How to optimize the AV delay and V-V timing after CRT implantation?

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Disclosure-of-Relationship

- *Participant in Industry-Sponsored Research*

–

Biotronik, Boston-Guidant, Medtronic,

St Jude Medical, Sorin-ELA

Questions?

- **Why do we need to optimize AV and VV timings?**
- **AV delay and VV timing optimization in real life?**
- **How to optimize AV and VV timings?**
- **The future?**

Why do we need to optimize AV and VV timings?

- **There is no a single dyssynchrony pattern in CRT patients**
  - **Normal versus long PR interval patients**
  - **Interatrial conduction delay**
  - **Different patterns of ventricular conduction disorders**
  - **Different magnitude of LV dysfunction**
  - **Different extent of LV dyssynchrony**
  - **Different underlying cardiomyopathies (ischemic versus non ischemic)**
  - **Impact of medical treatment on cardiac conduction**
  - **…**

Why do we need to optimize AV and VV timings?

- **Because all the devices allow AV and VV optimization**
- **Because it's not politically correct to let a patient without delays optimization**
- **Because inappropriate cardiac timings may enhance hemodynamic deterioration**
- **Because AV and VV delays optimization may improve the patient's outcome and thus might increase the rate of responders .**

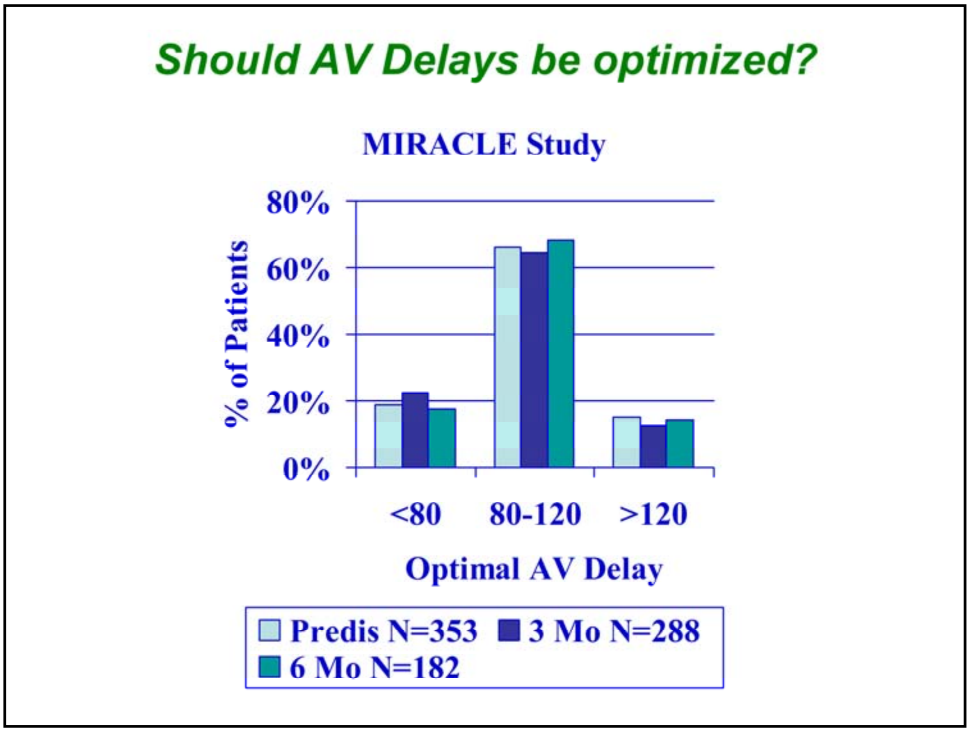
Why do we need to optimize AV and VV timings?

To expect to increase the rate of responders

- **Improvement in patient's selection?**
- **Improvement in leads positioning**
- **Improvement in optimization of device's programming**
- **Improvement in pacing modalities**

Impact of AV delay and VV timing optimization on patient's outcome

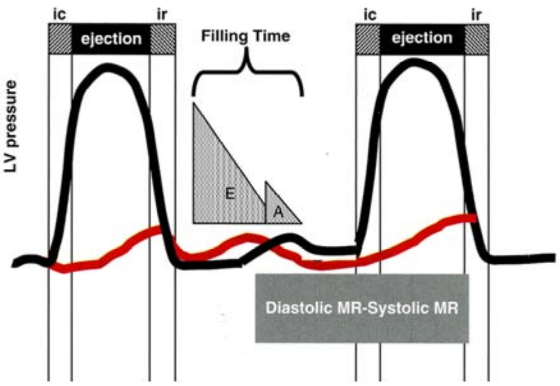
Abraham, HFSA 2007



Key Message:

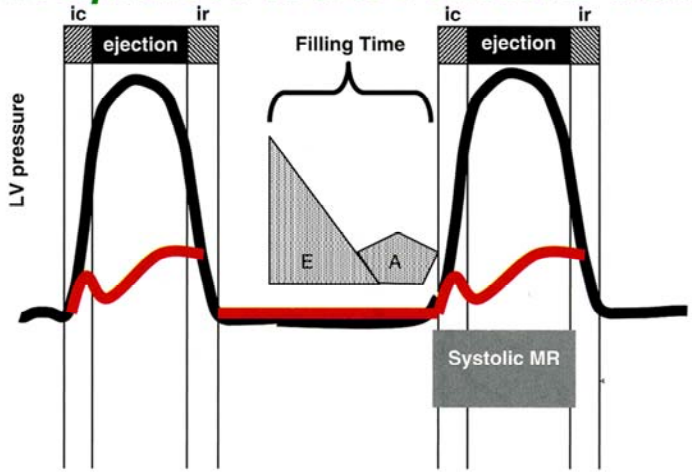
Optimal A-V delay is variable, and AV delay optimization results in greater improvement of LV function after CRT.

Consequences of a too long AV delay



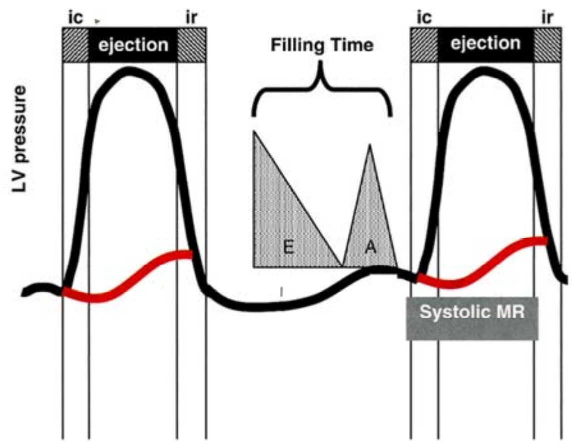
Consequences of a too long AV delay

Consequences of a too short AV delay



Consequences of a too short AV delay

Optimal AV delay



Optimization of AV delay and VV timings in real life

- 32 Europeans centers
- AVD and VV timing optimization at discharge and subsequent FU
- Method let at physicians' discretion
- 60 pts at discharge, 49 at M3 and 34 at M6

- 25%: no optimization
- 75%: optimization (42% once, 10% twice and 23% 3 times)

Cazeau HRS 2008

Optimization of AV delay and VV timings in real life

- **Optimized patients**

  AVD: Mitral duration: 64%
  Ritter's formula 17%
  aortic or mitral VTI 19%

  VV timing: TDI 21%,
  Aortic VTI 21%
  QRS width 8%
  and various methods…56%

Time spent for optimization: 20 ± 13 minutes

Cazeau HRS 2008

CRT Optimization in Clinical Practice
92 centers worldwide

- Independent research study

Courtesy of D. Gras

CRT Optimization in Clinical Practice
92 centers worldwide

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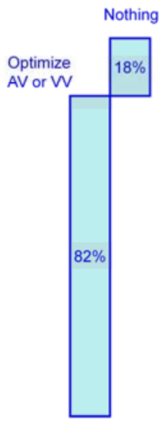

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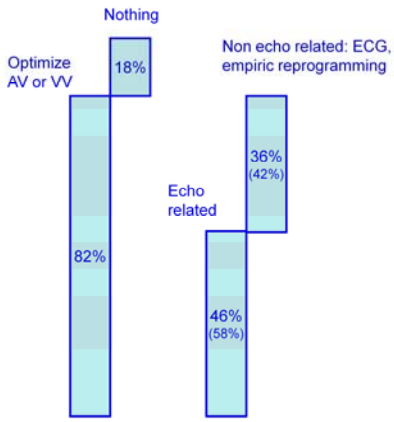

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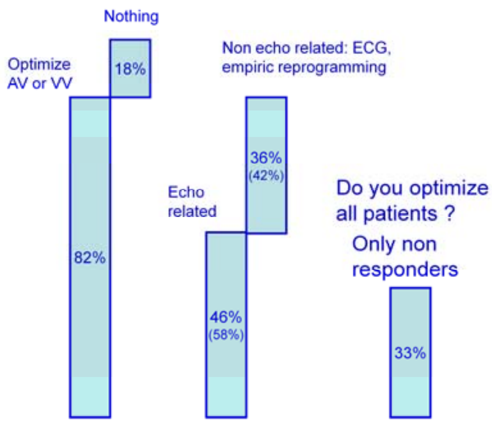

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CRT Optimization in Clinical Practice
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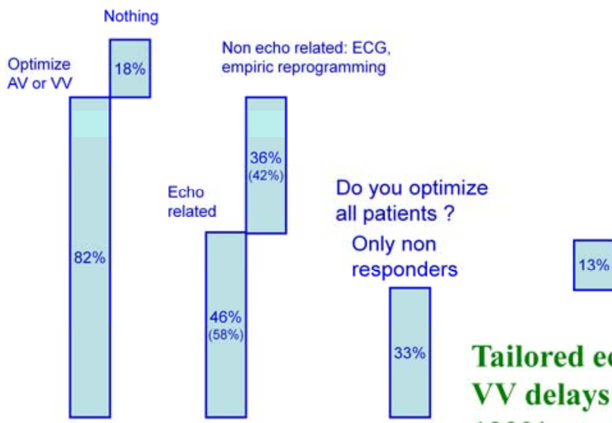
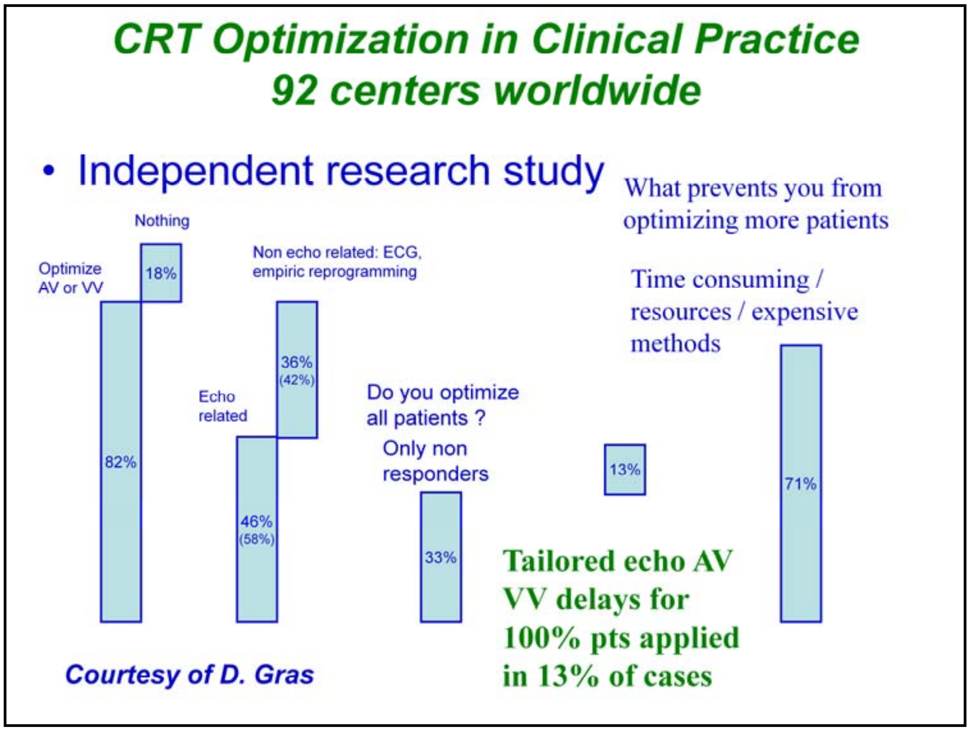
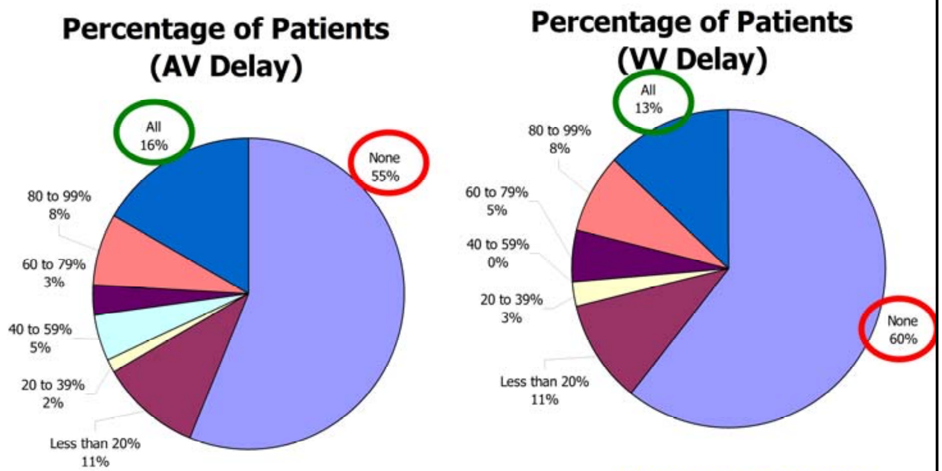


Tailored echo AV VV delays for 100% pts applied in 13% of cases

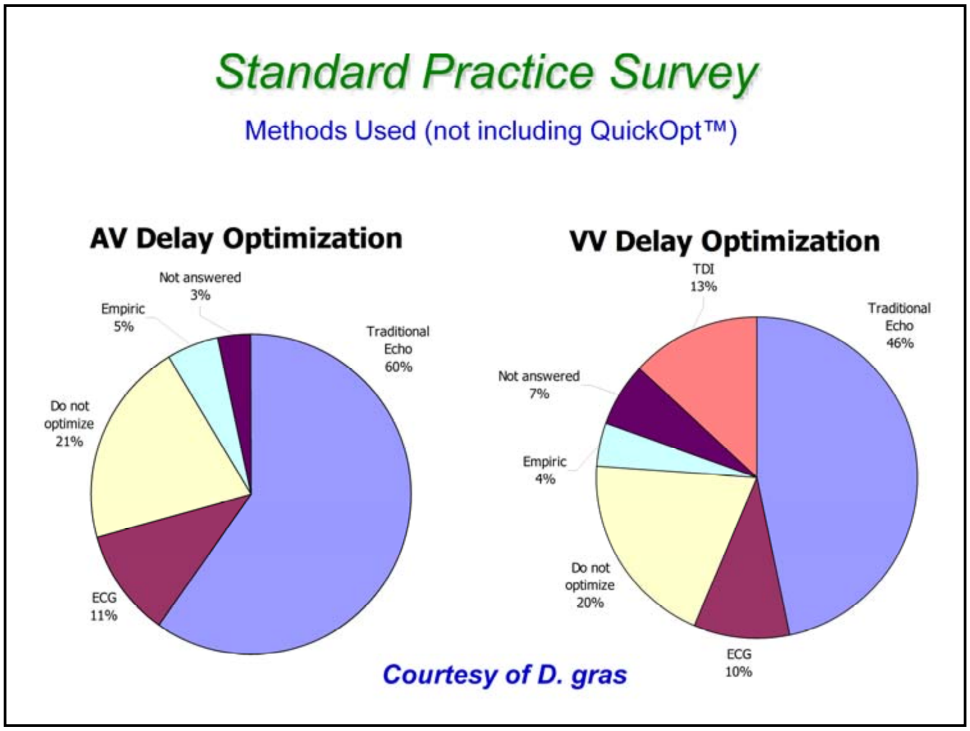
Courtesy of D. Gras


CRT Optimization in Clinical Practice
92 centers worldwide
• Independent research study
What prevents you from optimizing more patients
Nothing
Optimize AV or VV
18%
82%
Non echo related: ECG, empiric reprogramming
36% (42%)
Echo related
46% (58%)
Do you optimize all patients ?
Only non responders
33%
13%
Time consuming / resources / expensive methods
71%
Tailored echo AV VV delays for 100% pts applied in 13% of cases
Courtesy of D. Gras

Optimization before Pre-discharge

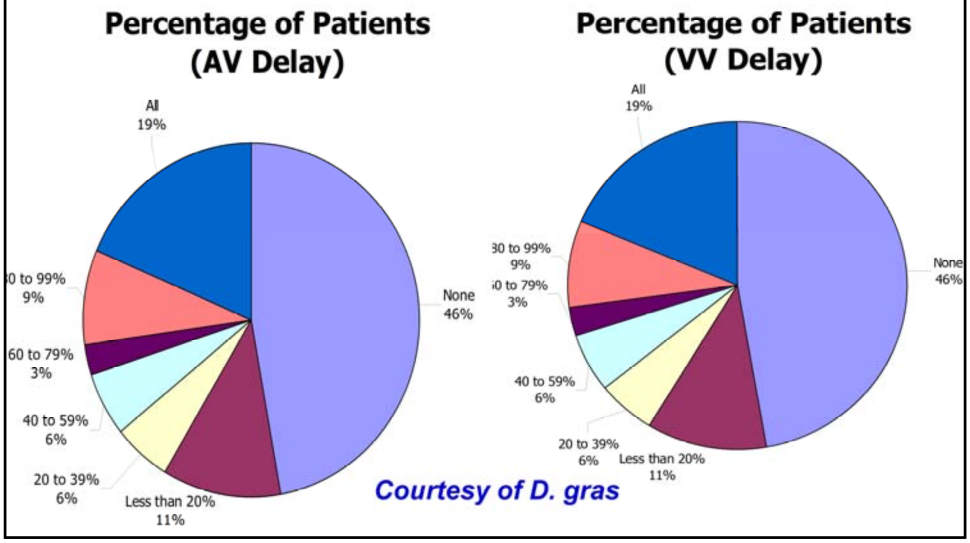


Courtesy of D. gras


Standard Practice Survey
Methods Used (not including QuickOpt™)
AV Delay Optimization
Not answered 3%
Empiric 5%
Traditional Echo 60%
Do not optimize 21%
ECG 11%
VV Delay Optimization
TDI 13%
Traditional Echo 46%
Not answered 7%
Empiric 4%
Do not optimize 20%
ECG 10%
Courtesy of D. gras

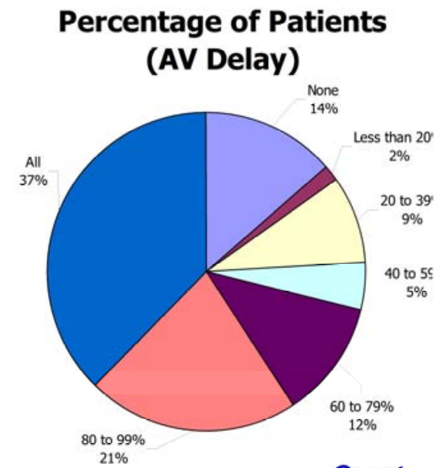
Optimization at 1st Follow-up

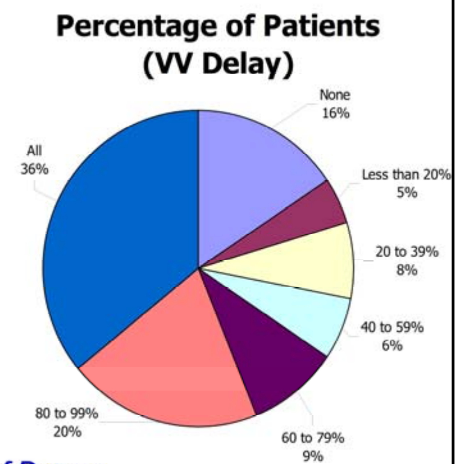
RESPONDERS - Average 1st Follow-up at 3 Months



Optimization at 1st Follow-up

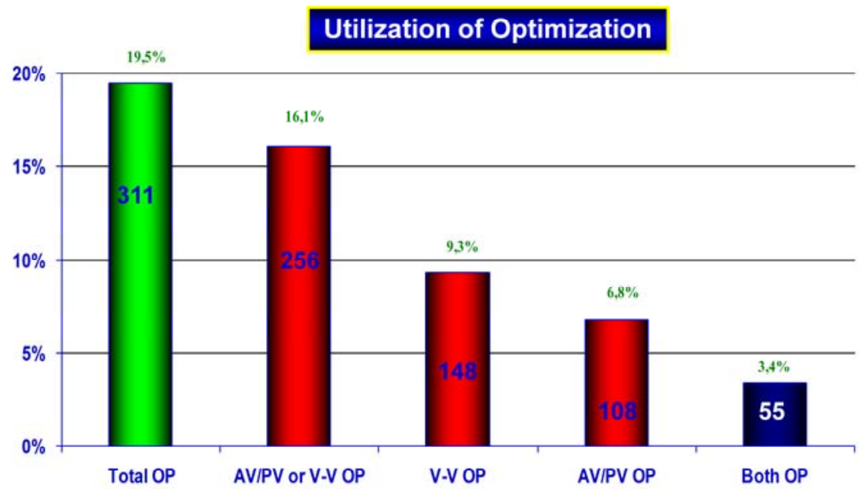
NON-RESPONDERS - Average 1st Follow-up at 3 M



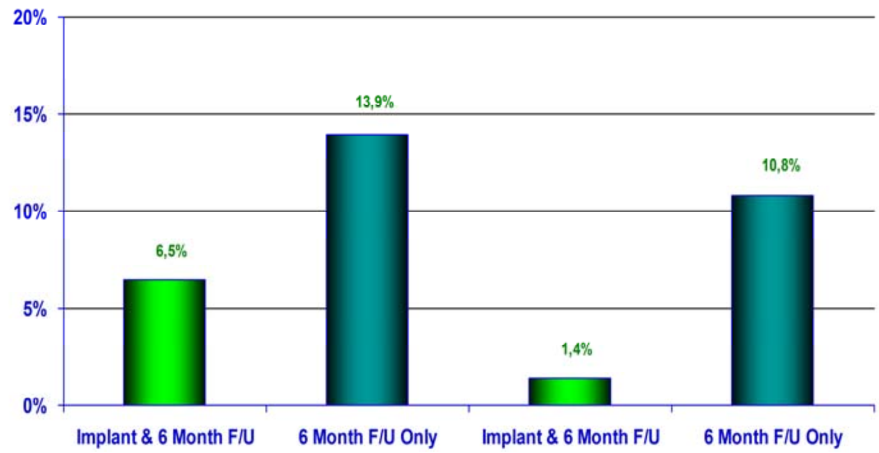


Courtesy of D. gras

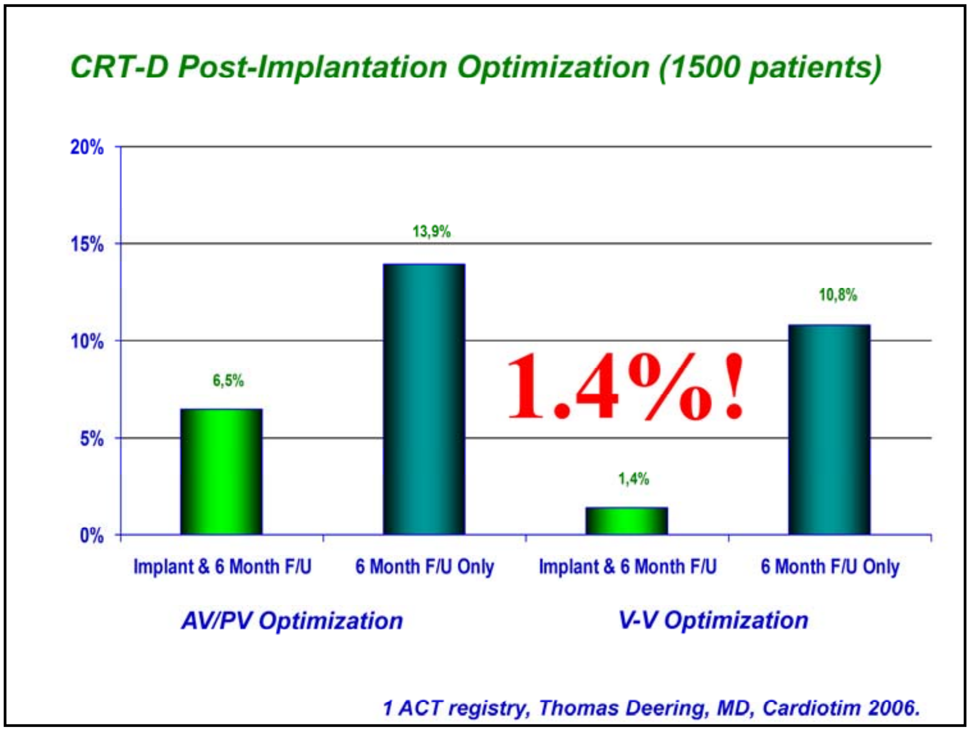
CRT-D Post-Implantation Optimization



CRT-D Post-Implantation Optimization (1500 patients)



1 ACT registry, Thomas Deering, MD, Cardiotim 2006.


CRT-D Post-Implantation Optimization (1500 patients)
20%
15%
10%
5%
0%
6,5%
13,9%
1,4%
10,8%
1.4%!
Implant & 6 Month F/U
6 Month F/U Only
Implant & 6 Month F/U
6 Month F/U Only
AV/PV Optimization
V-V Optimization
1 ACT registry, Thomas Deering, MD, Cardiotim 2006.

Importance of the exercise test
Inadequate AV delay

Which method to optimize AV delay?

- No optimization
- Invasive hemodynamic method (dP/dt)
- Echocardiographic methods
- Finger Plethysmography
- Impedance cardiography
- Acoustic cardiography
- Device-based algorithms
- …

No AV delay optimization

- Use of the empiric out-of-the–box AV delay settings of approximately 100 to 130 ms.
- Easy to perform
- Reproducible (for the same manufacturer)
- No time consuming

AV delay optimization
Echocardiographic methods

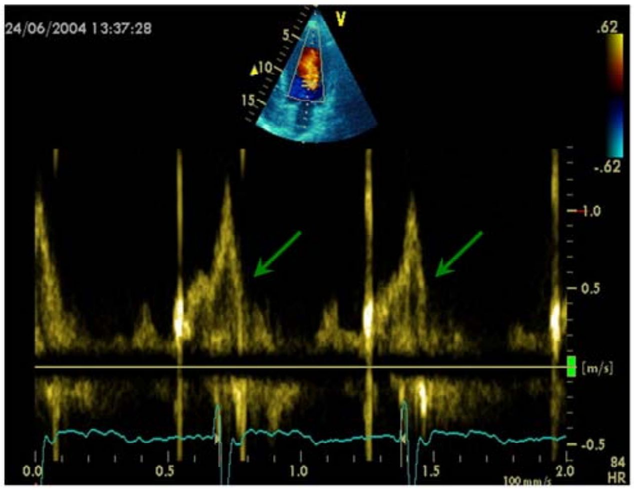
- **LV filling**
  - **Iterative method**
  - **Ritter's Method**
  - **Mitral inflow VTI method**
  - **Diastolic MR method**
  - **…**

- **LV systolic function**
  - **LVOT VTI method**
  - **Aortic valve VTI method**
  - **Doppler derived dP/dt**
  - **Myocardial performance Index**
  - **…**

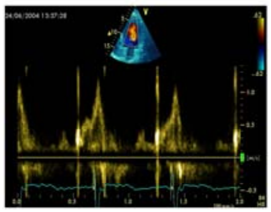
The iterative method

- Mitral Pulse Wave Doppler
- Measurement of diastolic filling time from the onset of E-wave to the end of the A-wave
- Programming of a long AV delay (200 ms)
- Decrease in 20 ms steps until the A-waves is truncated
- Increase in 10 ms increments
- Optimal AV delay: shortest AV delay without A-wave truncation and maximal filling time

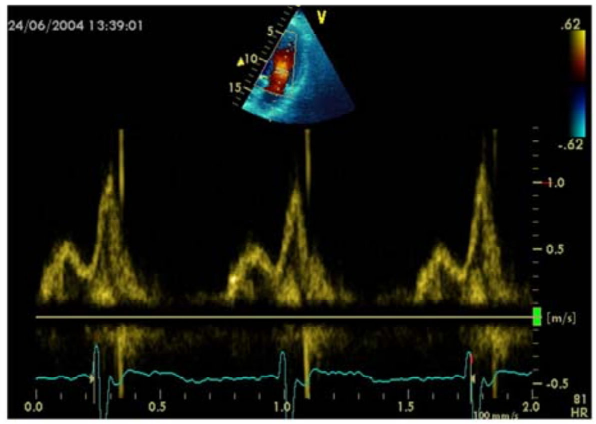
Example of truncated A wave



Then AV interval in increased by 10 ms to xxxxxxx



Before



Optimal

The iterative method

The iterative method

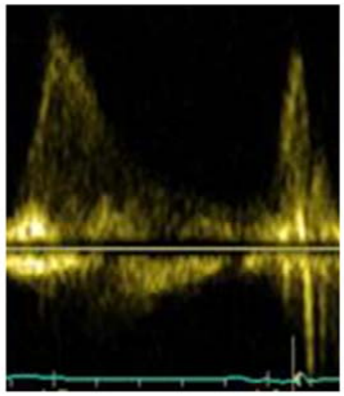
Long AV delay

(E and A fusion)

The iterative method

Long AV delay

(E and A fusion)

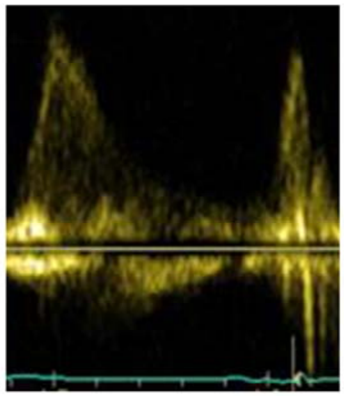


Decrease by 20 ms steps

Too short: truncated A-vawe

The iterative method

Long AV delay
(E and A fusion)



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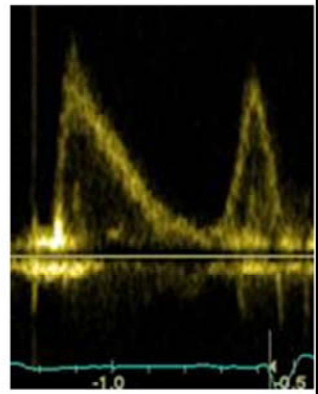


Optimal AV delay
LV filling > 40% RR cycle

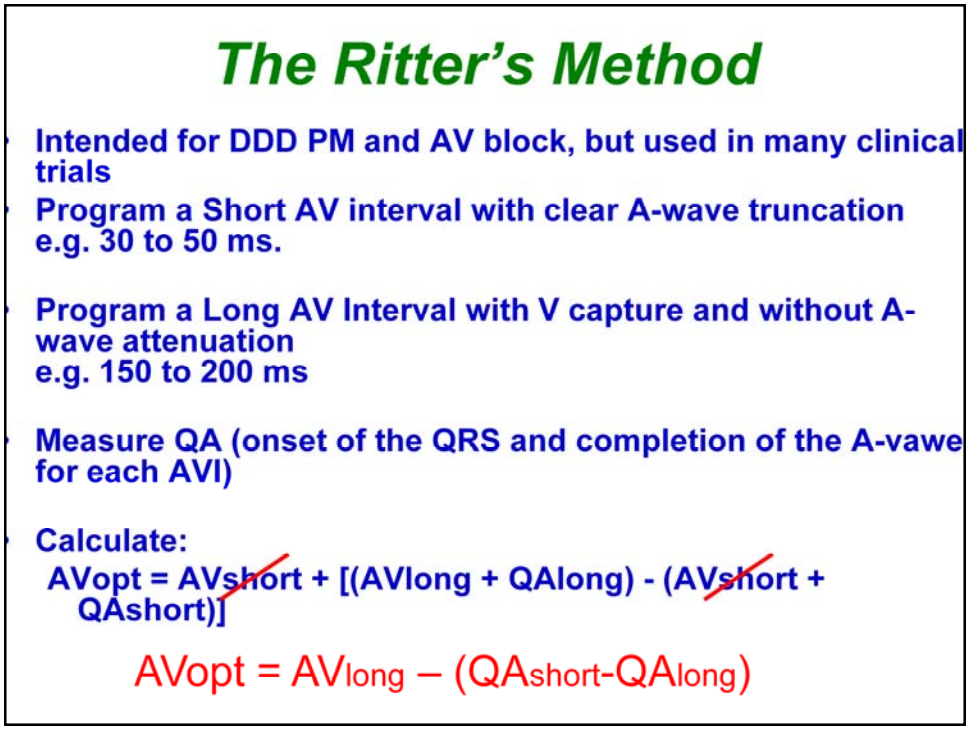
The Ritter's Method

- Intended for DDD PM and AV block, but used in many clinical trials
- Program a Short AV interval with clear A-wave truncation e.g. 30 to 50 ms.
- Program a Long AV Interval with V capture and without A-wave attenuation e.g. 150 to 200 ms
- Measure QA (onset of the QRS and completion of the A-vawe for each AVI)
- Calculate:
  AVopt = AVshort + [(AVlong + QAlong) - (AVshort + QAshort)]

Review the steps of the procedure. If the patient is chronically atrial pacing, the same steps can be performed with the PAV programmed as noted above. You may consider using a longer PAV due to atrial conduction time being lengthened with pacing vs. the conduction system.

The SHORT SAV, is intended to be so short that filling will not complete.

The LONG SAV should be long enough to allow ventricular conduction.



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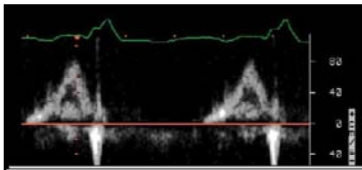
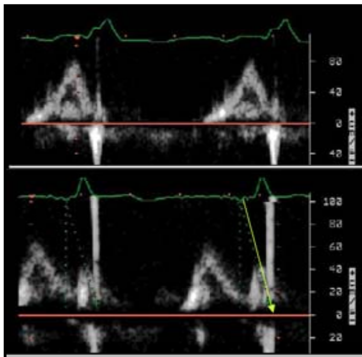
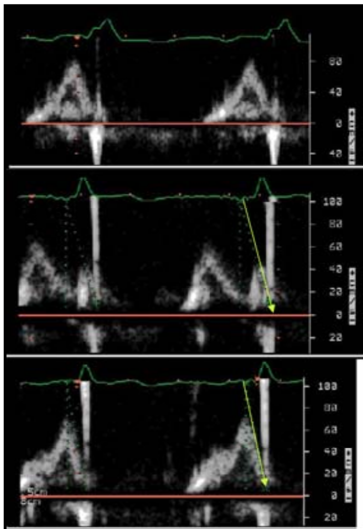


Intrinsic rhythm



Intrinsic rhythm

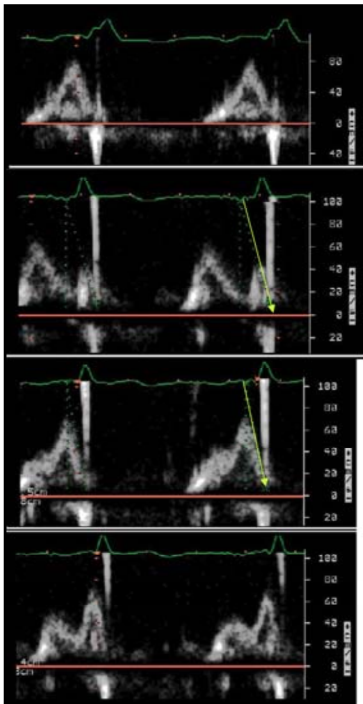
Short AVI (50ms)
⇨ **QA=120ms**



Intrinsic rhythm

Short AVI (50ms)
⇨ **QA=120ms**

Long AVI (150ms)
⇨ **QA=80ms**

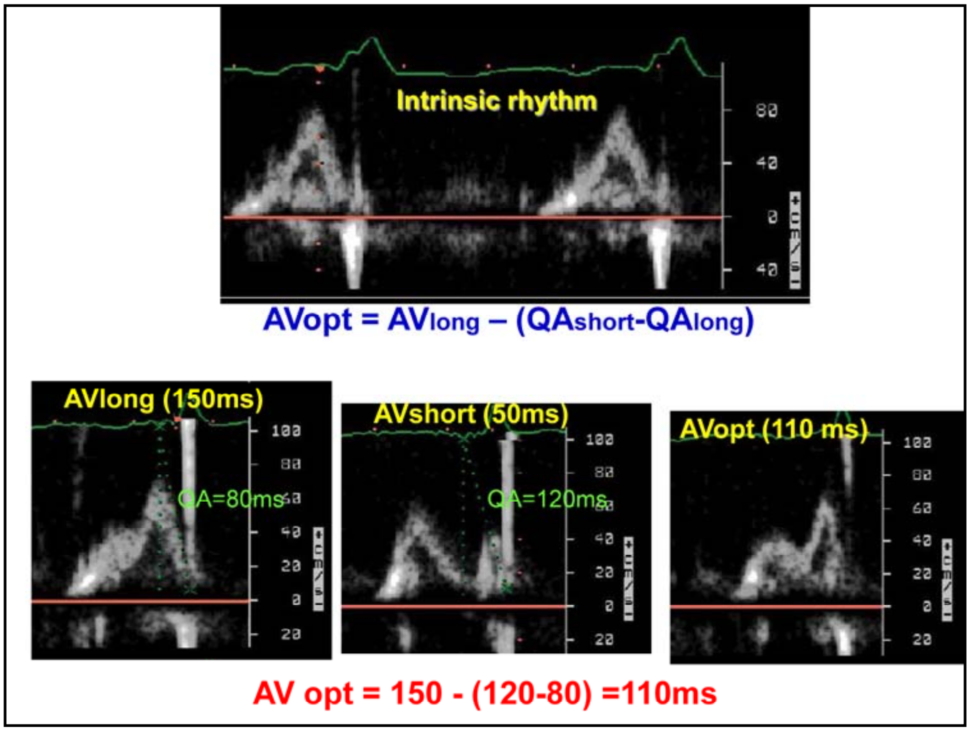


Intrinsic rhythm

Short AVI (50ms)
⇨ QA=120ms

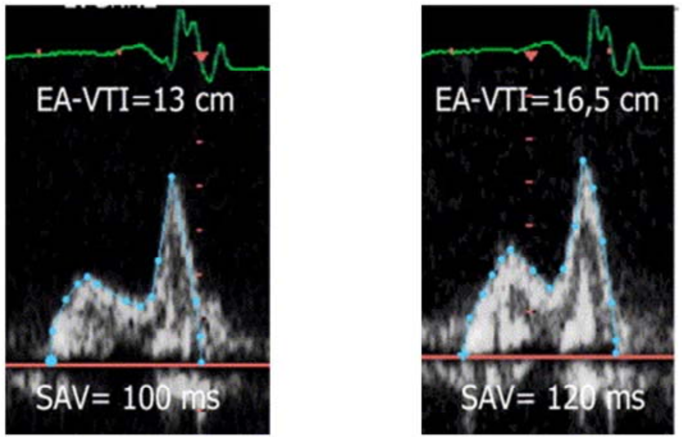
Long AVI (150ms)
⇨ QA=80ms

AV opt = 150 - (120-80) =110ms


Intrinsic rhythm
AVopt = AVlong – (QAshort-QAlong)
AVlong (150ms)
QA=80ms
AVshort (50ms)
QA=120ms
AVopt (110 ms)
AV opt = 150 - (120-80) =110ms

Mitral Inflow Velocity Time Integral

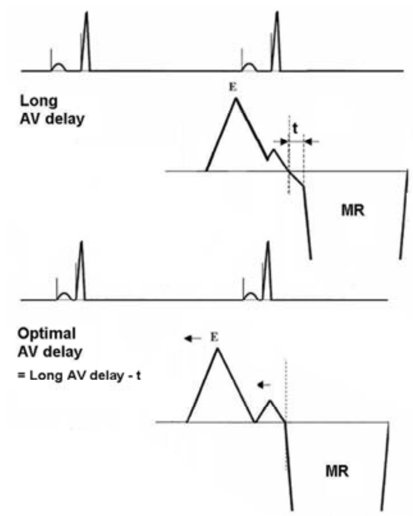
- Optimal AV delay : AV delay with maximal mitral inflow VTI



Simplified Mitral Inflow Method (Meluzin)

- **Maximum AV delay with full ventricular capture**
- **t: time between end of A wave and onset of systolic MR**

Opt AD delay: long AVD-t



Meluzin. PACE 2004. 27;58-64

AV delay optimization
Echocardiographic methods

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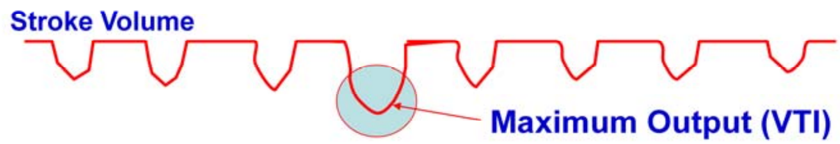
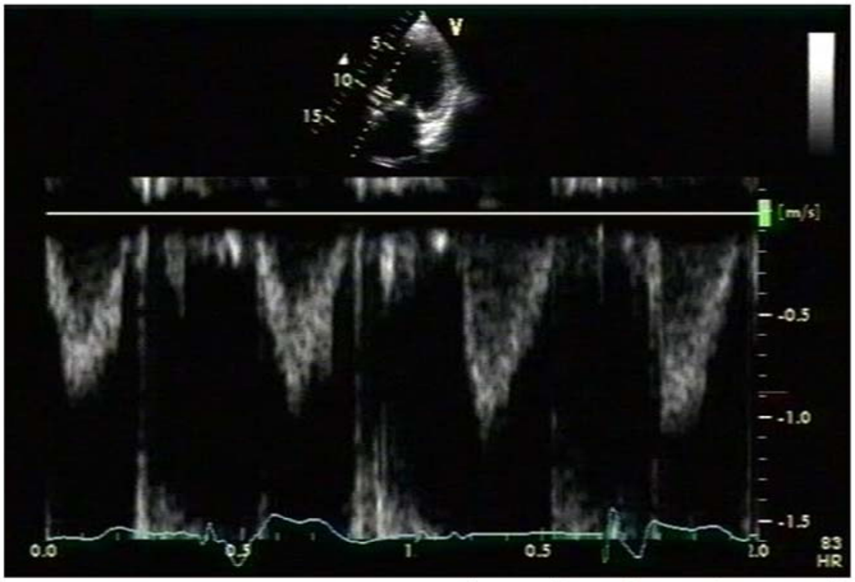
  - Iterative method
  - Ritter's Method
  - Mitral inflow VTI method
  - Diastolic MR method
  - …
- **LV systolic function**
  - LVOT VTI method
  - Aortic valve VTI method
  - Doppler derived dP/dt
  - Myocardial performance Index
  - …

Aortic VTI method

- Measurement of aortic VTI is a surrogate of stroke volume
- Use CWD rather than PWD
- Average of at least 3 measurements
- Different AV delays
- Opt AV delay → maximum Ao VTI

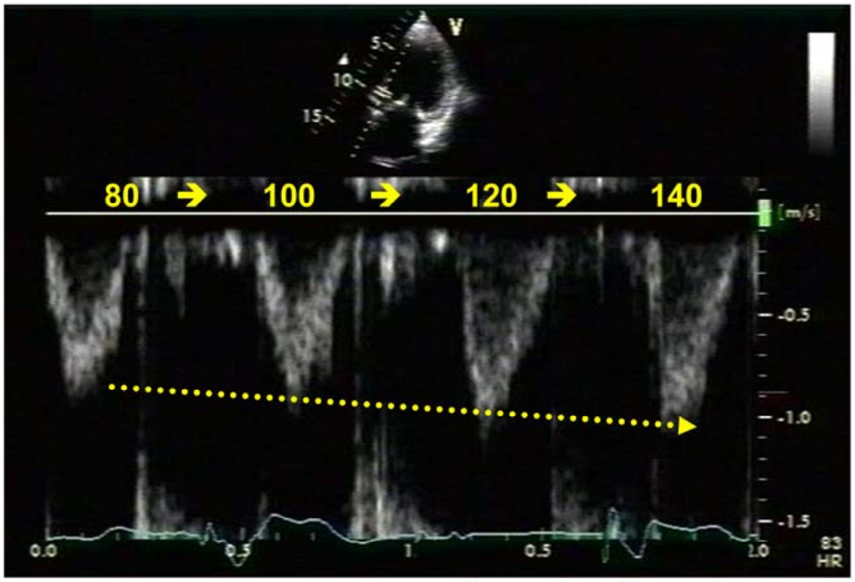


Aortic VTI method



(composed image from continuous recording)

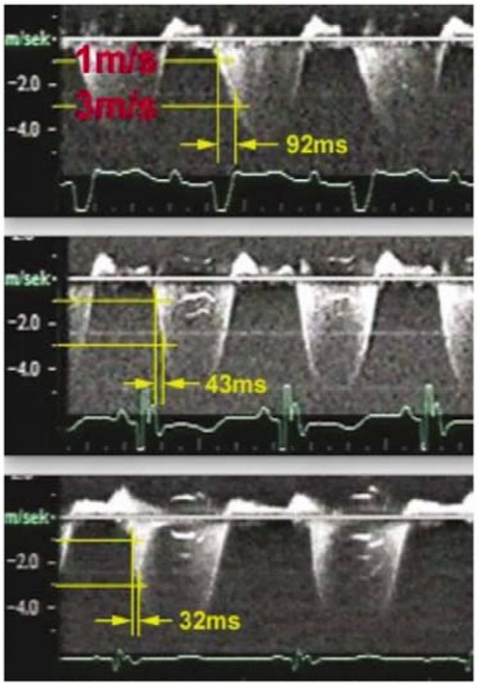
Aortic VTI method



(composed image from continuous recording)

Doppler derived dP/dt

- Optimal AV delay: greatest dP/dt
- MR CW Doppler velocity: instantaneous pressure difference between LV and LA in systole
- dt: time between 1m/s and 3m/s on the MR jet
- Dp/dt = 32/dt (mmHg/s)



AV delay 80 ms

AV delay 100 ms

AV delay 120 ms

Comparison of the different echocardiographic methods

- **Empiric AV delays 120 ms (N= 20) vs. Aortic VTI optimized AV delay (N= 20)**
- **Optimal AV delay: 119 ± 34 ms**

Sawhney. Heart Rhthm 2004. 1;562-7

Comparison of the different echocardiographic methods

	120 ms AVD	Opt AVD	p
Δ Ao VTI (cm)	4 ± 1.7	1.8± 3.6	<0.02
Δ LVEF (%)	8 ± 6	3.4 ± 4.4	<0.02
Δ NYHA class	1 ± 0.5	0.4 ± 0.6	<0.01
Δ QOL score	23 ± 13	13 ± 11	<0.03

Sawhney. Heart Rhthm 2004. 1;562-7

Comparison of the different echocardiographic methods

- **40 patients**
- **Acute measurement of stoke volume**
- **Aortic VTI vs. Mitral inflow method**

	AO VTI	MI	p
Opt AVD (ms)	119 ± 34	95 ± 24	<0.01
↗ Ao VTI (%)	19 ± 13	12 ± 12	<0.01

Kerlan. Heart Rhthm 2006. 3;148-54

Comparison of the different echocardiographic methods

- **30 patients with CRT devices**
- **Opt AVD determined by invasive measurements of dP/dt**
- **4 echo-based optimization of AVD**
  - **- Mitral VTI**
  - **- EA duration**
  - **- LVOT VTI**
  - **- Ritter's formula**

Jansen. AM J Cardiol 2006. 97;552-7

Comparison of the different echocardiographic methods

Concordance with Opt AVD

Mitral VTI: 29/30

EA duration: 20/30

LVOT VTI: 13/30

Ritter's formula: 0/30

Jansen. AM J Cardiol 2006. 97;552-7

Others non invasive methods

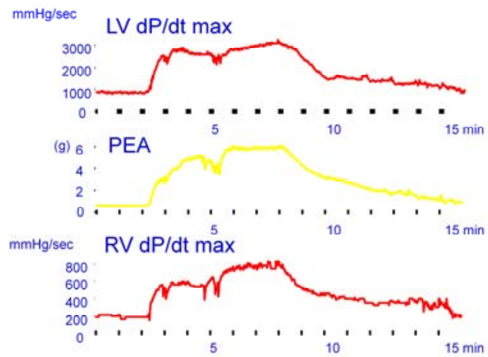
- **Impedance cardiography**
- **Finger plethysmography**
- **Acoustic cardiography**

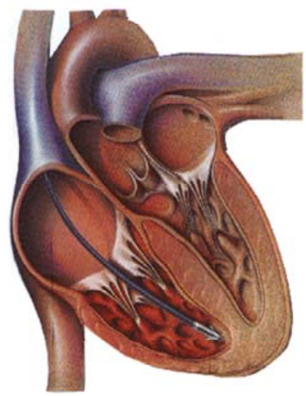
Device-based algorithms

- Intracardiac based electrograms
- Expert Ease for Heart Failure

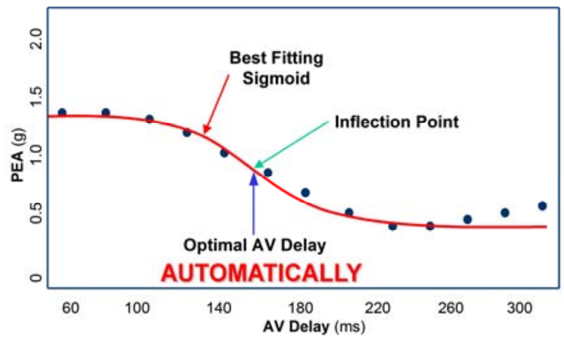
Gold. J Cardiovasc Electrophysiol 2007. 18;490-6

Device-based algorithms





Correlation between PEA and ECHO in Optimal AV Delay values in CRT pts



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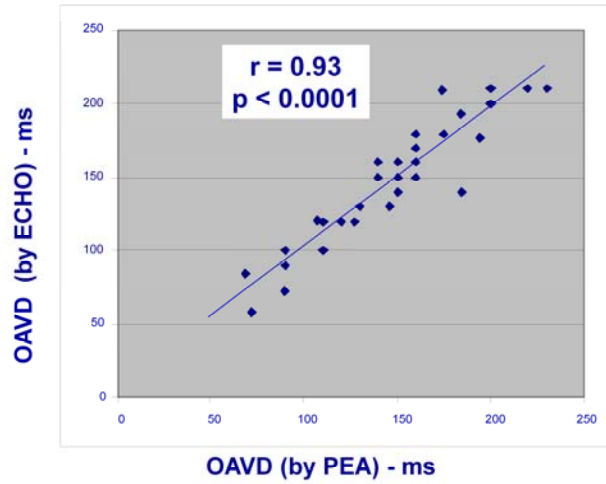
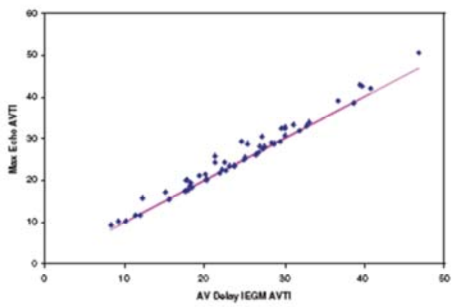
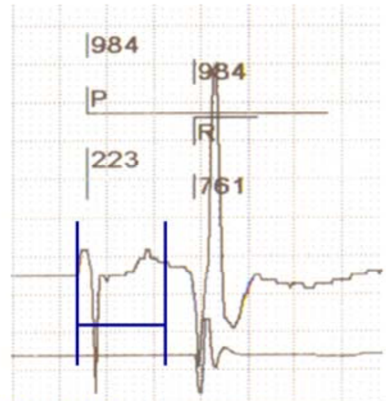


Ritter et al NASPE 2004

Device-based algorithms

- Intracardiac based electrograms
- Quick-opt®





Bakker. J Cardiovasc Electrophysiol 2007. 18;185-691

Device-based algorithms

- Intracardiac based electrograms
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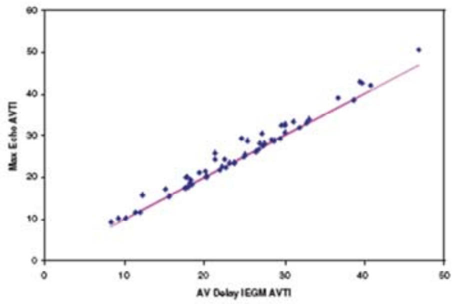
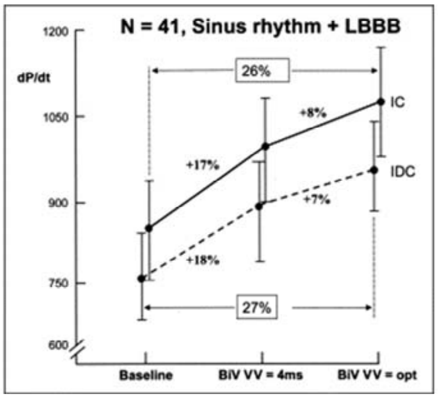


Bakker. J Cardiovasc Electrophysiol 2007. 18;185-691

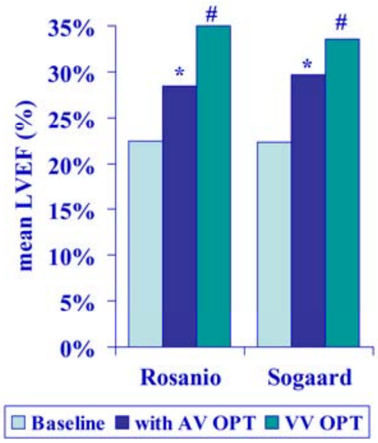
VV timing optimization

VV timing Optimization

- Theoretically attractive to optimize the correction of LV dyssynchrony

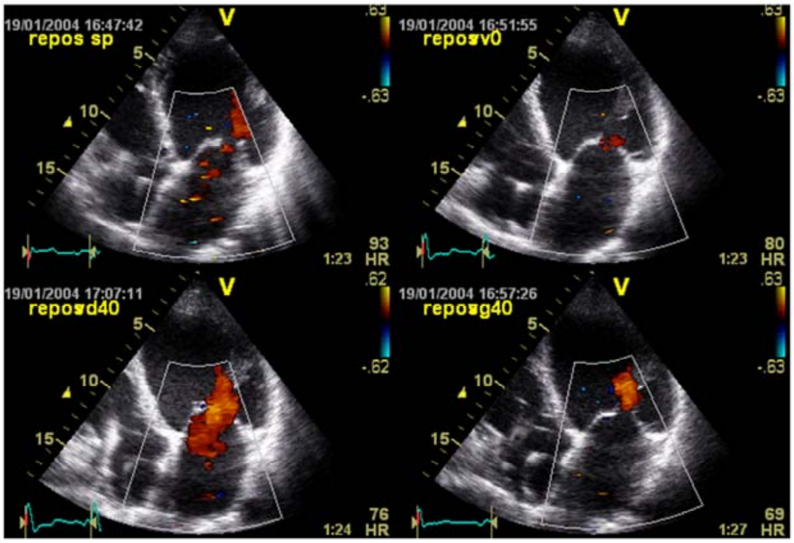


Van Gelder. Am J Cardiol 2004. 93;1500-3



Sogaard. Circulation 2002. 106;2078-84
Rosanio Circulation. 2003;108:IV-345

Improvement in MR

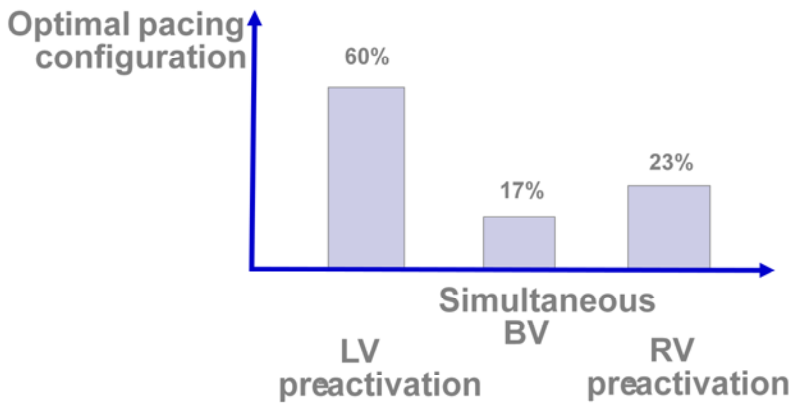


VV timing optimization

Variables	Baseline	Simultaneous BVP	Optimized Sequential BVP
Cardiac output (l/mn)	2.2±0.6	3.0±0.6 **	3.8±0.5 °°
LV filling time(ms)	290±74	377±54 *	426±59 °
EROA (mm^2)	29±12	20±9 *	12±7 °
Inter-V dyssynchrony (ms)	58.1±28	30.9±18 **	30.1±16
SPW-motion delay (ms)	63.4±38	31.5±21 **	19.2±21 °
Intra-LV $delay_{peak}$ (ms)	76.4±31	46.2±21 **	30.2±17 °°
Intra-LV $delay_{onset}$ (ms)	67.8±25	46.3±18 **	31.4±19 °°
Index of LV dyssynchrony	44±19	35±13 *	26±14 °
DLC (%)	48.6±18	30.6±09 *	20.4±09 °

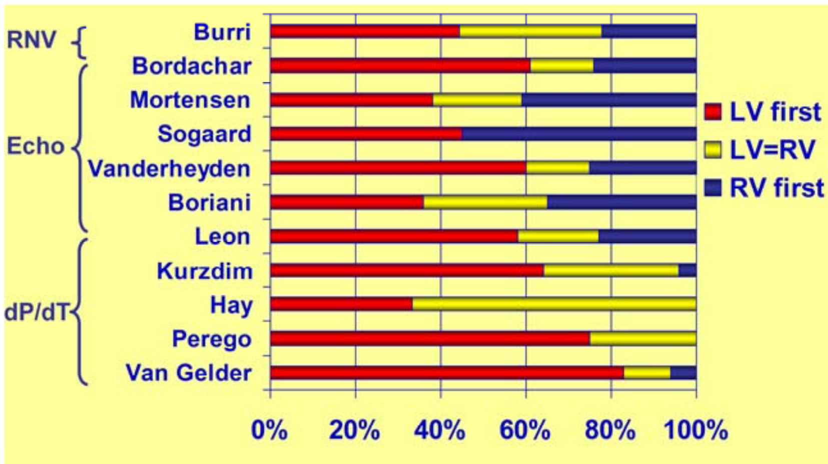
Bordachar. J Am Coll Cardiol 2004. 44;42157-65

VV timing optimization

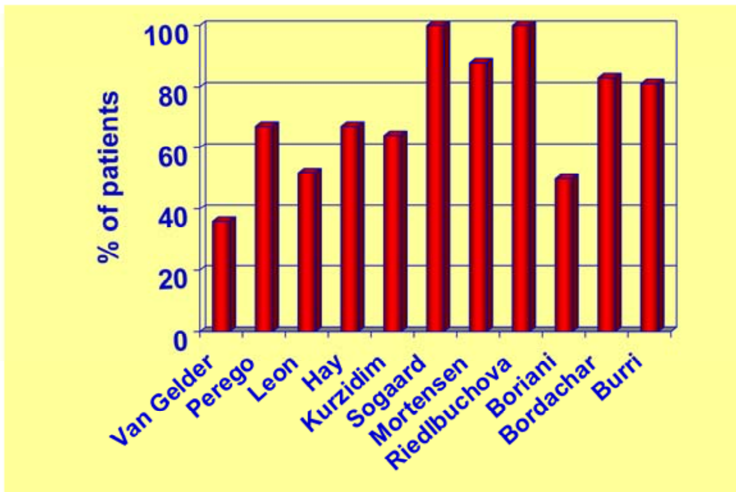


Bordachar. J Am Coll Cardiol 2004. 44;42157-65

VV timing optimization



Majority of optimal VV intervals are within +/- 20ms



Variation of optimal VV intervals over time

Leon J. Am Coll Cardiol 2005:2298-304

Non-randomized studies on VV optimization

- Insync III : no difference in NYHA and 6-min HWT at 3 months between VV optimized (n=46) and simultaneous (n=40)

Mortensen, PACE 2004; 27:339-45

- Insync III: at 6 months, greater improvement in 6 MHWT but not in QOL and NYHA class and in optimized patients (n=340) c MIRACLE CRT arm

Leon J. Am Coll Cardiol 2005:2298-304

Table 5. Comparison of Change From Baseline to Six Months of InSync III and MIRACLE Treatment Groups on Patient Outcomes

	InSync III	MIRACLE CRT	p Value*
6-min hall walk	(n = 340)	(n = 216)	
Median	53.0	37.9	<0.0001
Range	−314.0 to 613.0	−437.0 to 248.8	
Quality-of-life score	(n = 355)	(n = 216)	
Median	−19.0	−16.0	0.1126
Range	−91.0 to 29.0	−88.0 to 47.0	
NYHA functional class	(n = 359)	(n = 215)	
Median	−1.0	−1.0	0.3827
Range	−3.0 to 1.0	−3.0 to 1.0	

Randomized trials on VV optimization

- **RYHTHM II ICD**
  121 patients to simultaneous vs echo-optimized sequential pacing (VTI method)
  ⇨ No difference at 6 months of QOL, NYHA or 6MHWT
  Boriani, *Am Heart J* 2006;151:1050-8

- **DECREASE-HF**
  306 patients randomized to LV,simultaneous, or sequential pacing (IEGM method, median offset= LV-50ms) optimal VV=0.333 (RV-LV electrical delay)-20 ms*

  ⇨No advantage of sequential pacing in terms of LV volumes or LVEF
  Rao, *Circulation* 2007;115:2136-2144

Which method to optimize VV timings

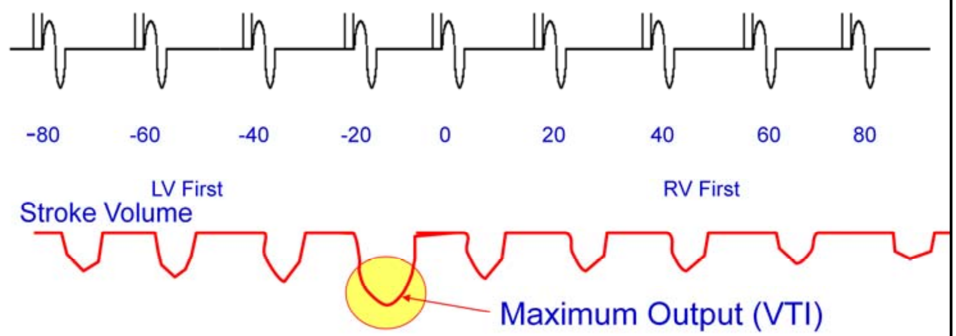
- **Invasive dP/dt measurements (only at implantation)**
- **Echocardiographic methods**

  - LVPE time and IV delay

  - LVOT VTI (InSync III and Rhythm ICD trials)

  - Tissue Doppler synchrony (which techniques?)
- **Finger Plethysmography**
- **Impedance cardiography**
- **Acoustic cardiography**
- **Device-based algorithms**

Aortic outflow VTI method



Which tissue Doppler synchrony methods?

The future

- Validation of the different methods
- Optimization at rest but also during exercise
- Optimization of AV and VV timings is time and persons consuming and not adequate with the decrease of medical demography in many countries
- Device based algorithms are very attractive at least because of the speed and automaticity
- The results of the FREEDOM and CLEAR trials would be instructive

FREEDOM (SJM) (ongoing)

Randomized trial parallel groups

1500 pts planned to be included, QuickOpt vs. standard practice.

HF composite score at 12 months

CLEAR (SORIN Group)

Recruitment completed

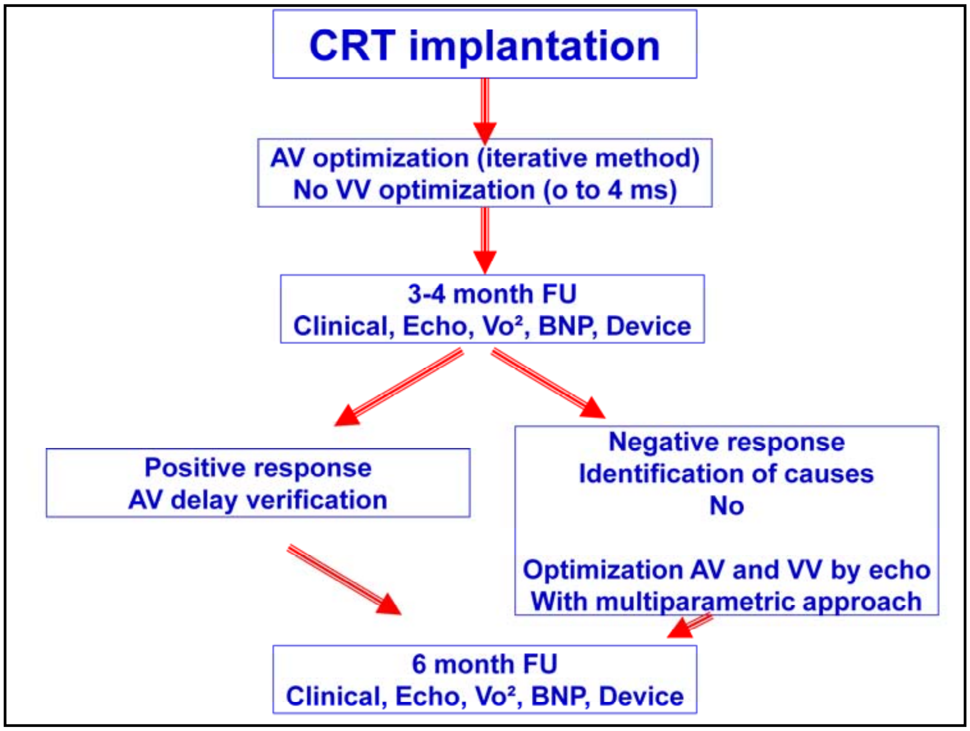
Randomized trial parallel groups

320 pts included, PEA vs. standard practice.

composite score (NYHA+ HF hospitalizations + QOL) at 12 months

AV delay optimization general considerations

- sensed and paced atrial events
- Low lower rate or VDD mode to favor sensed atrial events
- High upper tracking rate to ensure Biventricular pacing and AV synchronization
- Consider AV delay at rest but also during exercise (rate adaptative AV delay)


CRT implantation
AV optimization (iterative method)
No VV optimization (o to 4 ms)
3-4 month FU
Clinical, Echo, Vo², BNP, Device
Positive response
AV delay verification
Negative response
Identification of causes
No
Optimization AV and VV by echo
With multiparametric approach
6 month FU
Clinical, Echo, Vo², BNP, Device