How to Approach the Patient with CRT and Recurrent Heart Failure

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Response to CRT

- CRT proven to decrease morbidity and mortality
- Some patients derive little to no benefit from CRT
- These so-called “non-responders” are hard to predict in advance
- Between those who respond to CRT and those who don’t are many patients who have suboptimal response to CRT
- Challenges:
  - Converting non-responders to responders
  - Optimizing response

CRT Optimization

- Device programming so a non-responder or suboptimal responder will derive more benefit from CRT
- Two main device-based approaches
  - Promoting CRT
  - Optimizing timing
    - AV timing
    - VV timing
Promoting CRT
● Unlike conventional pacing, CRT should pace the heart as close to 100% of the time as possible
● To check on continuous CRT pacing
  ○ Use diagnostics to verify how much ventricular pacing is going on
  ○ Program key parameters to encourage maximum CRT pacing
  ○ Use advanced features to increase CRT pacing

Encouraging CRT: MTR
● The Maximum Tracking Rate sets the highest rate at which the ventricles will be paced in response to intrinsic atrial activity
● If the patient has very high intrinsic atrial rates (>MTR) with good conduction, it is possible that the ventricle will not be paced some of the time
● Make sure the MTR is high enough
  ○ Requires clinical judgment to avoid pacing at rates too high for the patient to tolerate
  ○ Atrial tachyarrhythmias can be problematic

Encouraging CRT: AV Delay
● The AV delay is the time between the atrial beat and the corresponding ventricular paced event
● A long AV delay gives the ventricle a lot of “opportunity” to beat on its own before the ventricular output pulse is delivered
● Shorten the AV delay as much as is reasonable
  ○ Paced AV delay
  ○ Sensed AV delay
Encouraging CRT: RRAVD
- Rate-responsive AV delay (RRAVD) is the automatic shortening of the AV delay as the patient’s heart rate increases
- This keeps the AV delay short even during periods of rapid activity
- Program this ON for CRT patients

Encouraging CRT: Negative AV Hysteresis
- Conventional hysteresis encourages intrinsic activity and is incompatible with CRT
- However, negative AV hysteresis automatically shortens the AV delay whenever an intrinsic ventricular event is sensed
- This is the “opposite” of conventional hysteresis and works to discourage intrinsic ventricular activity
- Program this ON

Negative AV Hysteresis

![ECG Diagram](image)
Advantages to Negative AV Hysteresis

- Use of Negative AV Hysteresis will likely permit the clinician to program “normal” AV delays
  ▪ Shorter AV delays can negatively affect ventricular filling
- The AV delay is automatically shortened by a programmable delta value when ventricular activity is sensed

Encouraging CRT: MS

- Mode Switching helps patients prone to high-rate intrinsic atrial activity
- Works by turning off atrial tracking during high-rate intrinsic atrial episodes
- Key in CRT: Program AMS base rate high enough to maintain ventricular pacing

Timing Optimization

- The theory being timing optimization is that proper CRT depends on precise timing of the AV and VV contractions
- Timing must allow for
  ▪ AV delay
    ▪ Adequate time for the passive filling of the ventricles
    ▪ Adequate time for the atrial contraction
    ▪ But not so much time that intrinsic conduction occurs
  ▪ VV timing
    ▪ Proper contraction of the right and left ventricles with respect to each other
Considerations for Timing Optimization

- Baseline dyssynchrony
  - What type of dyssynchrony does the patient have?
  - What is the latest moving ventricular segment?
  - How late is that ventricular segment?

The Most Delayed Site and Pacing Site (S.V. ECHO Evaluation)

Considerations for Timing Optimization

- LV lead position
  - Mid-left lateral position may offer better hemodynamics than anterior placement
  - However, LV lead placement depends greatly on the patient’s anatomy (sometimes the “ideal” position is not possible)
Echo Optimization

- Echocardiography is considered the "gold standard" of timing optimization
- Mitral velocity Doppler echo is used for AV timing optimization
  - Sensed and paced AV delays
- Aortic velocity time integral (VTI) echo is used for VV timing
  - RV and LV synchronization

Goals of AV Optimization

- Allow adequate time for passive filling of the ventricles
  - Atrial diastole
- Allow adequate time for a complete atrial contraction
  - Atrial systole
- Allow for ventricular contraction
  - Ventricular systole
- When AV timing is too short
  - Ventricular filling time may be cut short
  - The atrial kick can be cut short
  - Hemodynamics can be impaired
- When AV timing is too long,
  - Intrinsic ventricular activity can break through
Echo Velocity Doppler Waveform

Mitral Velocity Doppler Echo

Echo for CRT Optimization
Optimization of AV Timing with MVDE
- Measure the intrinsic PR interval and program the AV delay to a shorter value
- Using mitral velocity Doppler echo (MVDE), record and observe the E and A waves
- Shorten the AV delay in steps of 20 ms until you see A waves being cut off—the AV delay is too short
- Now step up the AV delay in 10 ms steps until you see E and A waves with no merging of the E and A waves
- That point is the optimized AV delay

Sensed vs. Paced AV Delay Timing
- Sensed AV delay is from AS to VP
- Paced AV delay is from AP to VP
- There is about a 25 ms difference in sensing relative to the start of atrial depolarization
- Program a sensed AV delay that is about 25 ms shorter than the paced AV delay

AV Delays with CRT Stimulation
- Patient has a good underlying atrial rhythm, optimize the sensed AV delay
  - The patient will likely spend most time in atrial tracking
- Patient requires a lot of atrial pacing, optimize the paced AV delay
  - The patient will mostly be paced in the atrium
- Patients that fall somewhere in-between
  - Optimize both sensed and paced AV delays
VV Timing Optimization
- VV timing refers to the synchronization of RV and LV contractions
- Programmable VV timing
  - Allows for simultaneous pacing (RV and LV together)
  - Allows for an offset (one ventricle before the other)
- The goal of VV timing optimization is to get the ventricles to contract as a unified whole

Programming VV Timing Optimization
Aortic Velocity Time Integral (VTI) Echo

- Measure speed of blood flow past the aortic valve during systole
- Aortic VTI is proportional to cardiac output (CO)
- Adjust the VV timing until you find the greatest possible VTI value

Using VTI Doppler Echo for VV Timing

- After optimizing the sensed and paced AV delays
- Measure the VTI while adjusting the interventricular settings
  - Do LV first and measure VTI values for 20, 40, 60 and 80 ms
  - Record the offset value that produces the greatest VTI value
- Repeat with the RV first
- Optimal VV timing delay is the one that produces the greatest VTI value
Programming QuickOpt™

QuickOpt™ Recommended Values

QuickOpt™ Optimization

QuickOpt™ optimization is clinically-proven to correlate with echo based methods:

- Prospective 11-patient pilot study\(^1\)
  - 99.2% correlation
- Retrospective 61-patient study\(^1\)
  - 97.6% correlation
- Prospective multi-center IDE clinical trial\(^2\)
  - 96.1% correlation for Sensed AV (PV) delay\(^2\)
  - 97.5% correlation for Paced AV delay\(^2\)
  - 96.6% correlation for VV Delay\(^2\)

VV Optimization Studies

**Sequential vs. Simultaneous BiV Pacing:**

- Results are mixed for VV delay optimization\(^1\)
- Optimizing VV delay appears to marginally improve hemodynamics\(^1\):
  - CO, SV, EF, filling time, synchrony, MR, etc.
- Important limitations of VV optimization\(^2\):
  - No additional clinical benefit shown (NYHA, QOL, 6-minute walk test)
  - Nobody has turned a ‘non-responder’ into a ‘responder’

\(^1\) Sogaard P et al. Circulation 2002; 106:2078-2084
\(^2\) van Gelder BM et al. Am J Cardiol 2004; 93:1500-1503
\(^3\) Hay I et al. Circulation 2004; 110:3404-3410
\(^4\) Bordachar P et al. Am J Cardiol 2006; 97:1622-1625
\(^5\) Mortensen PT et al. PACE 2004; 27:339-345
\(^6\) Boriani G et al. Am Heart J 2006; 151:1050-1058
\(^7\) Leon AR et al. JACC 2005; 46:2248-2304

**Timing Cycle Optimization – Essential**

Optimal Delays Change Acutely...and Often\(^1,2\)

- 63 pts, EF < 35%
- NYHA ≥ II, QRS > 150 ms
- LV lead in lateral or posterior-lateral vein

Results:
- Only 3 pts unchanged
- 18 pts needed adjustments at each FU
- VV 73 times in 27 pts
- AV 43 times in 21 pts


**Future: Electronic Repositioning**
Future: Exercise Optimization

Future: Optimization Centers

27 yo M with IDCM
- On transplant list
- Medicines optimized
- EF 17%
- NYHA III
- QRS 166 ms
- RBBB morphology
- NSVT up to 8 beats
27 yo M with IDCM
- Felt worse immediately after implant
- Complained of heart thumping
- Outputs minimized
- Device optimized
- Still felt worse
27 yo M with IDCM

- In clinic
  - Knew when pacing was ON and pacing was OFF
  - Unequivocally felt worse with pacing ON
  - Pacing was ultimately turned OFF
- Got heart transplant a few months later

Conclusions

- Not all HF patients will respond to CRT
- Maximize pacing to derive maximal benefit
- Timing optimization may play a key role in improving response
  - AV timing optimization-Mitral valve Doppler
  - VV timing optimization-Aortic VTI
- Echocardiography is considered the “gold standard” for timing optimization but is a time-consuming procedure
- Device based algorithms can quickly deliver optimization settings that correspond closely to echo results
- Optimization hasn’t been proven to improve outcomes
- Future:
  - Optimize more often
  - Optimize in more ways
Encouraging CRT: RRPVARP

- Rate-responsive PVARP (RRPVARP) automatically shortens the PVARP as the heart rate increases
- This has nothing to do with the accelerometer
- RRPVARP is automatic
- Program it ON

QuickOpt™ Algorithm

- Simple, device-based algorithm
- Works with the intracardiac EGM
- Allows for timing optimization in follow-up sessions
- Studies show that results from QuickOpt correlate extremely closely to results obtained from echocardiographic methods
- Quick, painless, noninvasive, easy

QuickOpt™ in Action: LV Pace
QuickOpt™ in Action: A Pace

QuickOpt™ in Action: V Sense

QuickOpt™ in Action: RV Pace
QuickOpt™ in Clinical Practice
- Recommended for use at every follow-up session
  - Regular optimization assures better CRT function
  - Optimal timing cycle changes frequently

How Important is Timing Optimization?
- AV and VV timing optimization were shown to improve LVEF scores