Cardiac vein selection for CRT

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Extent of LV Reverse Remodeling After 6 months of CRT

• 43% of CRT patients classified as non-responders or negative-responders by LVESV after 6 months (N=302)

Ypendburg et al. JACC 2009;53:483-490
# Factors affecting the outcomes of CRT

<table>
<thead>
<tr>
<th>Factors</th>
<th>Response more likely</th>
<th>Non-response more likely</th>
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</thead>
<tbody>
<tr>
<td><strong>Patient clinical characteristics</strong></td>
<td></td>
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</tr>
<tr>
<td>Cardiomyopathy</td>
<td>Non-ischemic</td>
<td>ischemic</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>male</td>
</tr>
<tr>
<td>QRS duration</td>
<td>&gt; 150 ms</td>
<td>&lt; 150 ms</td>
</tr>
<tr>
<td>QRS morphology</td>
<td>LBBB</td>
<td>RBBB, intraventricular conduction delay</td>
</tr>
<tr>
<td>LV end-diastolic volume</td>
<td>180-240 mL</td>
<td>&gt;240 mL</td>
</tr>
<tr>
<td>Ventricular dyssynchrony</td>
<td>Present</td>
<td>Not present</td>
</tr>
<tr>
<td>Scar burden</td>
<td>Low, not transmural</td>
<td>High transmural</td>
</tr>
<tr>
<td>Right ventricular enlargement, dysfunction</td>
<td>Not present</td>
<td>present</td>
</tr>
<tr>
<td><strong>Device-modifiable factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV lead position</td>
<td>Lateral, base-mid LV</td>
<td>Anterior or inferior septum, apex</td>
</tr>
<tr>
<td>Percentage of BiV pacing</td>
<td>99-100%</td>
<td>&lt; 99%, atrial fibrillation, PVC’s</td>
</tr>
<tr>
<td>AV and VV optimization</td>
<td>Optimal</td>
<td>Not optimal</td>
</tr>
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</table>
A Significant Percentage of Patients Do Not Achieve Optimal BiV Pacing %

In a cohort of > 80,000 patients, 40.7% exhibited less than 98% BiV pacing

Reasons for < 100% pacing
- Atrial fibrillation
- PVC’s
- Competitive AV nodal conduction

Circ Arrhythm Electrophysiol. 2012;5:884-888
Viability of myocardium

• When HF is ischemic, viability of LV myocardium is likely to be a crucial determinant of response to CRT and patients with extensive LV scarring → unlikely to benefit.

• Present practice does not generally include an assessment of LV viability before CRT and further studies are required to determine the role of such assessments in patient selection.

• Response poor to CRT when a posterolateral scar is present
Optimal LV lead placement

• Varies between patients
  - Venous anatomy
  - Regional and global LV mechanical function
  - Myocardial substrate
  - Characterization of electrical activation

• Successful resynchronization depends on pacing from a site which causes a change in activation sequence \(\rightarrow\) improvement in cardiac function

• Systolic improvement and mechanical resynchronization does not always require electrical synchronization

\(\rightarrow\) Lateral free wall - Best response (latest to be activated and stimulation at these sites reliably restores homogenous LV activation)
Optimal LV lead placement

• PATH-CHF II trial
  Anterior pacing – Worsened acute hemodynamics
  Lateral pacing – Increased LV + dP/dt & pulse pressure

• Activating later activated region produced a larger response because it more efficiently restores regional activation synchrony’

• ‘Best site yielded greater improvements in + dP/dt max than pacing the coronary sinus, the lateral LV wall, or the latest activated LV wall as determined by echocardiography’
• Options to overcome suboptimal positioning:
  - Thoracoscopic placement and telescoping method of lead delivery
  - Identifying areas of LV scar (scar imaging),
  - Assessing the latest mechanical or electrical LV activation
  - Image guided or electro-anatomical guided lead placement
  - Device programming

• Emerging techniques
  - Endocardial pacing
  - Implantation of multiple LV leads
  - Multisite pacing
  - Leadless LV pacing and quadripolar leads
Implant Procedure

1. Cannulate coronary sinus
2. Perform venograms
3. Select target vein and leads
4. Place leads
5. Remove implant tools
Initial Problems

- Inability to cannulate the CS = 1-5%
- CS anatomy not good in 20%
- Tortousity of CS
- Scarred LV-problem with high threshold
• Backup pacing should be readily available
  ▪ (LBBB + RBBB = complete heart block)

• RV lead first
  ▪ Can be used to provide backup pacing
  ▪ May also provide a landmark for coronary sinus ostium (proximal end of distal coil is a good marker for CS)
  ▪ Helps to visualize tricuspid valve, which can help locate CS ostium
  ▪ May be more difficult to cannulate the CS with the lead implanted

• LV lead first (alternate option)
  ▪ May be easier to cannulate the CS
  ▪ Additional method may be necessary to provide backup pacing
  ▪ May be more likely to dislodge when going to place RV lead
Step #1: Cannulate the Coronary Sinus
Anatomic Structures Surrounding CS Ostium

- Tricuspid annulus
- Eustachian ridge
- Coronary sinus ostium
- Thebesian valve

Deep STR (45%)
Large ER (25%)
Small CS ostium

Thread-like valve
Bridging valve
Fenestrated valve

Large EV
Step 1: CS Cannulation with Fixed Shape Catheters

• Obtain venous access
• Flush components with heparanized saline
• Attach valve to catheter hub
• Insert dilator through valve/catheter
• Pass guide catheter assembly over long introducer guide wire through introducer sheath, to the atrium
  ▪ It is recommended to use a guide wire when advancing into the heart
• Remove dilator
• Locate the CS by rotating the guide catheter tip posteriorly and to the patient’s left (typically a counter-clockwise rotation)
• Advance the guide catheter 2-3 cm over guide wire to engage the CS
Properly Curved CS Sheath

Three Coronary Access Catheters

Clinical Cardiac Pacing, Defibrillation, and Resynchronization Therapy, 5th, p. 739
Removal of Nonanatomic Catheter

Using standard tools, the optimal site may be as low as 30% as demonstrated in the STARTER Trial.

Removal of Anatomically Shaped Catheter

Clinical Cardiac Pacing, Defibrillation, and Resynchronization Therapy, 5th, p. 739
When one approaches the CS from below, catheter entrance is blocked by the thebesian valve.
Effects of counterclockwise Torque When Catheter Tip Starts **Above** CS

Effects of counterclockwise Torque When Catheter Tip Starts **Below** CS
Demonstration of Torque Control and change in Shape and Trajectory.

Counterclockwise Torque → moves posteroinferior to and toward the RA
CS Cannulation Catheters

Medtronic

Boston Scientific

St. Jude Medical

Pressure Products
Medical Supplies
## Technical difficulties to access the coronary sinus and potential solutions

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Reason of difficulty</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessing the coronary sinus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Prominent sub-eustachian pouch</td>
<td></td>
<td>• Use a large curved guiding sheath balanced on high right atrium</td>
</tr>
<tr>
<td>• Prominent thebesian valve</td>
<td></td>
<td>• Deflectable catheter with back bend moved into the coronary sinus</td>
</tr>
<tr>
<td>• Large left ventricle</td>
<td></td>
<td>• Enter from inferior and ventricular portion where the thebesian valve is less prominent</td>
</tr>
<tr>
<td>• Large right atrium</td>
<td></td>
<td>• Guide-wire and balloon dilatation of the coronary sinus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Remember that the angle between the coronary sinus and the inferior silhouette becomes larger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use large curved guiding sheath</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Looping of large curved deflectable catheter and using back bend to probe septum for coronary sinus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Find the fossa ovalis or bundle of His, working inferiorly to reach the coronary sinus from the roof</td>
</tr>
</tbody>
</table>
Step #2: Perform Venogram
Step 2: Perform Venogram

- Balloon occludes most coronary sinuses – inflates to 10 mm (pre-measure 1.25 cc syringe)
- Lead with a guide wire
- Balloon can be inflated and deflated several times
- Contrast solution can be injected through catheter

Attain® 6215
Venogram Balloon
RAO and LAO with CS branches
Cardiac Venous Anatomy: AP View
Cardiac Venous Anatomy: LAO View
Cardiac Venous Anatomy: RAO View
Lead in Lateral Cardiac Vein

- Atrial Lead
- Left Ventricular Lead
- Right Ventricular Lead
Step #3: Select Target Vein and Left Ventricular Lead
Selecting Vein for LV Lead Placement

- **Target**: Lt. ventricular free wall
  (Lateral, Poster-lateral, Antero-lateral)\(^1,2,3\)
  - A. Lateral (marginal) cardiac vein
  - B. Postero-lateral cardiac vein
  - C. Posterior cardiac vein

- **Sub-optimal lead location**: 
  - D. Middle cardiac vein
  - E. Great cardiac vein

Veins in the 2-5 o’clock positions (LAO) are the best

Load Vein Selector and Delivery Guide into CS Access
Braided core Advanced into CS Over Wire, Followed by Sheath
How to Cannulate a very Proximal Vein Using a vein selector and Extra-stiff wire

Clinical Cardiac Pacing, Defibrillation, and Resynchronization Therapy, 5th, p. 739
Delivery Guide Advanced
Using Vein Selector and Wire as Rail

Perforation of Vein by CS Access Catheter
Shape of Delivery Guide Determines Magnitude of Support

Despite Wire Placement, Pacing Lead Does Not Track into Target Vein.
Step #4:
Place Left-Heart Lead
Medtronic Attain Lt-sided Heart Leads

St. Jude Medical Over-the-Wire(OTW) LV Pacing Leads

Boston Scientific Over-the-Wire LV Pacing Leads

Biotronik Over-the-Wire LV Pacing Leads
Gently Curved, Soft Stabilization Stylet

When Stylet Is Not at Tip,

When Stylet Advanced to Tip,

Delivery Guide Supports Lead as Stylet Is Advanced
## Technical difficulties to advance within the CS and potential solutions

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<td>Advancing within the coronary sinus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Stenosis/spasm</td>
<td>• Pass the guide-wire and perform low-pressure balloon dilatation</td>
<td></td>
</tr>
<tr>
<td>• Valves in the coronary sinus</td>
<td>• Subselection of lateral branches of the proximal posterior vein</td>
<td></td>
</tr>
<tr>
<td>• Excessive tortuosity</td>
<td>• Use stiffer guide-wire</td>
<td></td>
</tr>
<tr>
<td>• Subselection of an atrial vein by a leading</td>
<td>• Use deflectable catheter to open a semi-occlusive valve</td>
<td></td>
</tr>
<tr>
<td>catheter</td>
<td>• Subselection of lateral branches of the proximal posterior vein to access the lateral wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Use soft guide-wires with constant venography</td>
<td></td>
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<tr>
<td></td>
<td>• Understand atrial and ventricular orientation of lead/wires/catheters in the right anterior oblique orientation</td>
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Stylet Dislodges LV Pacing Lead as it is Slowly Withdrawn

To prevent the stylet from displacing the pacing lead

- when the course of the lead and the shape of the stylet do not match,
- The stiffer stylet,
- The longer the stylet remains in a position,

→ Stylet is removed quickly
More Lead Length is Required When the Final Guides/Sheath is removed

The LAO projection is best for judging the amount of slack in the lead.
Step #5:
Remove Implant Tools
Integrated Sliceable Hemostatic Hub Technology

Universal Slitter and Guide Hub (Medtronic)
Remove Catheter: Slitting Procedure

Medtronic Universal II and Adjustable Slitters

Lead Securement
- Universal II – secure with thumb pressure
- Adjustable – mechanically secure in lead channel

Control Grip
- Larger grip with ergonomic hand position

Slit Twice
- Sharp blade to slit two Medtronic catheters in same procedure
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<tr>
<td>Placement of the LV pacing lead</td>
<td>on the lateral wall</td>
<td>• Wedging lead into a second-order branch</td>
</tr>
<tr>
<td></td>
<td>• Lead instability</td>
<td>• Understand fluoroscopic appearance of under- and over-slacked leads</td>
</tr>
<tr>
<td></td>
<td>• Absent lateral veins</td>
<td>• Use second- and third-order branches of veins to produce ‘U-shaped’ or ‘L-shaped’ lead tip</td>
</tr>
<tr>
<td></td>
<td>• Extensive myocardial scar (increased</td>
<td>• Use posterior or anterior veins and subselect anastomotic branches that drain the lateral wall</td>
</tr>
<tr>
<td></td>
<td>thresholds or capture latency)</td>
<td>• Use middle cardiac vein</td>
</tr>
<tr>
<td></td>
<td>• Small lateral ventricular veins</td>
<td>• Maximize tissue contact</td>
</tr>
<tr>
<td></td>
<td>• Variceal veins</td>
<td>• Place the lead slightly antero-lateral or postero-lateral to the scarred lateral wall</td>
</tr>
<tr>
<td></td>
<td>• Phrenic nerve stimulation</td>
<td>• Use anastomotic branches or second-order branches from antero-lateral or postero-lateral circulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use larger stylet-driven leads</td>
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<tr>
<td></td>
<td></td>
<td>• Use larger over-the-wire leads with prominent proximal ‘corkscrew’ curvature</td>
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<tr>
<td></td>
<td></td>
<td>• Subselect second-, third- or fourth-order branches until smaller veins are reached</td>
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<tr>
<td></td>
<td></td>
<td>• Change configuration options</td>
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<tr>
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<td></td>
<td>• Avoid repositioning the LV lead in the same main venous branch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Avoid using lower output but rather repositioning the lead in another ventricular vein</td>
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The Quartet LV lead

- Phrenic Nerve Stimulation
- High Thresholds
- Apical fixation and mid ventricular pacing
- Noninvasive lead repositioning
Short Bipolar Electrode Spacing

Reduces PNS Occurrence

Illustration of **Equal electrode spacing** with larger electrical field, *phrenic nerve stimulated.*

Illustration of **Short bipolar spacing** with smaller electrical field, *phrenic nerve not stimulated.*

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ECG-Steps for optimal LV Sites

1. Check LV free wall lead position using V1.

   • Positive QRS in lead V1 during LV pacing → Free wall in LV (R, Rs, RS)
ECG-Steps for optimal LV Sites (2)

2. Determine LV lead position in circumferential direction using aVF

- Superior axis  → inferior LV lead position
- Inferior QRS axis  → anterior LV lead position

- Lead aVF differentiates between LV lead positions in the circumferential direction

- Lead aVF is expected to differentiate between a more inferolateral (negative aVF) and anterolateral position (positive aVF).

→ Isoelectric QRS pattern in aVF is suggestive of a true lateral LV lead position.
3. Determine LV lead position in apico-basal direction using precordial leads

- Positive precordial QRS concordance during LV pacing → a basal LV lead position.
- QRS transition pattern in V4-6 → a mid-level LV lead position
- QRS transition pattern earlier than V4 → an apical LV lead position

- AqR or Qr complex in lead I is present in 90% of cases of BiV pacing
Distribution of LV lead positions (in percentages) according to the AHA standardized 17-segment model determined by chest radiographs.
The transverse plane location

- Anterior: 7%
- Anterolateral: 7%
- Lateral: 43%
- Posterolateral: 3%
- Posterior: 30%

The cranio-caudal lead position

- Basal: 22%
- Mid: 62%
- Apical: 15%

Anatomical distribution of LV leads

- The 21 studies using the ESC vein territory classification for 3,565 leads.
- In 10 studies & 1,463 leads.

- Combining MPP with acute optimization, both electrical and hemodynamic, be able to reverse the long-term progression of HF and to improve clinical outcomes, resulting in response rates of around 90%.
Conclusion

- With regard to long-term outcome,

  **Optimal positioning of the LV pacing lead, based on the latest electrical delay,**
  - a strong and independent association with reverse remodeling
  - quality of life and with reduced hospitalization
  - improved survival.

- The pacing site that provided optimal hemodynamics was patient-specific
  not associated with specific anatomical locations across the patient population.

- Alternative pacing sites, such as endocardial LV pacing or triple-site pacing,
  have been proposed to achieve a high CRT response rate.
Thank You For Your Attention!
The principle of ECG vector fusion and its use in optimizing BiV devices

RV vs LV vs BiV