Use of Echocardiography to Optimize Cardiac Resynchronization Therapy

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Echo & CRT

- **Before implantation**
  - Patient selection
  - Optimal site for LV pacing
- **After implantation**
  - Assess response to therapy
  - Optimize device function
Requirements

• Appropriate
• Feasible
• Reproducible
• Practical
Appropriate Use Criteria

- Initial evaluation or re-evaluation after revascularization and/or optimal medical therapy to determine candidacy for device therapy and/or to determine optimal choice of device (Appropriate)
- Initial evaluation for CRT device optimization after implantation (Uncertain)
Appropriate Use Criteria

• Symptoms possibly due to device complication or suboptimal device settings (Appropriate)
• Routine surveillance of implanted device without change in clinical status or cardiac examination (Inappropriate)
46 y/o woman with dilated cardiomyopathy has NYHA class III heart failure despite optimal medical therapy. LVEF=25% and QRS duration=150 ms. What would you recommend?

a. Biventricular pacemaker-defibrillator
b. CRT-D if septal-posterior wall motion delay $\geq 130$ ms
c. CRT-D if interventricular mechanical delay $\geq 40$ ms
d. CRT-D if Yu index $\geq 32$ ms
e. Cardiac MRI to determine presence or absence of myocardial fibrosis
PROSPECT

- 53 centers in Europe, Hong Kong & USA
- 498 patients with standard CRT indications
- 12 echo parameters of dyssynchrony
- Clinical composite score response
  - Sensitivity = 6% to 74%
  - Specificity = 35% to 91%
- LVESV response
  - Sensitivity = 9% to 77%
  - Specificity = 31% to 91%
- Wide variability in analysis
Mayo Clinic Study

- Single center study
- Less variability in analysis
- 131 patients with standard CRT indications
- 14 echo parameters of dyssynchrony
- Predicted reverse remodeling ($\geq 15\% \downarrow$ ESV)
  - Nonischemic: None
  - Ischemic: M-mode SPWMD, TD strain & isovolumic time, but only modest incremental value
- Predicted clinical response ($>10\%$ improvement in MLHFQ, 6MWD, or VO2max)
  - None
Can we do better?
Longitudinal Dyssynchrony Analysis Using TDI

Significant dyssynchrony present if difference in time to peak systolic velocity $\geq 60$ ms

Strain ($\epsilon$)

- Describes deformation (e.g., fractional change in length of myocardial segment)
- Unitless and usually expressed as percentage
- Positive strain (lengthening)
- Negative strain (shortening)
- Longitudinal, circumferential, and radial
Radial Dyssynchrony Analysis Using 2-D Speckle Tracking Strain

Significant dyssynchrony present if difference in time to peak strain $\geq 130$ ms

Response to CRT

<table>
<thead>
<tr>
<th></th>
<th>Longitudinal</th>
<th>Radial</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>72%</td>
<td>84%</td>
<td>88%</td>
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<tr>
<td>Specificity</td>
<td>77%</td>
<td>73%</td>
<td>80%</td>
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</tbody>
</table>

Response to CRT

# Change After CRT

<table>
<thead>
<tr>
<th></th>
<th>Target* (n=103)</th>
<th>Control* (n=104)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYHA Class</strong></td>
<td>-1.1 ± 0.7</td>
<td>-0.8 ± 0.7</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>6MWD (m)</strong></td>
<td>61 ± 76</td>
<td>38 ± 76</td>
<td>0.011</td>
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<tr>
<td><strong>MLHFQ</strong></td>
<td>-22 ± 20</td>
<td>-16 ± 19</td>
<td>0.024</td>
</tr>
<tr>
<td><strong>LVEDV (ml)</strong></td>
<td>-41 ± 34</td>
<td>-23 ± 23</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>LVESV (ml)</strong></td>
<td>-46 ± 33</td>
<td>-26 ± 23</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>LVEF (%)</strong></td>
<td>8 ± 7</td>
<td>5 ± 8</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Mean ± SD

*Adapted from* Khan F, Virdee M, Palmer C *et al.* Targeted left ventricular lead placement to guide cardiac resynchronization therapy—the TARGET study: a randomized, controlled trial. *J Am Coll Cardiol* 2012;59:1509-1518.
Concordant—At optimal site
Adjacent—Within one segment
Remote—At least 2 segments away

58 y/o man with ischemic heart disease has NYHA class III heart failure, an EF=30%, and QRS duration=110 ms. Medications are aspirin 81 mg daily, carvedilol 25 mg b.i.d., lisinopril 20 mg daily, spironolactone 25 mg daily, and furosemide 40 mg daily. What would you recommend?

a. Biventricular pacemaker-defibrillator
b. CRT-D if septal-posterior wall motion delay ≥130 ms
c. CRT-D if interventricular mechanical delay ≥40 ms
d. CRT-D if speckle tracking radial dyssynchrony ≥130 ms
e. Evaluate for heart transplantation
Borderline QRS Duration

• Single center study
• 221 consecutive patients
  - 135 with QRS >130 ms (168 ± 26 ms)
  - 86 with QRS 100-130 ms (115 ± 8 ms)
• 6 echo parameters of dyssynchrony
• Response
  - ≥15% increase in EF and
  - ≥10% decrease in ESV
• 201 with baseline echo data
• 187 with follow-up data after 8 ± 5 months
Ejection Fraction Response to CRT

From Oyenuga O, Hara H, Tanaka H et al. Usefulness of echocardiographic dyssynchrony in patients with borderline QRS duration to assist with selection for cardiac resynchronization therapy. *J Am Coll Cardiol Img* 2010;3:132-140.
Ejection Fraction Response to CRT

Reverse Remodeling After CRT

76 y/o man with ischemic heart disease underwent implantation of CRT-P six months ago. His condition improved initially, but he has developed increasing dyspnea on exertion during the past month. What would you recommend?

a. Increase lower rate limit of CRT pacemaker to increase cardiac output
b. Perform echo-guided device optimization
c. Reposition RV lead on septum
d. Reposition LV lead in another vein
e. Evaluate for heart transplantation
A-V Delay Optimization: Maximizing LV Filling

- Goals
  - Enhance atrial contribution to ventricular filling
  - Program shortest A-V delay without truncating active phase of LV filling
  - Ensure ventricular contraction begins immediately after active phase of LV filling
A-V Delay Optimization

- Inappropriate
  - Atrial fibrillation
  - Frequent PVCs
  - Tachycardia
  - Mitral valve prosthesis
A-V Delay Optimization

- Evaluate device function first
- Temporarily disable
  - Rate response
  - Mode switching
  - Rate adaptive A-V delay
CRT Optimization: Simplified Screening

• **Step 1**: Optimize ECG signal
• **Step 2**: Optimize pulsed Doppler mitral inflow velocity using
  - High sweep speeds
  - Low filters
  - Sample volume set at mitral annulus
CRT Optimization: Simplified Screening

- **Step 3**: Examine mitral inflow pattern at level of annulus. A-V optimization protocol may not be required if
  - E and A waves are clearly identified and separated, *and*
  - Termination of A wave occurs at least 40 milliseconds before QRS onset or mitral valve closure click, *and*
  - E wave less than A wave
A-V Delay Optimization

• Begin with long A-V delay
  - Fusion of E and A waves or
  - Loss of biventricular pacing

• Decrease A-V delay in 20 ms increments until
  - Loss of A wave or
  - A-V delay=60 ms

• Within this range of A-V delay settings, find
  - Optimal LV inflow pattern and
  - Largest stroke volume
Absent or Truncated A Wave: A-V Delay Too Short

E & A Waves Fused: A-V Delay Too Long
Diastolic Mitral Regurgitation: A-V Delay Too Long
Optimal E & A Waves
Optimal Stroke Volume

- Velocity-Time Integral (VTI)
- Assuming constant LVOT diameter, stroke volume is directly proportional to LVOT VTI
- Use VTI as surrogate for stroke volume
- Change >10% is significant
LVOT Velocity-Time Integral

LVOT VTI = 0.167 m
Vmax = 1.06 m/sec
Pk Grad = 4.7 mmHg
Mn Grad = 1.7 mmHg

LVOT 80
V-V Interval Optimization: Restoring Ventricular Synchrony & Maximizing Stroke Volume

- Goals
  - Increase ejection fraction
  - Reduce mitral regurgitation
V-V Interval Optimization

- Inappropriate
  - Frequent PVCs
  - Tachycardia
  - Ejection fraction $\geq 50\%$
V-V Optimization

- Program A-V delay before V-V timing
- Optimal V-V interval usually LV before RV by 20-40 ms
- V-V interval >40 ms uncommon
- Simultaneous biventricular pacing (V-V interval=0) may be best for some patients
LVOT VTI Method

- Use VTI as surrogate for stroke volume
- Change >10% is significant
- Keep RA-LV timing constant while varying V-V timing
  - Changes in RA-LV timing will change LV filling time, VTI, and stroke volume
Problem: Sensed A-V delay is different than optimized A-V delay when RV is paced before LV.

Solution: Pace the atrium above the intrinsic rate.
V-V Interval Optimization

- Exclude anodal stimulation during LV only pacing prior to V-V programming
  - Only applies if pacing polarity is LV tip to RV coil or RV ring

- Measure LVOT VTI
  - LV before RV by 0 ms, 10 ms, 20 ms, 40 ms, 60 ms & 80 ms
  - RV before LV by 10 ms, 20 ms, 40 ms, 60 ms & 80 ms

- Determine optimal V-V interval based on highest LVOT VTI
Tips: CRT Optimization

- Annotate settings on echo image
- Use LVOT VTI and LV inflow pattern obtained with pulsed Doppler
- Sample velocity parallel to flow to ensure measurement of maximum velocity
- Display with lower velocity scales to reduce error of measurements
- Use 100 mm/s sweep speed
- Breathing suspended at end expiration
- Acquire, measure, and average 3 beats
- Wait 1 minute between programming changes before measuring