



CRT Optimization and It's Follow-up

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Introduction

- **CRT : effective therapy in selected patients with advanced drug-refractory heart failure**
- **About 20-30% of patients in randomized trials do not respond clinically**



Lack of Favorable Response After CRT

- **Absence of mechanical dyssynchrony despite wide QRS**
- **LV pacing lead in an inappropriate location**
- **Failure to optimize the CRT setting**

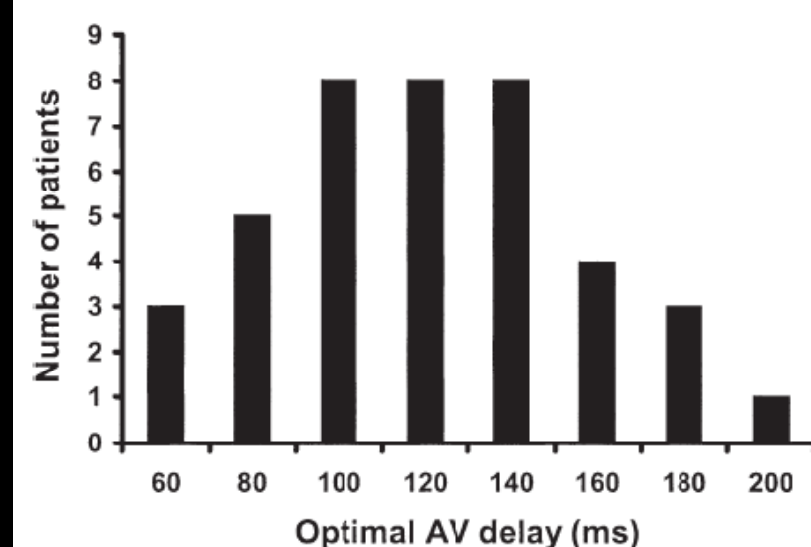
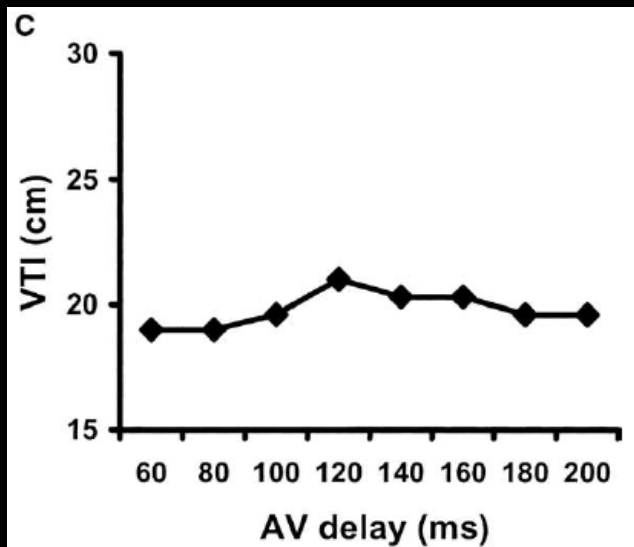
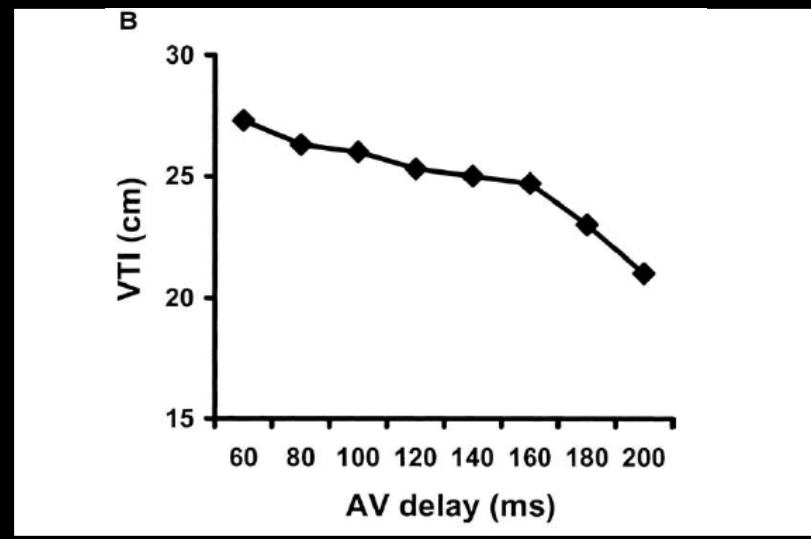
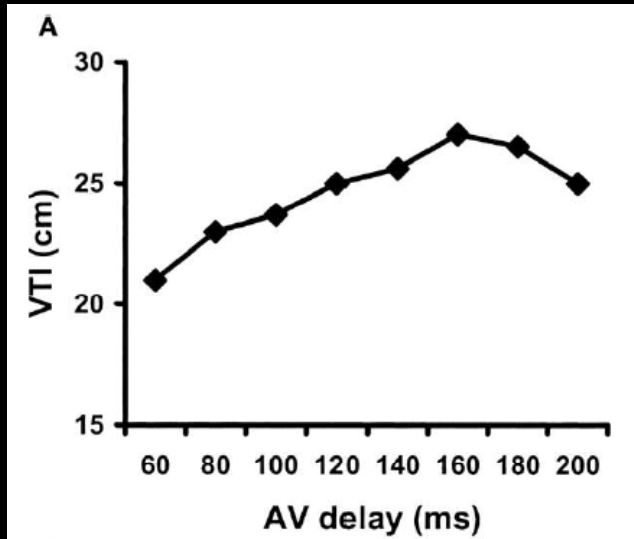


Optimization

- **Programming of standard parameters**
- **AV interval optimization**
 - Adjusts contraction sequence between LA and LV to optimize LV filling without truncating atrial contraction
- **VV interval optimization**
 - Adjusts contraction sequence between the left and right ventricles, ideally optimizing the left to produce the largest stroke volume



Is Optimization Necessary? AV Interval



Sawhney
et al.
Heart
Rhythm
2004;1:
562



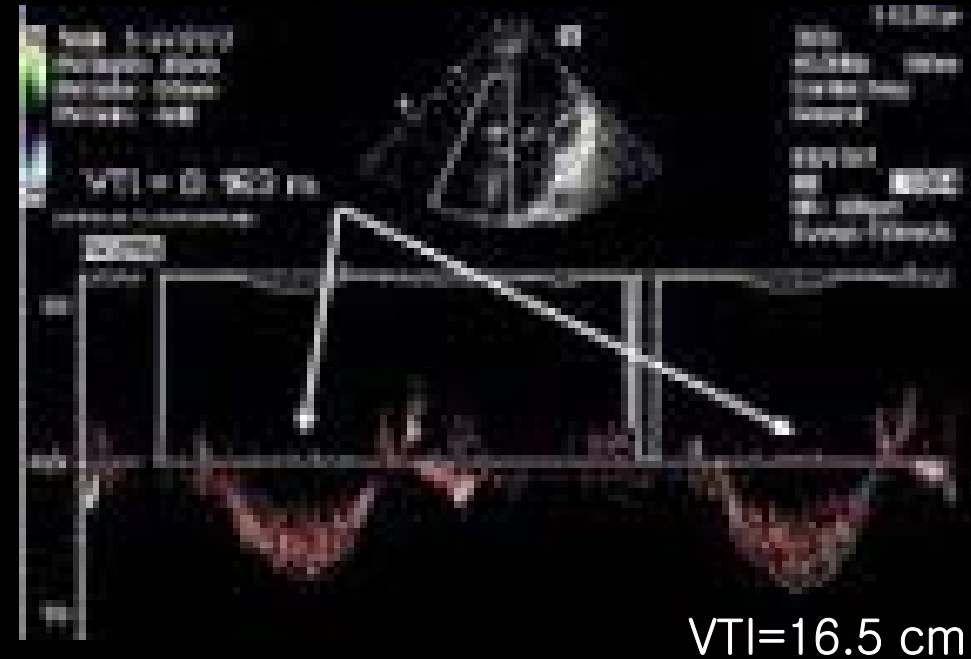
Is Optimization Necessary? AV Interval

	Optimized AV delay	Empiric delay of 120 ms	p
Δ Ao VTI, cm	4.0 \pm 1.7	1.8 \pm 3.6	< 0.02
Δ EF, %	7.8 \pm 6.2	3.4 \pm 4.4	< 0.02
Δ NYHA	1.0 \pm 0.5	0.4 \pm 0.6	< 0.01
Δ QOL score	23 \pm 13	13 \pm 11	< 0.03

Is Optimization Necessary? VV Interval

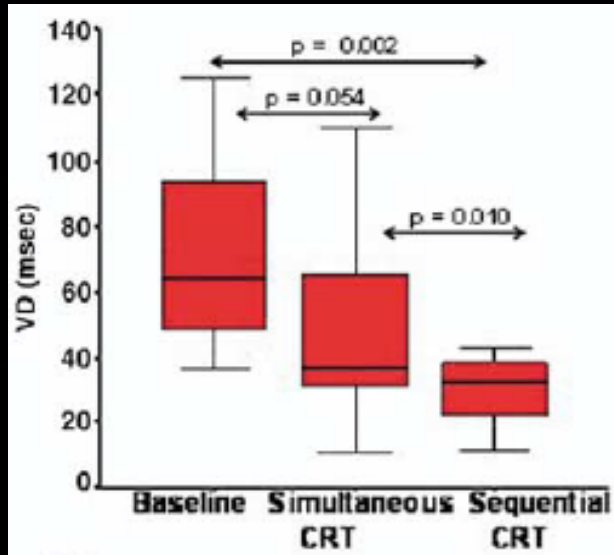
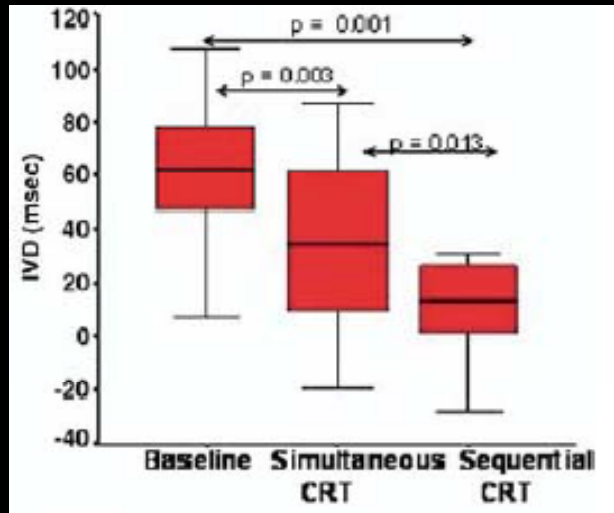


Simultaneous Biventricular
Pacing



Sequential Biventricular
Pacing : VVI = 40 ms (LV first)

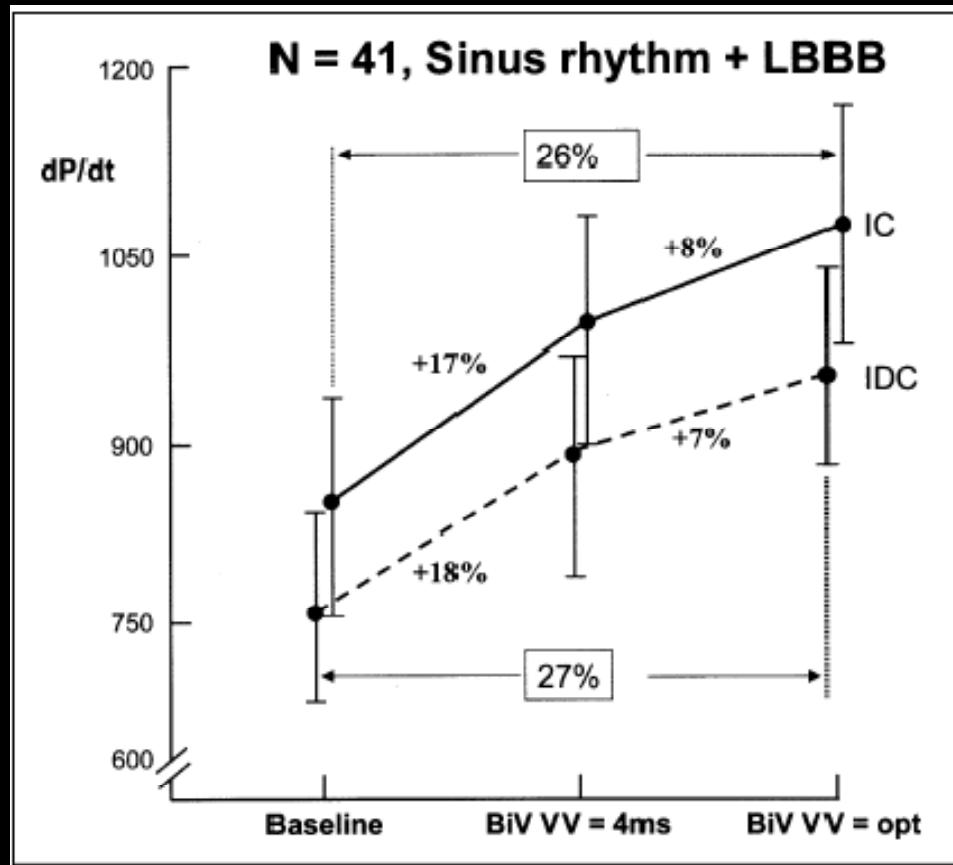
Is Optimization Necessary? VV Interval



- The highest VTI was found
 - LV first stimulation (n=12)
 - RV first stimulation (n=5)
 - Simultaneous (n=3)

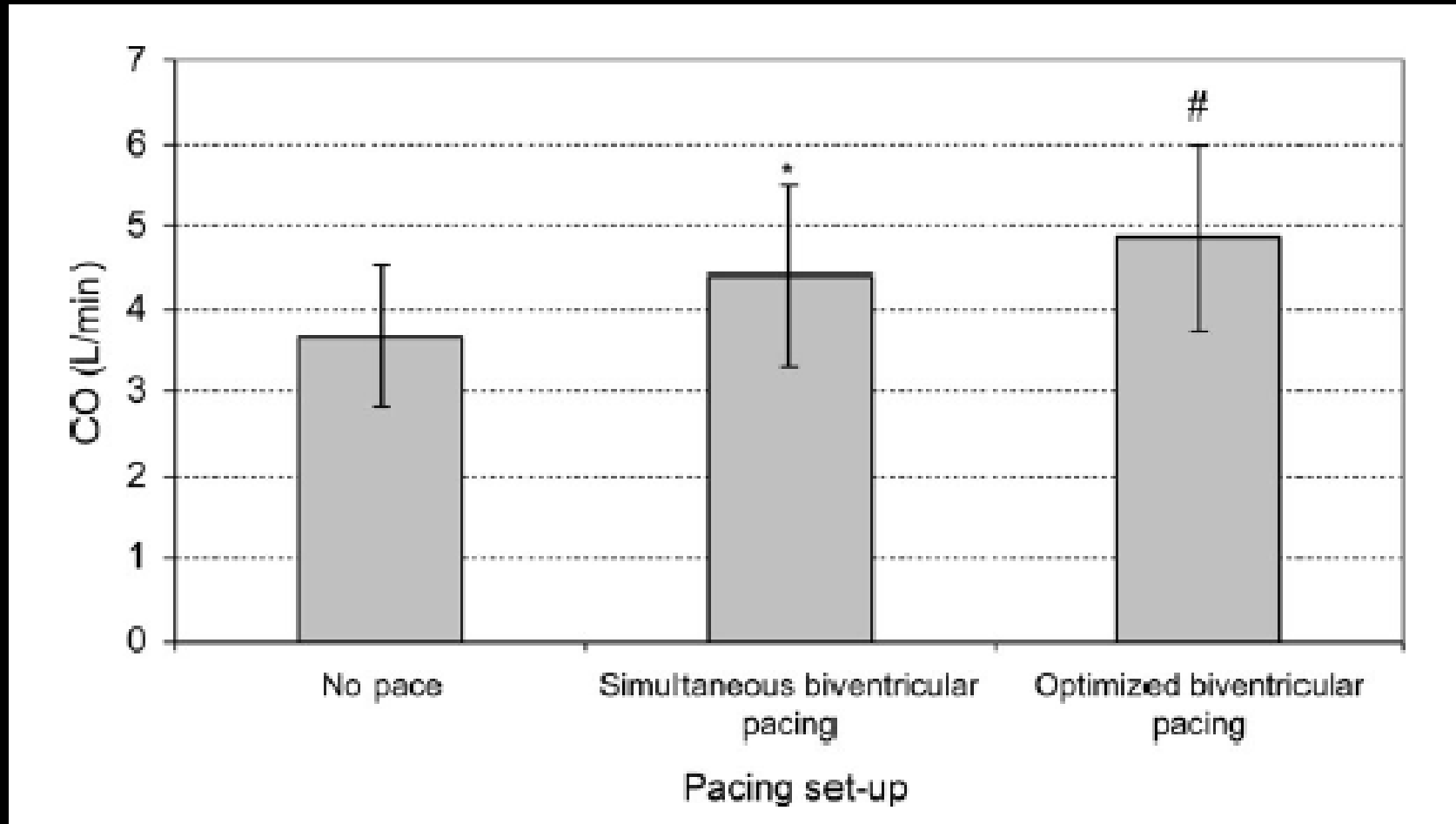
IVD : interventricular delay
VD : intraventricular delay

Is Optimization Necessary? VV Interval



- **Maximum dP/dt**
 - LV first stimulation (n=44)
 - RV first stimulation (n=3)
 - Simultaneous (n=6)

Is Optimization Necessary? VV Interval

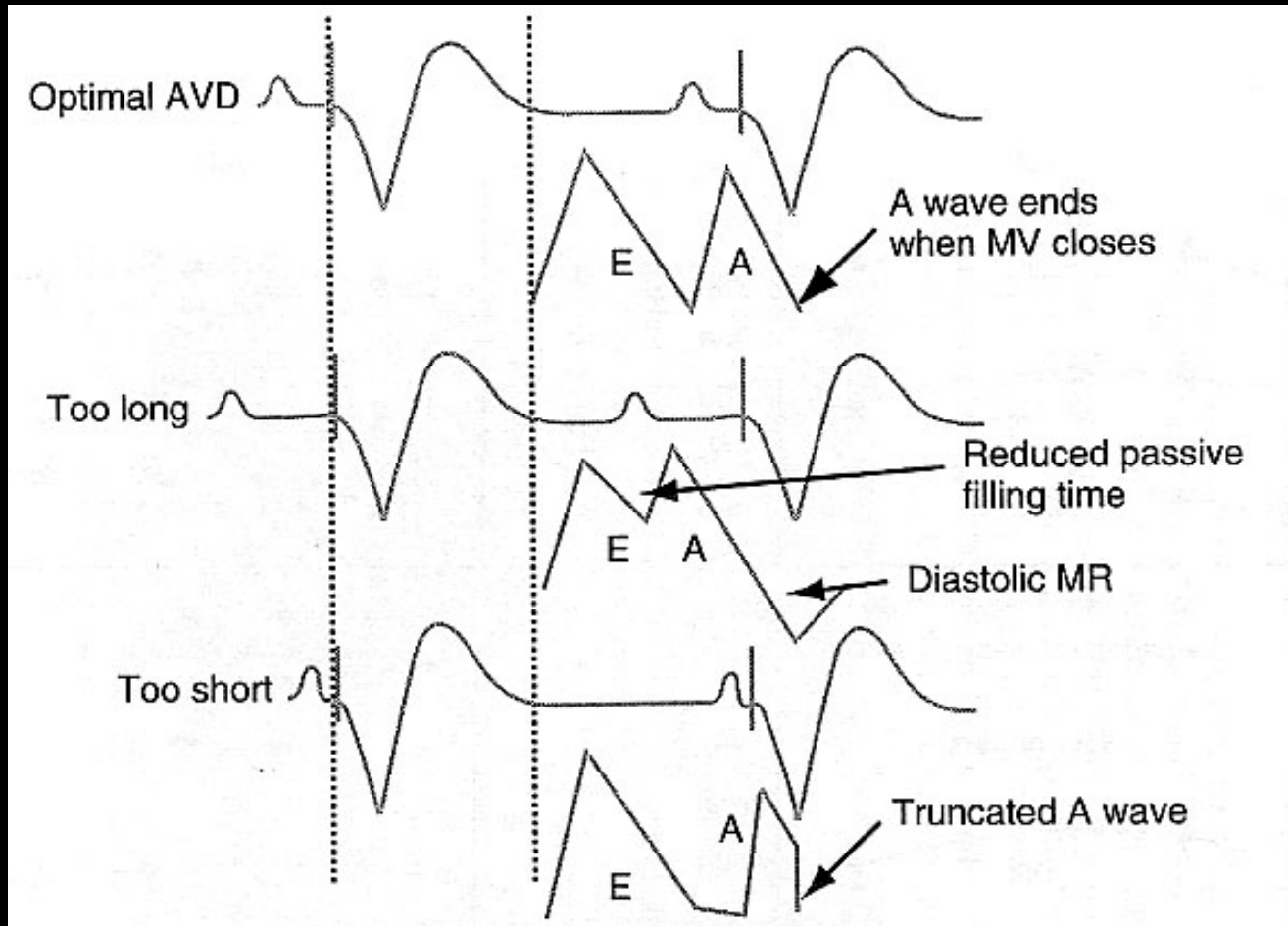




Optimal AV Interval

- **Allows completion of atrial contribution to diastolic filling in most favorable preload before ventricular contraction**
- **The AV interval optimizes stroke volume and minimizes mitral regurgitation**

Optimal AV Interval



When the AV delay is optimal, the mitral valve closes at the end of the mitral A wave.

If the AV delay is too long, the E and A waves become fused and the duration of diastolic filling reduced. Late diastolic mitral regurgitation may occur.

If the AV delay is too short, the A wave is truncated as the mitral valve closes before active filling from atrial contraction has completed.

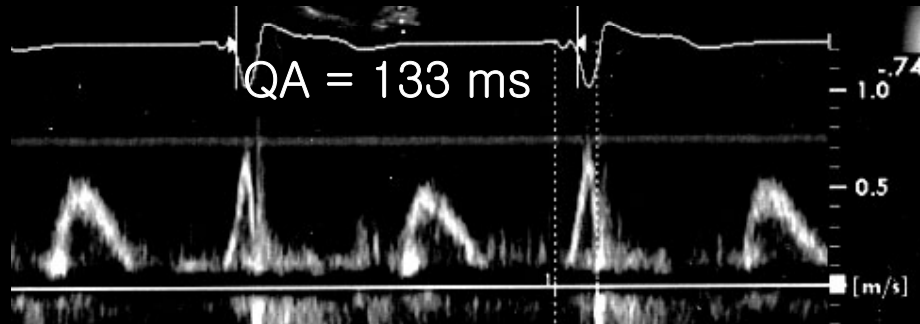


AV Interval Optimization

- **Echocardiography**
 - Ritter method
 - Simplified inflow method
 - Iterative method
 - Maximal filling time
 - Mitral VTI
 - Aortic VTI
- **Impedance cardiography**
- **Finger plethysmography**
- **Device algorithms**
 - Peak endocardial acceleration
 - AV EGM-based algorithm

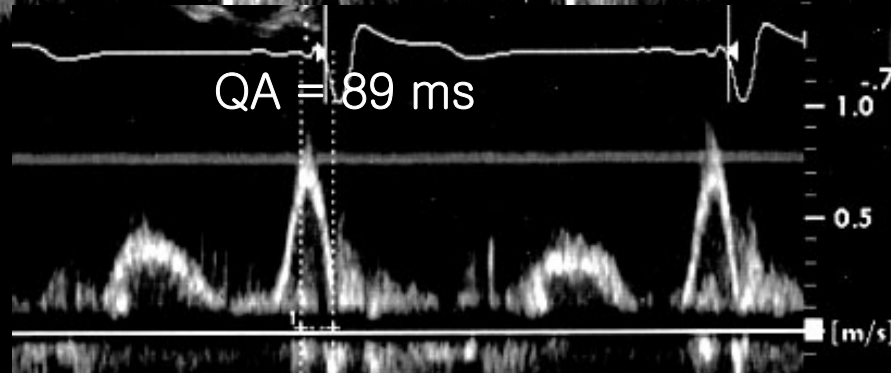
AV Interval Optimization Ritter Method

Short AVI
(50 msec)



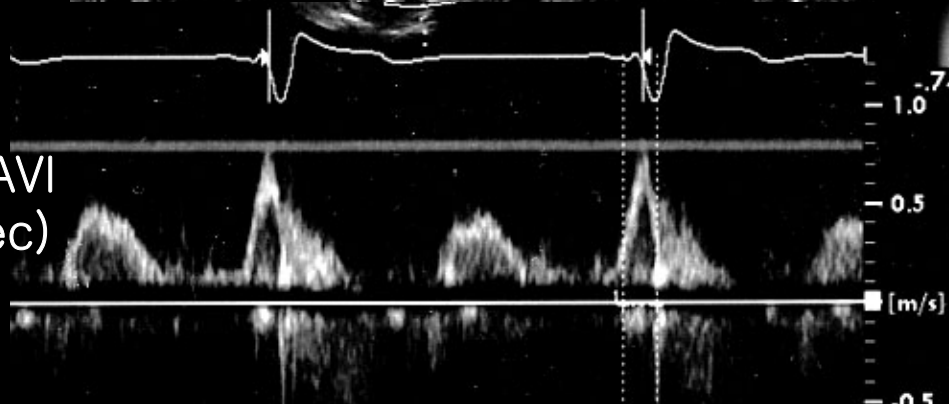
AV intervals are programmed to a short and to a long value that does not truncate the A wave (e.g., 50 and 150 ms).

Long AVI
(150 msec)



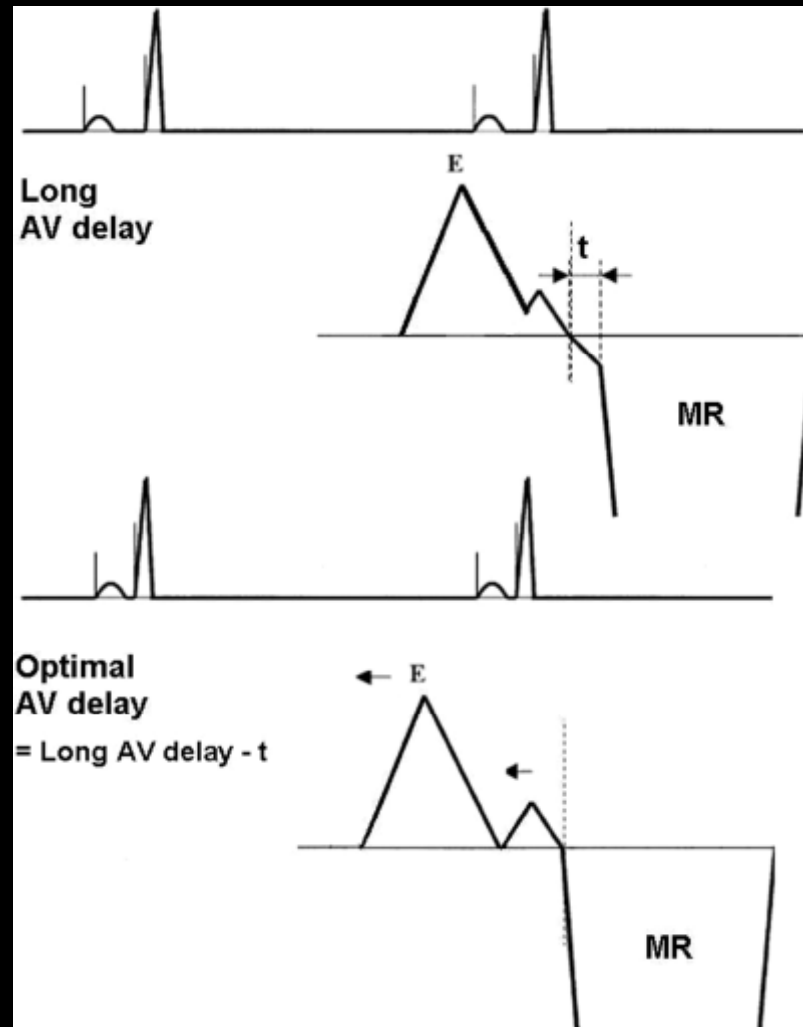
The time interval between QRS onset and the end of the A wave (QA interval) measured at each setting.

Optimal AVI
(106 msec)



$$\begin{aligned} \text{AV opt} &= \text{AV long} - (\text{QA short} - \text{QA long}) \\ &= 150 - (133 - 89) = 106 \text{ msec} \end{aligned}$$

AV Interval Optimization Simplified Mitral Inflow Method

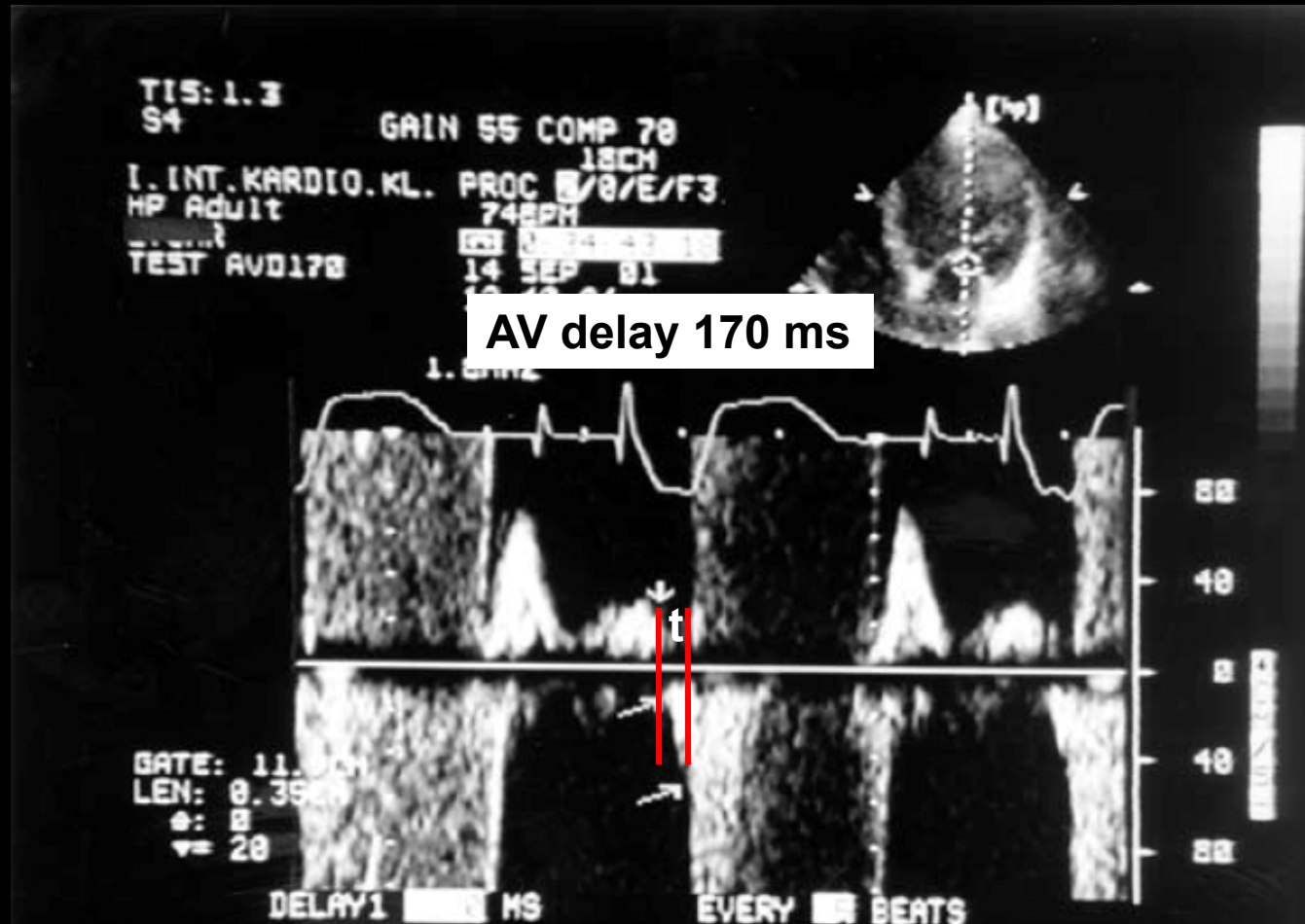


A long AV interval is programmed and the delay between the end of the A wave and the onset of mitral regurgitation (MR) is measured (t).

This value is then subtracted from long AV interval, yielding the optimal AV interval.

This approach relies on the presence of MR, which is a significant limitation.

AV Interval Optimization Simplified Mitral Inflow Method



Long AV delay = 170 ms
Optimal AV delay = 170 - t



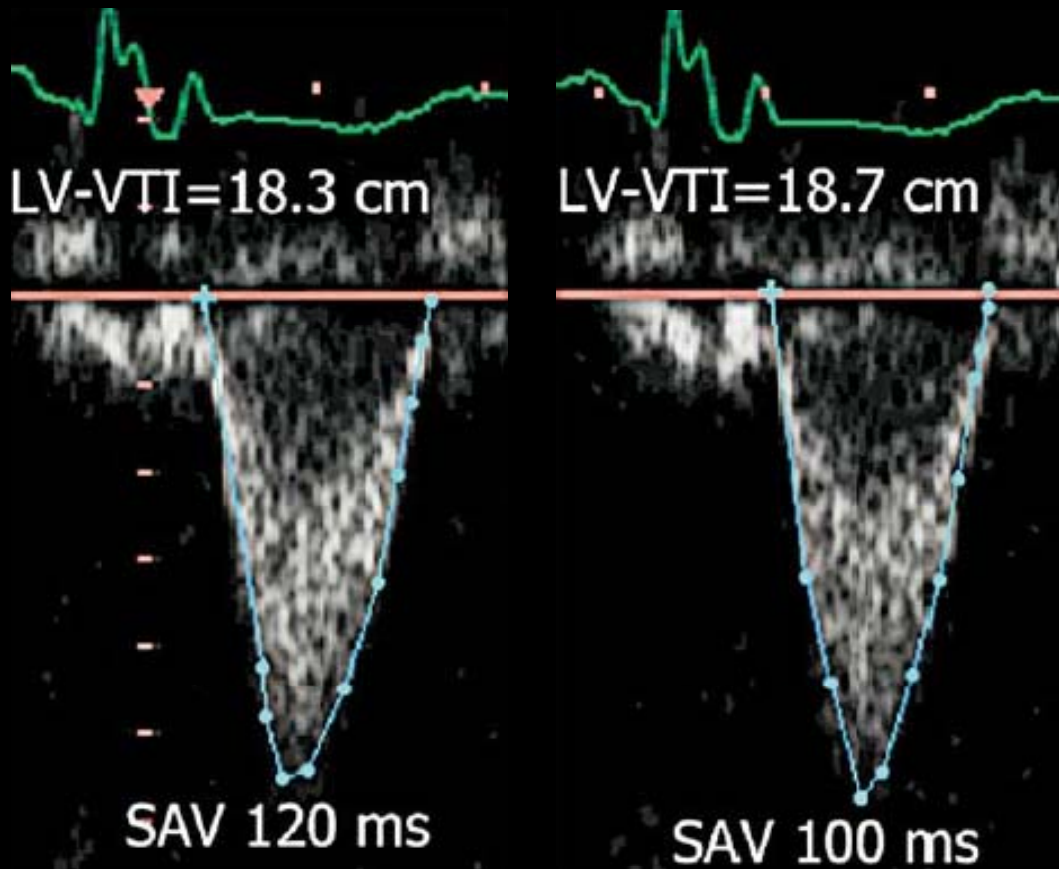
AV Interval Optimization

Iterative Method

- A long AV interval (e.g., 75% of the intrinsic AV interval) is programmed and the AV interval decremented in 20 ms steps, until A-wave truncation is observed.
- The AV interval may then be incremented in 10 ms steps to obtain the optimal setting.
- 200 ms >> 180 ms >> 60 ms
- Optimal AV delay
 - Minimal AV delay that allows for adequate E and A wave separation and termination of A wave at approximately 40 to 60 ms before onset of QRS

AV Interval Optimization

Aortic VTI Method



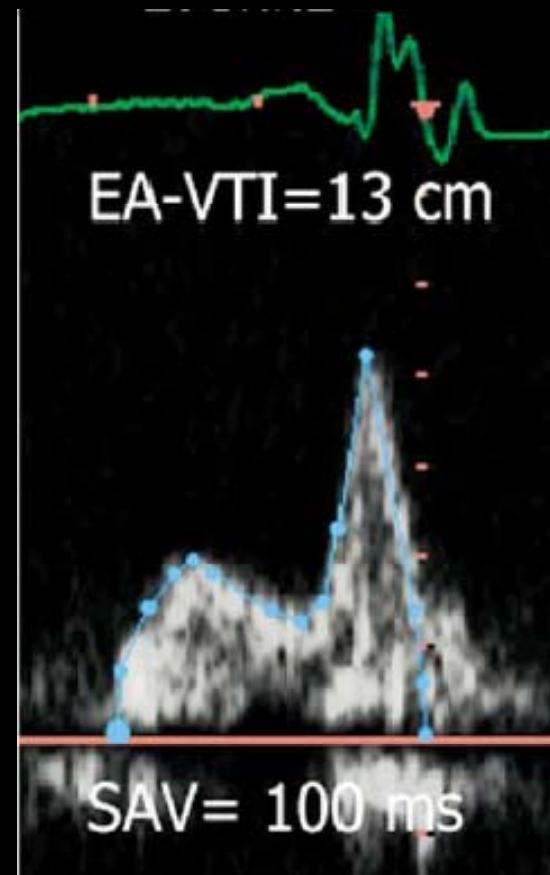
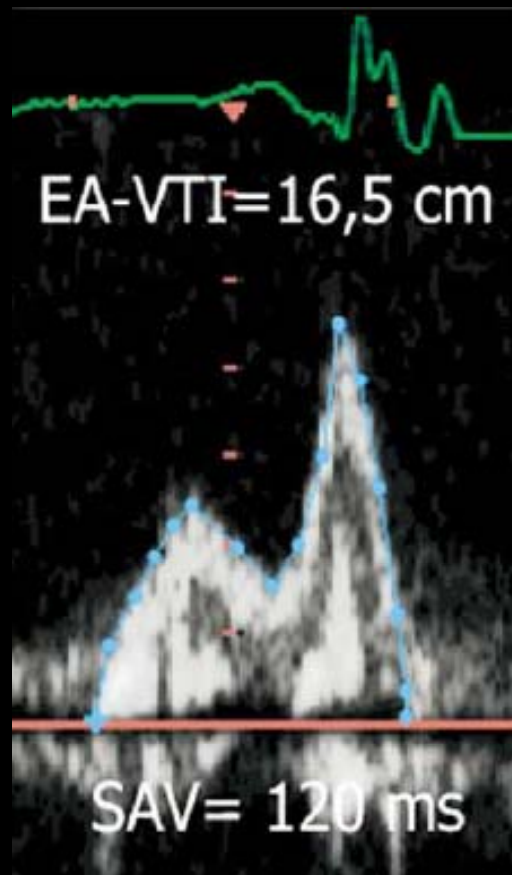
Measurement of aortic VTI is a surrogate of stroke volume, and may be measured at different programmed AV intervals.

CW Doppler may provide more stable measurements as compared to pulsed-wave Doppler.

AV intervals longer when calculated using the aortic VTI method than with the Ritter method.

AV Interval Optimization Mitral Inflow VTI Method

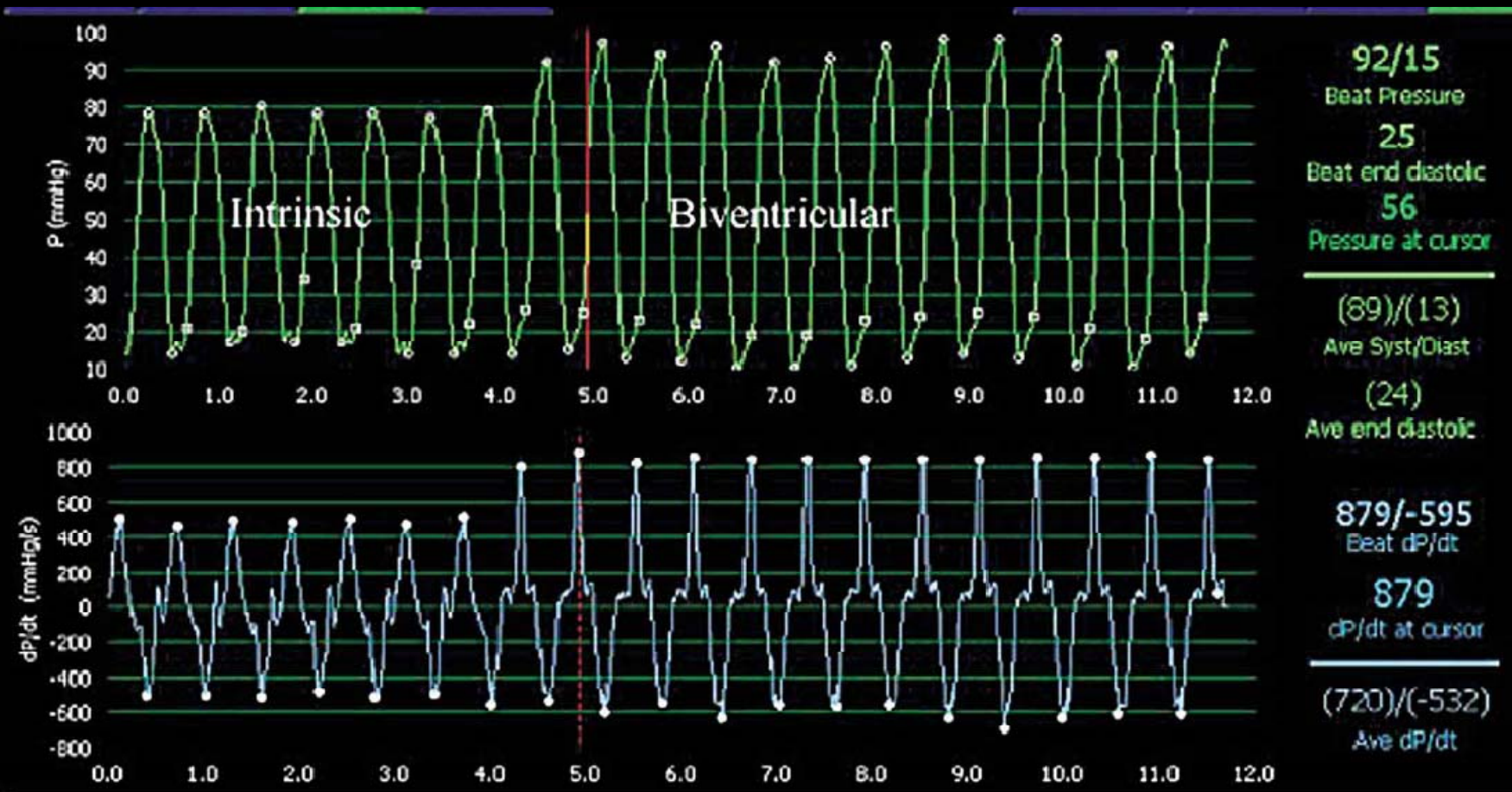
Pulsed-wave recording of transmitral VTI (maximal VTI of E and A waves)





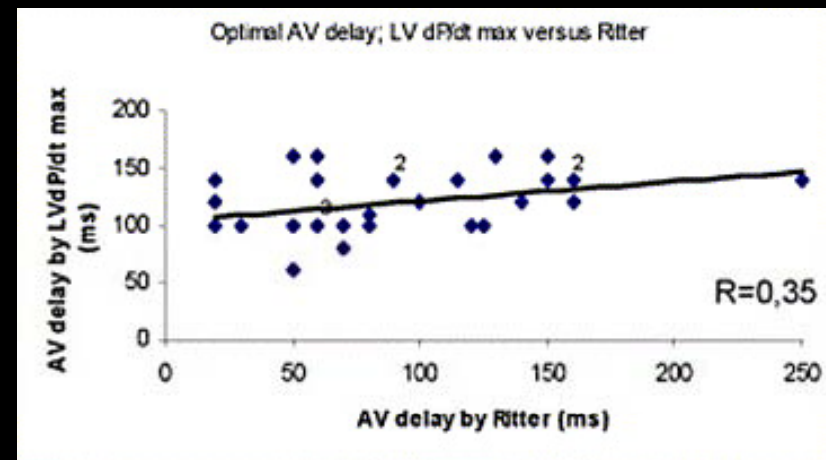
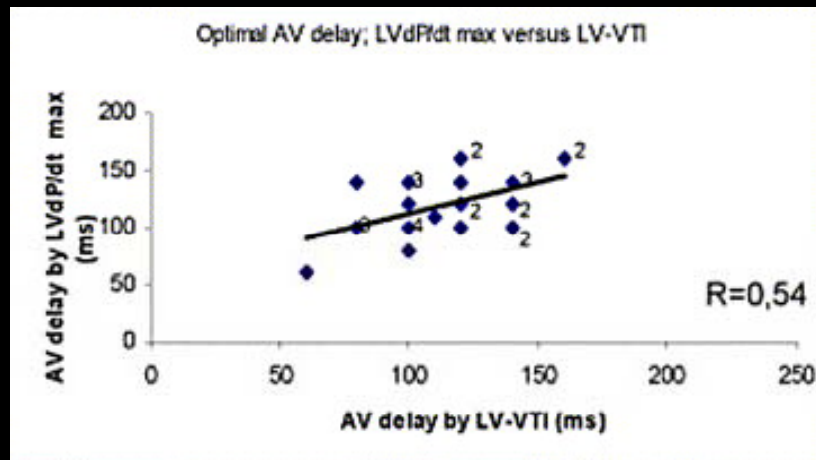
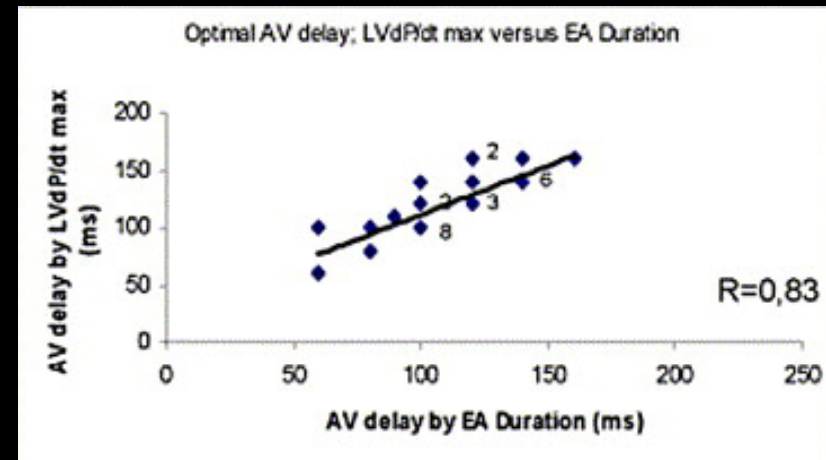
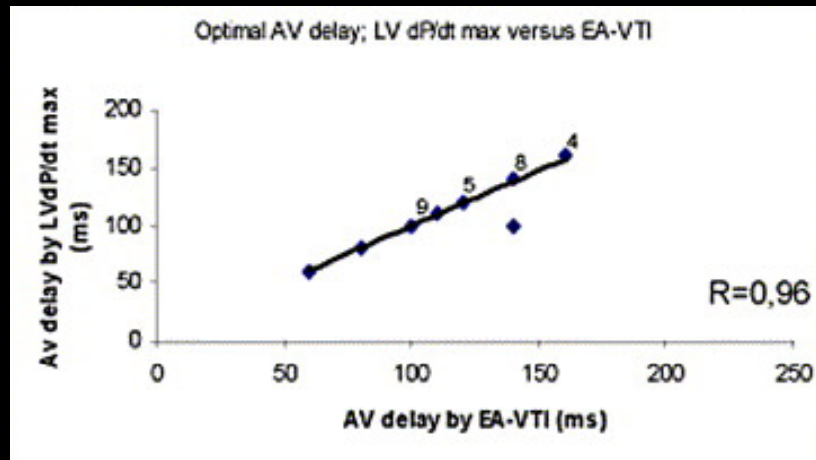
AV Interval Optimization Head-to-Head Comparison

LV dP/dT max for comparing 4 different methods (maximal filling time, mitral VTI, aortic VTI, and Ritter formula) in 30 patients

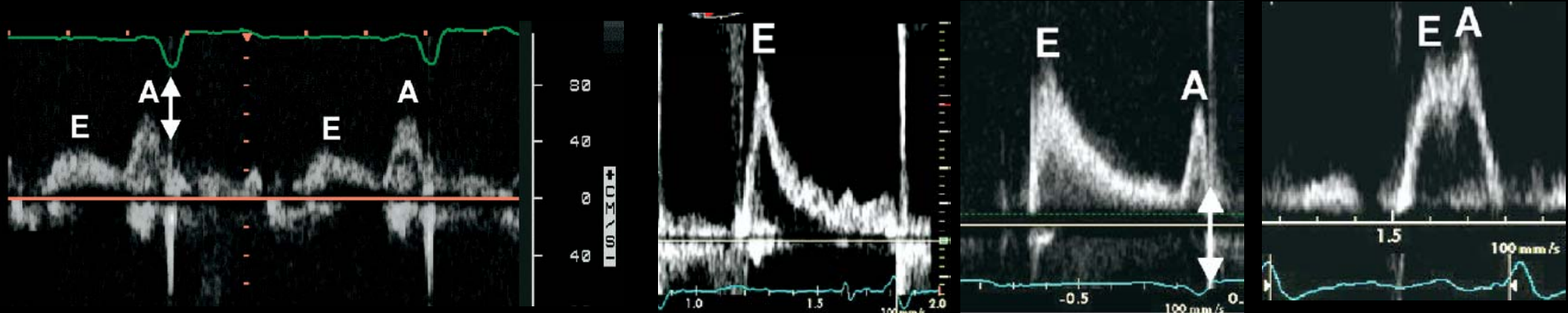




AV Interval Optimization Head-to-Head Comparison



AV Optimization



Satisfactory AV Delay

1. E and A waves separated
2. Termination of A after QRS onset or mitral closure click aligned with end of A and QRS complex

Absent A wave	Truncated A wave	Merged E & A
AV Much Too Short	AV Too Short	AV Too Long



AV Optimization



AV Interval Optimization

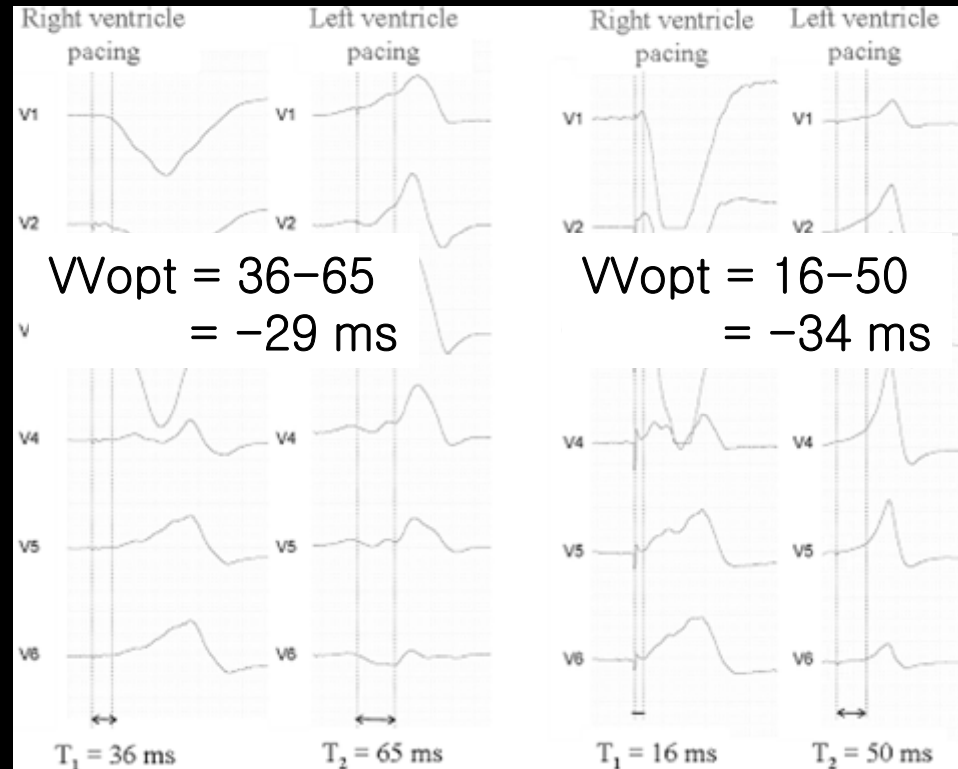
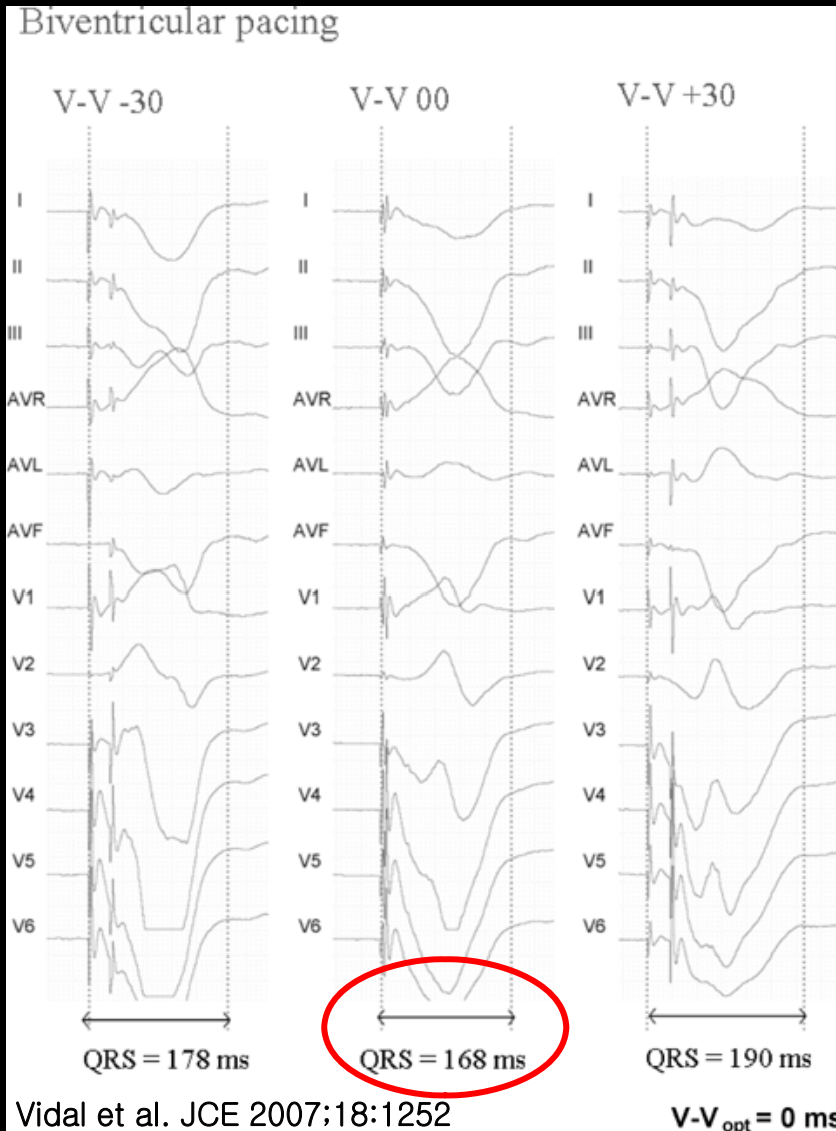
- **Although AV delay often positively impacts hemodynamics, LV resynchronization of intraventricular dyssynchrony is more important**
 - AV interval 100 to 130 ms
 - AV optimization enhanced LV hemodynamics in only a minority of patients with CRT



VV Interval Optimization

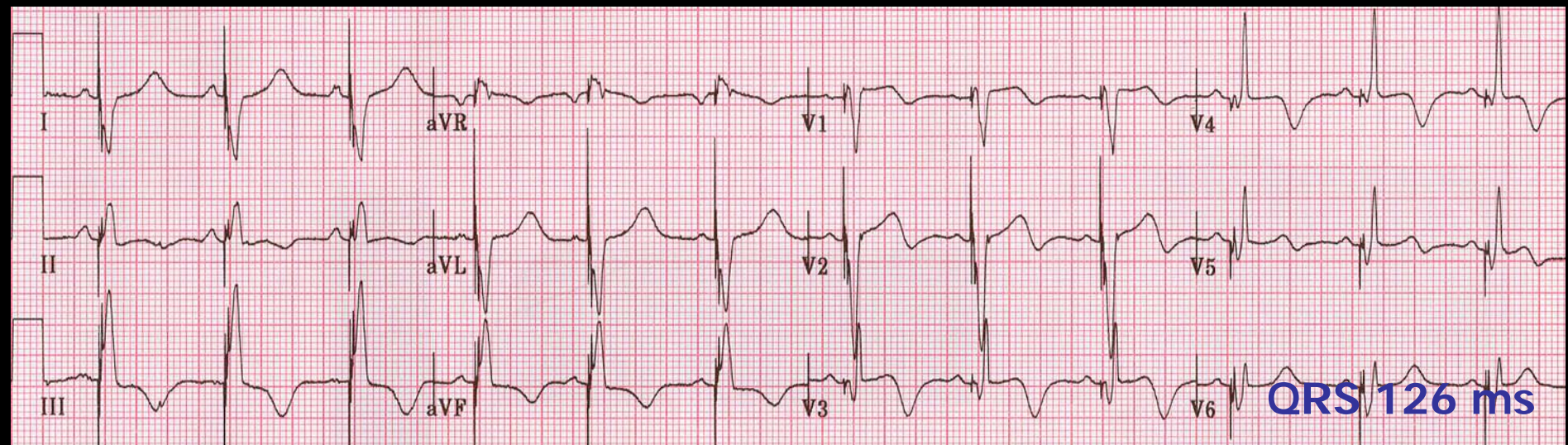
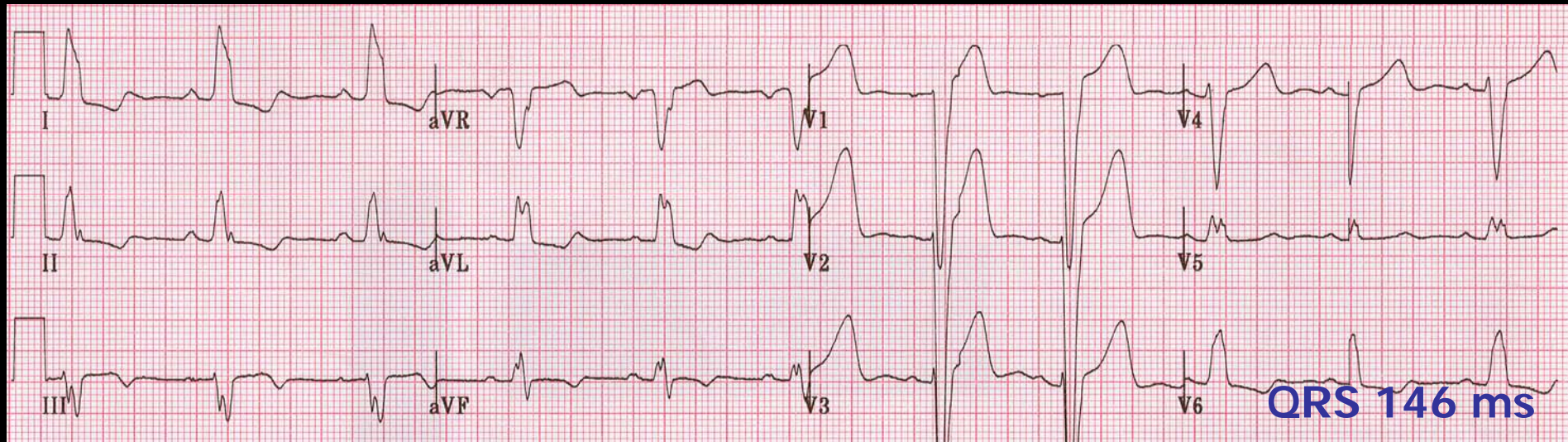
- **Electrocardiography**
- **Echocardiography**
 - M mode
 - Aortic VTI
 - TDI : highest mean global TDI velocity
 - 3D echocardiography
- **Radionuclide ventriculography (LVEF)**
- **Finger plethysmography**
- **Device algorithms**

VV Delay Optimization ECG Method



1. QRS width measurement
- Narrowest QRS width
2. Interventricular activation delay measurement
- Time from pacing spike to beginning of earliest fast deflection of QRS complex

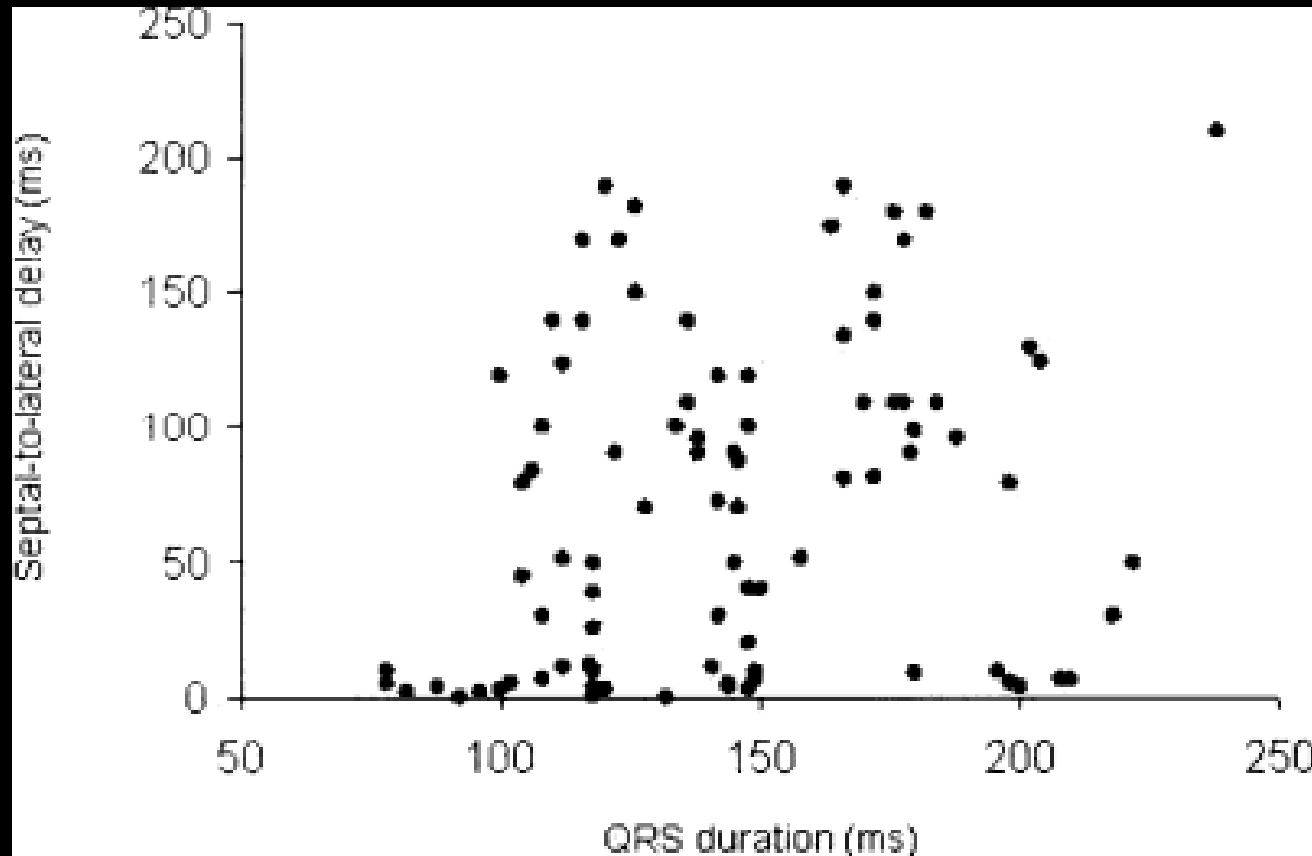
VV Delay Optimization ECG Method-QRS Width





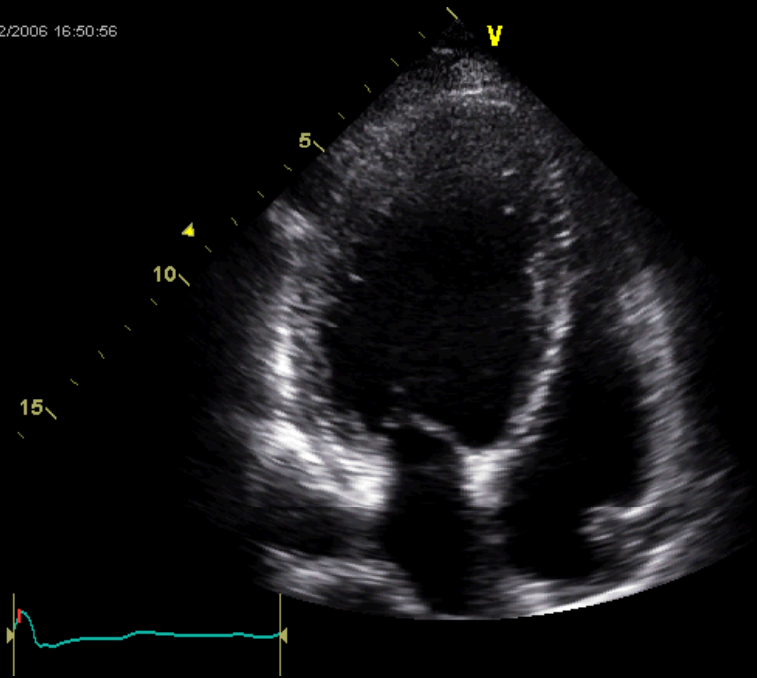
VV Interval Optimization ECG Method

No significant relation existed between QRS duration and septal to lateral delay.



VV Interval Optimization 2D-Echo

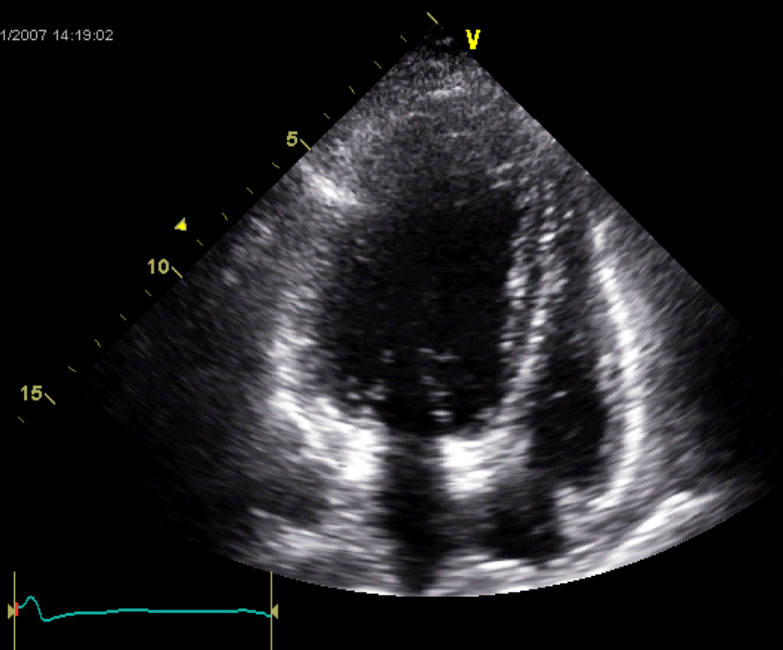
26/12/2006 16:50:56



53:103 63 HR

Before CRT Intraventricular dyssynchrony
EF=18%
LVEDD=61mm

04/01/2007 14:19:02



2:55 62 HR

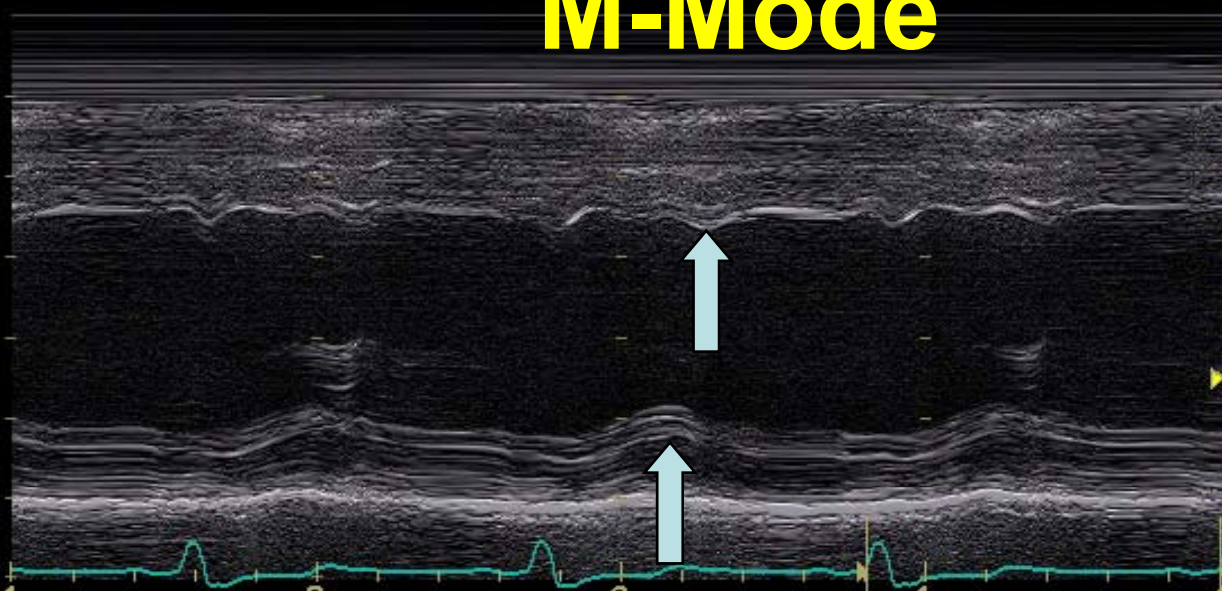
After CRT
EF=30%
LVEDD=51mm

VV Interval Optimization M-Mode

Before CRT

EF=18%

LVEDD=61mm



Septal to posterior wall motion delay : time delay between peak septal and posterior inward LV wall motion

Reproducibility is low.

M-mode is not advocated.

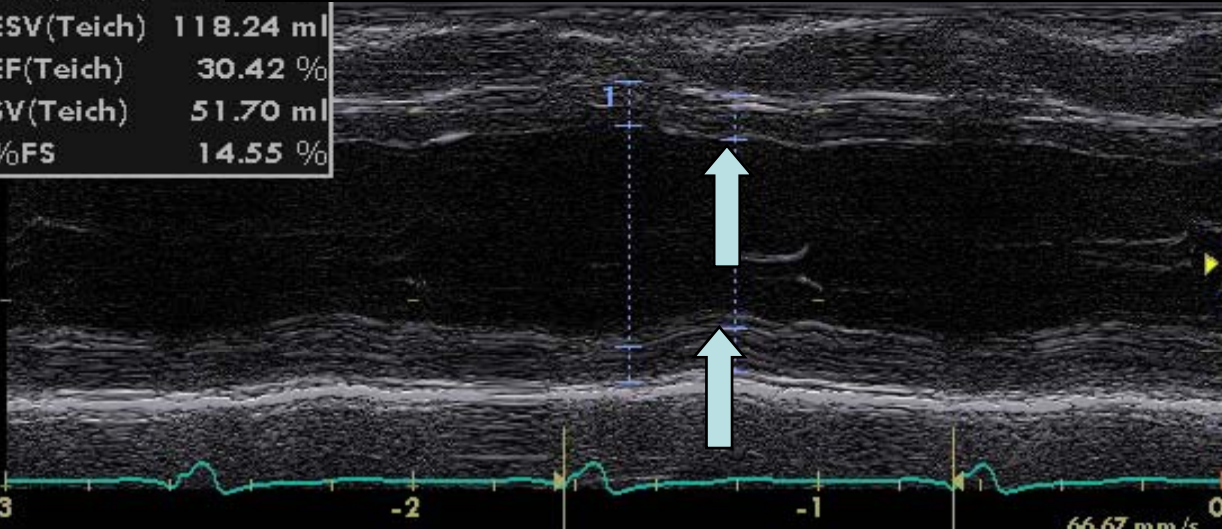
Intraventricular dyssynchrony > 130 ms

LVPWs	11.1
EDV(Teich)	169
ESV(Teich)	118.24 ml
EF(Teich)	30.42 %
SV(Teich)	51.70 ml
%FS	14.55 %

After CRT

EF=30%

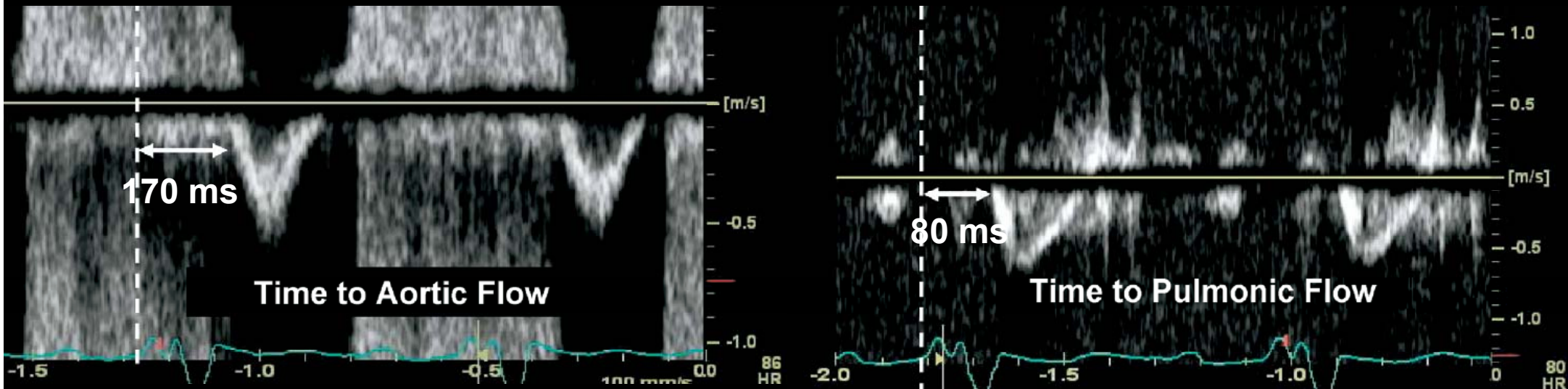
LVEDD=51mm



VV Interval Optimization PW/CW-Doppler RVOT/LVOT

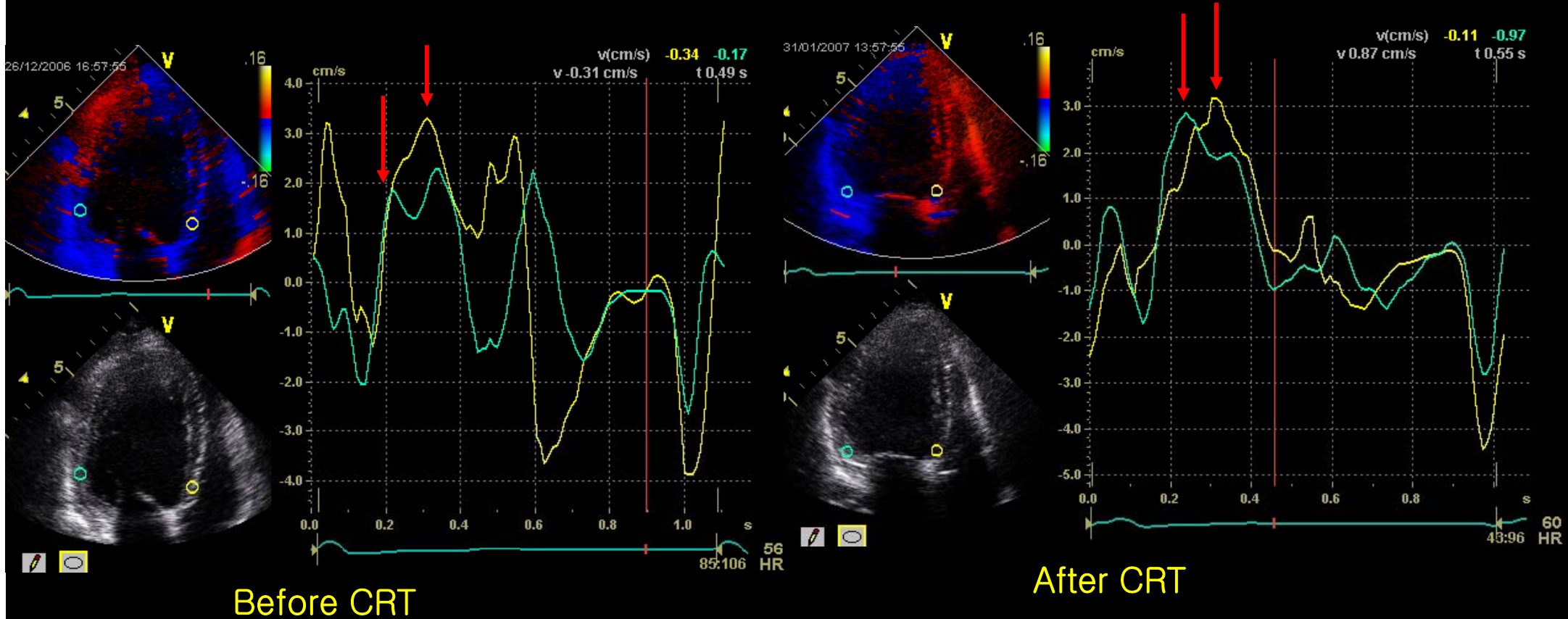
**Mechanical IV Delay =
Aortic Preejection interval – Pulmonary Preejection interval**

Interventricular dyssynchrony > 40 ms



Mechanical IV Delay = 170 – 80 ms

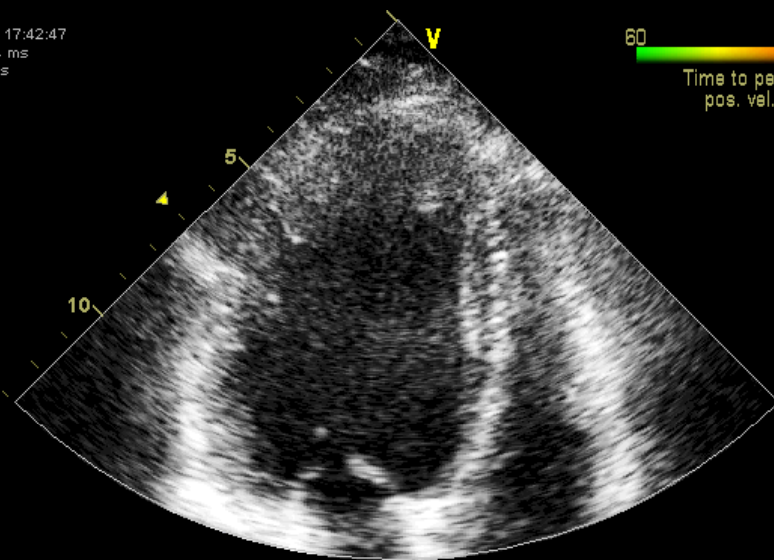
VV Interval Optimization Tissue Doppler Imaging



Time to peak systolic velocity : Intraventricular dyssynchrony > 65 ms

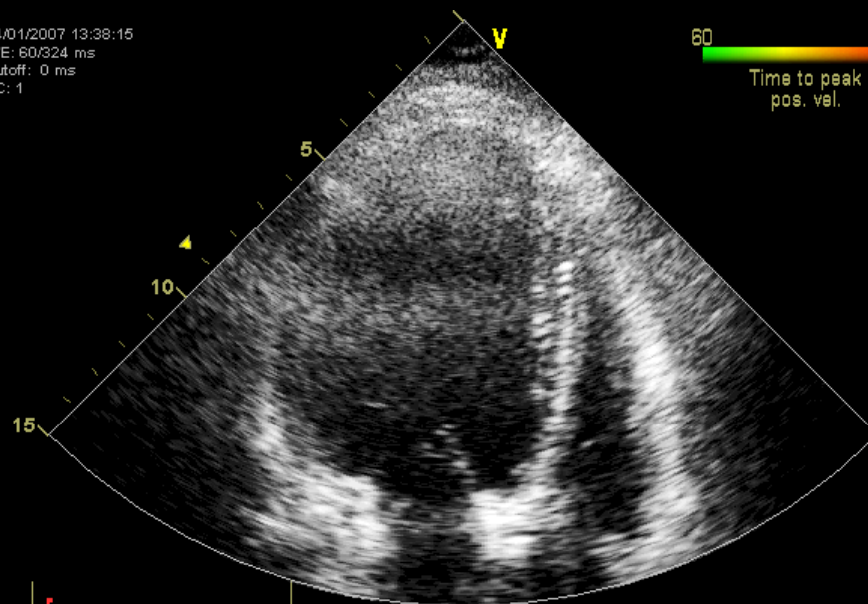
VV Interval Optimization 2D-Strain Imaging

26/12/2006 17:42:47
S/E: 60/334 ms
Cutoff: 0 ms
CC: 1



Before CRT

04/01/2007 13:38:15
S/E: 60/324 ms
Cutoff: 0 ms
CC: 1



After CRT

2:105
53
HR

2:93
61
HR

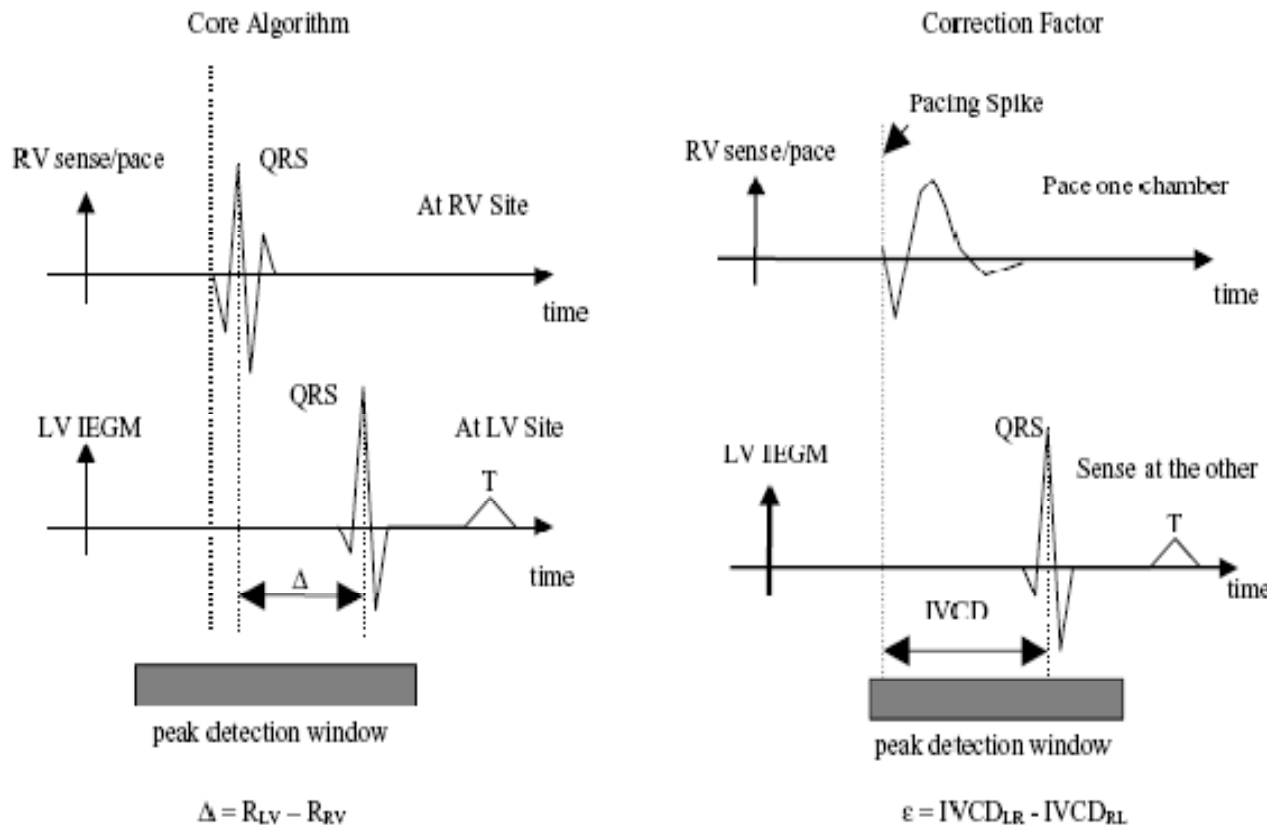
The magnitude of the calculated strain is expressed by colors in 2D image.
Homogenous patterns of diastolic and systolic myocardial colors suggest normal contraction.



Device-Based Algorithms

- **Guidant's Expert Ease for Heart failure algorithm**
 - Data of the PATH-CHF I and II studies
 - Optimal sensed and paced AV delay based on the patient's QRS width and intrinsic AV interval
- **Peak endocardial acceleration**
 - Measured by a RV lead equipped with a microaccelerometer located on its distal end (Sorin group, Milano, Italy)
 - Automatic measurement of optimal AV and VV intervals

VV Delay Optimization IEGM Method



Formula: IEGM VV = 0.5 (Δ + ε)

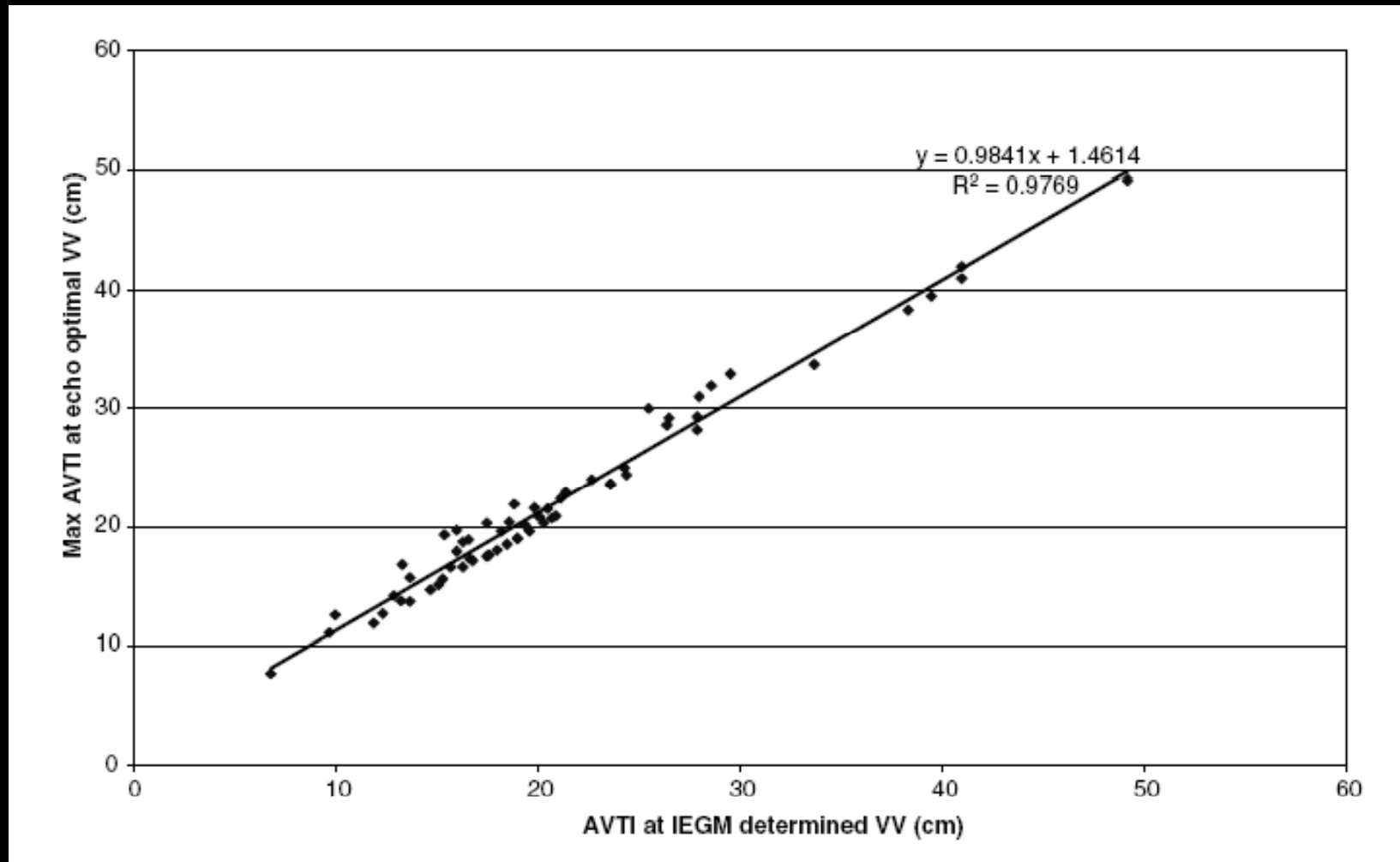
$\Delta = R_{LV} - R_{RV}$
(difference between time of peak intrinsic activation on LV lead and RV lead)

$\epsilon = IVCD_{LR} - IVCD_{RL}$
(difference in interventricular conduction delay between two ventricular paced propagation waveform time delay)

Optimal VV delay
= 0.5 * (Δ + ε)

The AVTI at IEGM-predicted VV delay was correlated very closely with maximum AVTI at echo optimal VV delay.

VV Delay Optimization IEGM Method



VV Interval Optimization

Index	Method	Cutoff	Advantage	Disadvantage
Intraventricular longitudinal dyssynchrony				
Opposing wall delay, two sites	Color TD peak velocity	≥ 65 ms	Rapidly applied	Affected by passive motion or tethering
Maximum wall delay	Color TD peak velocity	≥ 100 ms	More complete detection of longitudinal dyssynchrony	Affected by passive motion or tethering
Yu index	Color TD, 12-segment SD	≥ 33 ms	More complete detection of longitudinal dyssynchrony	Affected by passive motion or tethering
Delay in onset of systolic velocity	Pulsed TD	≥ 100 ms	More widely available	Acquisition technically difficult
Delayed longitudinal contraction	Color TD strain-strain rate	N/A	Less affected by passive motion or tethering	Technically demanding
Intraventricular radial dyssynchrony				
Septal to posterior wall delay	M-mode	≥ 130 ms	Widely available	Largely affected by passive motion or tethering
Septal to posterior wall delay	Radial strain	≥ 130 ms	Less affected by passive motion or tethering	Assesses only radial dynamics
Interventricular dyssynchrony				
Interventricular mechanical delay	Routine PW Doppler	≥ 40 ms	Widely available	Nonspecific, affected by LV and RV function



Conclusion

- **Optimal follow-up of patients with CRT plays an important role in ensuring that patients will derive maximum benefit from this treatment**
- **Most common way to optimize CRT devices is guided by echocardiography**
- **However, no ideal approach has yet been found.**

Thank you for your attention!

