>
<td>NYHA functional class I/II/III/IV, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0/0/41/1</td>
<td>0/0/36/2</td>
<td>0.50</td>
</tr>
<tr>
<td>6 months follow-up</td>
<td>10/31/1/0*</td>
<td>2/8/26/2a</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV end systolic-volume (ml)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>150 ± 47</td>
<td>143 ± 54</td>
<td>0.50</td>
</tr>
<tr>
<td>6 months follow-up</td>
<td>107 ± 39a</td>
<td>149 ± 54</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>26 ± 6</td>
<td>26 ± 5</td>
<td>0.97</td>
</tr>
<tr>
<td>6 months follow-up</td>
<td>38 ± 7a</td>
<td>27 ± 7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic Dyssynchrony Index (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>8.1 ± 2.3</td>
<td>6.4 ± 1.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6 months follow-up</td>
<td>5.1 ± 1.8a</td>
<td>8.0 ± 3.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak subendocardial LV twist (°)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>4.0 ± 3.1</td>
<td>4.5 ± 2.7</td>
<td>0.45</td>
</tr>
<tr>
<td>6 months follow-up</td>
<td>5.7 ± 2.9a</td>
<td>3.8 ± 2.8</td>
<td>0.004</td>
</tr>
<tr>
<td>Peak subepicardial LV twist (°)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>1.9 ± 1.8</td>
<td>2.6 ± 1.8</td>
<td>0.10</td>
</tr>
<tr>
<td>6 months follow-up</td>
<td>4.0 ± 2.1a</td>
<td>1.9 ± 1.8†</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*: p <0.01 vs. baseline; †: p <0.05 vs. baseline
LV: left ventricular; NYHA: New York Heart Association
**Figure 1.** Changes immediately after cardiac resynchronization therapy (CRT) in left ventricular ejection fraction (LVEF, Panel A), systolic dyssynchrony index (SDI, Panel B), subendocardial left ventricular (LV) twist (Panel C) and subepicardial LV twist (Panel D) in patients with favorable outcome (LV reverse remodeling associated to clinical improvement at 6 months follow-up, white bars) and without favorable outcome (no LV reverse remodeling and clinical improvement at 6 months follow-up, black bars).

**Figure 2.** Example of patient with LV reverse remodeling associated to clinical improvement at 6 months follow-up. Subendo- and subepicardial left ventricular (LV) twist were both significantly increased at 6 months follow-up and a parallel reduction of systolic dyssynchrony index (SDI) was observed between baseline and 6 months follow-up.
Finally, at 6 months follow-up, a further improvement in subendo- and subepicardial LV twist was observed in patients showing favorable outcome (from $4.0 \pm 3.1^\circ$ to $5.7 \pm 2.9^\circ$, $p = 0.002$ for subendocardial LV twist and from $1.9 \pm 1.8^\circ$ to $4.0 \pm 2.1^\circ$, $p <0.001$ for subepicardial LV twist; Table 2). In Figure 2 an example of a patient with favorable outcome (LV reverse remodeling associated to clinical improvement at 6 months follow-up) is shown. In contrast, patients without favorable outcome showed a trend towards a deterioration of subendocardial LV twist (from $4.5 \pm 2.7^\circ$ to $3.8 \pm 2.8^\circ$, $p = 0.11$; Table 2), and a significant worsening of subepicardial LV twist, (from $2.6 \pm 1.8^\circ$ to $1.9 \pm 1.8^\circ$, $p = 0.037$; Table 2).

At univariable logistic regression, ischemic etiology for heart failure, baseline SDI, immediate improvement in LVEF, immediate improvement in SDI, and immediate improvement in subendo- and subepicardial LV twist were significantly related to favorable outcome. At multivariable logistic regression analysis, only the immediate improvement of subepicardial LV twist was independently related to favorable outcome at 6 months (odds ratio $= 2.31$, 95%CI $= 1.29-4.15$, $p = 0.005$; Table 3).

### Table 3. Variables related to favorable outcome (left ventricular reverse remodeling associated to clinical improvement at 6 months follow-up)

<table>
<thead>
<tr>
<th>Dependent variable: favorable outcome</th>
<th>Univariable analysis</th>
<th>Multivariable analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td><strong>Baseline independent variables:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>$0.98$ (0.93-1.03)</td>
<td>0.36</td>
</tr>
<tr>
<td>Male gender</td>
<td>$0.52$ (0.20-1.36)</td>
<td>0.18</td>
</tr>
<tr>
<td>Ischemic etiology</td>
<td>$0.36$ (0.14-0.89)</td>
<td>0.027</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>$1.00$ (0.92-1.01)</td>
<td>0.97</td>
</tr>
<tr>
<td>Systolic Dyssynchrony Index (%)</td>
<td>$1.75$ (1.26-2.43)</td>
<td>0.001</td>
</tr>
<tr>
<td>Peak subendocardial LV twist (°)</td>
<td>$0.94$ (0.81-1.02)</td>
<td>0.45</td>
</tr>
<tr>
<td>Peak subepicardial LV twist (°)</td>
<td>$0.81$ (0.62-1.05)</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Immediately after CRT independent variables:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ LV ejection fraction (%)</td>
<td>$1.25$ (1.11-1.40)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Δ Systolic Dyssynchrony Index (%)</td>
<td>$0.68$ (0.55-0.85)</td>
<td>0.001</td>
</tr>
<tr>
<td>Δ Subendocardial LV twist (°)</td>
<td>$1.23$ (1.04-1.47)</td>
<td>0.017</td>
</tr>
<tr>
<td>Δ Subepicardial LV twist (°)</td>
<td>$2.21$ (1.50-3.27)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI: confidence intervals; CRT: cardiac resynchronization therapy; LV: left ventricular; OR: odds ratio; Δ: immediate change (immediately after CRT value – baseline value)
Figure 3. Incremental value of the variables detected immediately after CRT over the baseline variables. Bar graph illustrating the incremental value (depicted by chi-square value on the Y-axis) of the immediate improvement in left ventricular (LV) ejection fraction (LVEF) after cardiac resynchronization therapy (CRT) and of the immediate improvement in subendo- and subepicardial LV twist after CRT for the prediction of favorable outcome (LV reverse remodeling associated to clinical improvement at 6 months follow-up). The addition of the immediate improvement in LVEF provides incremental prognostic information to baseline variables (Model 2). Conversely, the addition of the immediate improvement of subendocardial LV twist does not add further incremental prognostic value (Model 3). Finally, the addition of the immediate improvement of subepicardial LV twist provides significant incremental prognostic information over baseline variables and the immediate improvement in LVEF (Model 4).

Model 1: baseline variables (ischemic etiology and systolic dyssynchrony index).
Model 2: model 1 + immediate improvement in LVEF.
Model 3: model 2 + immediate improvement in subendocardial LV twist.
Model 4: model 3 + immediate improvement in subepicardial LV twist.

particular, the immediate improvement of subepicardial LV twist had incremental prognostic value over baseline SDI and the immediate improvement of LVEF. In contrast, the immediate improvement of subendocardial LV twist did not provide any significant incremental prognostic value over baseline SDI and the immediate changes of LVEF (Figure 3).

**DISCUSSION**

The current study provides novel insights in the effects of CRT on LV mechanics by demonstrating that the immediate improvement of subepicardial LV twist after CRT was independently related to favorable outcome at 6 months follow-up. Particularly, the immediate improvement of subepicardial LV twist provided incremental progno-
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...tic value over immediate improvement of LVEF, whereas the immediate improvement of subendocardial LV twist did not.

The contraction of the subepicardial fibers rotates the LV apex in the counterclockwise direction and the LV base in the clockwise direction. Conversely, shortening of the subendocardial fibers rotates the LV apex and LV base in clockwise and counterclockwise directions, respectively. The larger radius of rotation for the subepicardial layer results in the subepicardial fibers having a mechanical advantage in dominating the overall direction of rotation.

Advanced systolic heart failure patients have extensive LV remodeling with severely deteriorated subendo- and subepicardial LV twist, partially related to the LV dilatation and distortion of the spiral architecture of the myofibers and to the altered LV electromechanical activation. Recently, novel speckle-tracking echocardiography analysis has been introduced that permits exploration of subendo- and subepicardial LV twist, and this approach was applied in the current study. A typical patient population was included, characterized by end-stage systolic heart failure, dilated LV and prolonged QRS duration. The patients showed pronounced impairment of rotational parameters, and particularly subendo- and subepicardial LV twist were severely reduced (4.2 ± 2.9° and 2.3 ± 1.8°, respectively) underscoring transmural myocardial dysfunction.

It has recently been shown that CRT can increase global LV twist by restoring a more physiological LV electromechanical activation in advanced heart failure patients. The current findings extend these results by exploring the LV twist in the subendo- and subepicardial layers. In patients with favorable 6 months outcome after CRT (defined as improved symptoms and reverse remodeling), an acute improvement of LV twist was observed in both layers, possibly related to a (partially) restored LV electromechanical activation. These patients showed a further improvement of LV twist in both layers at 6 months follow-up, probably related to LV reverse remodeling with subsequent partial restoration of the spiral architecture of the LV myofibers. It was particularly interesting to note that the immediate improvement in subepicardial LV twist was an independent predictor of favorable outcome at 6 months follow-up, whereas the immediate improvement of subendocardial LV twist was not. Moreover, the immediate improvement in subepicardial LV twist added incremental value over the classical parameters including mechanical LV dyssynchrony and LVEF. This observation underscores that the beneficial effects of CRT at 6 months follow-up may mostly rely on the acute improvement in subepicardial LV twist. Several reasons may explain this important finding. First, subepicardial LV twist may reflect the positive effects of CRT better than subendocardial LV twist, because the subepicardial layer is the major determinant of LV twist. Second, LV pacing in CRT is applied from the epicardial surface which may be more closely
related to mechanical changes in the subepicardial than the subendocardial LV layer. Finally, the immediate changes in subepicardial LV twist is more strongly related to LV energetics and LV dP/dt max than LVEF; therefore, immediate improvement in subepicardial LV twist may identify patients who have better LV energetics after CRT and most likely these patients will improve clinical status and reduce LV volumes.

Accordingly, immediate assessment of changes in rotational mechanics of the subepicardial layer after CRT implantation may be useful to predict a favorable mid-term outcome, although the long-term prognostic value remains to be demonstrated.

Speckle-tracking echocardiography provides reliable values of LV apical rotation, but only when acquisition of the short axis view close to the real LV apex is possible; for this reason, patients without adequate apical acoustic window were excluded in the current study. Moreover, motion throughout the planes of the myocardial regions during the cardiac cycle may reduce the accuracy of speckle tracking analysis in particular at the basal level where this motion is more pronounced.
REFERENCES


