Echocardiographic parameters to select patients for CRT

Disclosures: None

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2010 Focused Update of ESC guidelines on device therapy in heart failure

Considering limited resources, it would be prudent to target the population most likely to respond favourably. In patients with mild symptoms and a QRS width of 120–150 ms, clinicians may wish to assess other criteria associated with a favourable outcome such as dyssynchrony by echocardiography, LV dilatation, LBBB, non-ischaemic cardiomyopathy, or recent NYHA class III symptoms.

Dickstein et al. Eur Heart J 2010

Patient selection for CRT

Role of rest echocardiography

ESC HF guidelines 2012

I a

- **QRS ≥ 120 ms**
- Sinus rhythm
- LBBB morphology
- LVEF ≤ 35%

Patient selection for CRT

Far from clear !

Electrical criterion: QRS ≥ 120 ms

- **Lenient**
  - approx 40% of non-responders
- **Restrictive**
  - patients with narrow QRS are denied CRT

Cost of non-response

- Financial: 7.5 billion €

  (all potential CRT non-responders in Europe)

- Human:
  - risk of death at time of implantation
  - risk of complications
  - risk of inducing dyssynchrony

Yu CM et al. Eur Heart J 2010

Auger et al. Eur Heart J 2012

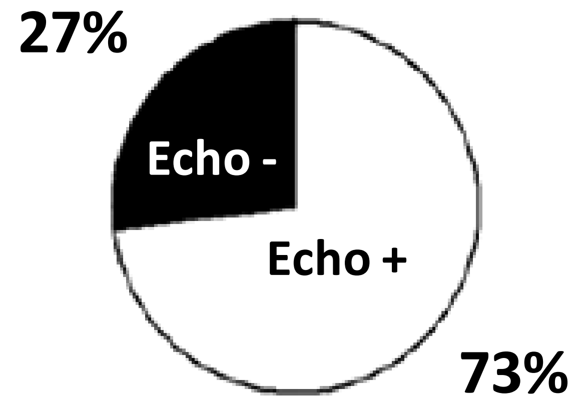
Who are responders?

Clinical

- NYHA improvement ≥1
- QoL scores
- 6MWD improvement 10-25%
- Morbidity and mortality

Echocardiographic

- Reverse remodeling (↓ESV 10-15%)
- Stroke volume increase >15%
- LVEF increase >5-25%



Clinical responders

Bleeker GB et al. AJC 2006

The role of echocardiography

Evaluation of LV global function

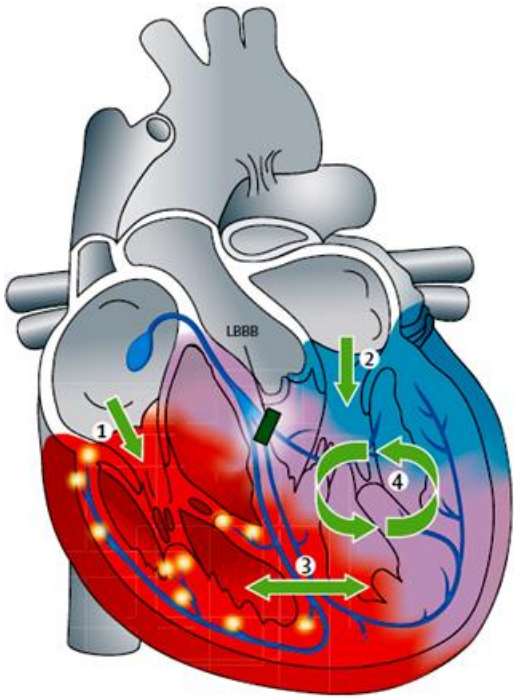
- LVEF and volumes
- candidacy and response to CRT

Evaluation of LV regional function

- extent and localization of scar
- high scar burden / PL scar

Evaluation of cardiac dyssynchrony

Cardiac dyssynchrony

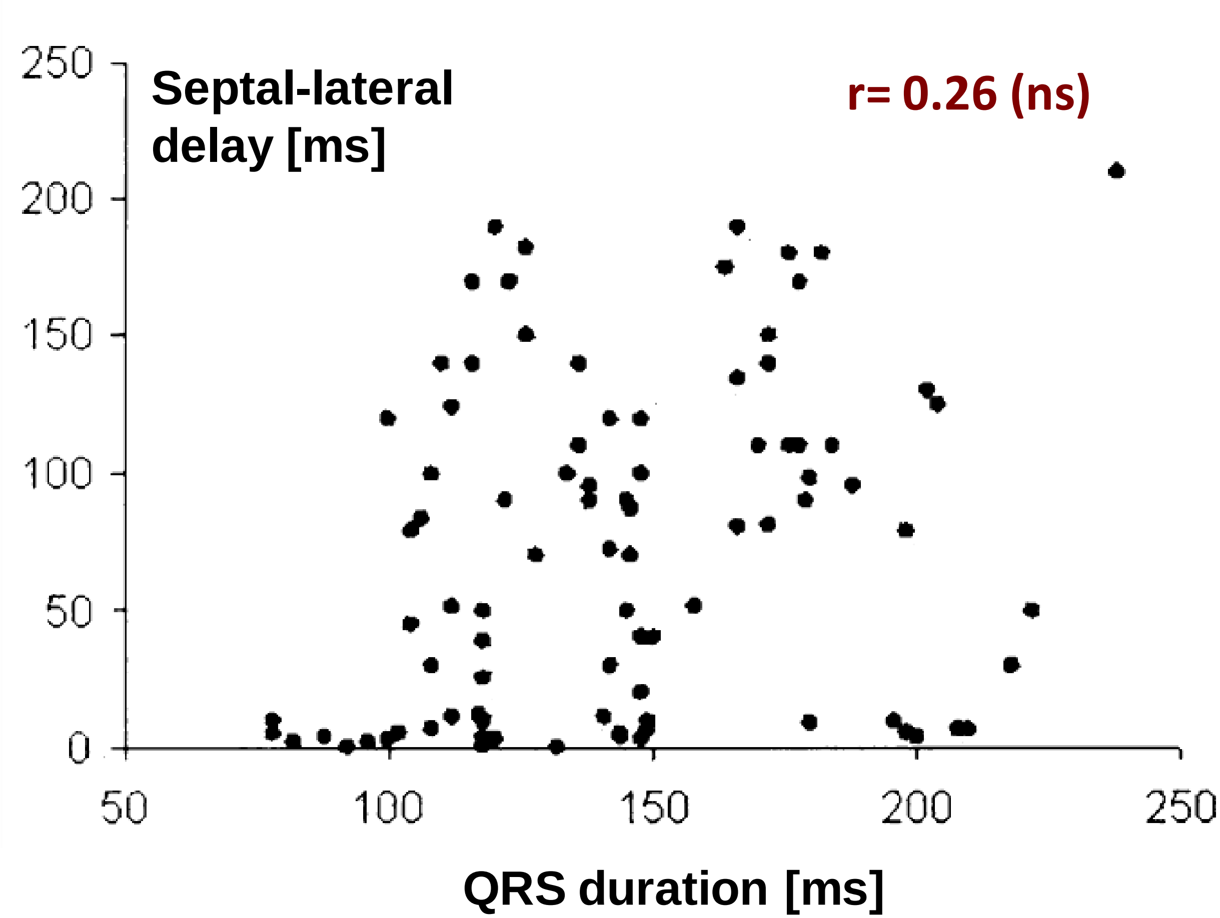


Holzmeister J et al. Lancet 2011

- Atrio-ventricular
- Inter-ventricular
- Intra-ventricular

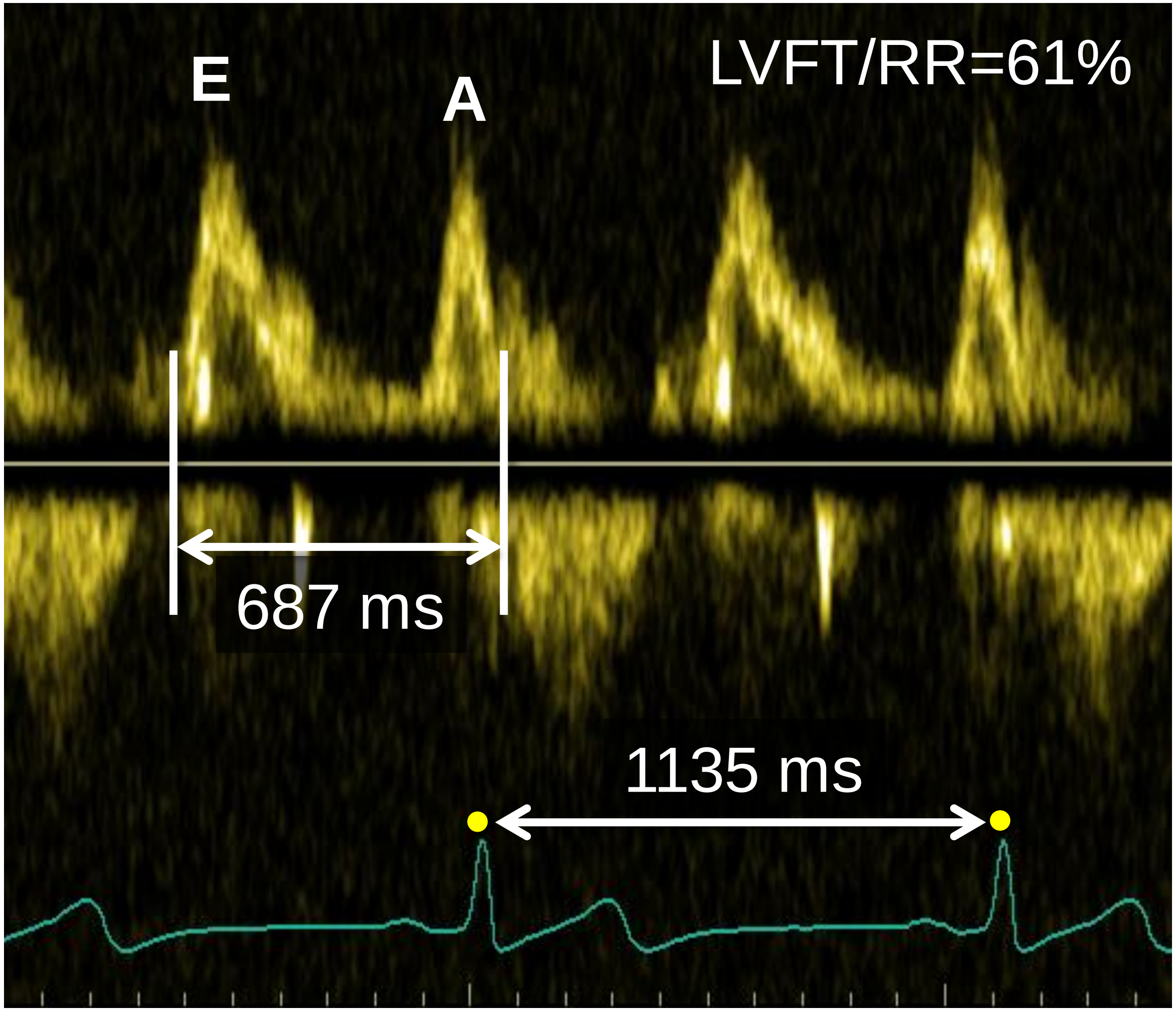
QRSd ~ LV dyssynchrony

30-40% with wide QRS do not exhibit LV dyssynchrony



Bleeker GB et al. J Cardiovasc Electrophysiol 2004

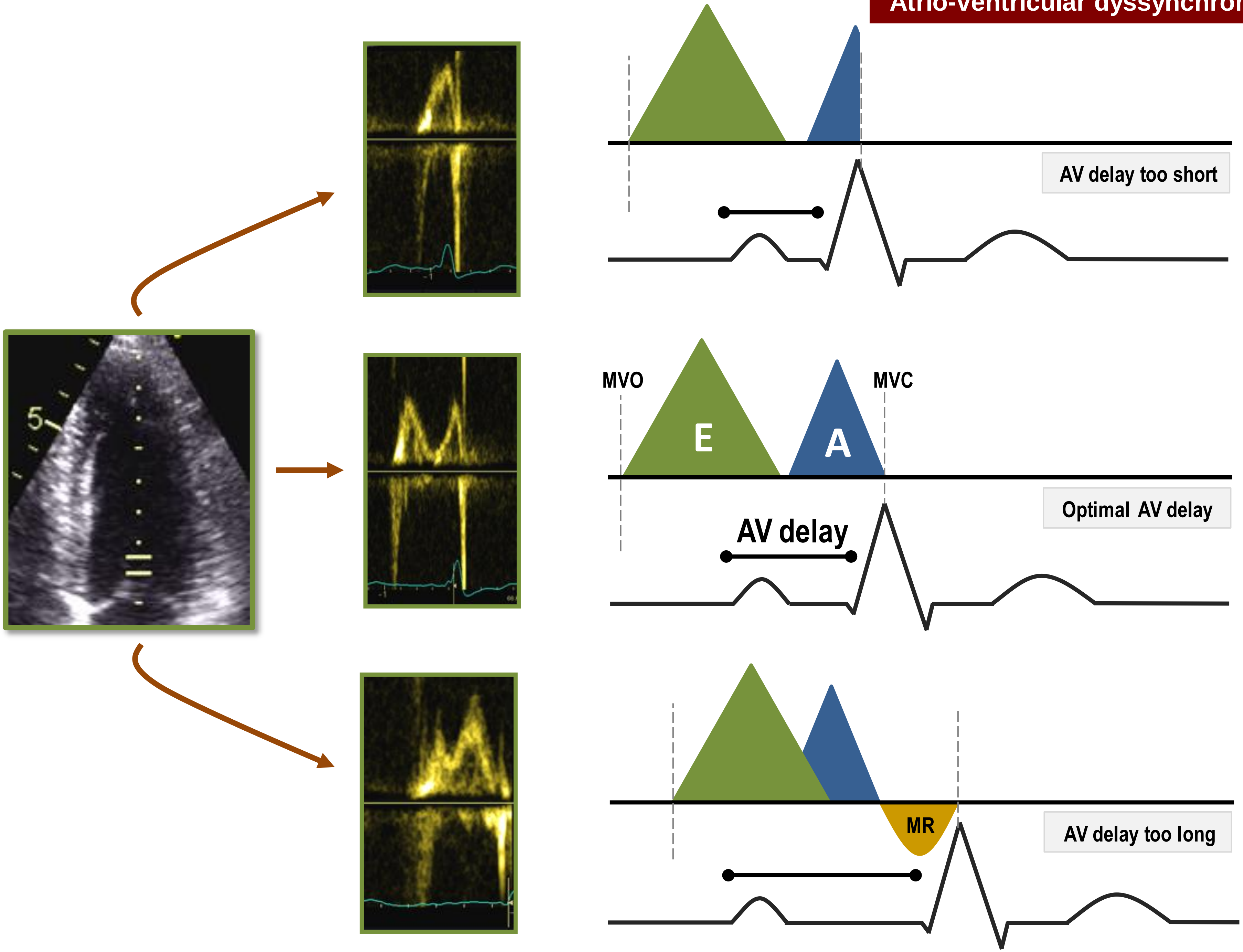
Atrio-ventricular dyssynchrony



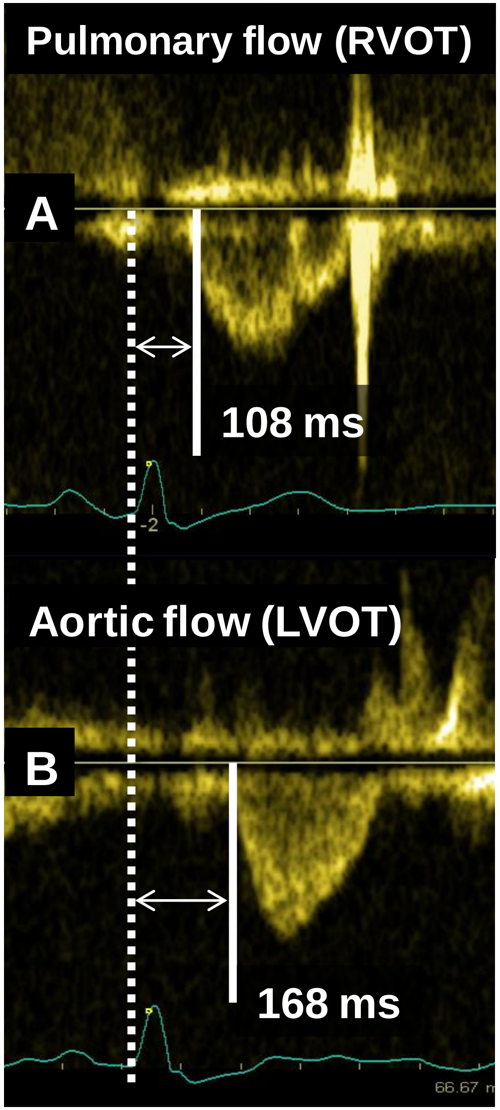
LVFT/RR <40%

Cleland JG et al. Eur J Heart Fail. 2001

Atrio-ventricular dyssynchrony



Inter-ventricular dyssynchrony

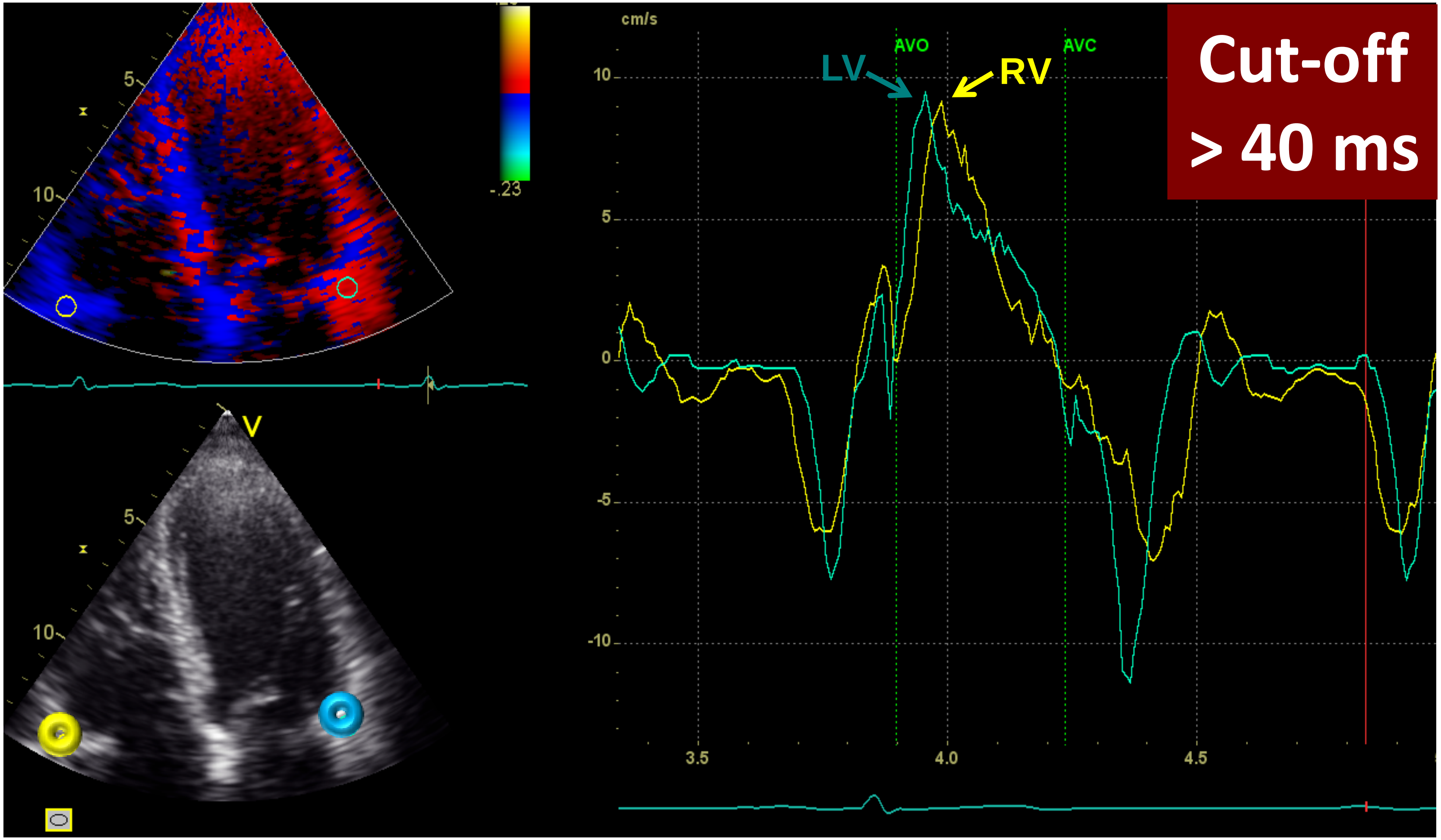


Conventional PW Doppler

Cut-off > 40 ms

Cleland JG et al. Eur J Heart Fail. 2001

Inter-ventricular dyssynchrony



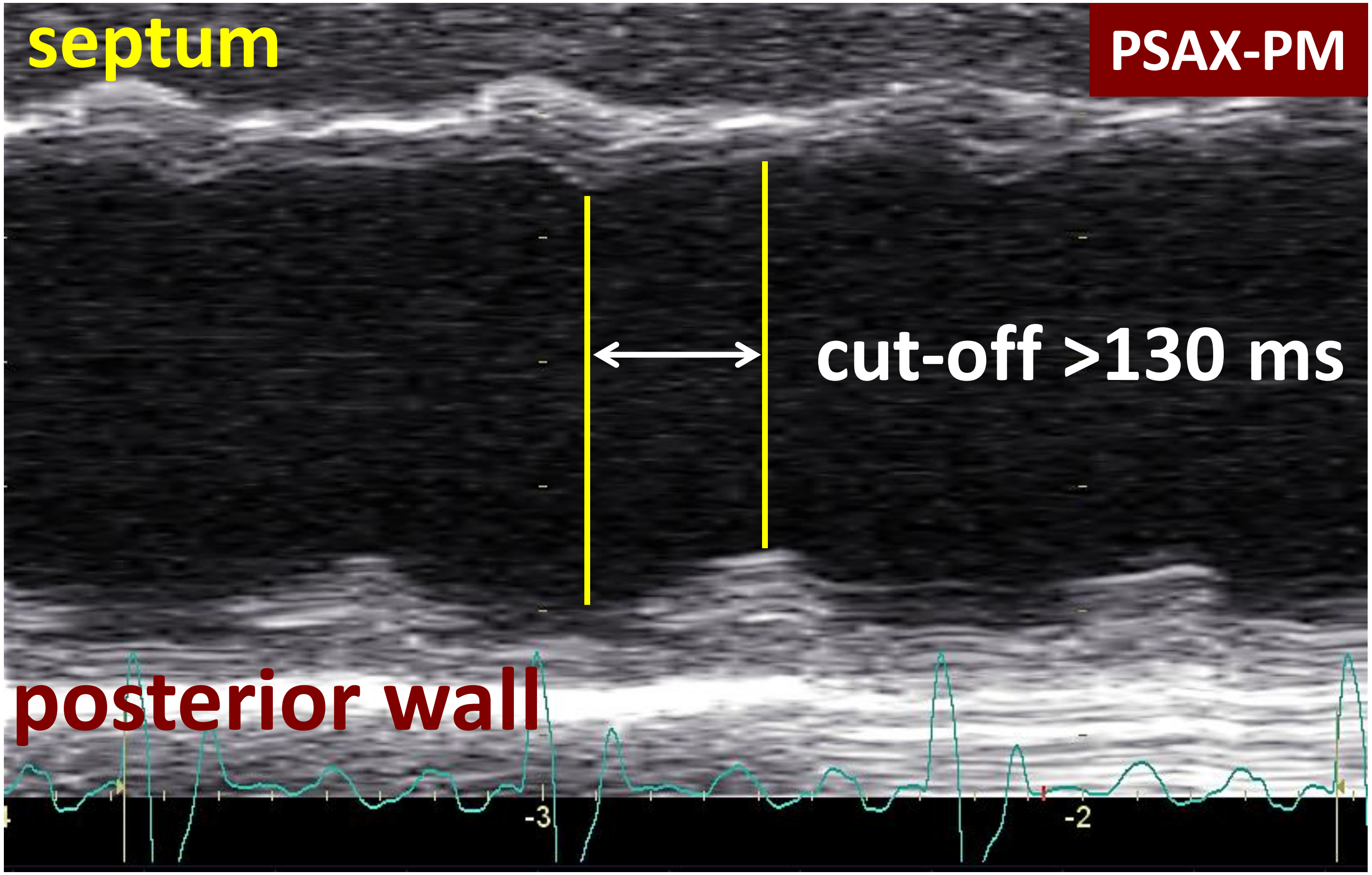
Cleland JG et al. Eur J Heart Fail. 2001

Intraventricular dyssynchrony

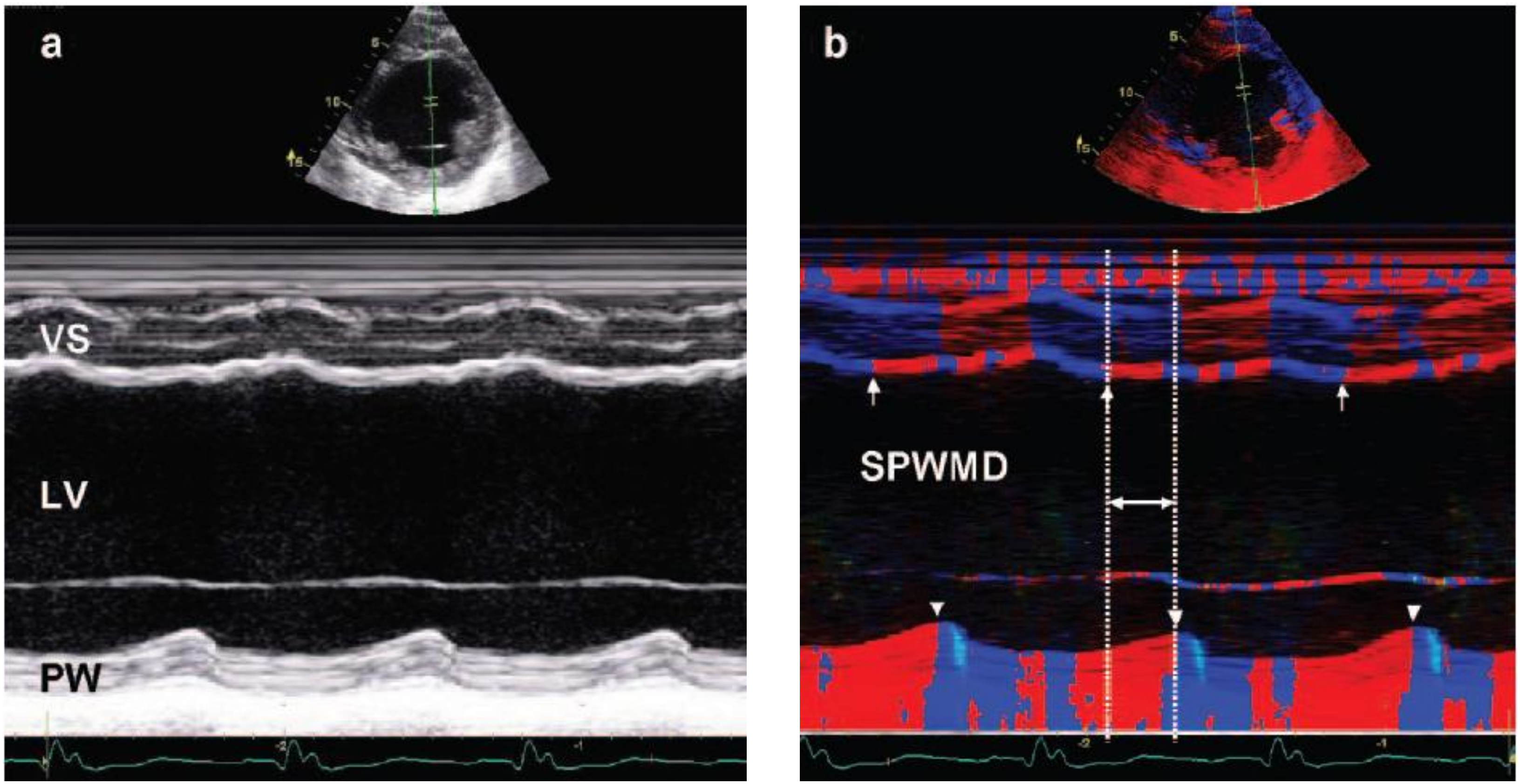
- M-mode
- PW Doppler
- Tissue Velocity Imaging
- Strain Imaging
- Visual assessment

Intraventricular dyssynchrony

M-mode: septal to posterior wall motion delay



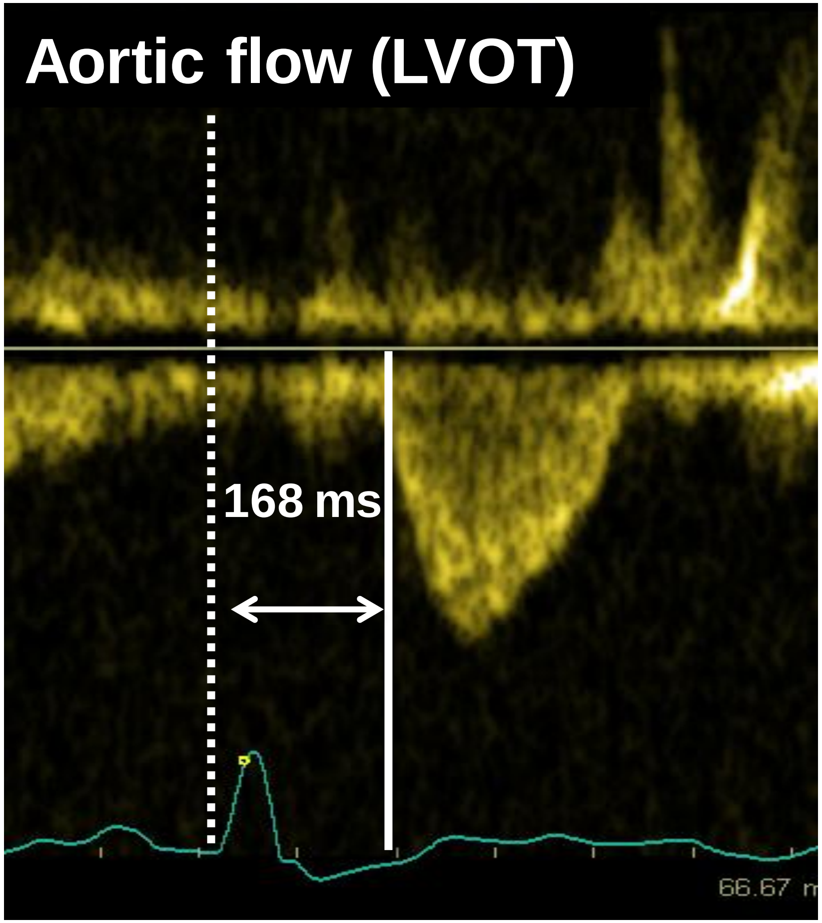
The lack of distinct peaks?



Anderson L et al. Circulation 2008

Intraventricular dyssynchrony

PW Doppler: LV electromechanical delay



Cut-off >140 ms

Delayed electrical activation

↓

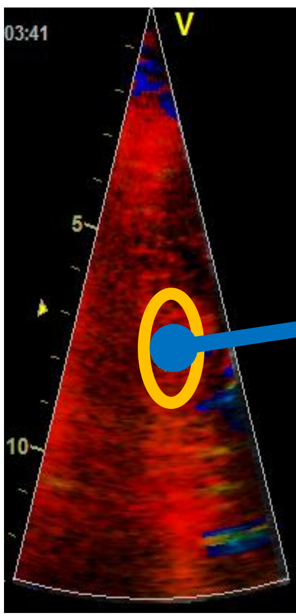
Slow pressure development within the LV

↓

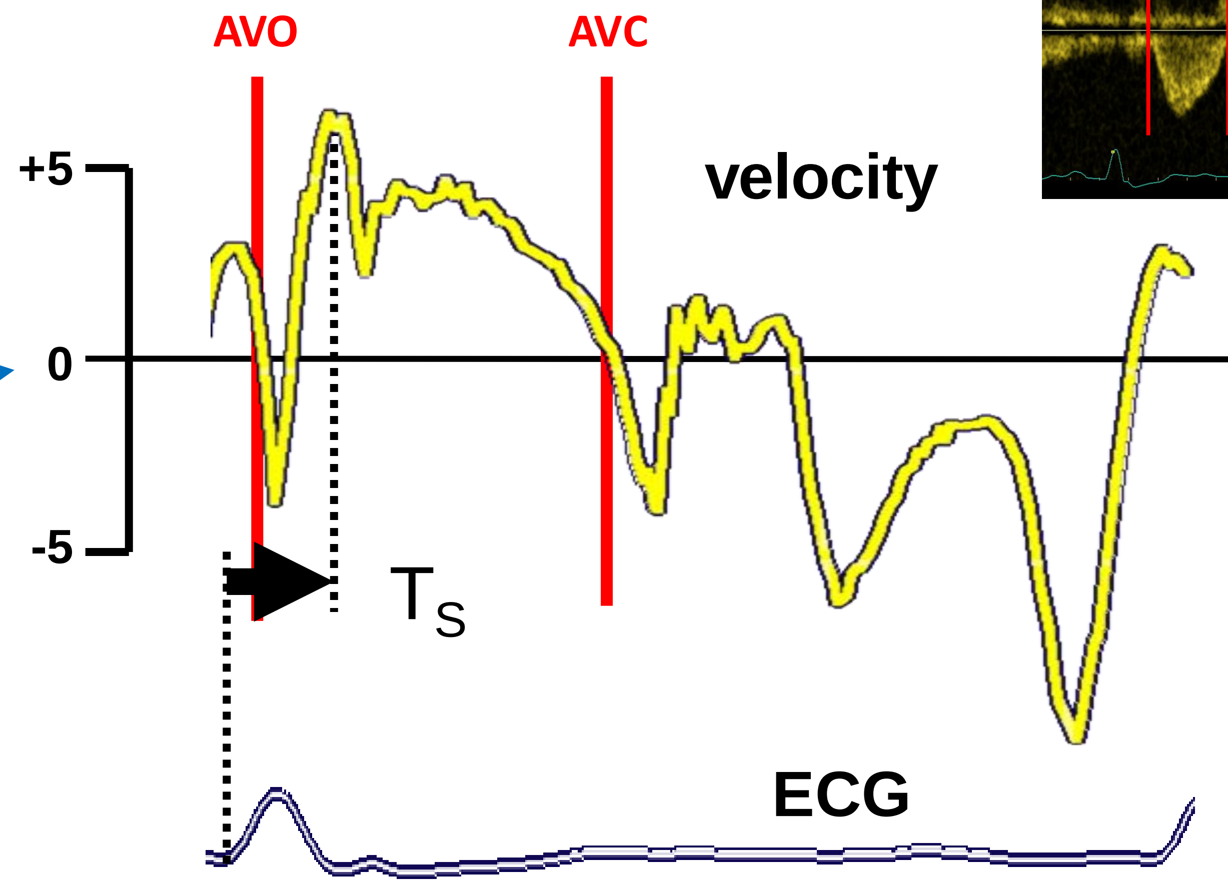
Delay in aortic valve opening

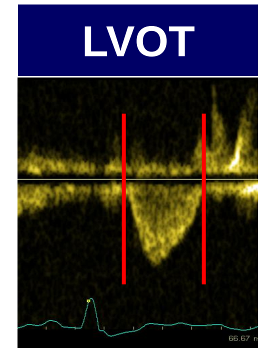
Dyssynchrony by Tissue Velocities

Time from the onset of QRS to the *highest systolic peak during the ejection* phase



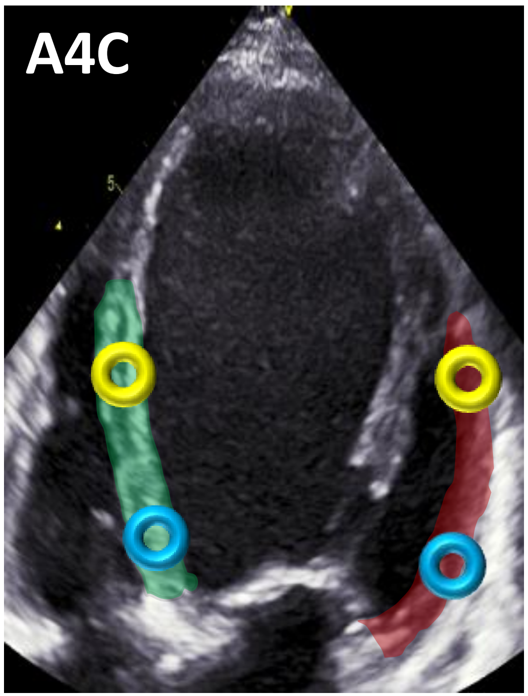
TVI

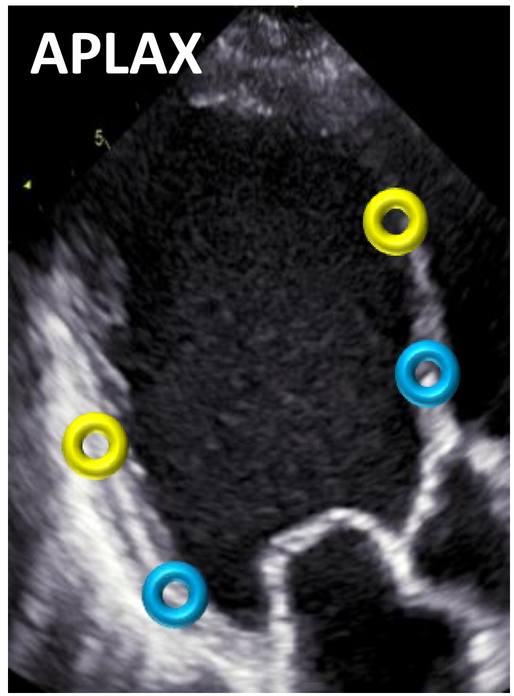




Dyssynchrony by Tissue Velocities

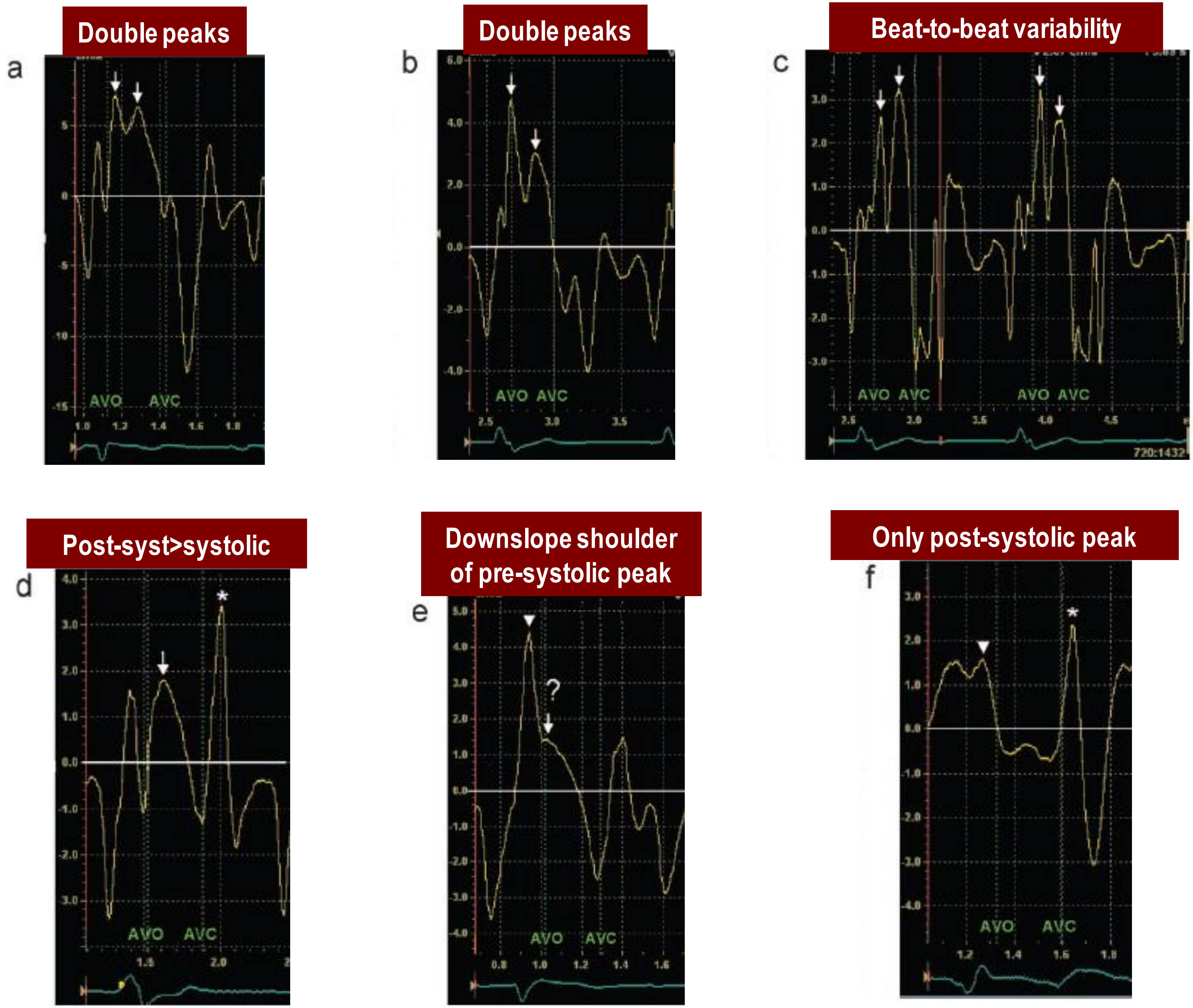
Max difference = the longest – the shortest Ts
Standard deviation of Ts (6 or 12 segments)





Septal to lateral delay	Cut-off 65 ms	Sn 87%	Sp 100%
Ts-SD12	Cut-off 33 ms	Sn 87%	Sp 81%

Gorcsan et al AJC 2004; Yu et al JACC 2005



Anderson L et al. Circulation 2008

Tissue velocities: Troubleshooting

Multiple peaks in ejection phase?

- Take the highest (not the first) peak

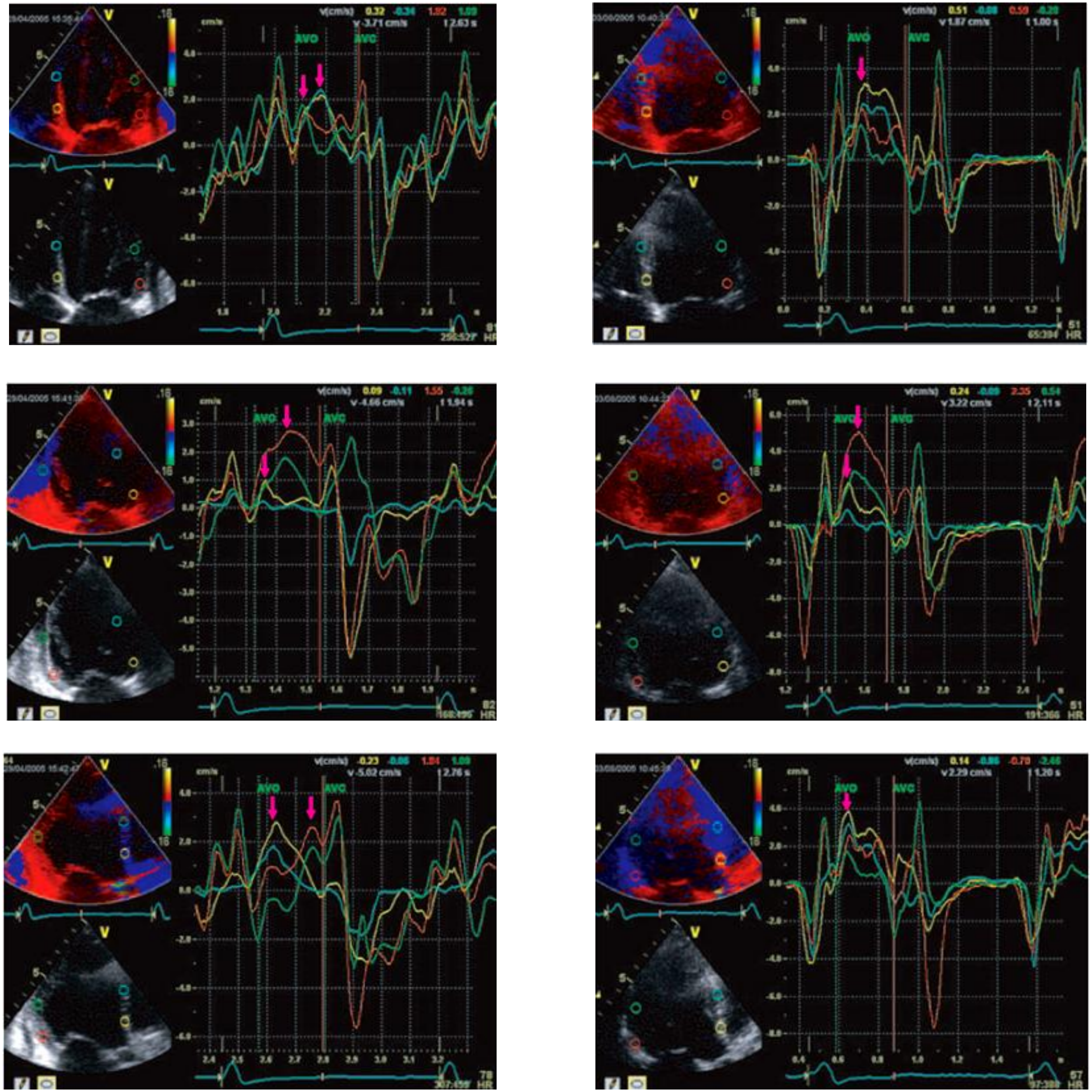
≥ 2 peaks with the same amplitude?

- Choose the earliest peak

Only a negative peak?
The velocity is too noisy/very low?

- Neglect those particular segments

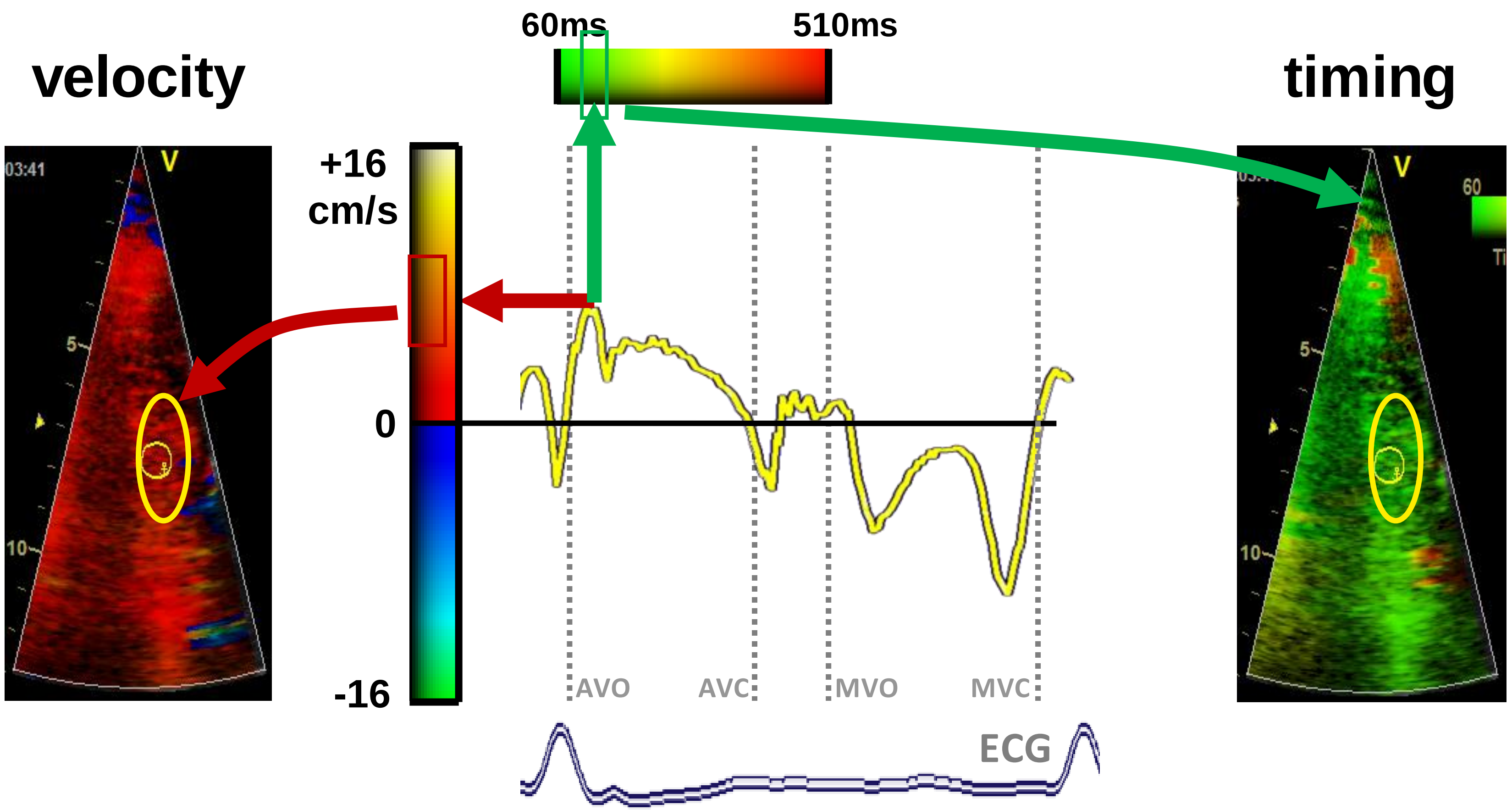
Before CRT



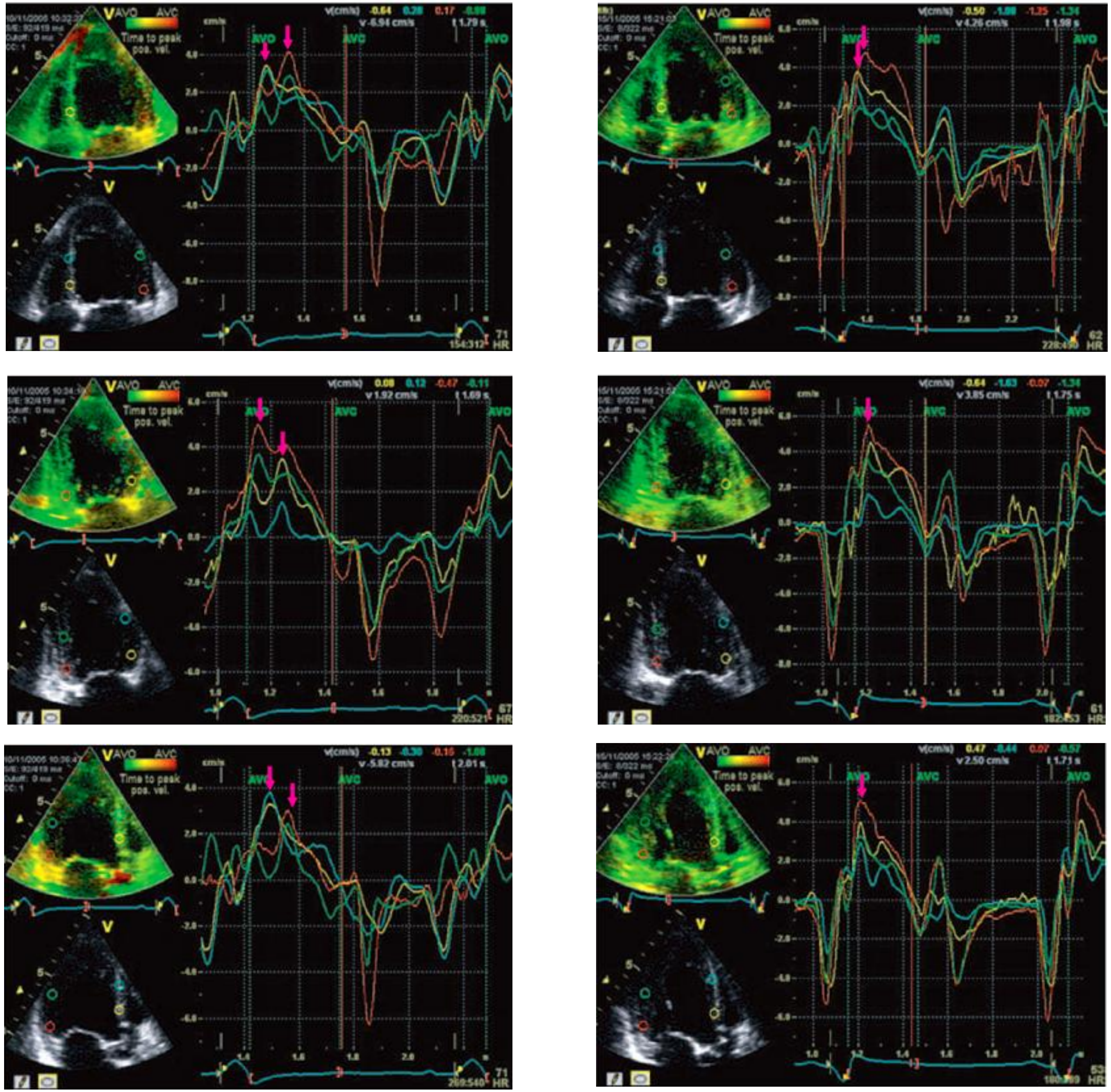
After CRT

Tissue Synchronicity Imaging

peak velocity vs. time to peak velocity

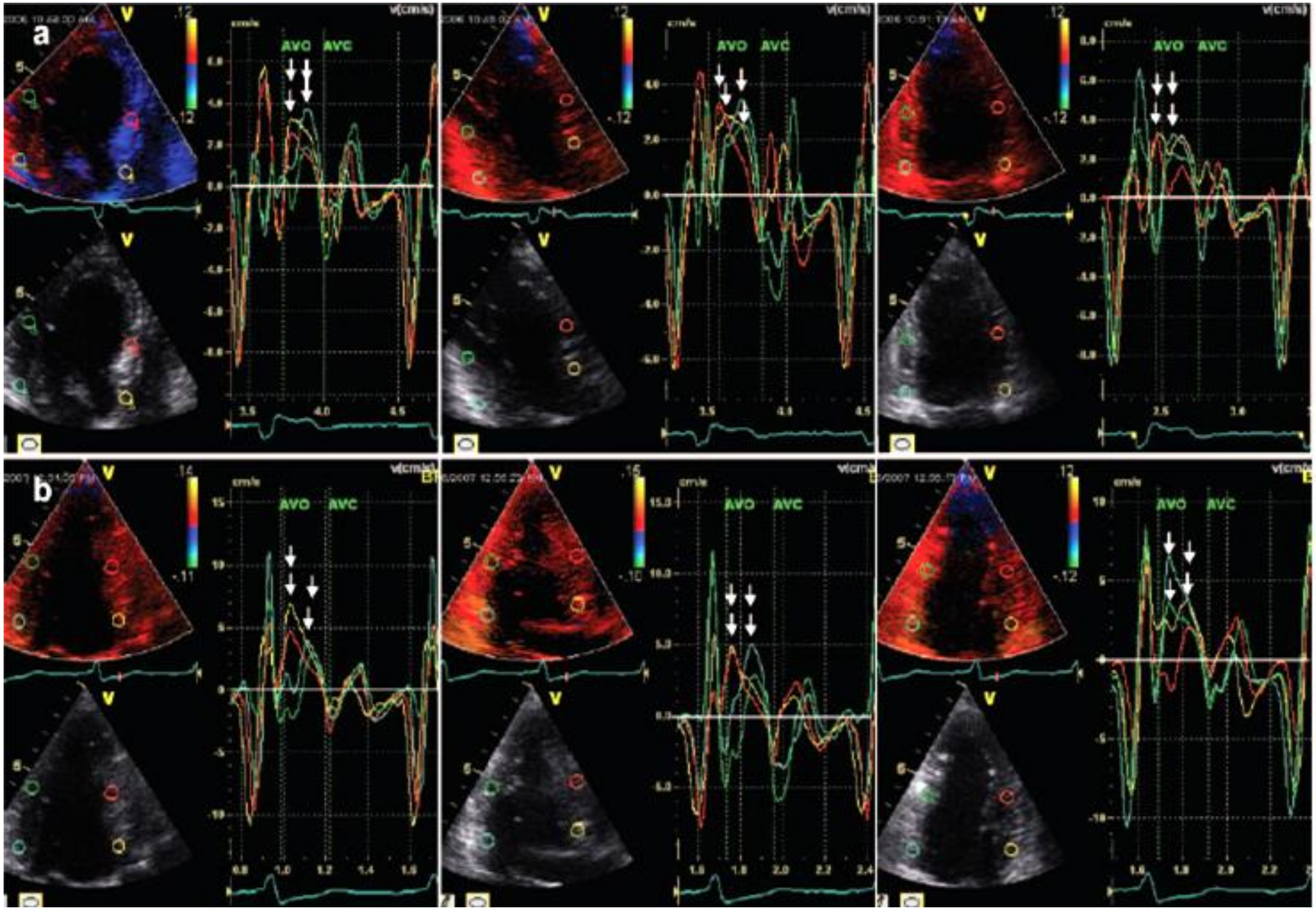


Before CRT



After CRT

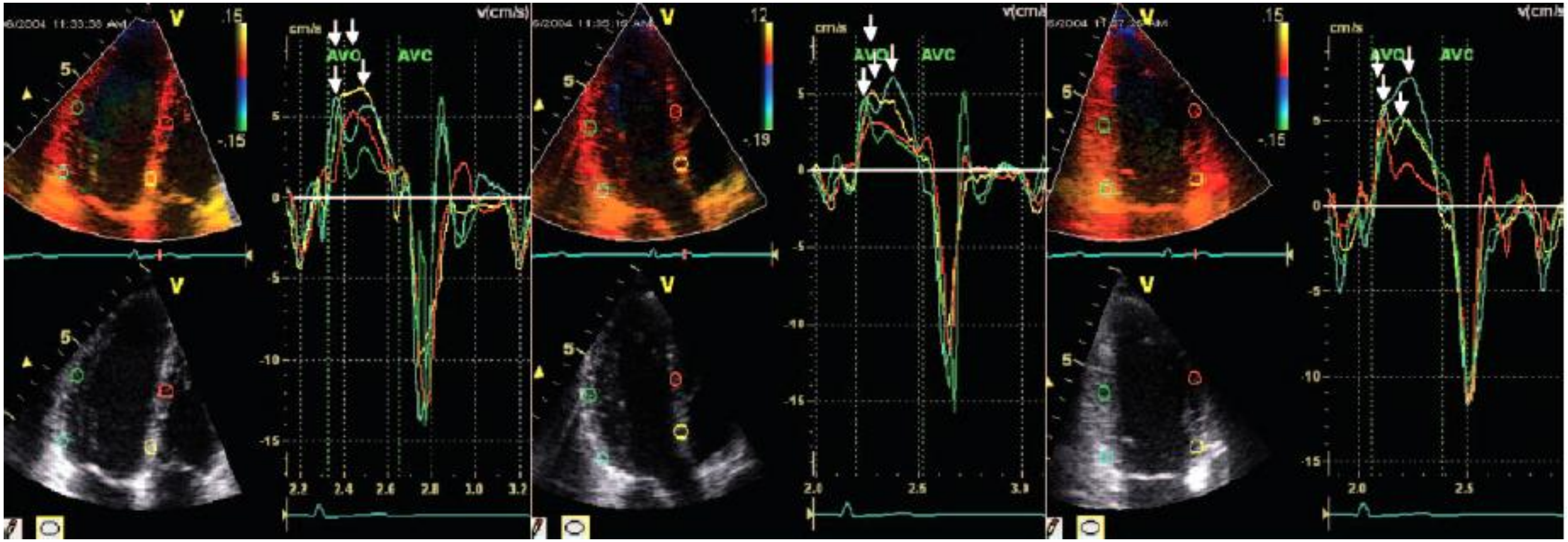
Before CRT



After CRT: LVEF ↑ 20%

Anderson L et al. Circulation 2008

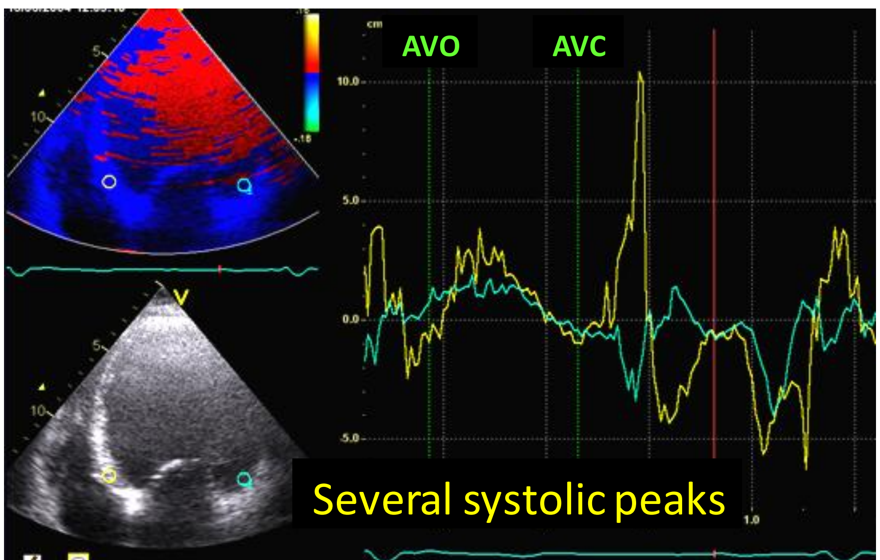
Normal subject



- **Septal-lateral wall motion delay: 100 ms (≥ 60 ms)**
- **Ts-SD12: 55 ms (> 32ms)**
- **CRT?**

Limitations of Tissue Velocities

- Challenging acquisition
- Challenging interpretation
- Motion (tethering) vs. contractility



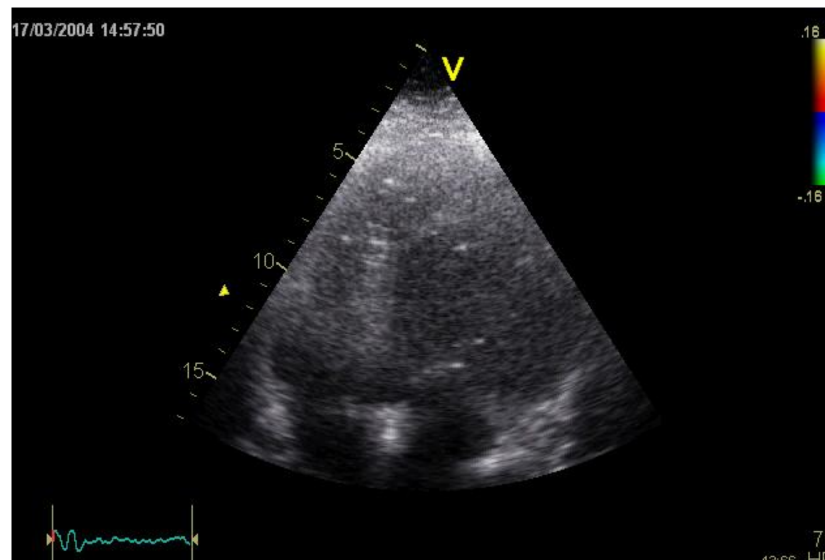


Table 1. Summary of Echocardiographic Predictors of Response to CRT

Echocardiographic Predictor	Description of Method	Echocardiography Method	Cutoff
SPWMD[10]	Septal-posterior wall motion delay; M mode measured by parasternal short-axis view	M mode	≥130 ms
IVMD[14]	Interventricular mechanical delay defined as the difference between left and right ventricular preejection intervals	Pulsed Doppler	≥40 ms
LVFT/RR[14]	Left ventricular filling time (LVFT) in relation to cardiac cycle length (RR) as measured by transmitral Doppler echo expressed as percentage	Pulsed Doppler	≤40%
LPEI[14]	Left ventricular preejection interval defined as the time interval between the beginning of QRS and beginning of left ventricular ejection by Doppler	Pulsed Doppler	≥140 ms
LLWC[14]	Intraventricular dyssynchrony left lateral wall contraction defined as the presence of overlap between the end of lateral wall contraction (via M mode) and onset of LV filling (by Doppler echocardiography)	M mode and pulsed Doppler	Any overlap
Ts-(lateral-septal)[15]	Delay between time to peak systolic velocity in ejection phase at basal septal and basal lateral segments	TDI	≥60 ms
Ts-SD[11,13]	SD of time from QRS to peak systolic velocity in ejection phase for 12 left ventricular segments (6 basal and 6 middle)	TDI	≥32 ms
PVD[16]	Peak velocity difference derived from subtracting the maximal from the minimal difference of time to peak velocity (excluding velocities occurring during isovolumic contraction time) for 6 segments at basal level	TDI	≥110 ms
DLC[17,18]	Delayed longitudinal contraction measured in the 6 basal left ventricular segments with a systolic contraction component in early diastole by TDI and confirmed with strain rate imaging	TDI+SRI	≥2 basal segments
Ts-peak displacement	Maximum difference of time to peak systolic displacement for 4 segments	TDI	≥Median
Ts-peak (basal)	Maximum difference of time to peak systolic velocity for 6 segments at basal level	TDI	≥Median
Ts-onset (basal)	Maximum difference of time to onset of systolic velocity for 6 segments at basal level	TDI	≥Median

Chung ES et al. Circulation 2008

Heart Failure

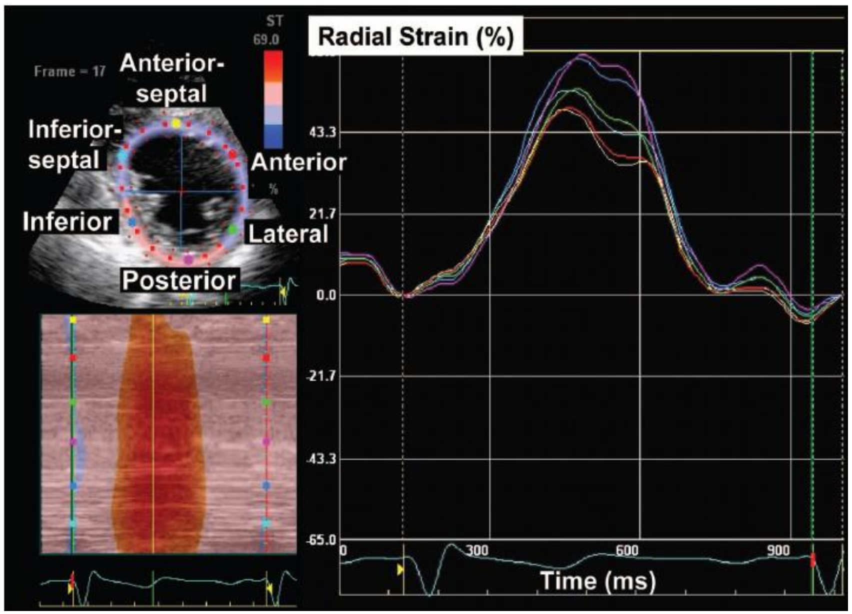
Results of the Predictors of Response to CRT (PROSPECT) Trial

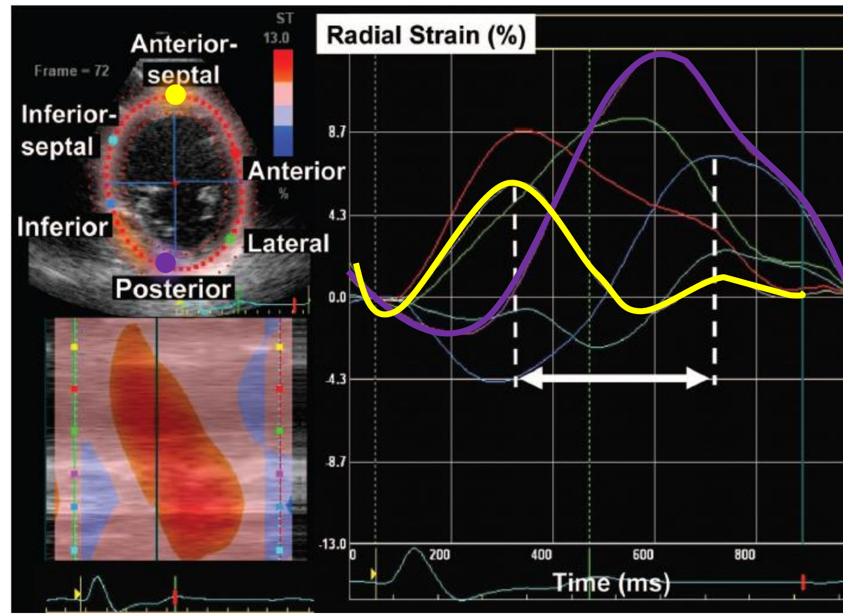
Eugene S. Chung, MD; Angel R. Leon, MD; Luigi Tavazzi, MD; Jing-Ping Sun, MD;
Petros Nihoyannopoulos, MD; John Merlino, MD; William T. Abraham, MD; Stefano Ghio, MD;
Christophe Leclercq, MD; Jeroen J. Bax, MD; Cheuk-Man Yu, MD, FRCP; John Gorcsan III, MD;
Martin St John Sutton, FRCP; Johan De Sutter, MD, PhD; Jaime Murillo, MD

Circulation 2008

Dyssynchrony by Radial Strain

- 2D Speckle tracking
- Frame rate 30-90 Hz





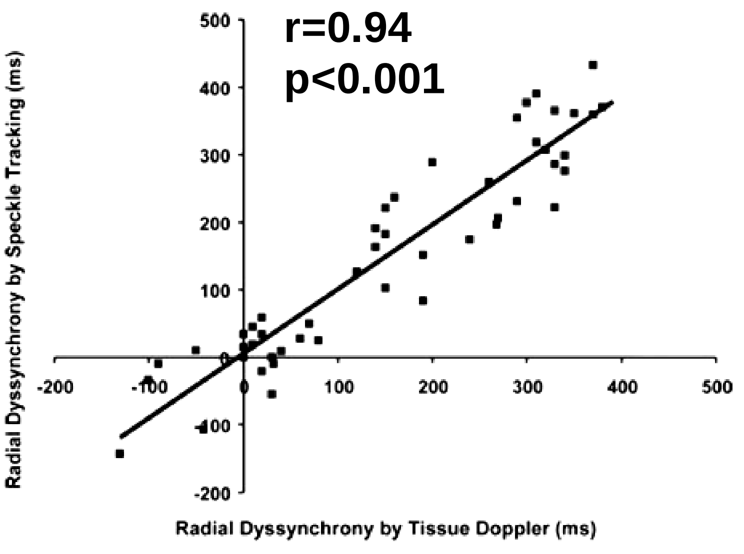
Cut-off ≥ 130 ms

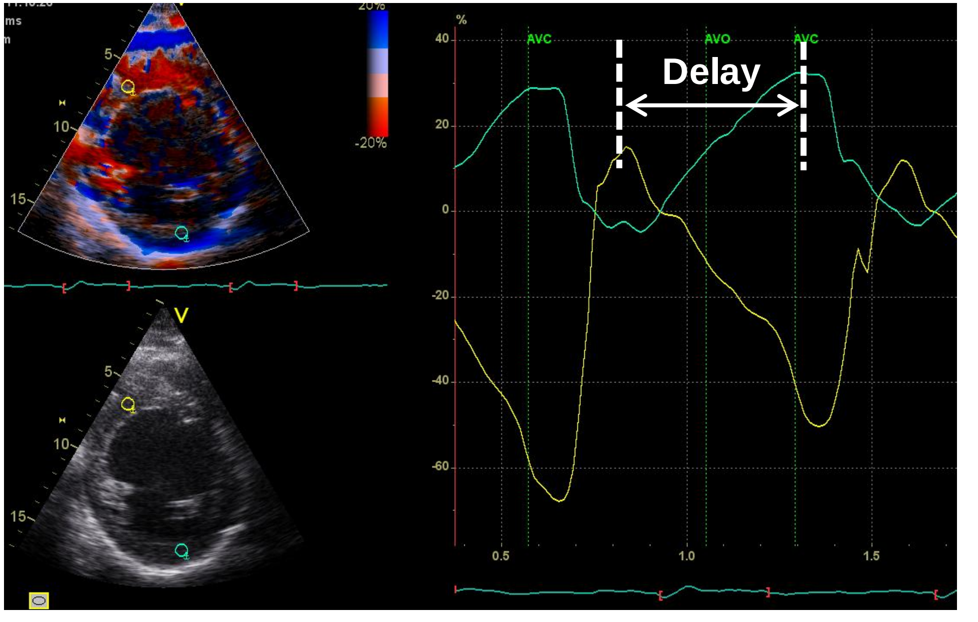
Sn 89% Sp 83%

Suffoletto MS et al. Circulation 2006

Dyssynchrony by Radial Strain

Speckle Tracking ~ Tissue Doppler

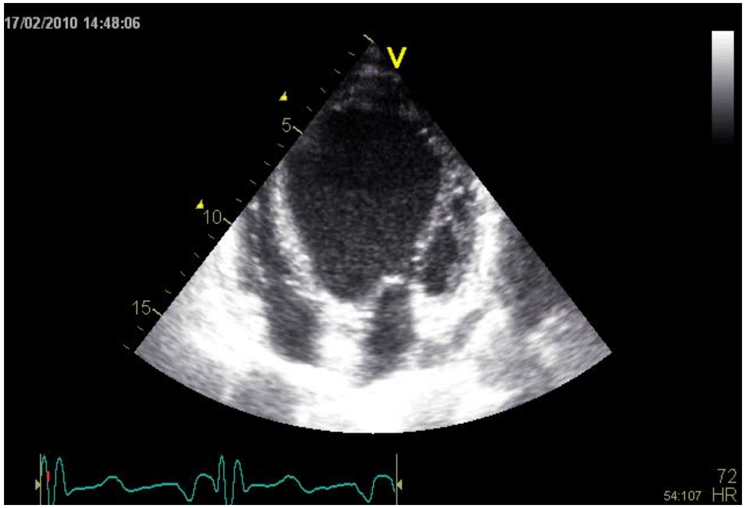


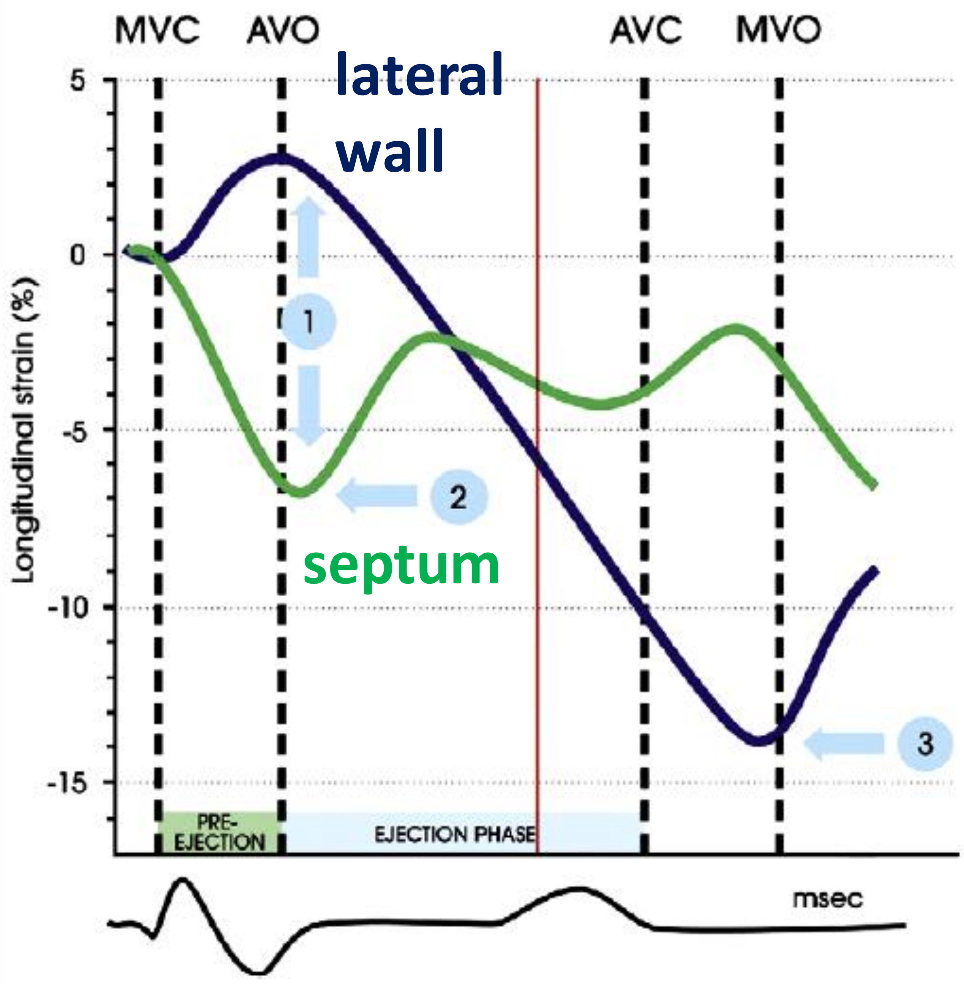


Suffoletto MS et al. Circulation 2006

Strain pattern recognition

2D Speckle tracking derived strain

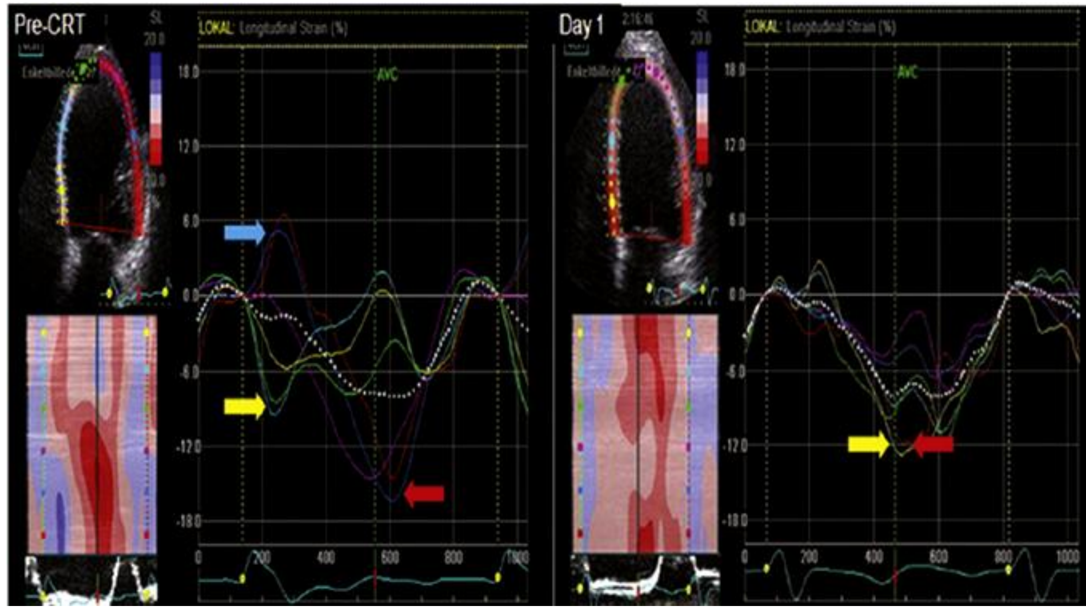




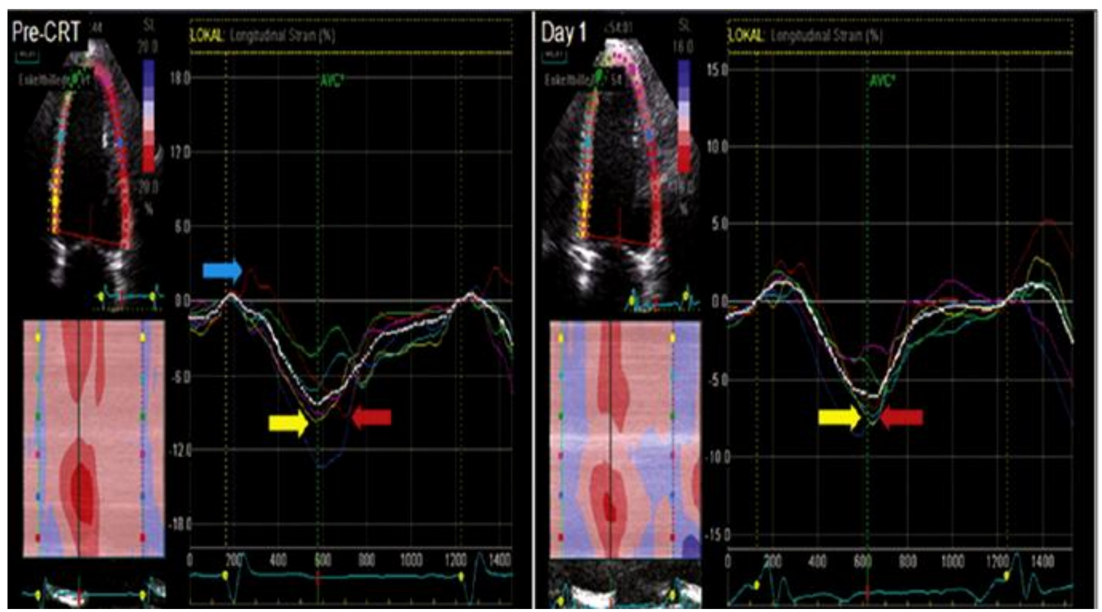
Risum N et al. AHJ 2012

Classical LBBB strain pattern

Sn 95%
Sp 91%

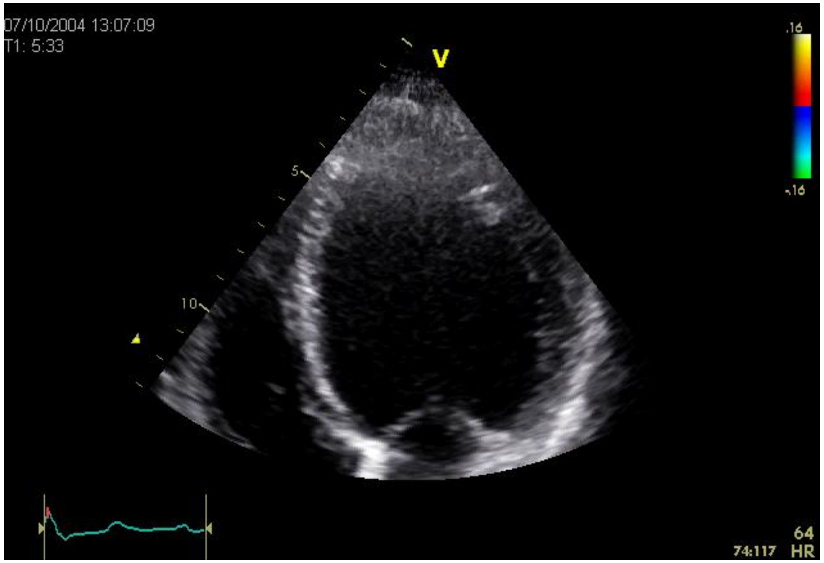


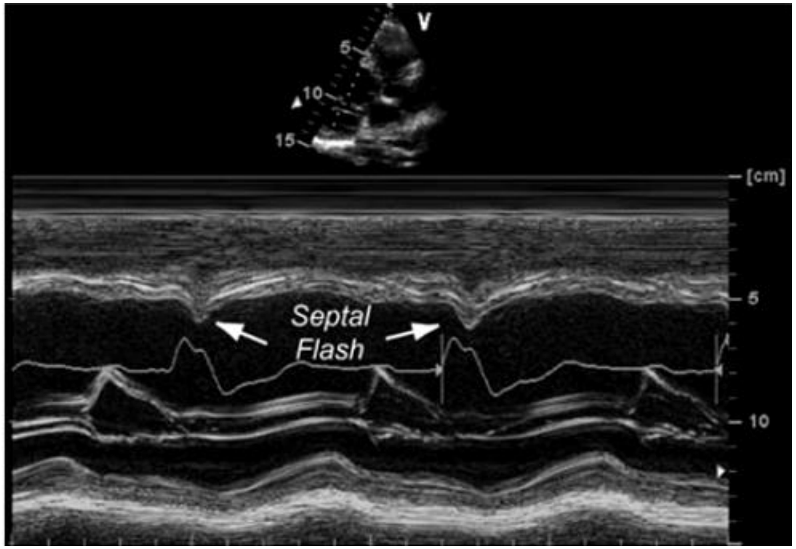
Heterogeneous strain pattern

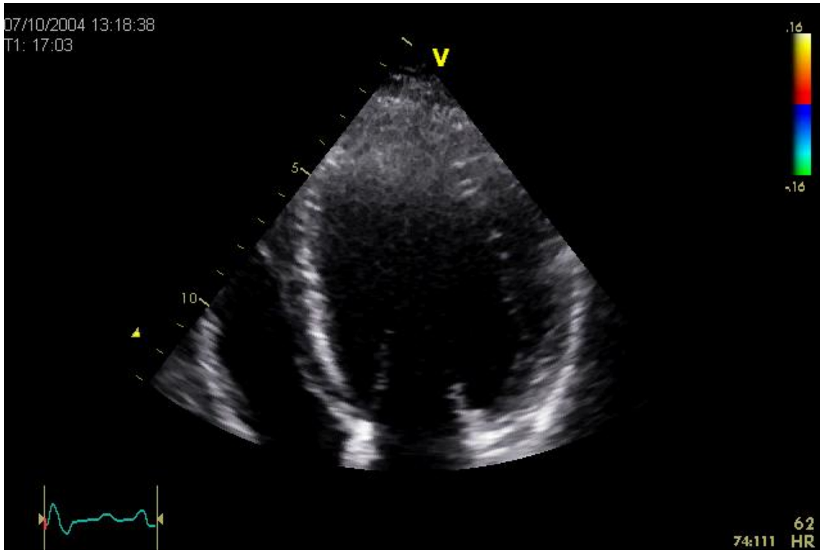


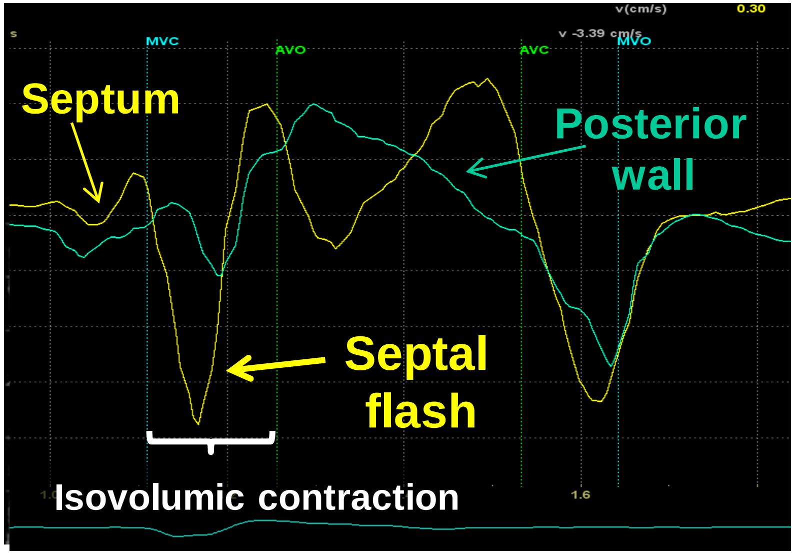
Risum N et al. AHJ 2012

Septal bounce

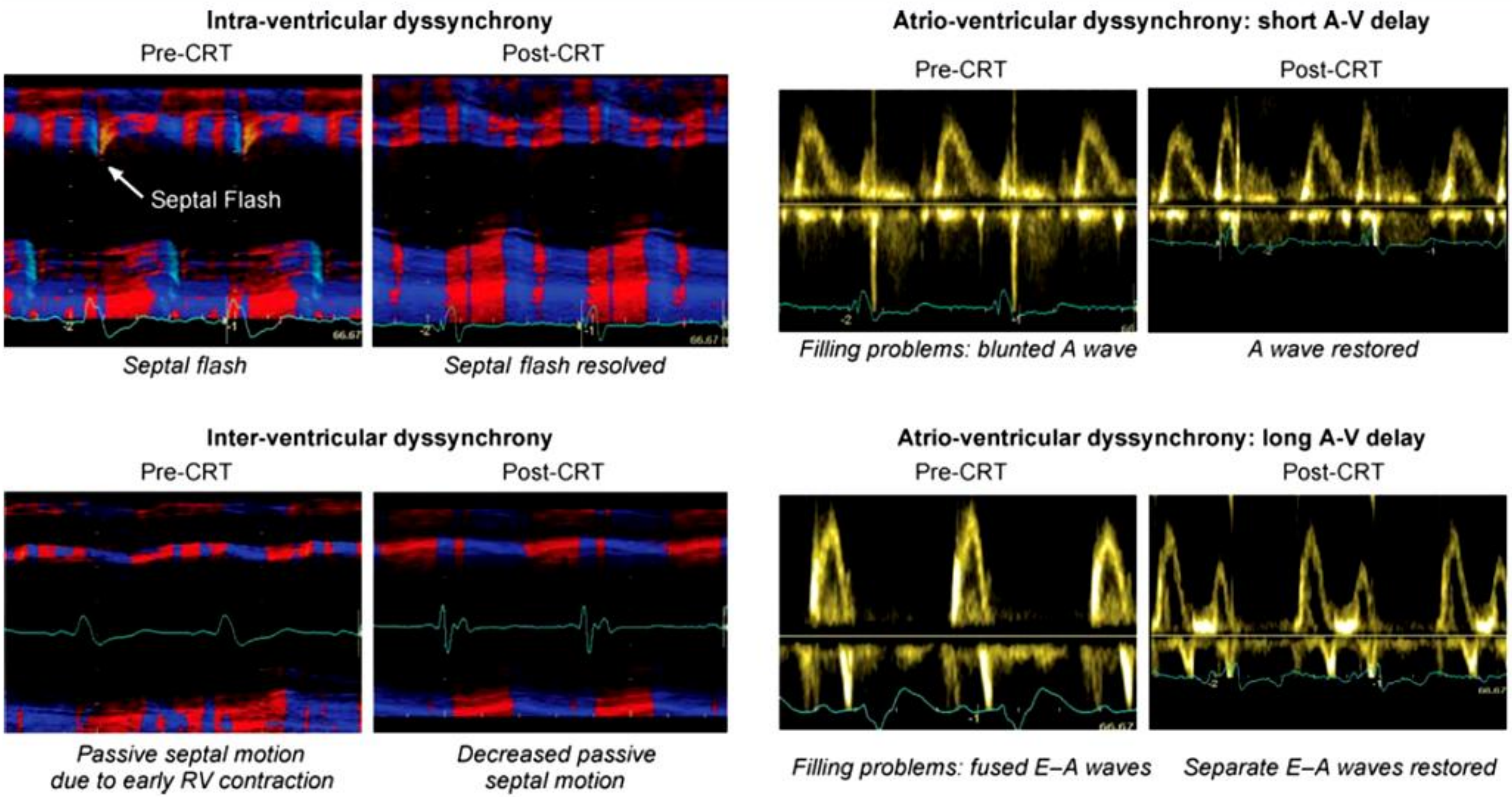






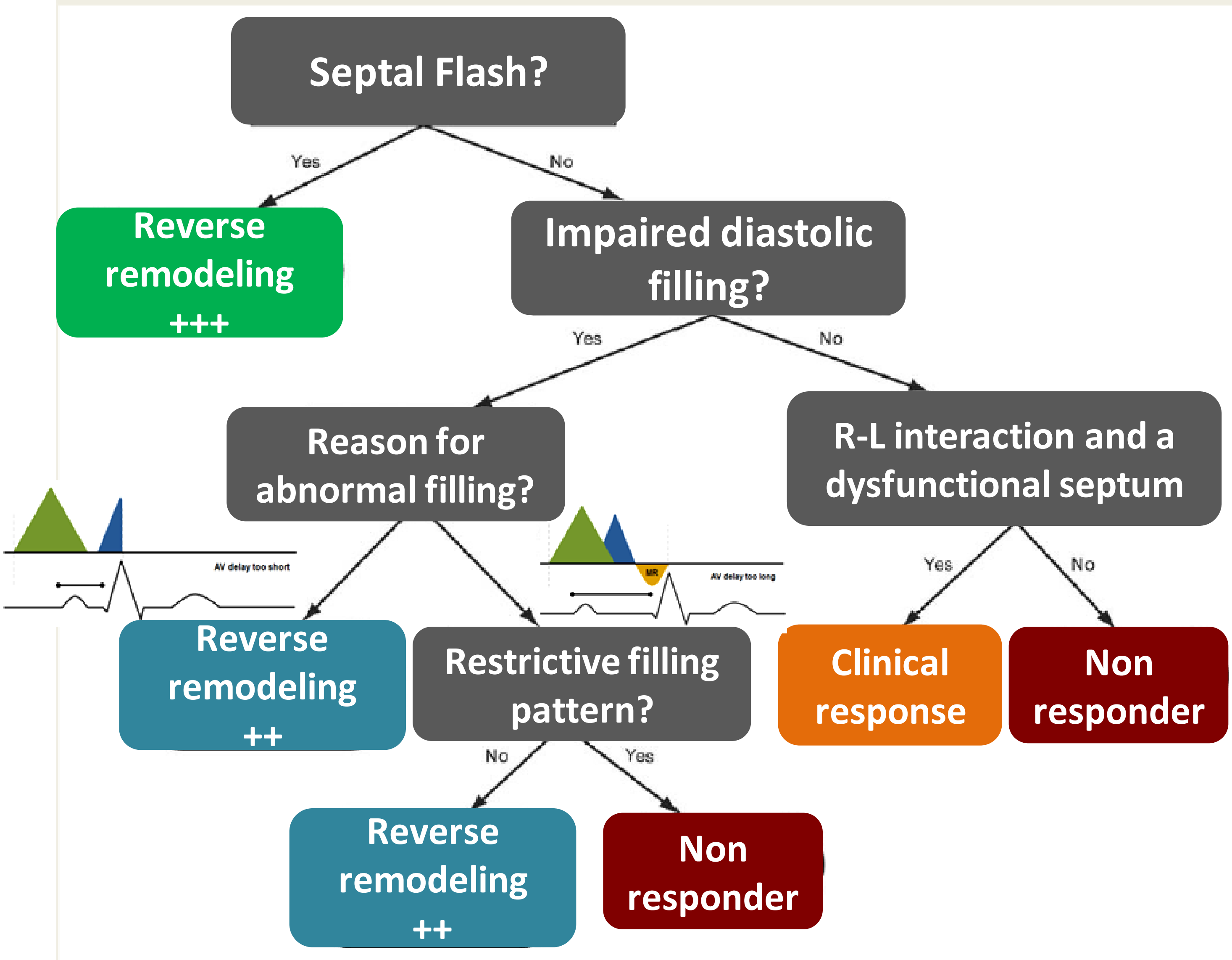


Multiple mechanisms



Parsai C et al. Eur Heart J 2009

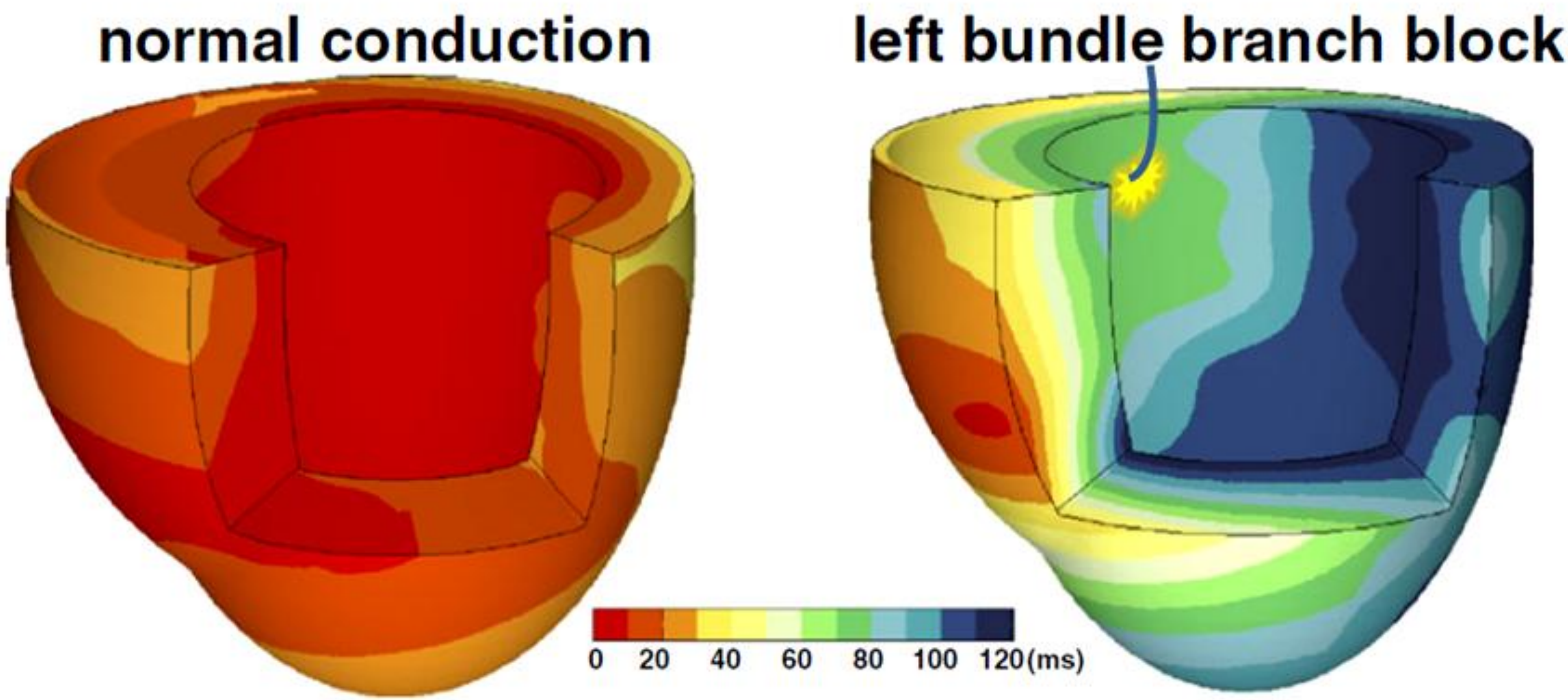
Multiple mechanisms ?



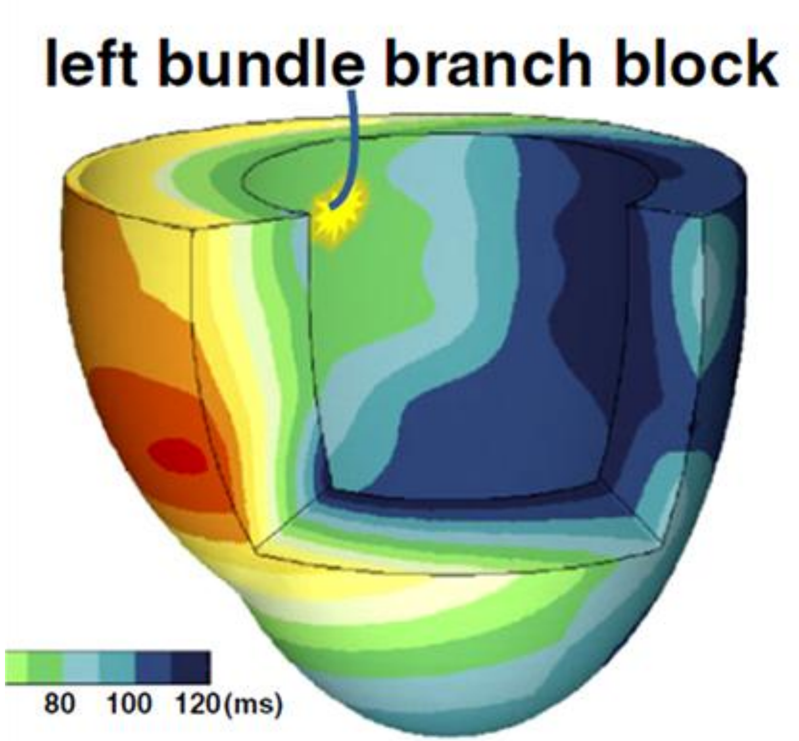
Septal flash
Sn 64%
Sp 55%

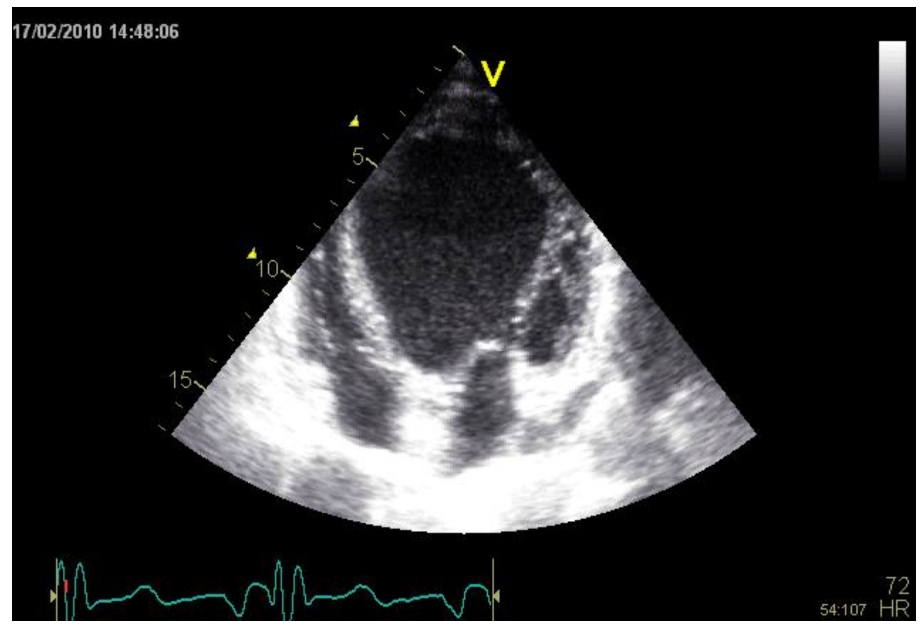
Decision tree
Sn 100%
Sp 55%

Parsai C et al. Eur Heart J 2009


normal conduction
left bundle branch block
0 20 40 60 80 100 120(ms)

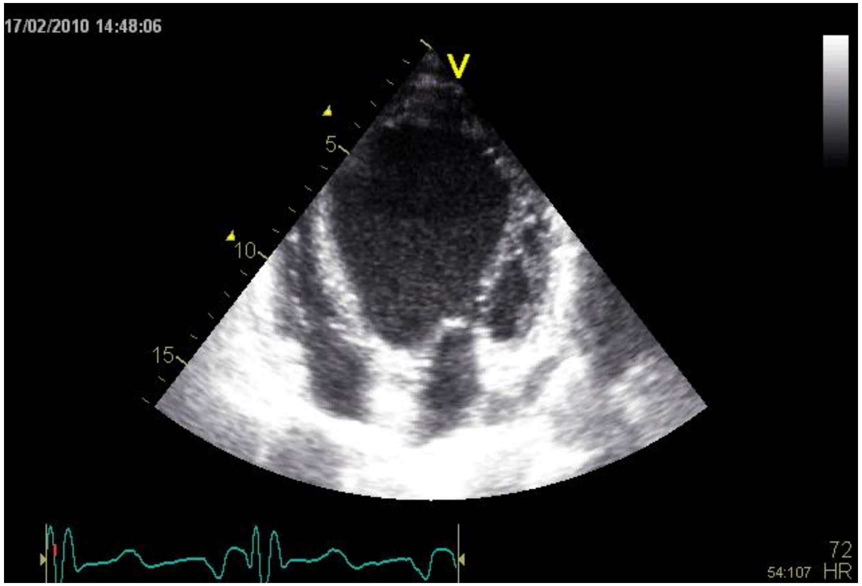
SF & ApRock

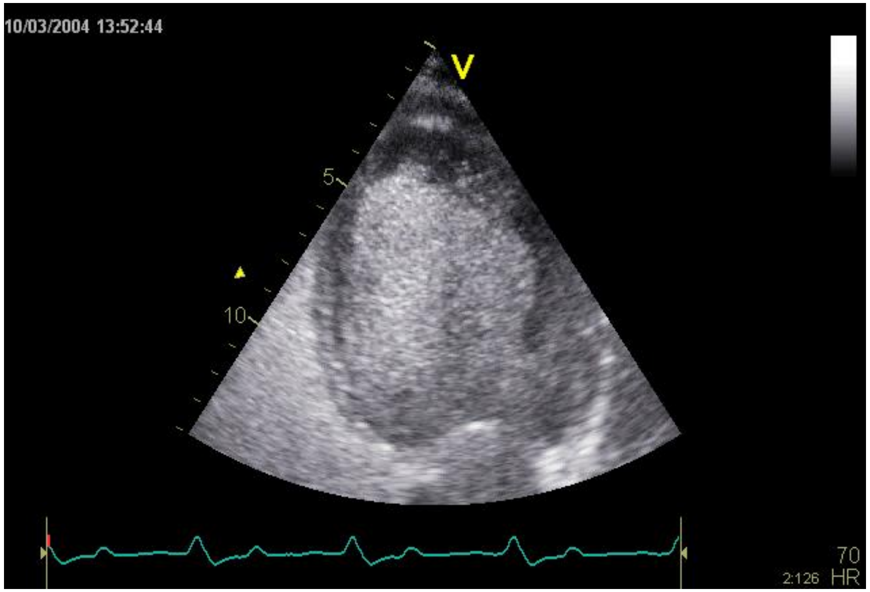

left bundle branch block
80
100
120(ms)


17/02/2010 14:48:06
V
5
10
15
72
54:107
HR

Apical rocking

- Direct mechanical consequence of LBBB
- Quantification (apical transverse motion)
- Visual assessment



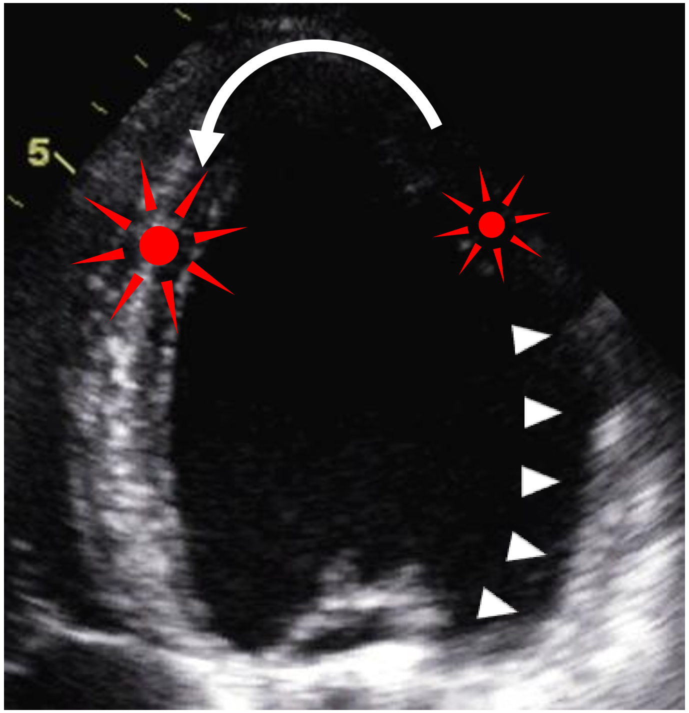


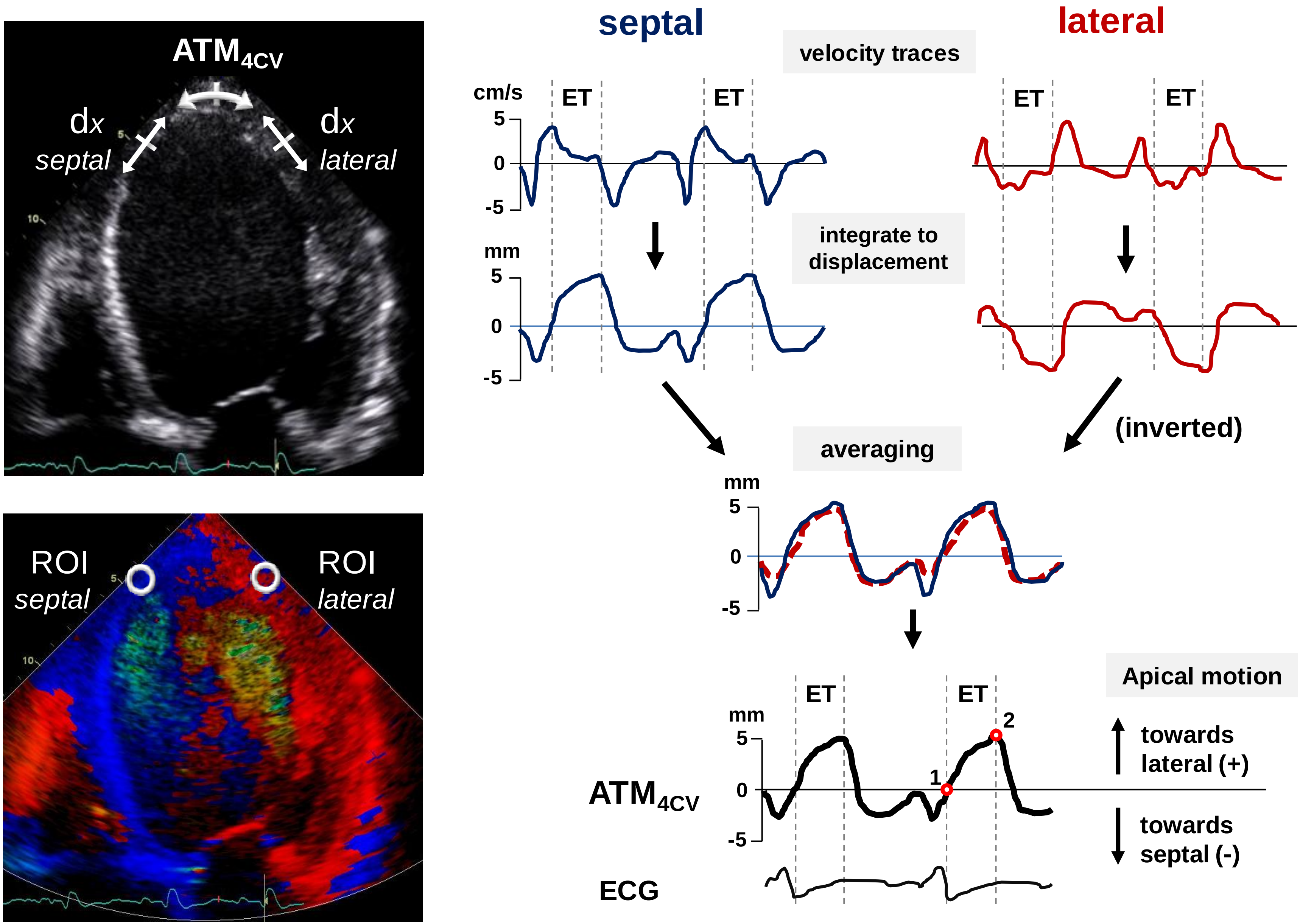
Apical rocking is a surrogate parameter

Dyssynchrony and scar assessment

Temporal inhomogeneity
(left bundle branch block)

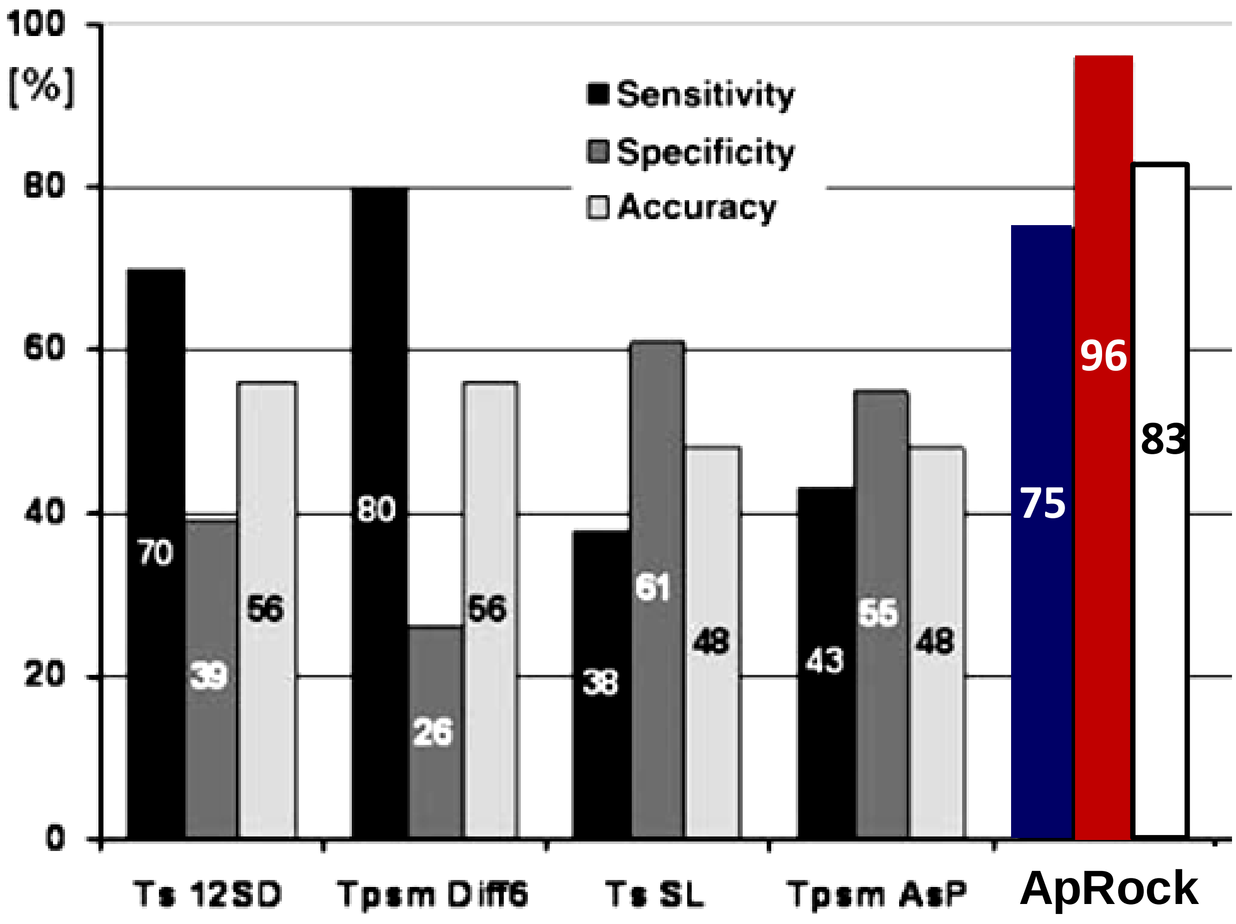
Functional inhomogeneity
(infarct scar)





Voigt JU et al. Eur Heart J 2009

Apical rocking predicts CRT response



Szulik M et al. Eur J Echocardiogr 2009

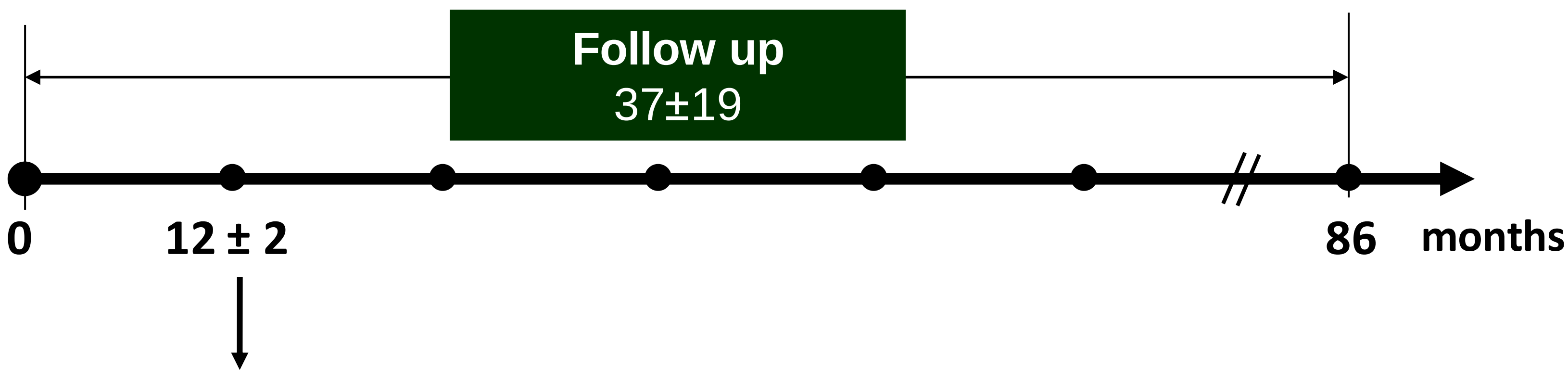
Apical rocking: visual assessment

Does it predict response and survival?

Visual assessment of dyssynchrony

Baseline assessments
- Apical rocking and Septal flash (visual)
- Scar burden (visual)
- Prediction (Responder/Non-responder)
- LV volumes (modified Simpson's rule)

n= 201/1100
Belgium, Germany
Norway, Poland

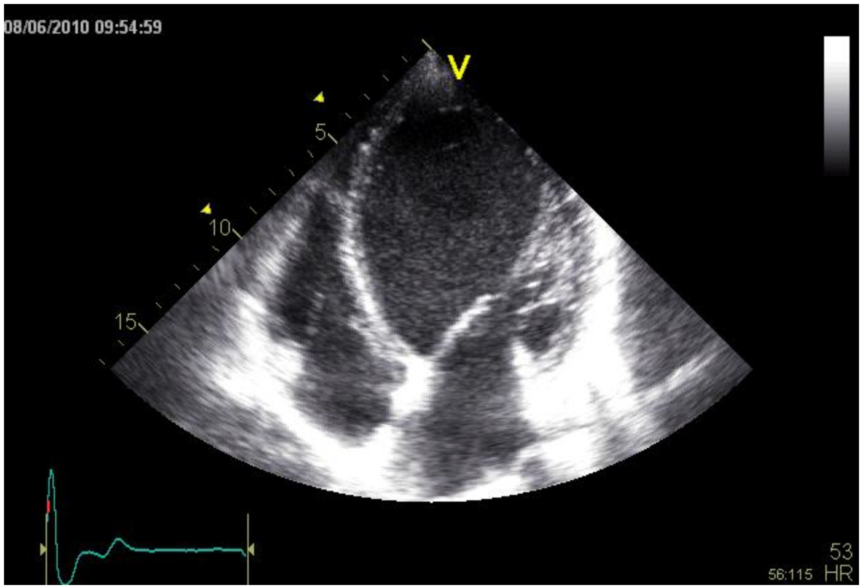


Response to CRT
- LV volumes (modified Simpson's rule)
- **Response: ΔESV ≥ 15%**
- Apical rocking and Septal flash after CRT (visual)

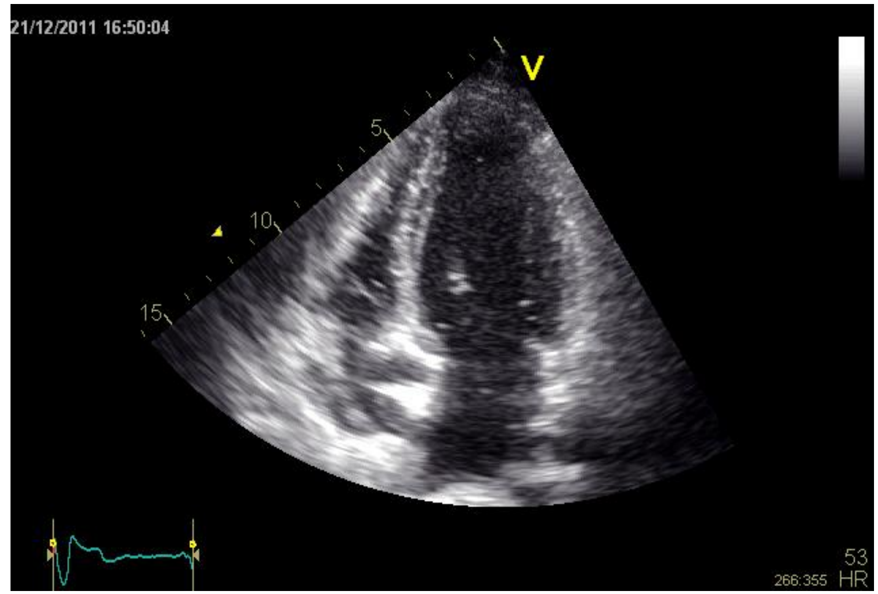
Stankovic I; Voigt JU et al. ESC Congress 2012

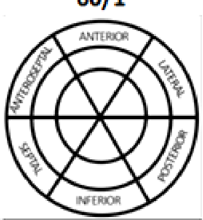
Case 1

Baseline



Follow up



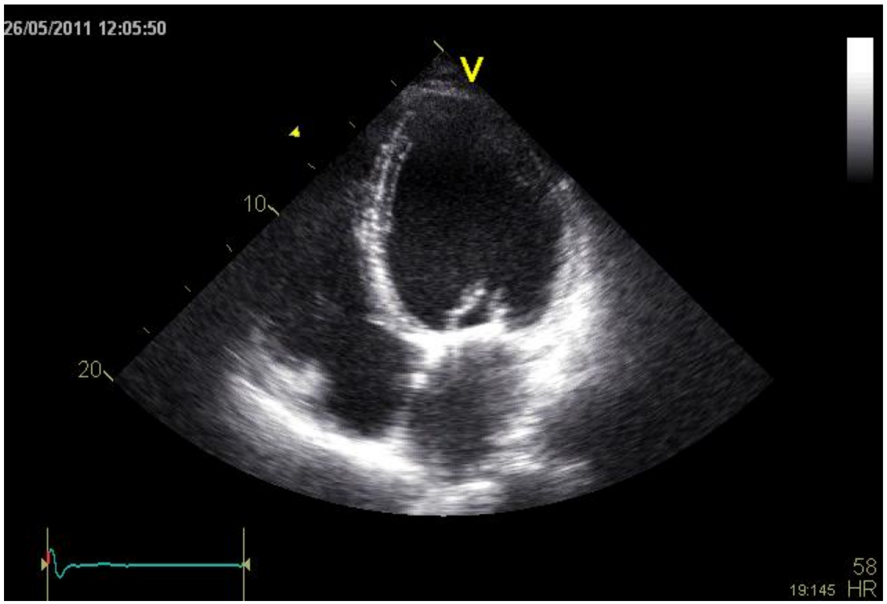
ID	Septal Flash	Apical Rocking	Prediction
60/1 	Yes No	Typical No Opposite	Responder Non-responder

Dyssynchrony post CRT		If YES		Comment
YES	NO	SF	ApRock	
YES	NO	SF	ApRock	

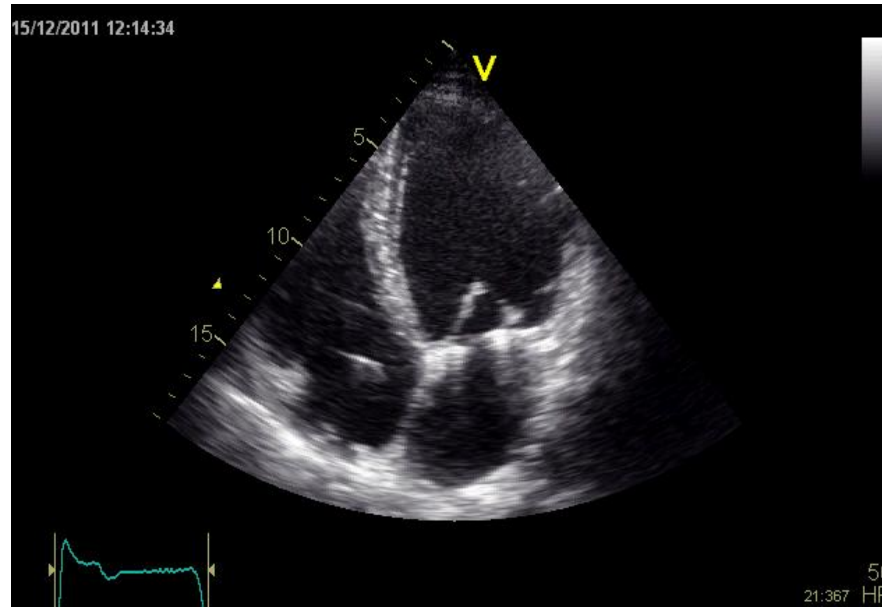
Stankovic/Voigt ESC 2012

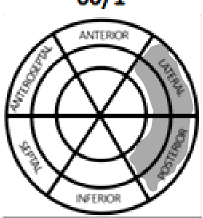
Case 2

Baseline



Follow up



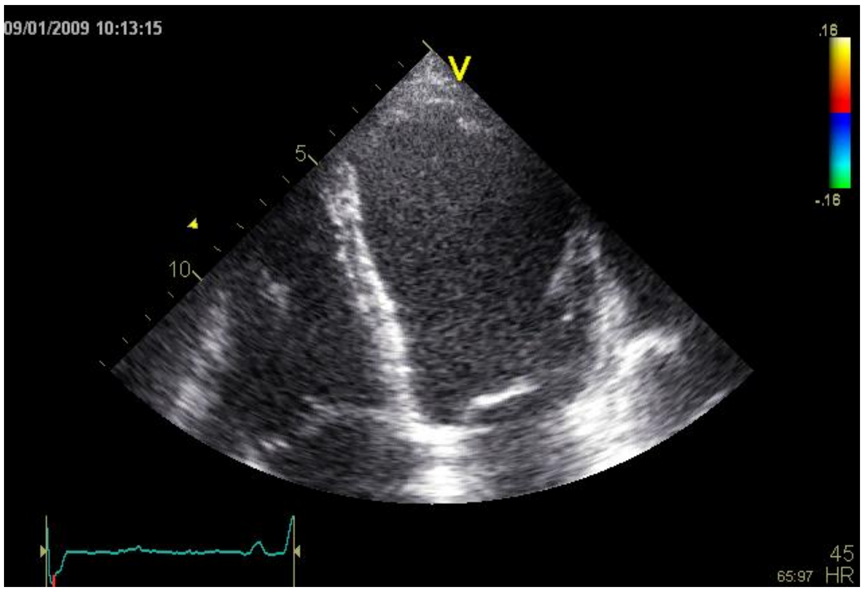
ID	Septal Flash	Apical Rocking	Prediction
60/1 	Yes No	Typical No Opposite	Responder Non-responder

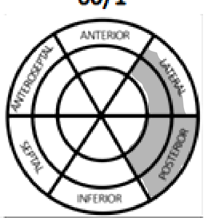
Dyssynchrony post CRT		If YES		Comment
YES	NO	SF	ApRock	
YES	NO	SF	ApRock	

Stankovic I; Voigt JU et al. ESC Congress 2012

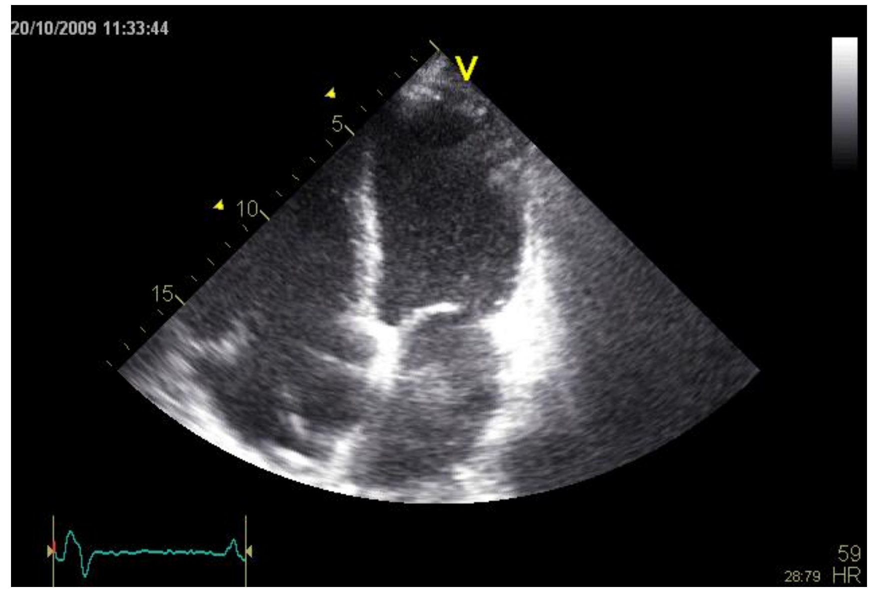
Case 3

Baseline



ID	Septal Flash	Apical Rocking	Prediction
60/1 	Yes No	Typical No Opposite	Responder Non-responder

Follow up



Dyssynchrony post CRT	If YES	Comment
YES NO	SF ApRock	
YES NO	SF ApRock	

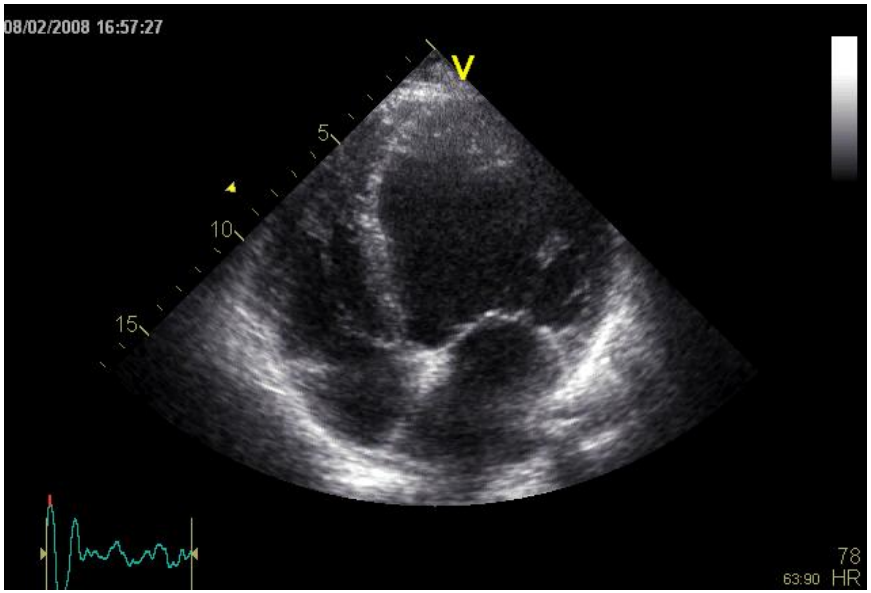
Stankovic/Voigt ESC 2012

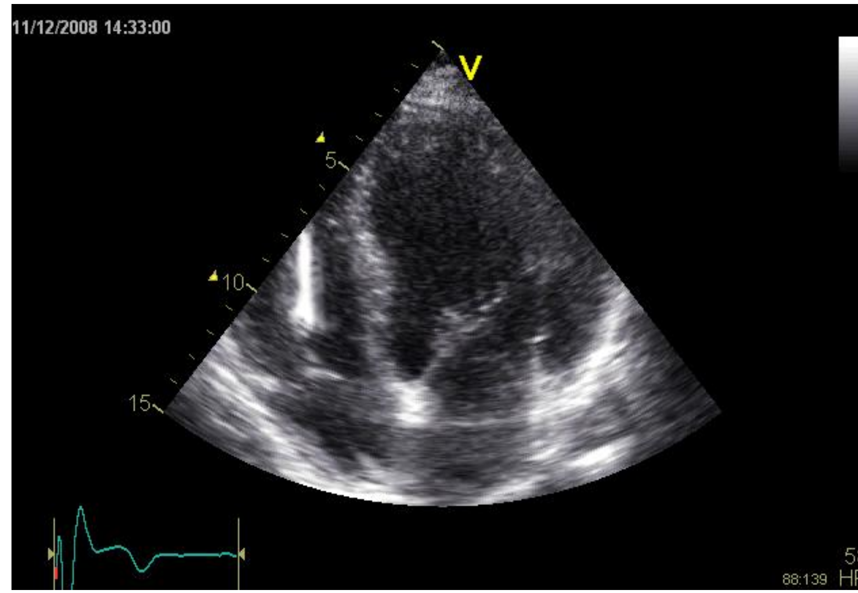
Case 4: prediction or Th failure?

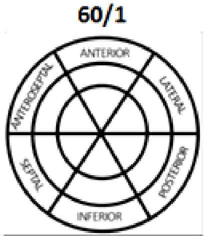
Baseline

Follow up

≈ 8% of patients
Approx 70% non-ischemic





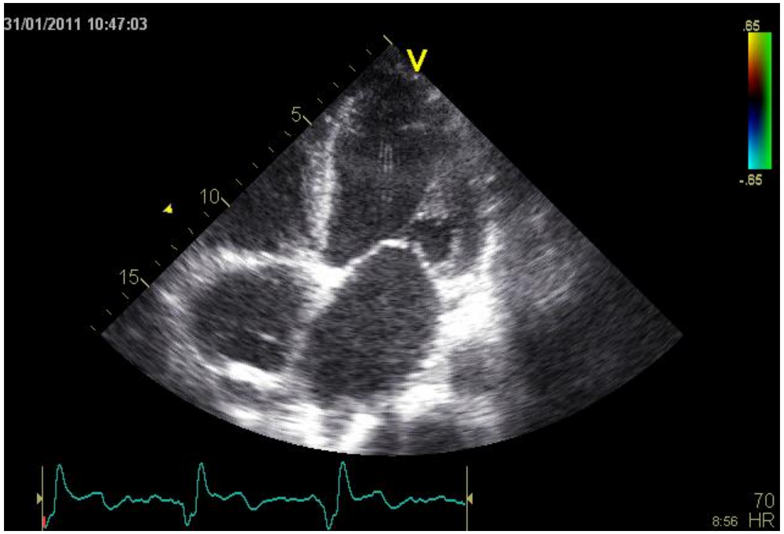
ID	Septal Flash	Apical Rocking	Prediction
60/1 	Yes No	Typical No Opposite	Responder Non-responder

Dyssynchrony post CRT	If YES	Comment
YES NO	SF ApRock	
YES NO	SF ApRock	

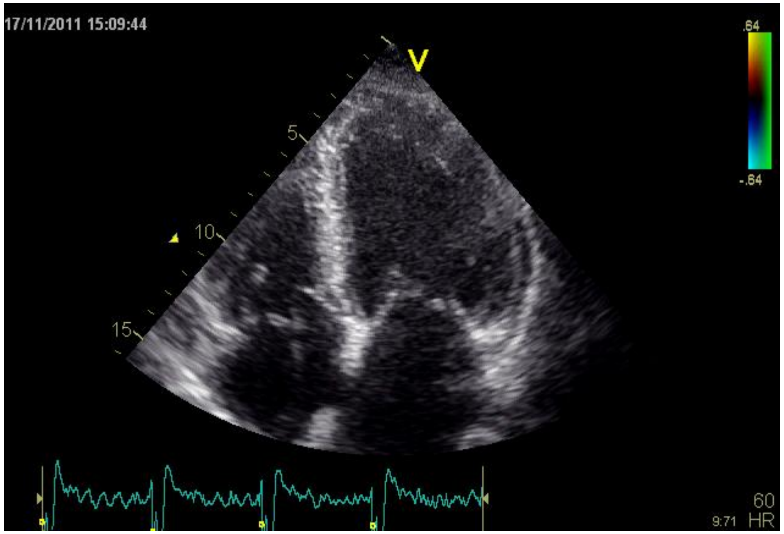
Stankovic I; Voigt JU et al. ESC Congress 2012

Prediction or treatment failure?

10 months after CRT

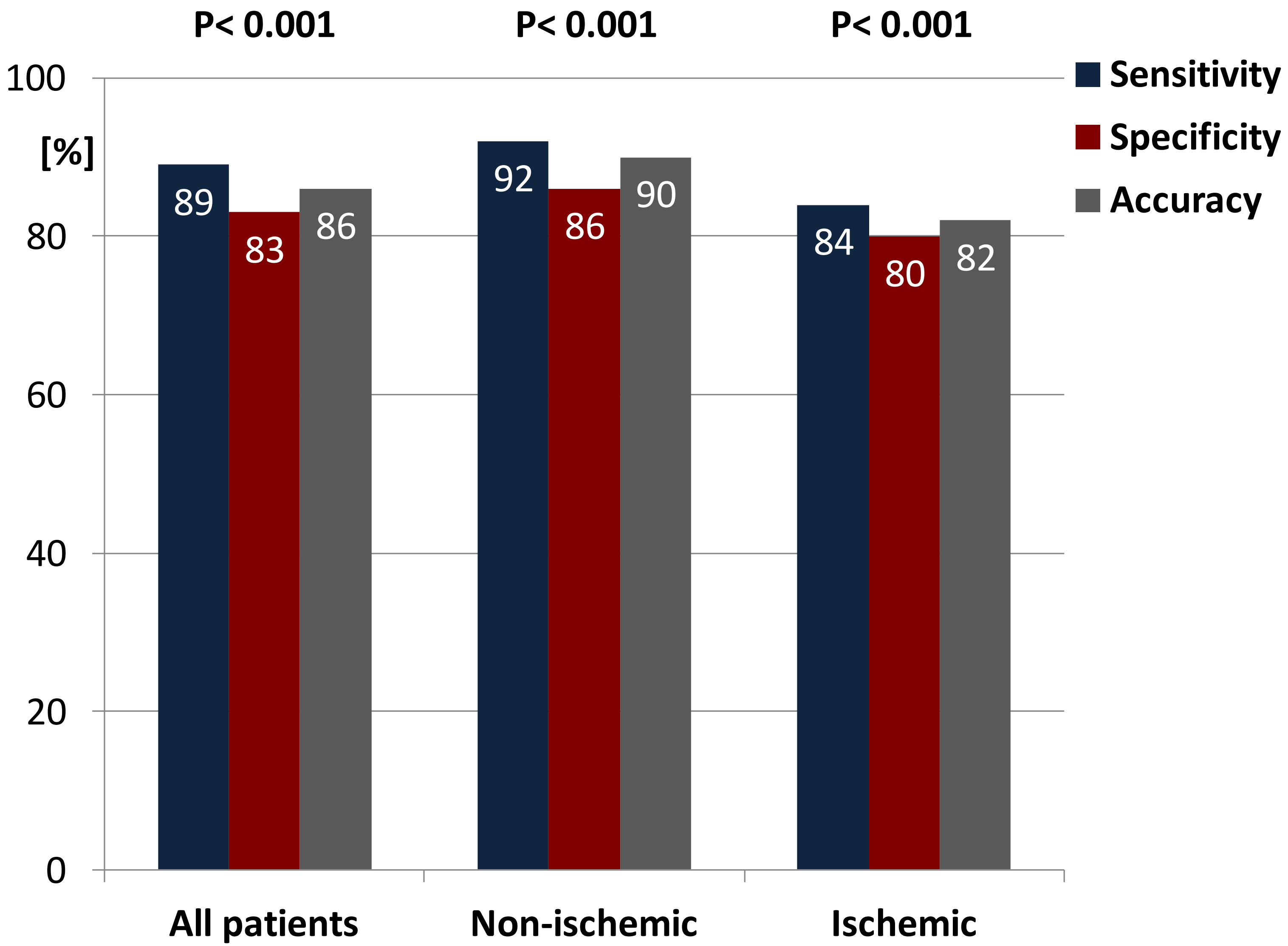


5 months after reimplantation



Stankovic I; Voigt JU et al. ESC Congress 2012

Prediction of response: Apical Rocking



Stankovic I; Voigt JU et al. ESC Congress 2012

Predictors of CRT success: Apical Rocking

Multivariate logistic regression

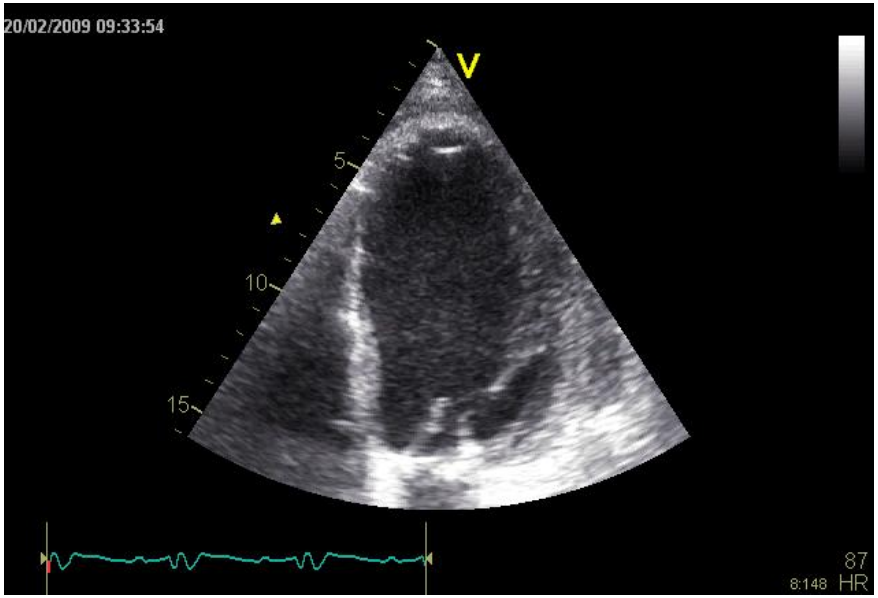
Tested variables

- Gender, baseline NYHA class
- **Apical Rocking**, Scar burden
- Baseline EF, LVEDD, LV volumes
- LBBB, QRS duration

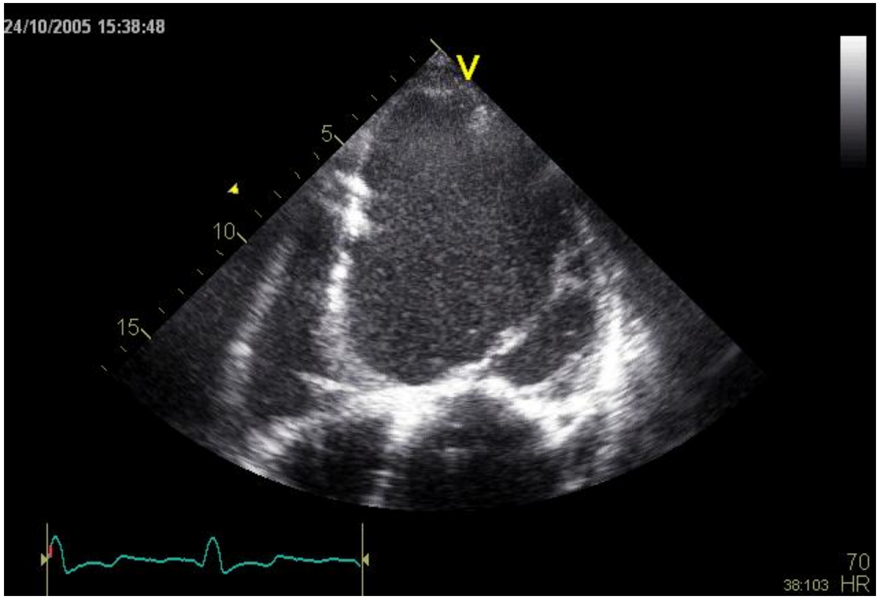
Predictors	B	P-value	Exp (B)	95%CI
Apical Rocking	3.9	<0.001	51.1	20.8-125.3
Scar ≥ 6 segments	- 2.1	<0.001	0.11	0.04-0.37

Stankovic I; Voigt JU et al. ESC Congress 2012

Impact of scar burden on prediction of CRT success



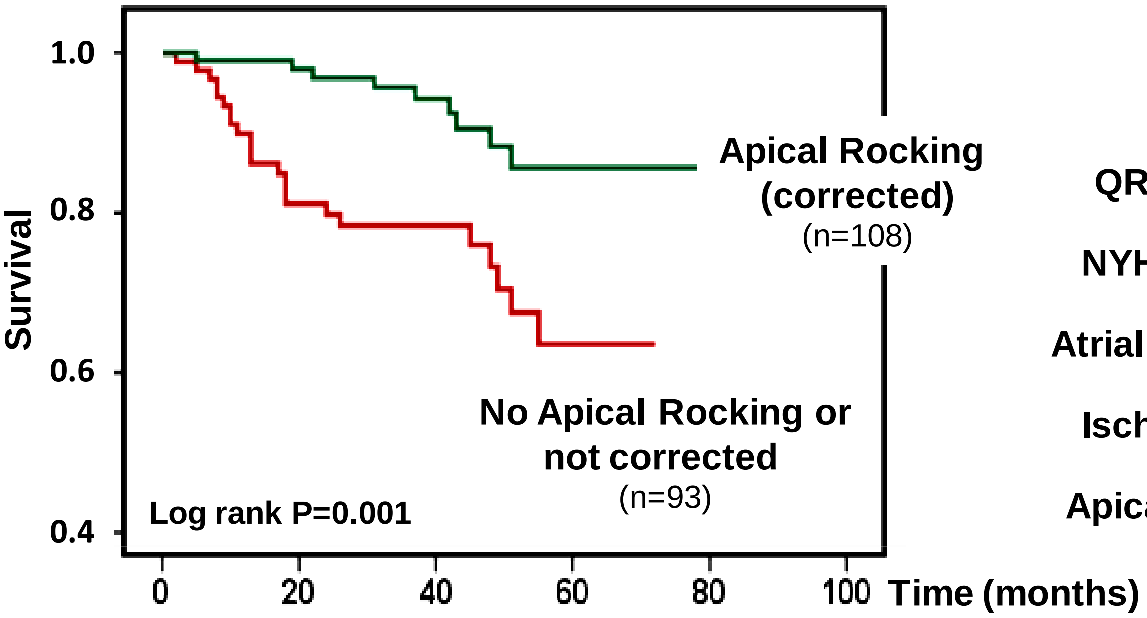
Visible dyssynchrony ++
Scar extend +
Response +

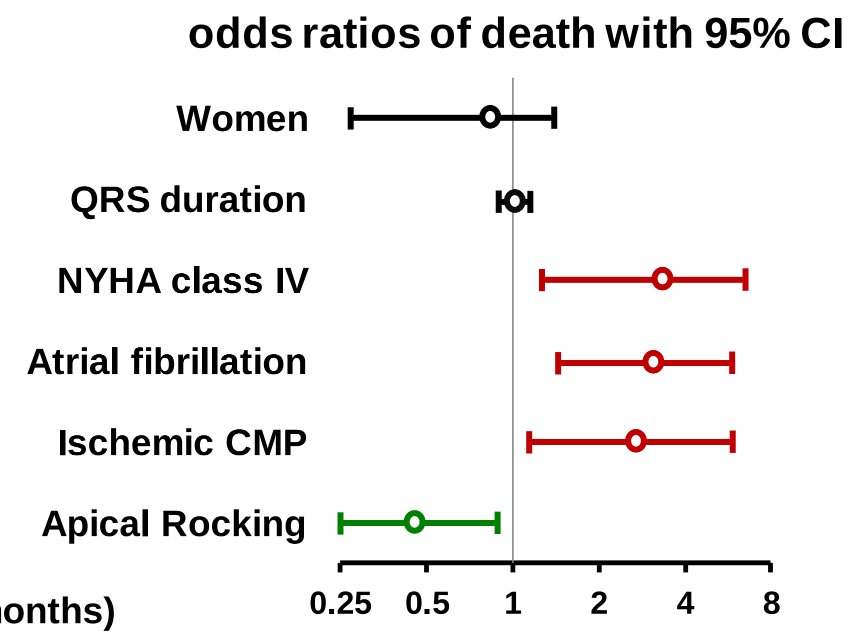


Visible dyssynchrony ++
Scar extend +++
Response -

Stankovic I; Voigt JU et al. ESC Congress 2012

Apical Rocking and Survival



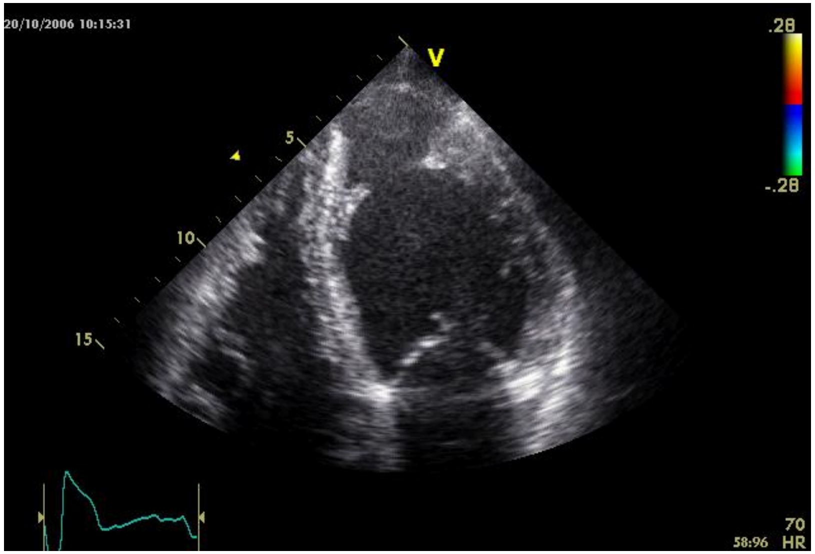


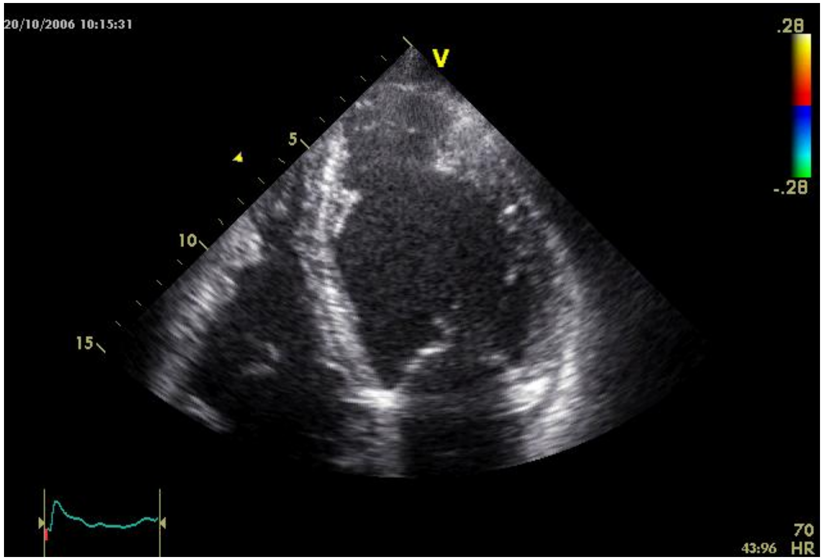
Stankovic I; Voigt JU et al. ESC Congress 2012

The use of CRT where the evidence is less strong/uncertain

Permanent Afib

Patients in permanent AF			
CRT-P/CRT-D may be considered in patients in NYHA functional class III or ambulatory class IV with a QRS duration ≥120 ms and an EF ≤35%, who are expected to survive with good functional status for >1 year, to reduce the risk of HF worsening if:			
• The patient requires pacing because of an intrinsically slow ventricular rate	IIb	C	–
• The patient is pacemaker dependent as a result of AV nodal ablation	IIa	B	163a
• The patient's ventricular rate is ≤60 b.p.m. at rest and ≤90 b.p.m. on exercise.	IIb	C	–

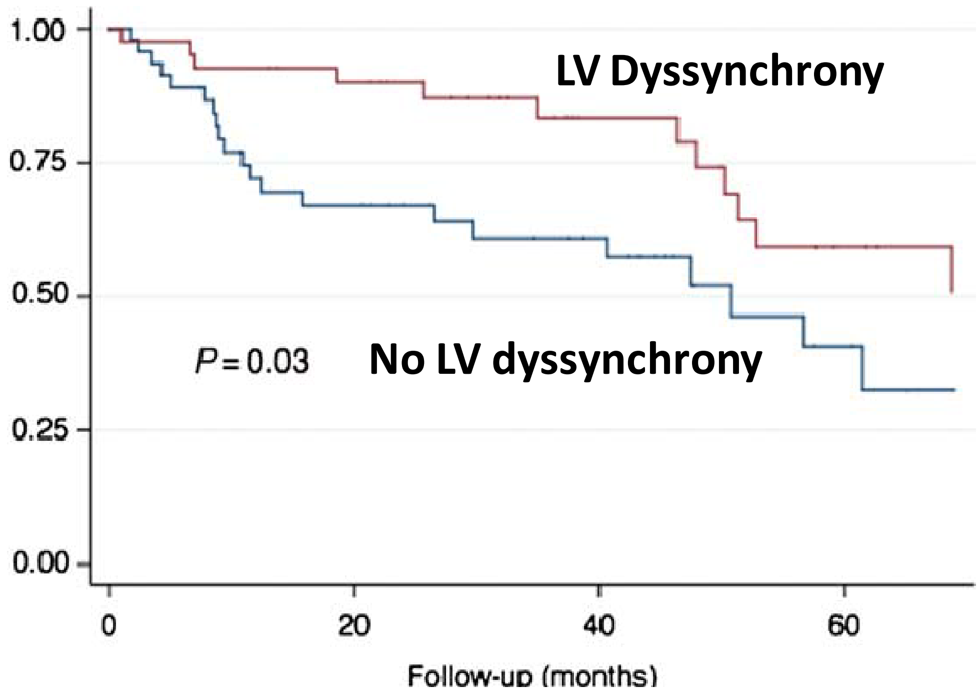




ESC HF guidelines 2012

Right bundle branch block

Non-LBBB QRS morphology CRT, preferably CRT-D should be considered in patients in sinus rhythm with a QRS duration of ≥150 ms, irrespective of QRS morphology, and an EF ≤30%, who are expected to survive for >1 year with good functional status, to reduce the risk of HF hospitalization and the risk of premature death.	IIa	A	154, 155



Dyssynchrony

- Septal-to-lateral wall delay
- Less prevalent than in LBBB
- Predictive of CRT response
- Predictive of event-free survival

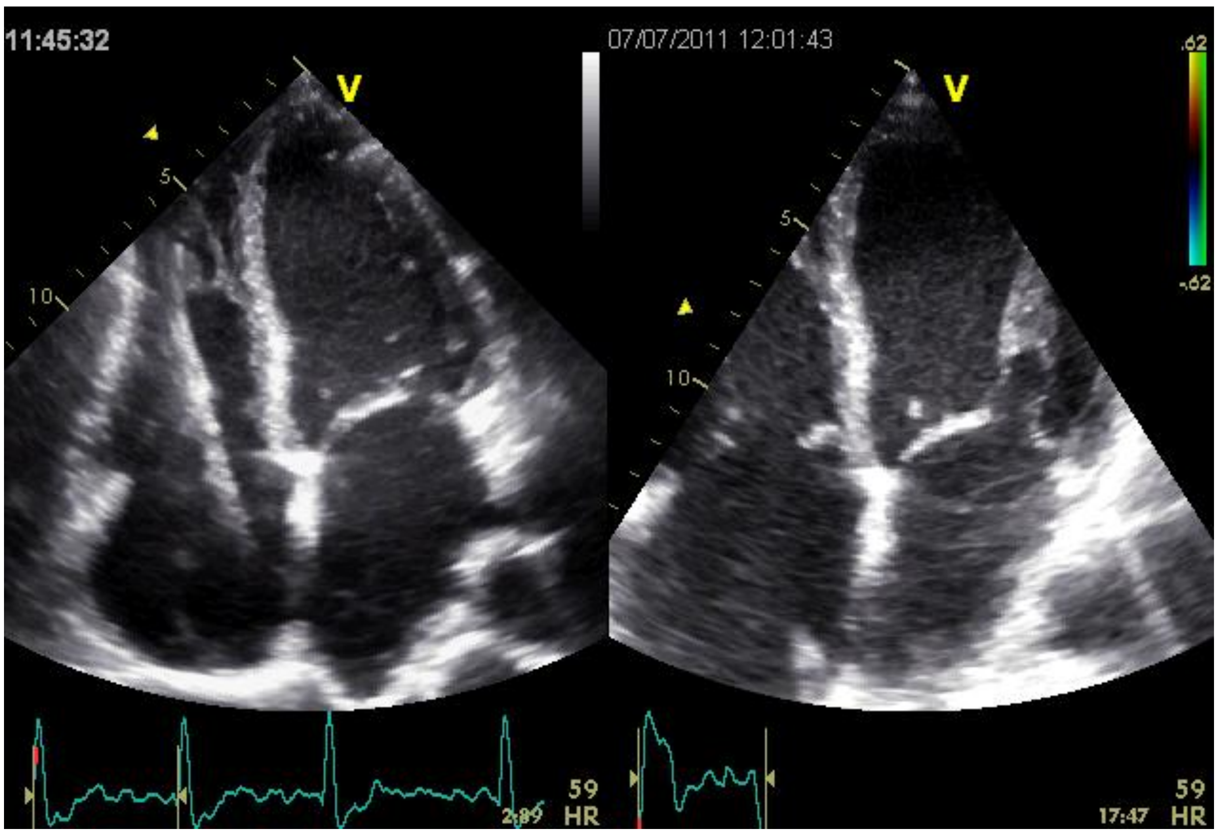
Event= Death and HF hospitalization

Leing DP et al. Eur Heart J 2012; ESC HF guidelines 2012

Pacemaker-induced dyssynchrony

Patients with an indication for conventional pacing and no other indication for CRT			
In patients who are expected to survive with good functional status for >1 year: • CRT should be considered in those in NYHA functional class III or IV with an EF ≤35%, irrespective of QRS duration, to reduce the risk of worsening of HF	IIa	C	–
• CRT may be considered in those in NYHA functional class II with an EF ≤35%, irrespective of QRS duration, to reduce the risk of worsening of HF.	IIb	C	–

PM Off



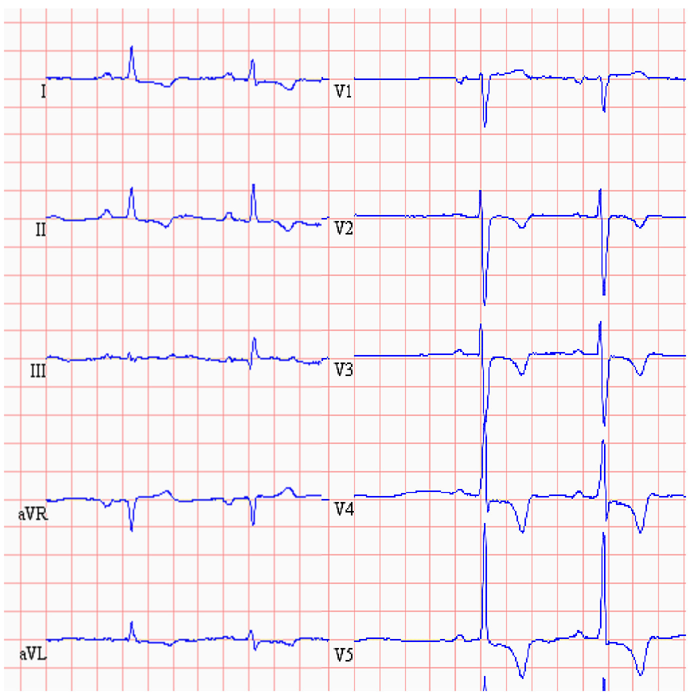
PM On

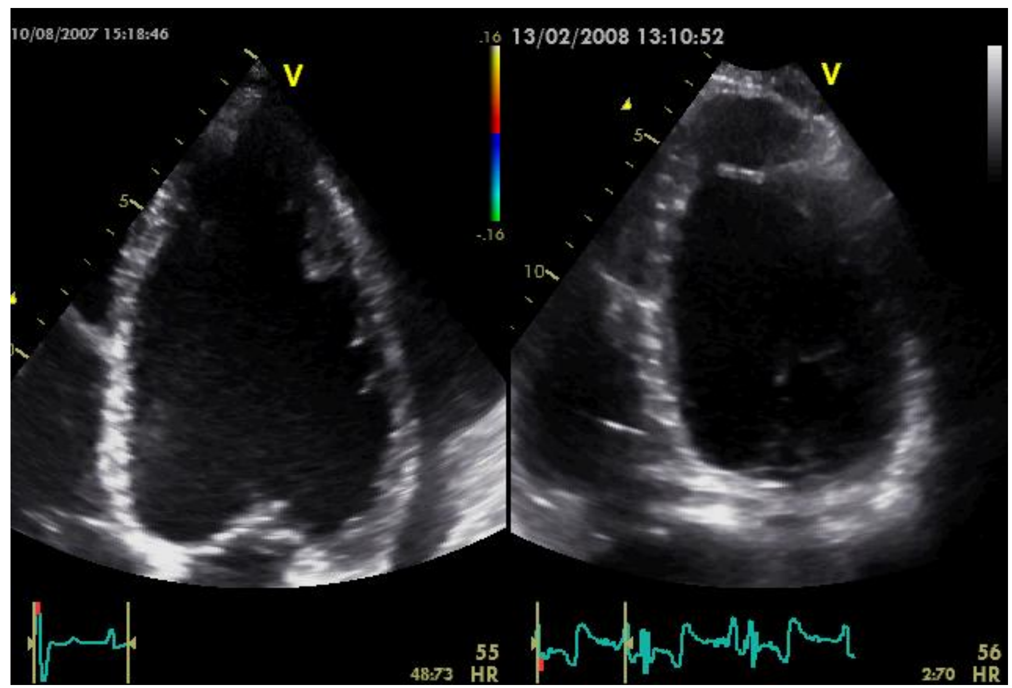
ESC HF guidelines 2012

Narrow QRS (<120 ms)

Guidelines: Not indicated!

Vent. rate	56	BPM
PR interval	196	ms
QRS duration	90	ms
QT/QTc	422 / 407	ms





Conclusions

- CRT patient selection is still subject to debate
- Added clinical value of TVI approach is disputed
- New approaches (ApRock, SF, radial strain) appear promising
- Until a reliable parameter becomes available, an ECG criterion should be employed to provide CRT to all deserving patients