Περιορισμοί της ηχωκαρδιογραφίας στην εκτίμηση ασθενών με καρδιακό ασυγχρονισμό

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New ESC Guidelines for Cardiac Pacing and Cardiac Resynchronisation Therapy
EHJ 28/8/2007, Europace 2007

Recommendations for the use of cardiac resynchronisation therapy by biventricular pacemaker (CRT-P) or biventricular pacemaker combined with an ICD (CRT-D) in HF patients.

Heart failure patients who remain symptomatic in NYHA Class III-IV despite optimal pharmacological treatment, with low ejection fraction (LVEF ≤ 35%), left ventricular dilatation*, normal sinus rhythm and wide QRS complex (≥ 120 ms)

- Class I - Level of evidence A for CRT-P to reduce morbidity and mortality.
- CRT-D is an acceptable option for patients who have expectancy of survival with a good functional status for more than 1 year, Class I - Level of evidence B.

* Left ventricular dilatation/Different criteria have been used to define LV dilatation in controlled studies on CRT: LV end diastolic diameter > 55 mm; LV end diastolic diameter > 30 mm/m², LV end diastolic diameter > 30 mm/m (height).

- **Many echocardiographic criteria evaluating inter- and intra-ventricular dyssynchrony have been proposed.**
- **At the present time, there is no consensus about which echocardiographic parameters may best determine baseline dyssynchrony and which of these can predict response to CRT.**
- **The majority of studies on the evaluation of inter- or intra-ventricular delay was not randomized and enrolled limited patient populations with short follow-up**

ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities
JACC 2008

- Meta-analyses of initial clinical experiences and then larger subsequent trials confirmed
- approximately 30% decrease in hospitalizations and,
- more recently, a mortality benefit of 24% to 36%

Effects of CRT on overall mortality and mode of death: a meta-analysis of randomized controlled trials Rivero Ayersa et al EHJ 2006

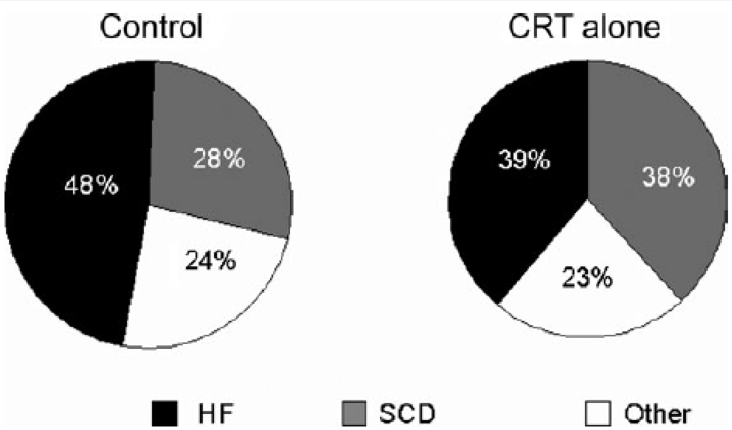


Figure 5 Relative contribution of each mode of death to overall mortality in patients treated with of CRT alone vs. control.

Cardiac Resynchronization Therapy for Patients With Left Ventricular Systolic Dysfunction .A Systematic Review

Table 1. Response Rates Reported in Observational Studies: CRT Alone or Combined CRT-ICD Devices

Source	Follow-up, mo	Sample Size	Definition of Responder	Proportion of Responders, %	Independent Predictors of Positive Response
Functional definition of response					
CRT alone					
Bleeker et al,[34] 2005	6	170	Improved ≥1 NYHA class	78	Analysis by age <70 vs ≥70 years*
Chan et al,[47] 2003	3	63	6-min walk test increased 10%	67	Not performed
Lecoq et al,[72] 2005	6	139	Alive, no CHF hospitalizations, improved ≥1 NYHA class or >10% increase $\dot{V}O_2$max during 6-min walk test	72	Δ QRS (step of 20 milliseconds)
Lenom et al,[73] 2005	6	36	Improved NYHA class	71	Not performed
Molhoek et al,[86] 2005	6	74	Improved ≥1 NYHA class	68	Analysis by etiology*
Sawhney et al,[109] 2004	3	40	Improved ≥1 NYHA class	63	Acute response to CRT by aortic Doppler VTI
Ståhlberg et al,[112] 2005	6	35	Alive, no CHF hospitalizations, improved ≥1 NYHA class and/or 10% increase in 6-min walk test distance	66	Not performed
Combined CRT-ICD					
Alonso et al,[25] 1999	6	26	Alive, improved ≥1 NYHA class, 10% increase in peak $\dot{V}O_2$max	73	Not performed
Bax et al,[33] 2004	6	85	Improved ≥1 NYHA class, improved 6-min walk test ≥25%	74	Baseline LV dysynchrony of ≥65 milliseconds
Díaz-Infante et al,[53] 2005	6	143	Alive, no heart transplant, 10% increase in 6-min walk test	80	Etiology, mitral regurgitation, LVEDD <75 mm
Hernández et al,[63] 2004	6	28	Improved 6-min walk test ≥10%	79	BNP level, etiology, baseline NYHA
Kiès et al,[65] 2005	6	97	Improved ≥1 NYHA class	74	Analysis by diabetes mellitus vs no diabetes mellitus*
Molhoek et al,[83] 2004	6	60	Improved ≥1 NYHA class	72	Not performed
Molhoek et al,[84] 2004	6	117	Improved ≥1 NYHA class	78	NYHA class 3 vs 4
Molhoek et al,[85] 2004	6	61	Improved ≥1 NYHA class	74	Analysis by baseline QRS*
Reuter et al,[104] 2002	12	102	Improved NYHA class associated with improved quality of life score	82	Etiology, cardiac output
Echocardiographic definition of response					
CRT alone					
Bax et al,[32] 2003	6	25	Absolute increase in LVEF ≥5%	68	Septal to lateral delay
Penicka et al,[97] 2004	6	49	Relative increase in LVEF ≥25%	55	Tissue doppler imaging derived indices of asynchrony
Yu et al,[122] 2002	3-6	141	Reduction in LV end-systolic volume >10%	62	None
Multiple definitions of response					
CRT alone					
Mascioli et al,[80] 2002	6	68	Improved ≥1 NYHA class, LVEF increased by ≥10%	69	Analysis performed but none found
Yu et al,[124] 2004	3	30	Reduction in LV end-systolic volume >15%	57	Systolic dysynchrony by tissue doppler imaging
Combined CRT-ICD					
Notabartolo et al,[92] 2004	3	49	Clinical: any 2 of (1) improved ≥1 NYHA class, (2) >50 m increase in 6-min walk test, or (3) decrease in quality of life score = 15 points Echocardiographic: reduction in LV end-systolic volume >15%	75 (clinical) 59 (echo)	PVD predicted echocardiographic response; no significant predictors of clinical response

Mcallister et al

JAMA 2007

- **During a median 11-month follow-up, 6.6% (95% CI, 5.6%-7.4%) of CRT devices exhibited lead problems and 5% (95% CI, 4%-7%) malfunctioned.**

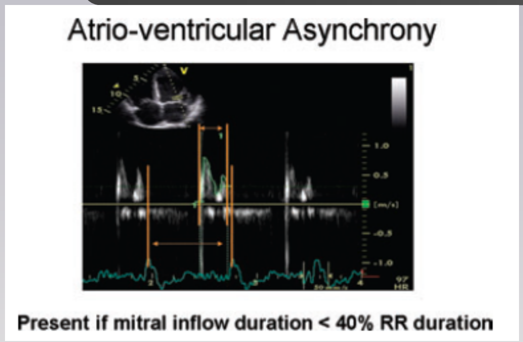
Echocardiography for CRT Selection

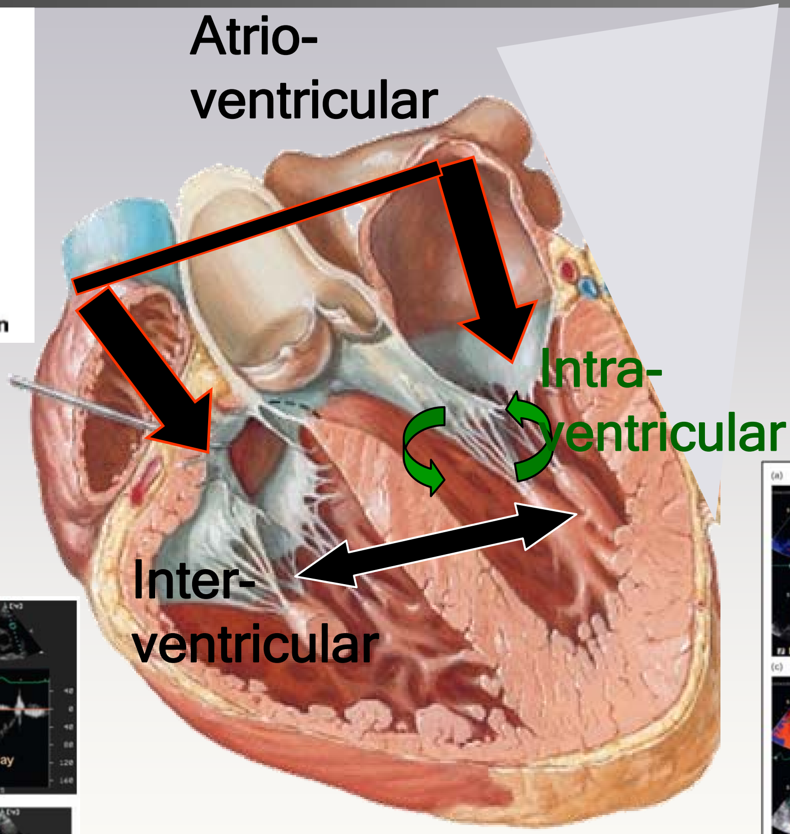
Fatally Flawed or Misjudged?

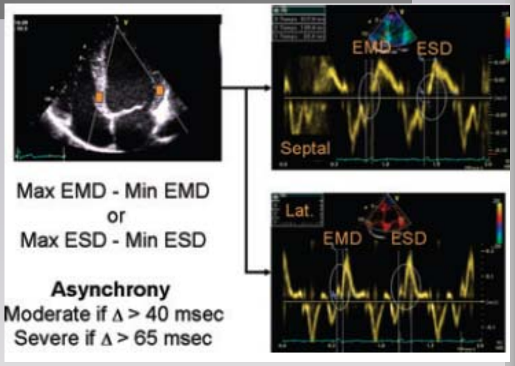
John E. Sanderson, MD JACC 2009

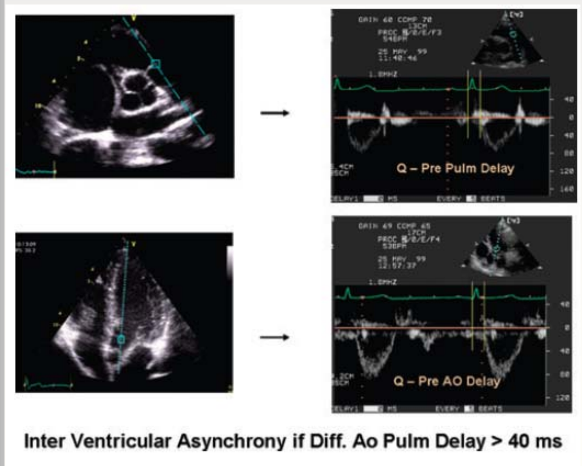
- Therefore, possibly there are 5 million people with heart failure and LBBB in Europe.
- Of these potential 5 million candidates for CRT (i.e., that have heart failure and LBBB) in Europe, 30% may well turn out to be nonresponders, which is about 1.5 million people.
- At a conservative estimate of €5,000 per device, this equals €7.5 billion, which could be a complete waste of money.
- In addition, these 1.5 million nonresponders would have a risk of death at time of implantation of 0.5%, which of 1.5 million nonresponders approximates to 22,500 people.
- It is possible, therefore, 22,500 people in Europe could die at the time of implantation during a procedure that would have given them no possible clinical benefit in terms of symptoms or functional improvement.

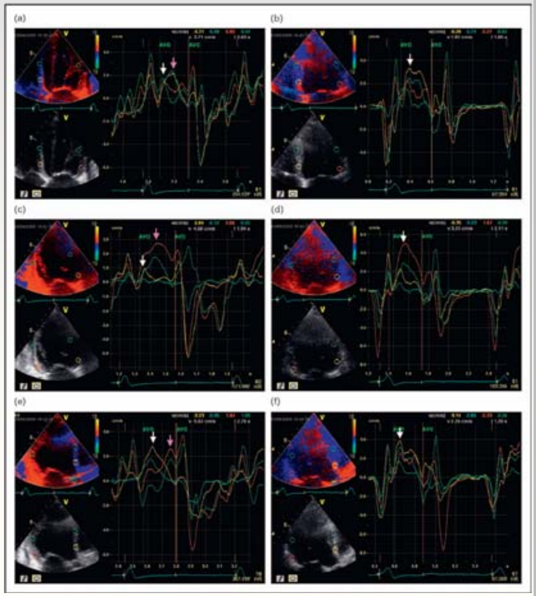
Elements of Cardiac Dyssynchrony











Main ultrasound techniques, parameters and reference values for detection of intra-ventricular dyssynchrony and prediction of LV reverse remodeling

Technique	Parameter	Authors	Cut-off point
M-mode	SPWMD	Pitzalis et al, J Am Coll Cardiol 2002	> 130 ms
M-mode and PW Doppler	LWPSD	Sassone et al, Am J Cardiol 2007	> 1
PW Tissue Doppler	Diff. of T_s between LV segments	Bax JJ et al, J Am Coll Cardiol 2004	> 65 ms
TVI	T_s-SD	Yu et al, Am J Cardiol 2003	> 32.6 ms
TSI	T_s-SD	Yu et al, J Am Coll Cardiol 2005	> 34.4 ms
SRI	TPS-SD	Mele et al, Eur Heart J 2006	> 60 ms
SRI	ExcT	Porciani MC et al, Eur Heart J 2006	> 760 ms
2D radial strain	Time diff. in peak septal wall-to-posterior wall strain	Suffoletto et al, Circulation 2006	≥ 130 ms
3D echo	Triplane T_s-SD	Van der Veire NR et al, Am J Cardiol 2007	≥ 35.8 *

Echocardiographic Studies on Prediction of Response to CRT

Table III.

Echocardiographic Studies on Prediction of Response to CRT

Author	Nr pts.	Follow-up (month)	Measurement	Description	Technique	Definition of Response	Cut-Off Value	Sens (%)	Spec (%)
Pitzalis et al.[21]	20	1	SPWMD	Septal-to-posterior wall motion delay	M-mode	↓ ≥ 15% LVESV	≥130 ms	100	63
Pitzalis et al.[121]	60	6	SPWMD	Septal-to-posterior wall motion delay	M-mode	↑ ≥ 5% LVEF	≥130 ms	92	78
Marcus et al.[22]	79	6	SPWMD	Septal-to-posterior wall motion delay	M-mode	↓ ≥ 15% LVESV	≥130 ms	24	66
Bleeker et al.[23]	98	6	SPWMD	Septal-to-posterior wall motion delay	M-mode	↓ > 10% LVESV	≥130 ms	65	48
							≥148ms	55	55
			Septal-to-lateral delay	Delay in Ts between basal septal and lateral wall	Color-coded TDI		≥65 ms	90	82
Diaz-Infante et al.[122]	67	6	SPWMD	Septal-to-posterior wall motion delay	M-mode	↓ ≥ 15% LVESV	≥130 ms	50	38
Achilli et al.[26]	133	6	IVMD	Interventricular mechanical delay	Doppler	↑ ≥ 5% LVEF	>44 ms	66	55
Penicka et al.[12]	49	6	Sum asynchrony	Delay in Ts of three basal LV (septal, lateral, posterior) and basal RV segment	Pulsed-wave TDI	↑ ≥ 25% LVEF	>102 ms	96	77
Yu et al.[33]	30	3	Ts-SD	SD of Ts of 12 LV segments	Color-coded TDI	↓ > 15% LVESV	≥32.6 ms	100	100
Bax et al.[30]	25	Acute	Septal-to-lateral delay	Delay in Ts between the basal septal and lateral wall	Color-coded TDI	↑ ≥ 5% LVEF	≥60 ms	76	78
Bax et al.[31]	85	12	Septal-to-lateral delay	Delay in Ts between the basal septal, lateral, inferior, and anterior wall	Color-coded TDI	↓ ≥ 15% LVESV	≥65 ms	92	92
Notabartolo et al.[37]	49	3	PVD	Peak velocity difference; Max delay in Ts of 6 basal LV segments	Color-coded TDI	↓ ≥ 15% LVESV	≥110 ms	97	55
Yu et al.[35]	54	3	Ts-SD	SD of Ts of 12 LV segments	Color-coded TDI	↓ > 15% LVESV	≥31.4 ms	96	78

Echocardiographic Studies on Prediction of Response to CRT

Author	Nr pts.	Follow-up (month)	Measurement	Description	Technique	Definition of Response	Cut-Off Value	Sens (%)	Spec (%)
Yu et al.[34]	55	3	SD-12	SD of Ts of 12 LV segments	Color-coded TDI	↓ > 15% LVESV	≥31.4 ms	96	78
			Diff-12	Max delay in Ts of 12 LV segments			≥98.5 ms	90	76
Knebel et al.[38]	38	6	Max delay	Max delay in Ts of six basal opposing walls	Color-coded TDI	↓ ≥ 15% LVESV + ↑ ≥5% LVEF	≥105 ms	64	80
Yu et al.[36]	256	6 ± 3	Ts-SD	SD of Ts of 12 LV segments	Color-coded TDI	↓ > 15% LVESV	≥33 ms	93	78
			Ts-diff	Max delay in Ts of 12 LV segments			≥100 ms	92	68
			TS-OW	Max delay in Ts of opposing walls of 12 LV segments			≥90 ms	81	80
			Ts-sept-lat	Delay in Ts between basal septal and lateral wall			≥60 ms	70	76
Van de Veire et al.[123]	49	Acute	Ts-SD-6	SD of Ts of six basal segments	Triplane TDI	↓ ≥ 15% LVESV	≥36.5 ms	91	81
			Ts-SD-12	SD of Ts of 12 LV segments			≥35.8 ms	91	85
			Max delay-6	Max delay in Ts of six basal segments			≥95 ms	74	81
			Max delay-12	Max delay in Ts of 12 LV segments			≥95 ms	74	81
			Septal-to-lateral delay	Delay in Ts between basal septal and lateral wall	Color-coded TDI		≥65 ms	87	81
Van de Veire et al.[39]	60	6	Ts-SD-12	SD of Ts of 12 LV segments	Triplane TDI	↓ ≥ 15% LVESV	>33 ms	90	83
Gorcsan et al.[124]	29	Acute	(Antero)septal-to-posterior delay	Max delay in Ts between (antero)septal and posterior wall	TSI	↑ ≥ 15% stroke volume	≥65 ms	87	100

Usefulness of tissue Doppler velocity and strain dyssynchrony for predicting LV reverse remodeling response after CRT.

Table 1 The cutoff values, sensitivities and specificities of various parameters of systolic dyssynchrony for predicting left ventricular reverse remodeling after cardiac resynchronization therapy

		All patients		QRS 120–150 ms		QRS >150 ms		Ischemic		Nonischemic	
Parameters	Cutoff (ms)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Standard deviation of Ts from 12 LV segments	33	93	73	96	79	94	67	92	74	97	77
Maximal difference in Ts from 12 LV segments	100	92	68	96	76	90	59	92	71	94	68
Septal-to-lateral delay in Ts	60	70	76	63	86	73	71	66	74	75	78
QRS duration	145	81	36	NA	NA	NA	NA	77	37	85	36

Yu et al Am J Cardiol 2007

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

PROSPECT Study

Predictors of Response to CRT

Stefano Ghio, Pavia, Italy
Eugene S. Chung, Cincinnati, US
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Jing Ping Sun, Atlanta, US
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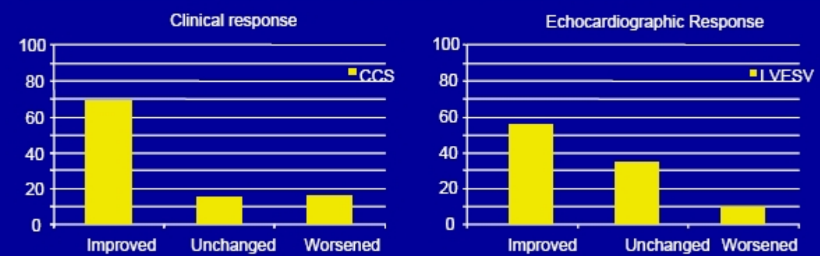
John Merlino, Atlanta, US
William T. Abraham, Columbus, US
Christophe Leclercq, Rennes, France.

on behalf of the PROSPECT Study Investigators

PROSPECT Study

Clinical and Echocardiographic Response at 6 Months

Patient characteristics and the magnitude of response to CRT is representative for previous RCTs



Overall CCS improved rate is
75.6% in non-ischemic
63.7% in ischemic patients (p=0.01)

Overall LVESV improved rate is
63.0% in non-ischemic
50.3% in ischemic patients (p=0.03)

3

Source of Funding

Medtronic Inc provided funding for this study and manufactured the CRT system used in this research.

Disclosures

Drs Abraham, Bax, Chung, Gorcsan, Nihoyannopoulos, St. John Sutton, Tavazzi, and Yu have served as consultants to and received research grants from Medtronic. Drs De Sutter, Ghio, Leclercq, Leon, Murillo, Nihoyannopoulos and Sun have received honoraria from or consulted for Medtronic.

TDI data obtained with the Siemens machines were excluded from analysis because of suboptimal data quality as determined by the core laboratories.

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Results of the predictors of response to CRT (PROSPECT) trial.

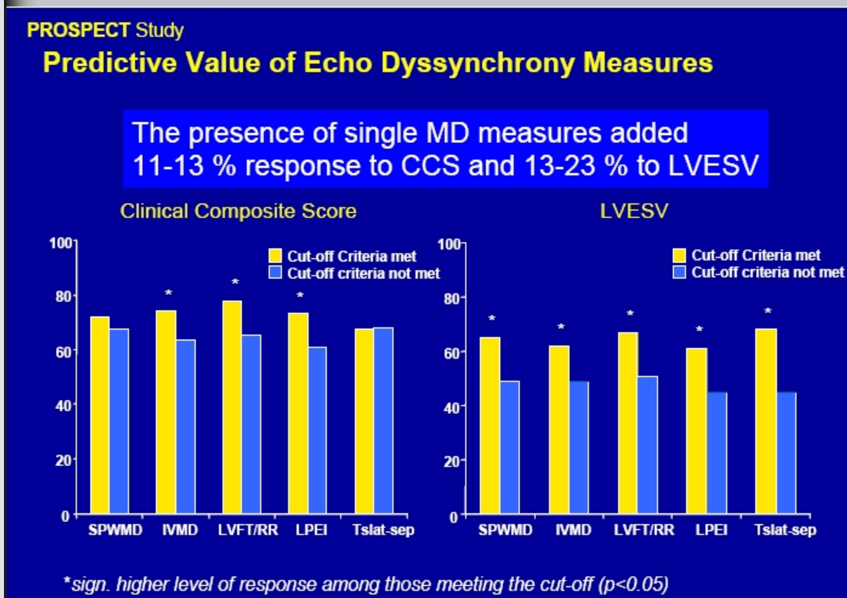

Table 3. Interobserver and Intraoperator Variability Summary

Echocardiographic Measure	Intraobserver CV, %	Interobserver CV, %	Interobserver κ Coefficient*
LVESV	3.8	14.5	NA
LPEI	3.7	6.5	0.67
SPWMD	24.3	72.1	0.35
Ts-SD	11.4	33.7	0.15
Ts-peak (basal)	15.8	31.9	0.25

LPEI indicates left ventricular preejection interval.

*Based on binary predictor variable that indicates if echocardiographic measure is above or below the cutoff.

We observed relatively low yield and high variability for the TDI measures. Specifically, the percent of individual parameters deemed interpretable by the core laboratories ranged between 61% and 95% for the routine non-TDI methods and between 37% and 82% for TDI-based tests.

Results of the predictors of response to CRT (PROSPECT) trial.

Table 5. Sensitivity, Specificity, and Area Under the Curve for Primary End Points

Echocardiography Type	Dyssynchrony Measure	Evaluable Echocardiograms, (yield) %	CCS Sensitivity, %	CCS Specificity, %	CCS AUC	CCS *P* for AUC	LVESV Sensitivity, %	LVESV Specificity, %	LVESV AUC	LVESV *P* for AUC
M mode	SPWMD	71.7	55.4 (48.3–62.3)	50.0 (39.1–60.9)	0.54	0.27	63.6 (54.8–71.8)	52.1 (41.6–62.4)	0.62	0.003
Pulsed Doppler	IVMD	92.4	55.2 (48.9–61.4)	56.4 (46.9–65.6)	0.58	0.013	59.7 (51.5–67.6)	54.1 (44.8–63.2)	0.59	0.009
	LVFT/RR	85.3	36.3 (30.2–42.7)	76.6 (67.5–84.3)	0.57	0.032	41.0 (32.9–49.5)	74.1 (65.0–81.9)	0.60	0.007
	LPEI	94.6	66.3 (60.2–72.0)	47.1 (38.0–56.4)	0.60	0.001	72.0 (64.3–78.8)	42.4 (33.6–51.6)	0.59	0.014
M mode+ Doppler	LLWC	60.7	6.3 (3.2–11.0)	91.7 (82.7–96.9)	0.52	0.63	9.5 (4.7–16.8)	92.9 (85.3–97.4)	0.50	0.98
TDI, published	Ts (Lat-Sep)	66.8	42.4 (34.4–50.7)	56.9 (44.7–68.6)	0.50	0.85	52.6 (42.1–63.0)	69.2 (57.8–79.2)	0.61	0.012
	Ts-SD	50.0	74.1 (65.2–81.8)	35.3 (22.4–49.9)	0.60	0.034	77.5 (66.0–86.5)	30.6 (19.6–43.7)	0.55	0.35
	PVD	81.4	67.6 (60.3–74.3)	37.8 (27.8–48.6)	0.51	0.89	67.8 (58.6–76.1)	34.4 (25.0–44.8)	0.55	0.30
TDI+SRI	DLC	81.1	41.7 (34.4–49.2)	60.4 (49.6–70.5)	0.51	0.75	43.6 (34.4–53.1)	59.4 (48.9–69.3)	0.51	0.75
TDI, median value used as cutoff	Ts-peak displacement	37.4	54.8 (43.5–65.7)	56.1 (39.7–71.5)	0.56	0.32	58.0 (43.2–71.8)	54.5 (38.8–69.6)	0.57	0.25
	Ts-peak basal	82.0	51.9 (44.4–59.3)	53.8 (43.1–64.4)	0.55	0.19	52.1 (42.8–61.3)	55.7 (45.2–65.8)	0.57	0.10
	Ts-onset basal	82.0	54.1 (46.6–61.5)	60.4 (49.6–70.5)	0.58	0.047	52.9 (43.6–62.2)	51.5 (41.2–61.8)	0.48	0.53

See Table 1 for descriptions and definitions. Sensitivity and specificity are derived from the cutoff values in Table 3. The values in parentheses are exact binomial 95% CIs. This table uses receiver-operating characteristics curve analysis to investigate whether changing the cutoff value (as given in Table 3) could give a better prediction of improvement on the CCS or reduction in LVESV. If the probability value for the area under the curve (AUC) (H_0: AUC=0.5) is considerably smaller than the Fisher exact probability value in Table 3, then it is likely that a better cutoff value can be found.

Critical appraisal of methods to assess mechanical dyssynchrony

Cheuk-Man Yu[a], Jeroen J. Bax[b] and John Gorcsan III[c]

The PROSPECT study

Published multicenter study: controversies rather than conclusion

assessment and echocardiographic issues. For study site selection, the vendor chose sites based on experience of device implantation rather than considering the ability to perform dyssynchrony assessment and TDI in parallel. Intriguingly, the study was commenced in 2003, when only a few institutions in the world performed dyssynchrony assessment as single-studies. Despite limited experience, the study sites were only provided with very basic training for the complex echocardiographic assessment of 15 dyssynchrony parameters. Similarly to the

echocardiographic core laboratories to perform robust analysis of LV volume and dyssynchrony were not ascertained when they were being selected, and interestingly one core-laboratory was actually supervised by a none-chocardiographic physician. The variability test in PROSPECT study is misleading as it was not a predefined analysis, but was conducted retrospectively after all the offline analysis had been completed. Therefore, potential problems of core laboratories with respect to dyssynchrony measurement were unable to be identified and addressed before offline analysis of echocardiographic images was commenced. These factors, together with the use of low-end echocardiographic machines of multiple vendors incapable of collecting high-quality color-coded TDI images, would have contributed to the high variability of dyssynchrony parameters. This

bility of 5–10% [3,13•,20]. Furthermore, the suboptimal echocardiographic image quality in the PROSPECT study resulted in a large drop-out rate in offline analysis. For example, LV end-systolic volume for determination of reverse remodeling was analyzable in only 286 out of 426 patients (67%) whereas Ts-SD by TDI was only analyzable in 167 (39%) patients! Lastly, quality assur-

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Characteristics of heart failure patients associated with good and poor response to cardiac resynchronization therapy: a PROSPECT (Predictors of Response to CRT) sub-analysis

Rutger J. van Bommel[1], Jeroen J. Bax[1]*, William T. Abraham[2], Eugene S. Chung[3], Luis A. Pires[4], Luigi Tavazzi[5], Peter J. Zimetbaum[6], Bart Gerritse[7], Nina Kristiansen[7], and Stefano Ghio[8]

European Heart Journal Advance Access published August 30, 2009

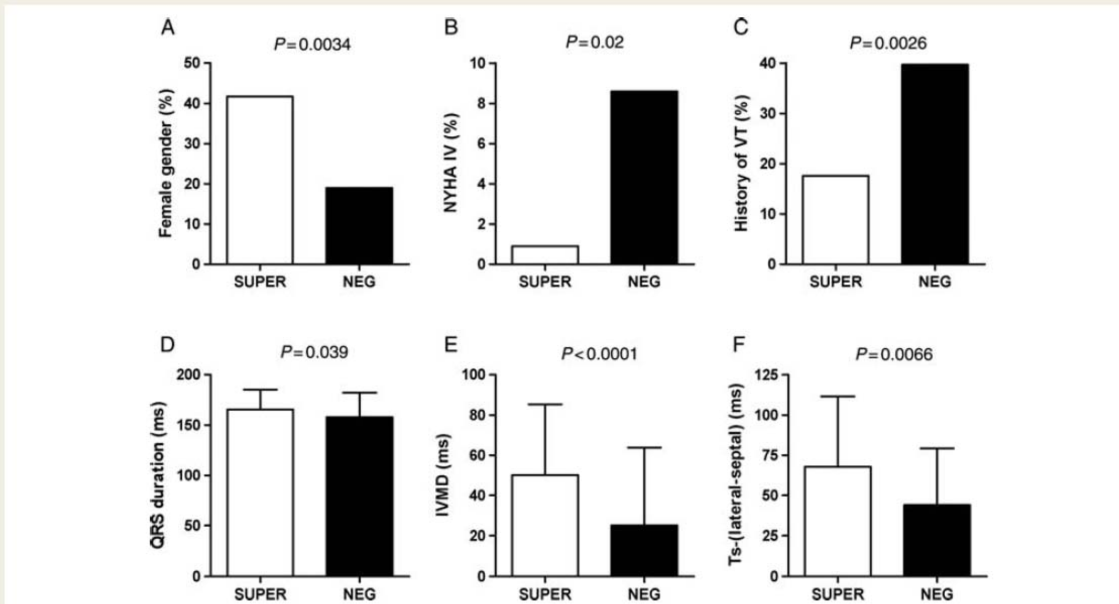


Figure 2 Differences in clinical (*A–D*) and echocardiographic (*E–F*) baseline characteristics between left ventricular end-systolic volume super-responders (SUPER) and negative responders (NEG). (D–F) mean and 1 standard deviation. IVMD, inter-ventricular mechanical delay; NYHA, New York Heart Association; Ts, time to peak systolic velocity; VT, ventricular tachycardia.

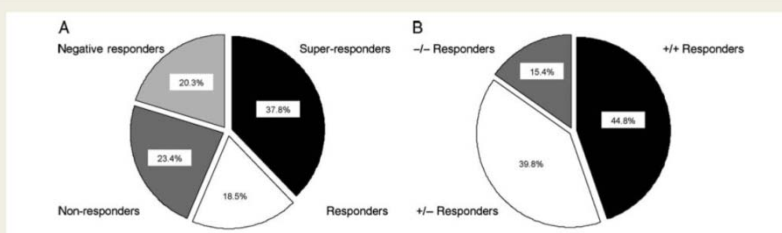


Figure 1 Percentage of responders, according to the extent of reduction in left ventricular end-systolic volume (*A*) and the combination of clinical response and a reduction in left ventricular end-systolic volume ≥15% (*B*).

Echocardiography and Noninvasive Imaging in Cardiac Resynchronization Therapy: Results of the PROSPECT Study in Perspective

- **Bax, Gorscan JACC 2009**

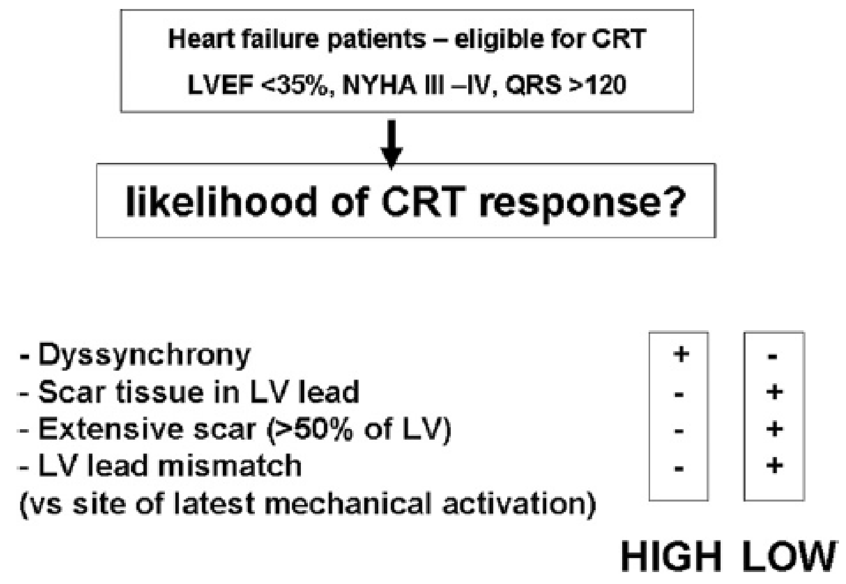
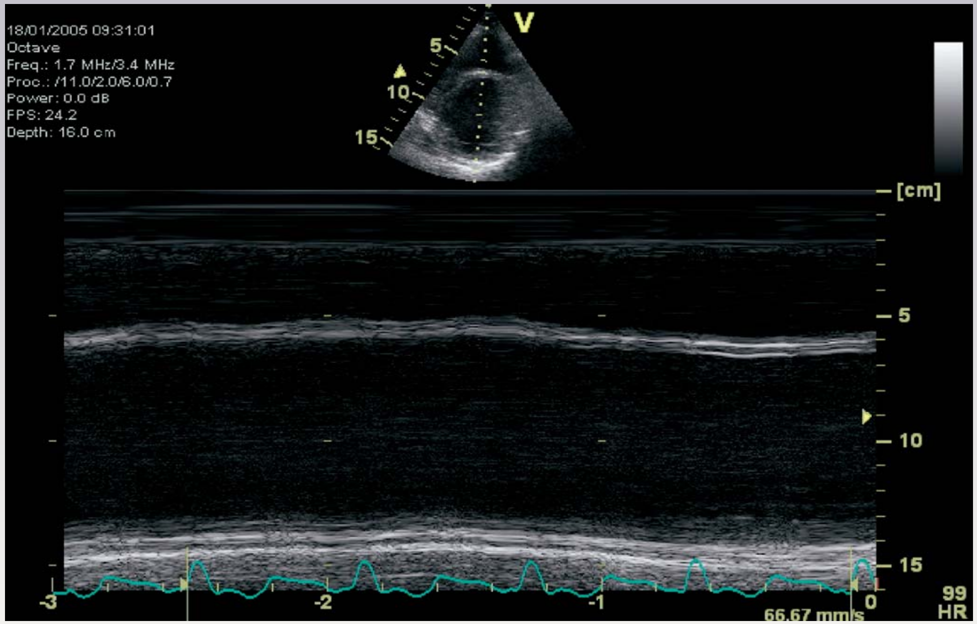


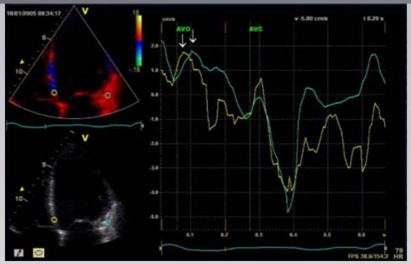
Figure 10 Integrated Information on Dyssynchrony, Scar, and Region of Latest Mechanical Activation May Improve Response to CRT

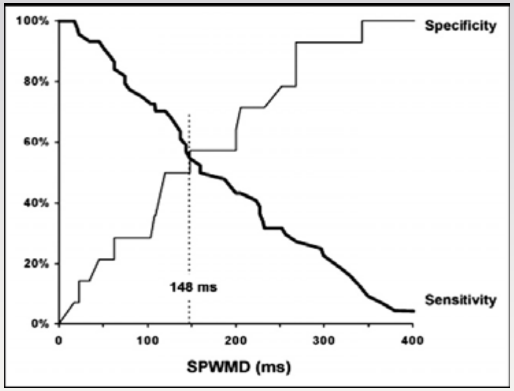
Various factors for prediction of response to cardiac resynchronization therapy (CRT) are important, including left ventricular (LV) dyssynchrony, scar tissue in the region where the LV pacing lead is positioned, the total extent of scar in the LV, and whether the LV lead is positioned in the site of latest mechanical activation. Based on these factors, one can distinguish patients with a low and high likelihood of response to CRT. LVEF = left ventricular ejection fraction; NYHA = New York Heart Association.

Relative Merits of M-Mode Echocardiography and TDI for Prediction of Response to CRT in Patients With HF Secondary to Ischemic or Idiopathic Dilated Cardiomyopathy

(Bleeker et al Am J Card 2007)







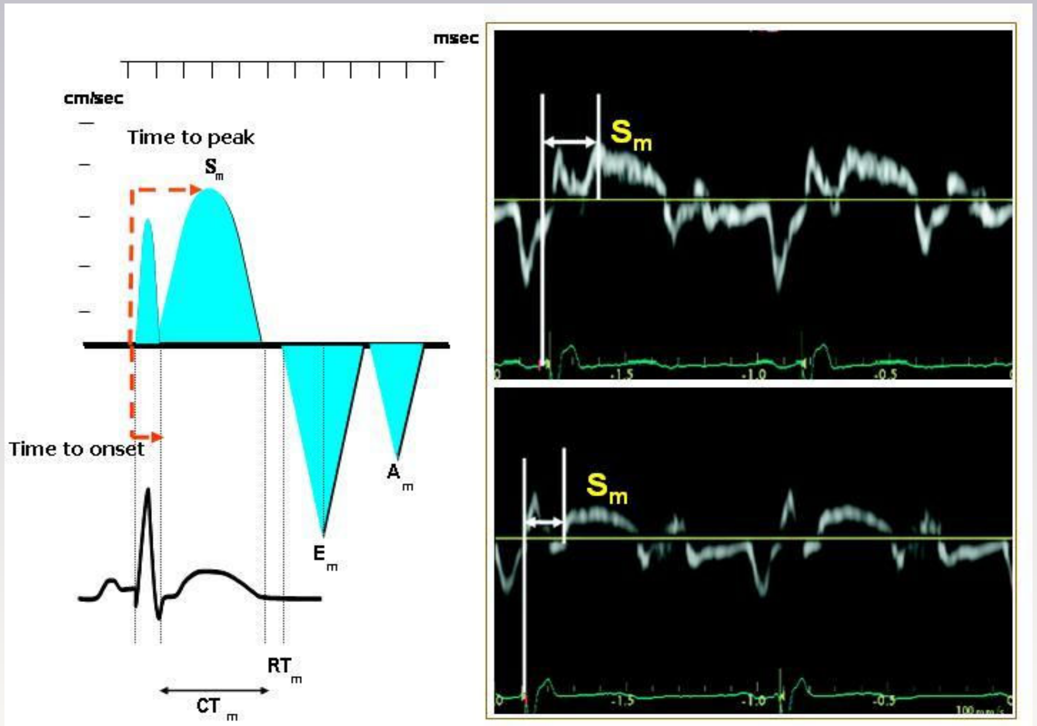
	SPWMD >130 ms	SPWMD ≤130ms
S-L Delay ≥65ms	29 (50%)	12 (21%)
S-L Delay <65ms	7 (12%)	10 (17%)

Sensitivity, specificity, positive, and negative predictive values of septal-to-lateral delay ≥65 ms and septal-to-posterior wall motion delay >130 ms for prediction of response to cardiac resynchronization therapy

	Septal-to-Lateral Delay ≥65 ms	SPWMD >130 ms
Sensitivity	90%	66%
Specificity	82%	50%
Positive predictive value	94%	81%
Negative predictive value	72%	32%

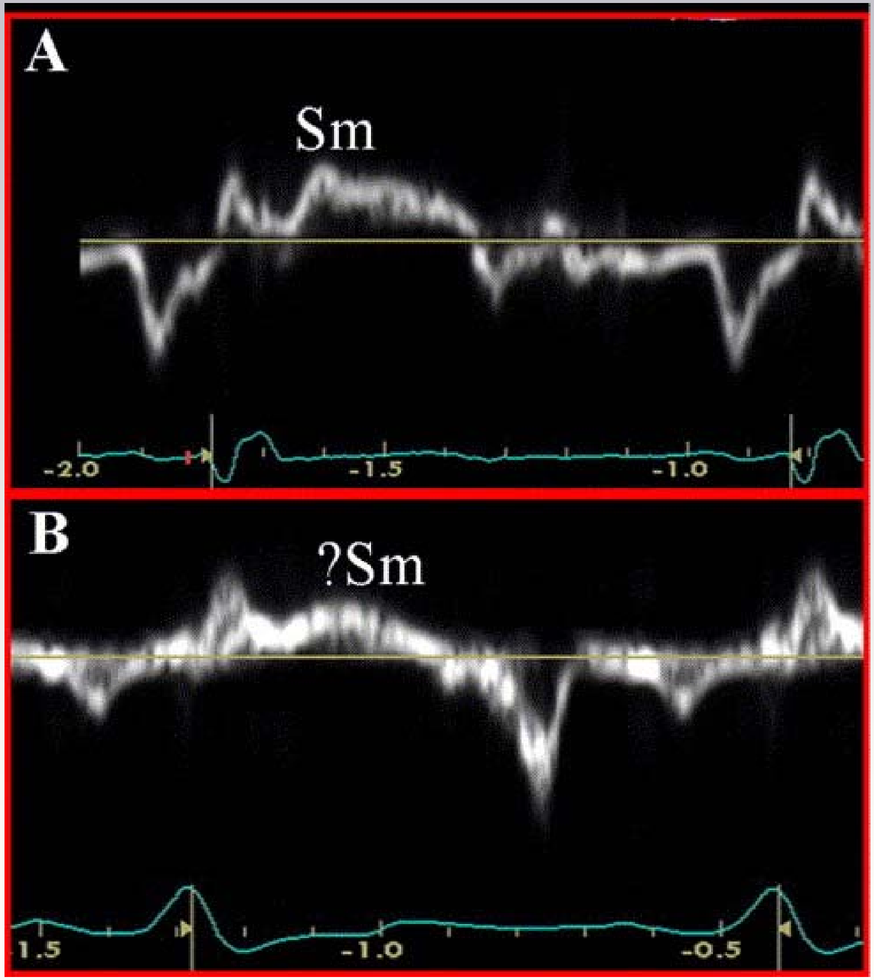
Spectral PW- TDI for LV Dyssyncrony

JASE 2008



- The velocity profiles were recorded with a sample volume placed in the middle of the basal segment of each wall
- Intra-ventricular mechanical delay has been defined for differences of > 65 ms of time to Sm peak between LV segments

Spectral PW- TDI for LV Dyssyncrony



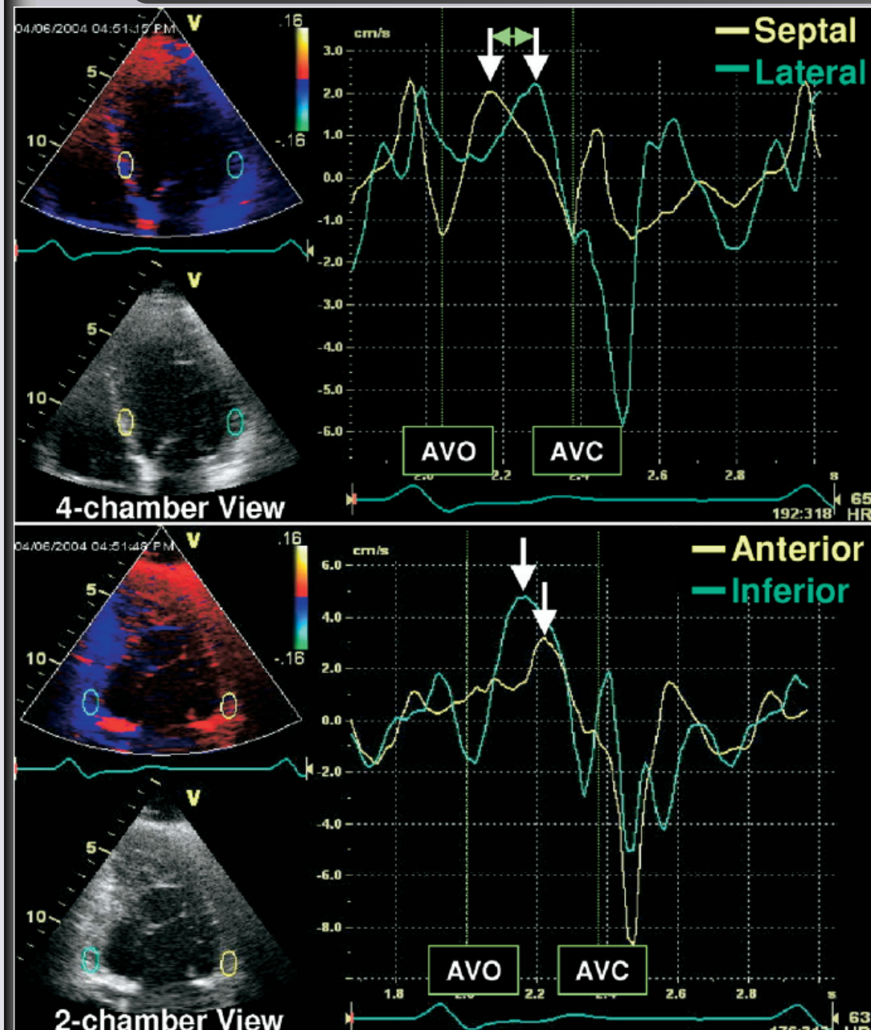
- Excellent temporal resolution
- Limitation
- Not the same cycle
- An initial positive deflection of the Sm velocity that occurs during the QRS reflects the ICT.
- inability to align the Doppler cursor parallel to the LV segment
- There may be no clearly defined peak Sm and, therefore, the Q wave to onset of Sm velocity can be used
- Thin or infarcted myocardial segments may also potentially impact the accuracy of the time to onset or time to peak Sm.
- Although DTI-derived Sm velocities can be obtained at the LV base in nearly all patients, it may not be possible in the mid-LV segments.
- It also remains to be established how many LV segments should be analyzed for determining the extent of LV dyssynchrony.
- Furthermore, the DTI Sm velocities recorded in apical views reflect longitudinal shortening and do not reflect circumferential LV contraction.

ASE EXPERT CONSENSUS STATEMENT

Echocardiography for Cardiac Resynchronization Therapy: Recommendations for Performance and Reporting–A Report from the American Society of Echocardiography Dyssynchrony Writing Group

Endorsed by the Heart Rhythm Society

Color – Coded TDI in CRT



Step 1: Determine the timing of LV ejection, usually from the beginning to the end of pulsed Doppler flow of the LV outflow tract. The details vary according to ultrasound system used, but timing usually is performed using the ECG as a time marker. The timing of beginning ejection to end ejection is then superimposed as the ejection interval on the subsequent time-velocity curve analysis.

Step 2: Size and place regions of interest (a minimum of 5 × 10 mm to 7 × 15 mm) in the basal and midregion of opposing LV walls (4 regions/view) to determine time-velocity plots.

Step 3: If possible, identify components of velocity curve, as a check for physiologic signal quality. These include isovolumic contraction velocity (usually <60 milliseconds from the onset of the QRS), the systolic wave, or S wave, moving toward the transducer and the early diastolic, or E wave, and late diastolic, or A wave, moving away from the transducer

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ASE EXPERT CONSENSUS STATEMENT

Echocardiography for Cardiac Resynchronization Therapy: Recommendations for Performance and Reporting–A Report from the American Society of Echocardiography Dyssynchrony Writing Group

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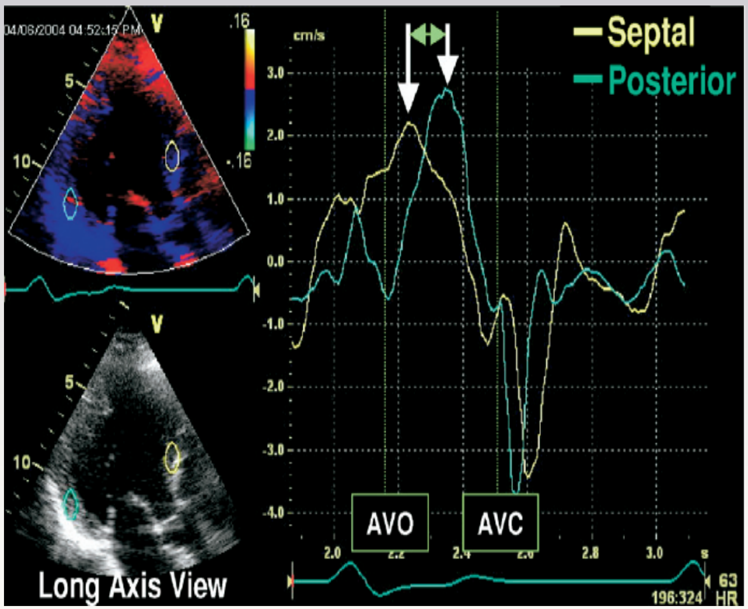
Color – Coded TDI in CRT



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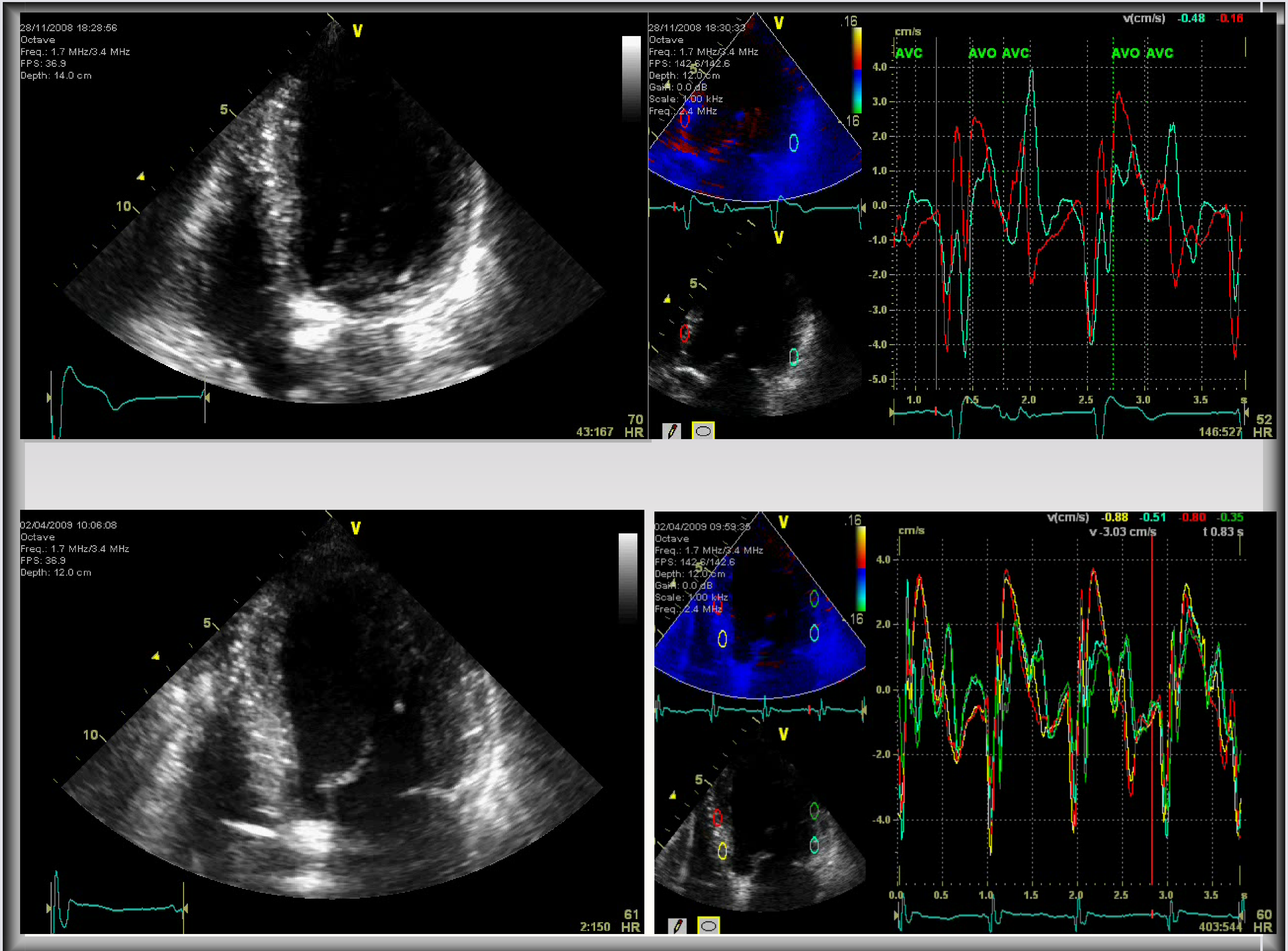
Step 4: Manually adjust the regions of interest within the segment both longitudinally and side-to-side within the LV wall to identify the site where the peak velocity during ejection is most reproducible. This is an important step to search for the most reproducible peak of greatest height, in particular where there is more than one peak or signal noise. If fine tuning of the region of interest fails to produce a single reproducible peak during ejection, the earlier peak is chosen if there are two or more peaks of the same height.

Step 5: Determine time from onset of the QRS complex to the peak systolic velocity for each region: 4 segments per view, for each of 3 views, for a total of 12 segments. An alternative is to determine the difference in the time to peak S wave from opposing walls, as described in the opposing wall delay method below. This is simply the time from the S wave of one wall to the S wave of the opposing wall on the same cineloops, and does not require measuring the onset from the QRS.

Step 6: Average the time to peak values in captured beats to improve reproducibility, because beat-to-beat variability may occur. A minimum of averaging 3 to 5 beats is recommended, with the number of averaged beats increased if beat-to-beat variability is encountered, excluding sequences with atrial or ventricular premature complexes. Analysis of TD data in atrial fibrillation is especially complex and problematic, and no data are currently available to support dyssynchrony analysis in this scenario.



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cm/s
AVC
AVO AVC
AVO AVC
146:527
52 HR
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Freq.: 2.4 MHz
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t 0.83 s
cm/s
403:544
60 HR

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Assessment of Left Ventricular Dyssynchrony in Patients With Conduction Delay and Idiopathic Dilated Cardiomyopathy

Head-to-Head Comparison Between Tissue Doppler Imaging and Velocity-Encoded Magnetic Resonance Imaging

Jos J. M. Westenberg, PhD,*† Hildo J. Lamb, MD, PhD,† Rob J. van der Geest, MSc,*† Gabe B. Bleeker, MD,‡ Eduard R. Holman, MD, PhD,‡ Martin J. Schalij, MD, PhD,‡ Albert de Roos, MD, PhD,† Ernst E. van der Wall, MD, PhD,‡ Johan H. C. Reiber, PhD,*† Jeroen J. Bax, MD, PhD‡
Leiden, the Netherlands

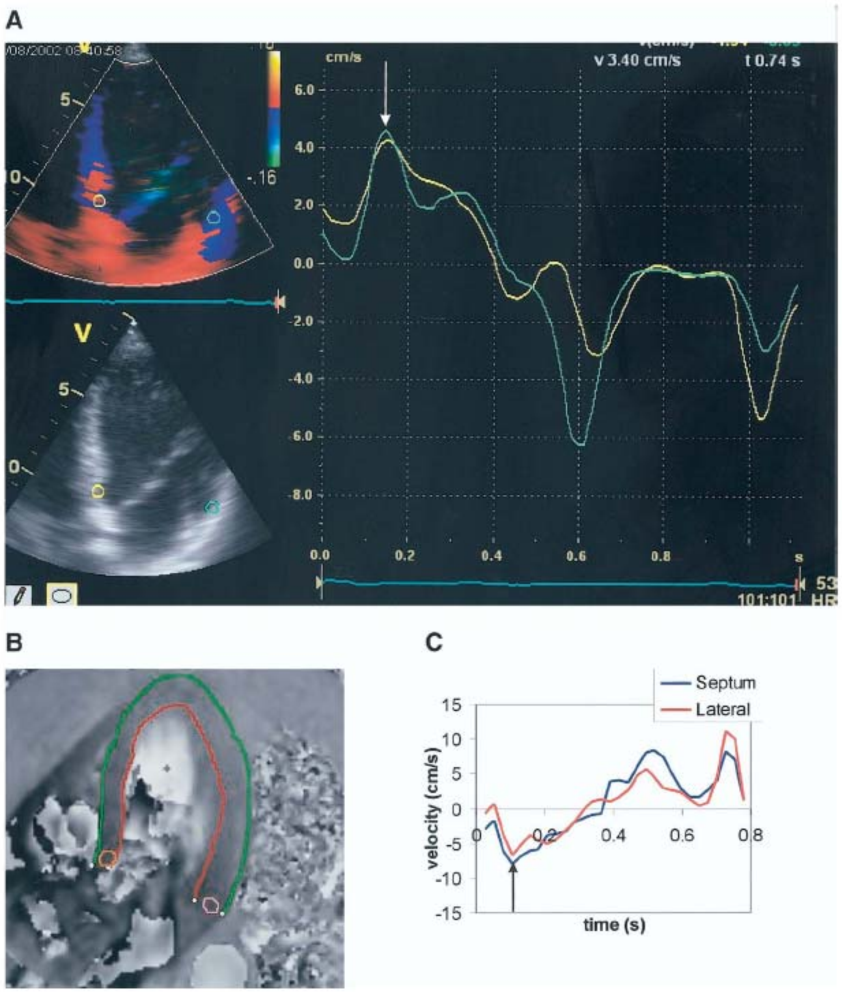


Figure 1. Example of the assessment of left ventricular (LV) dyssynchrony in a normal individual. In the color-coded tissue Doppler images (A, four-chamber view), sample volumes are placed in the basal part of the septum and lateral wall. Velocity graphs derived from the velocities measured in sample volumes are presented in the right panel of A. In this normal individual, LV dyssynchrony is not present, as indicated by a septal-to-lateral delay in systolic velocity (arrow) of 0 ms. (B) The accompanying velocity encoded magnetic resonance imaging is presented. Similar to TDI, sample volumes are placed basal level of the septum and lateral wall. The velocity graphs are presented in panel C, confirming the absence of LV dyssynchrony (septal-to-lateral delay 0 ms).

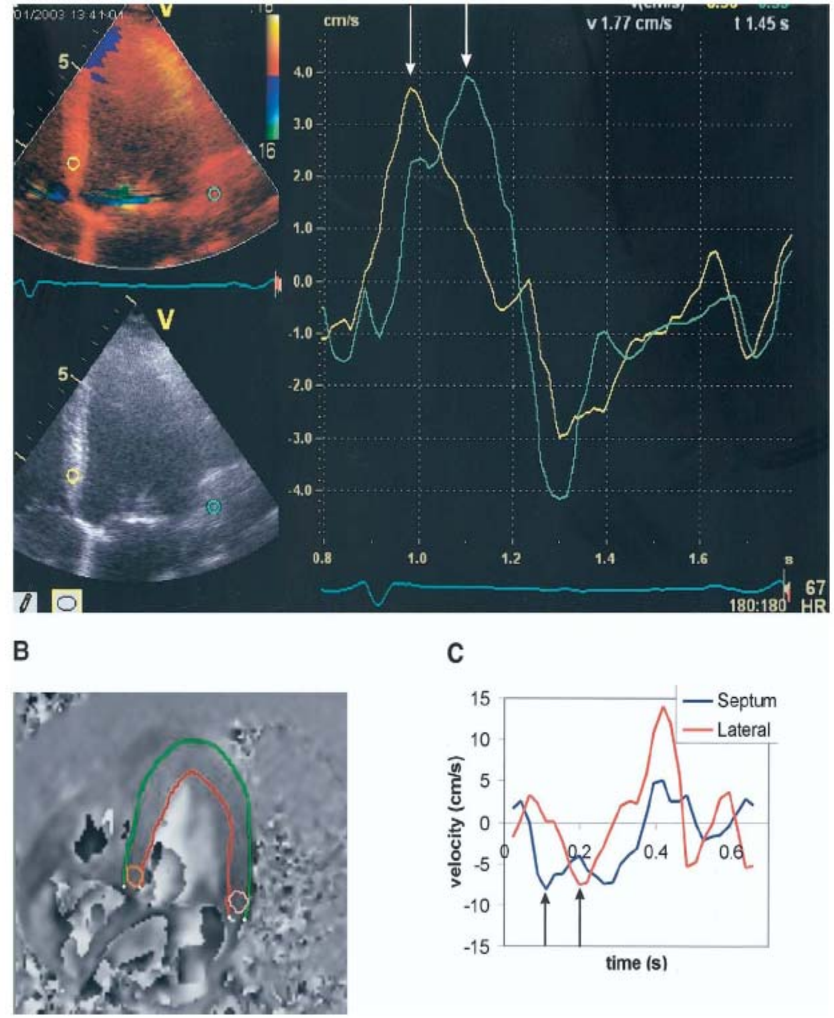
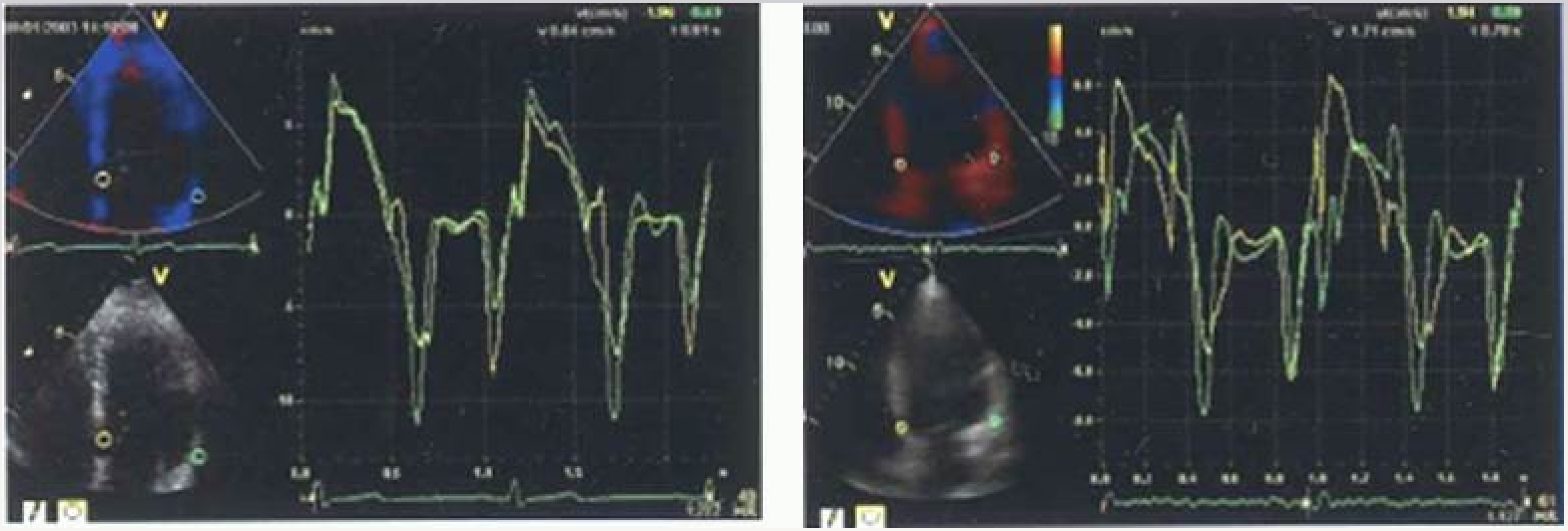


Figure 2. Example of left ventricular (LV) dyssynchrony assessment in a patient. (A) The color-coded tissue Doppler images four-chamber view. The velocity graphs are presented in the right panel of A. There is extensive LV dyssynchrony with a septal-to-lateral delay in peak systolic velocities of 115 ms (arrows). The accompanying velocity encoded magnetic resonance imaging and velocity graphs are presented in panels B and C, respectively, confirming extensive LV dyssynchrony with a septal-to-lateral delay of 116 ms.

Echocardiographic Evaluation of CRT: Intraventricular dyssynchrony as assessed by Tissue Doppler Imaging

Normal

Dyssynchrony



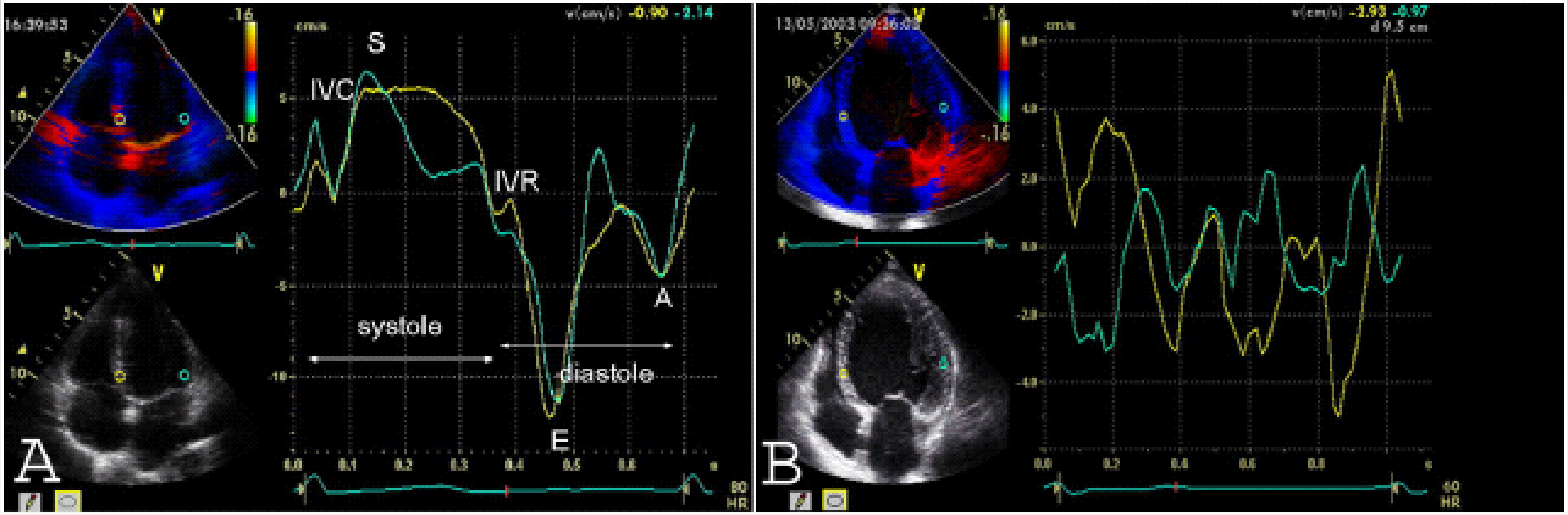
Difference in septal-lateral time-to-peak TDI, cut-off > 60 ms

Yu et al Am J Card 2002

Echocardiographic Evaluation of CRT:
Intraventricular dyssynchrony as assessed by Tissue Doppler Imaging

Normal

Dyssynchrony



Difference in septal-lateral time-to-peak TDI, cut-off > 60 ms

Penicka et al Circ 2004

Bax et al Am J Card 2003

Sogaard et al JACC 2002

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ISSN 0735-1097/04/$30.00
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STATE-OF-THE-ART PAPER

Echocardiographic Evaluation of Cardiac Resynchronization Therapy: Ready for Routine Clinical Use?

A Critical Appraisal

Jeroen J. Bax, MD, PhD,* Gerardo Ansalone, MD,† Ole A. Breithardt, MD,‡
Genevieve Derumeaux, MD,§ Christophe Leclercq, MD,|| Martin J. Schalij, MD, PhD,*
Peter Sogaard, MD,¶ Martin St. John Sutton, MD,# Petros Nihoyannopoulos, MD, FRCP, FACC**

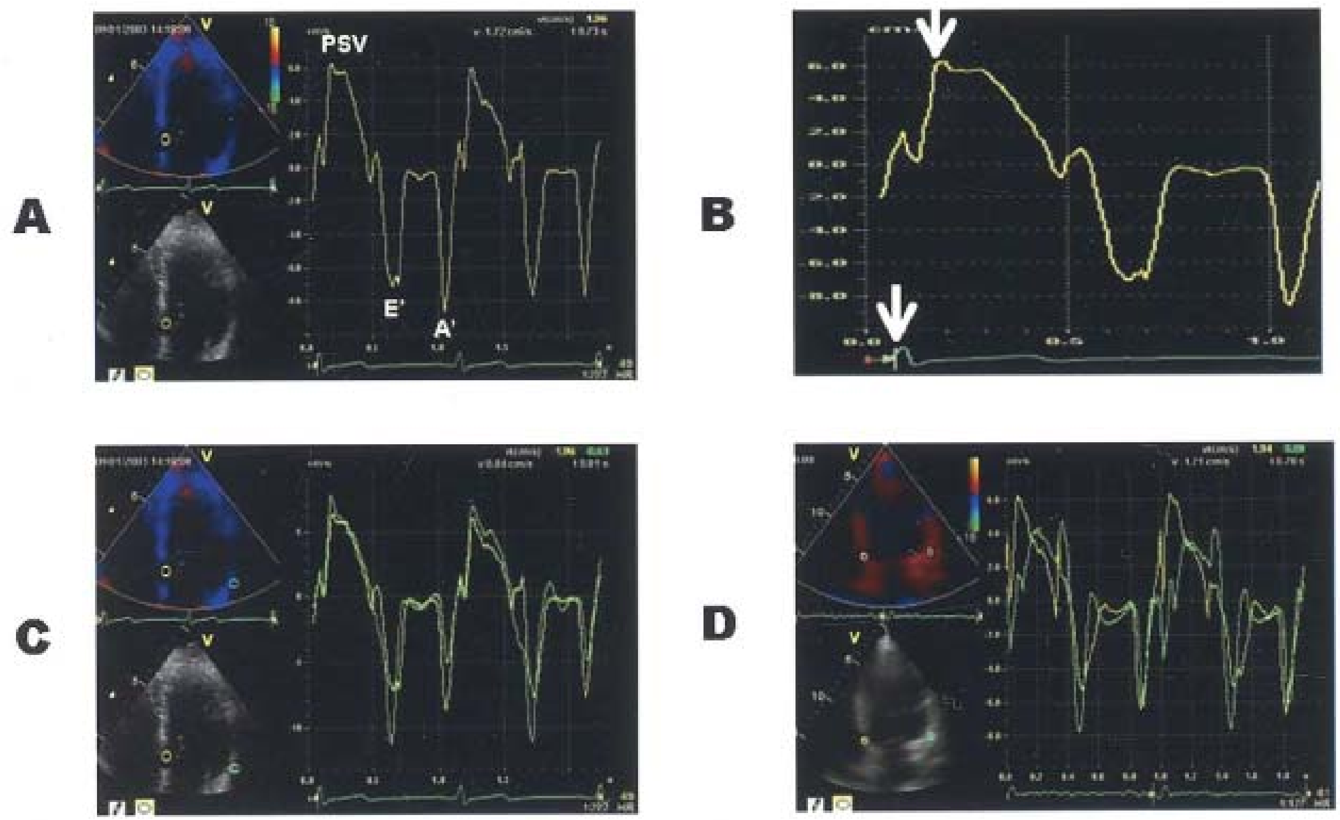

Figure 5. (A) The typical tissue Doppler imaging tracings (peak systolic velocity [PSV], diastolic velocities [E' and A']) obtained in the septum of a normal individual. (B) Illustration of assessment of timing from onset of QRS to peak systolic velocity. (C) Evaluation of intraventricular (dys)synchrony by placing sample volumes on the septum (yellow curve) and lateral wall (green curve). Data from a normal individual showing complete intraventricular synchrony. (D) Severe intraventricular dyssynchrony between the septum (yellow curve) and lateral wall (green curve).

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FOCUS ISSUE: CARDIAC RESYNCHRONIZATION THERAPY

STATE-OF-THE-ART PAPERS

Cardiac Resynchronization Therapy

Part 1—Issues Before Device Implantation

Jeroen J. Bax, MD,* Theodore Abraham, MD, FACC,† S. Serge Barold, MD, FACC,‡
Ole A. Breithardt, MD,§ Jeffrey W. H. Fung, MD,|| Stephane Garrigue, MD, PHD,¶
John Gorcsan III, MD, FACC,# David L. Hayes, MD, FACC,** David A. Kass, MD,†
Juhani Knuuti, MD, PHD,†† Christophe Leclercq, MD, PHD,‡‡ Cecilia Linde, MD, PHD,§§
Daniel B. Mark, MD, PHD, FACC,|||| Mark J. Monaghan, PHD,¶¶
Petros Nihoyannopoulos, MD, FRCP, FACC, FESC,*** Martin J. Schalij, MD,*
Christophe Stellbrink, MD,††† Cheuk-Man Yu, MD||

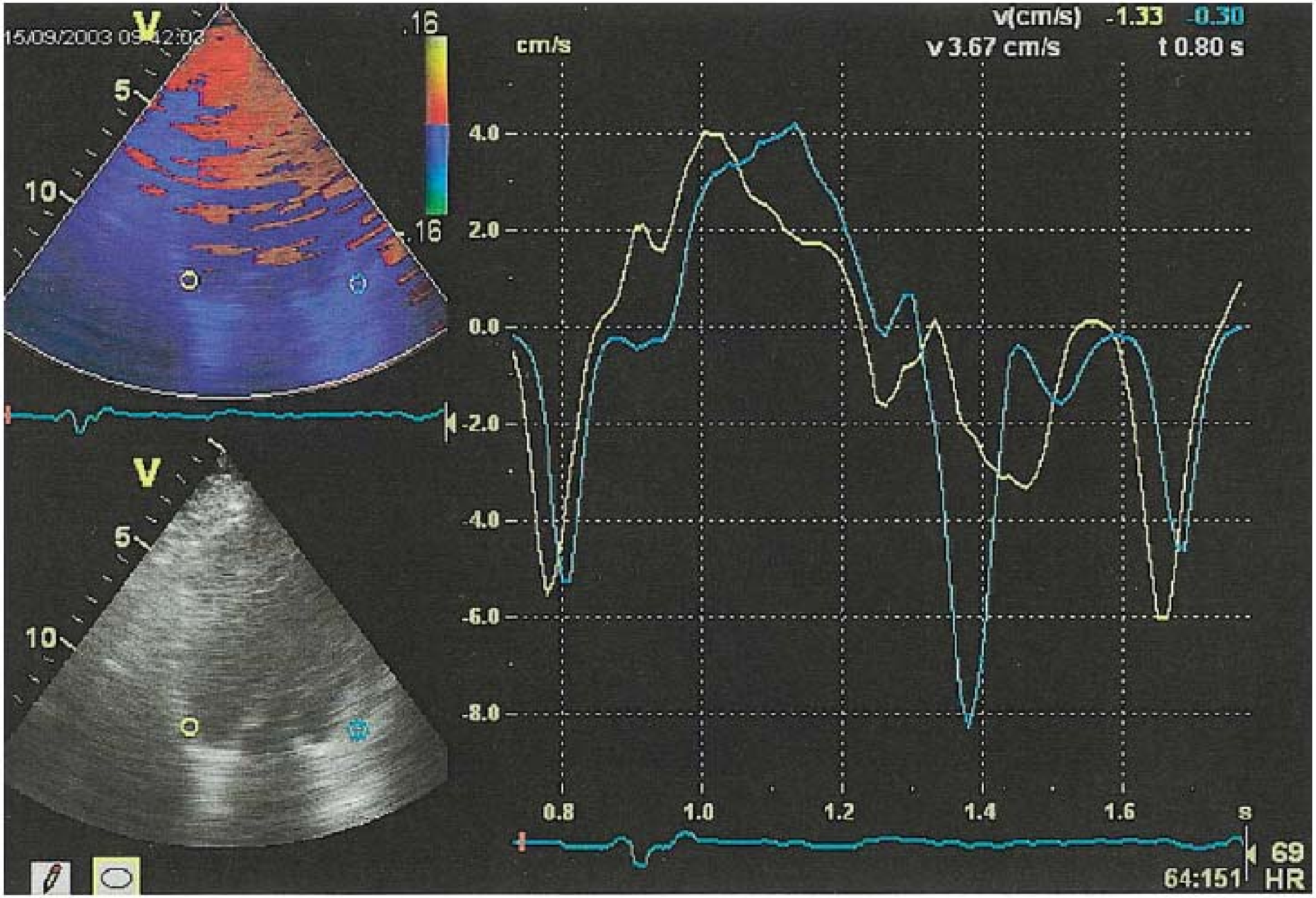
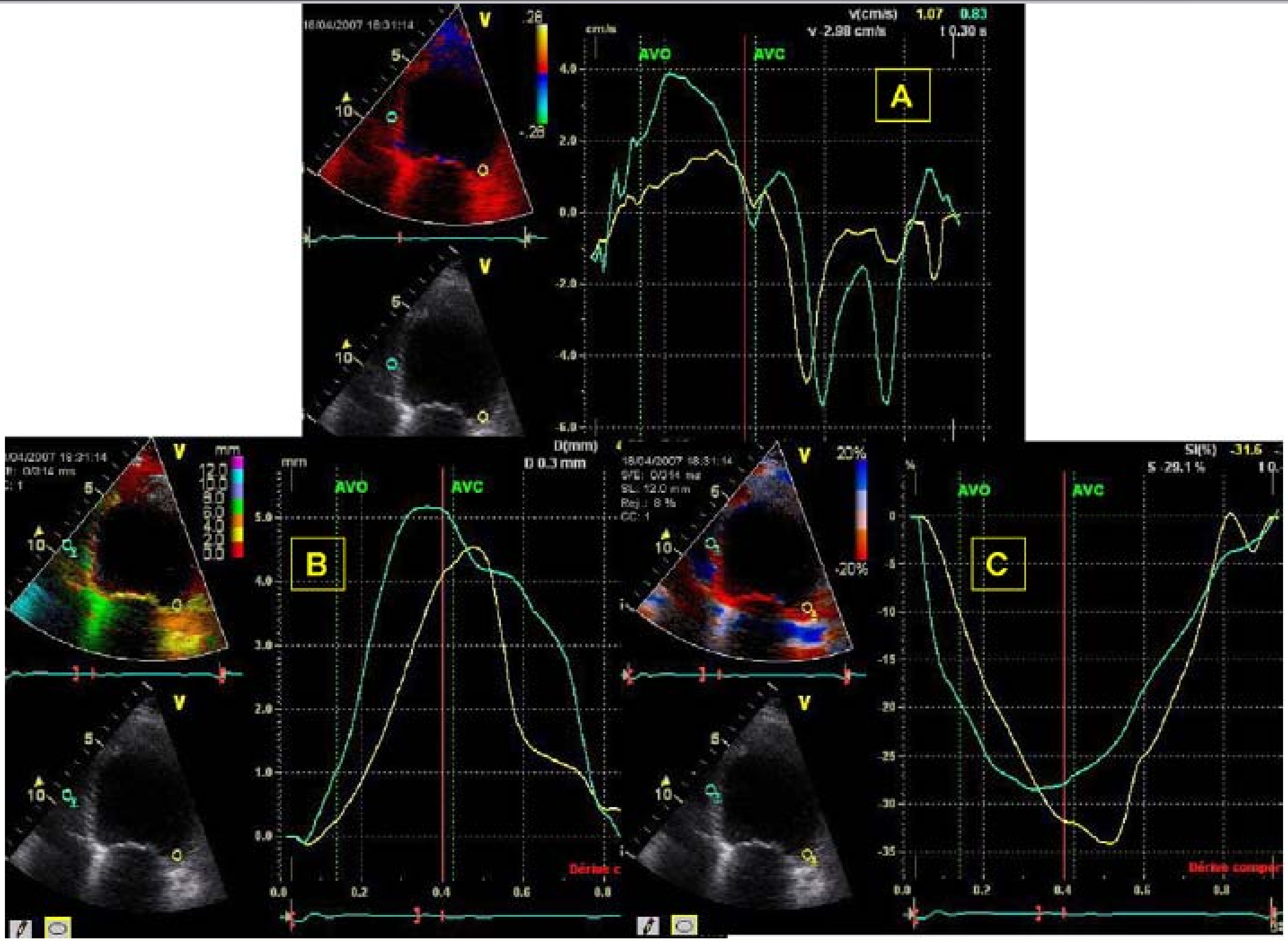


Figure 3. Color-coded four-chamber tissue Doppler image **(upper left)**. Post-processing yields velocity tracings **(right)**; severe left ventricular dyssynchrony is present as indicated by the delay in the peak systolic velocity of the septum **(yellow curve)** as compared to the lateral wall **(green curve)**.

Selection of patients responding to cardiac resynchronisation therapy: Implications for echocardiography

Erwan Donal*, Christian de Place,
Christophe Leclercq, Jean-Claude Daubert

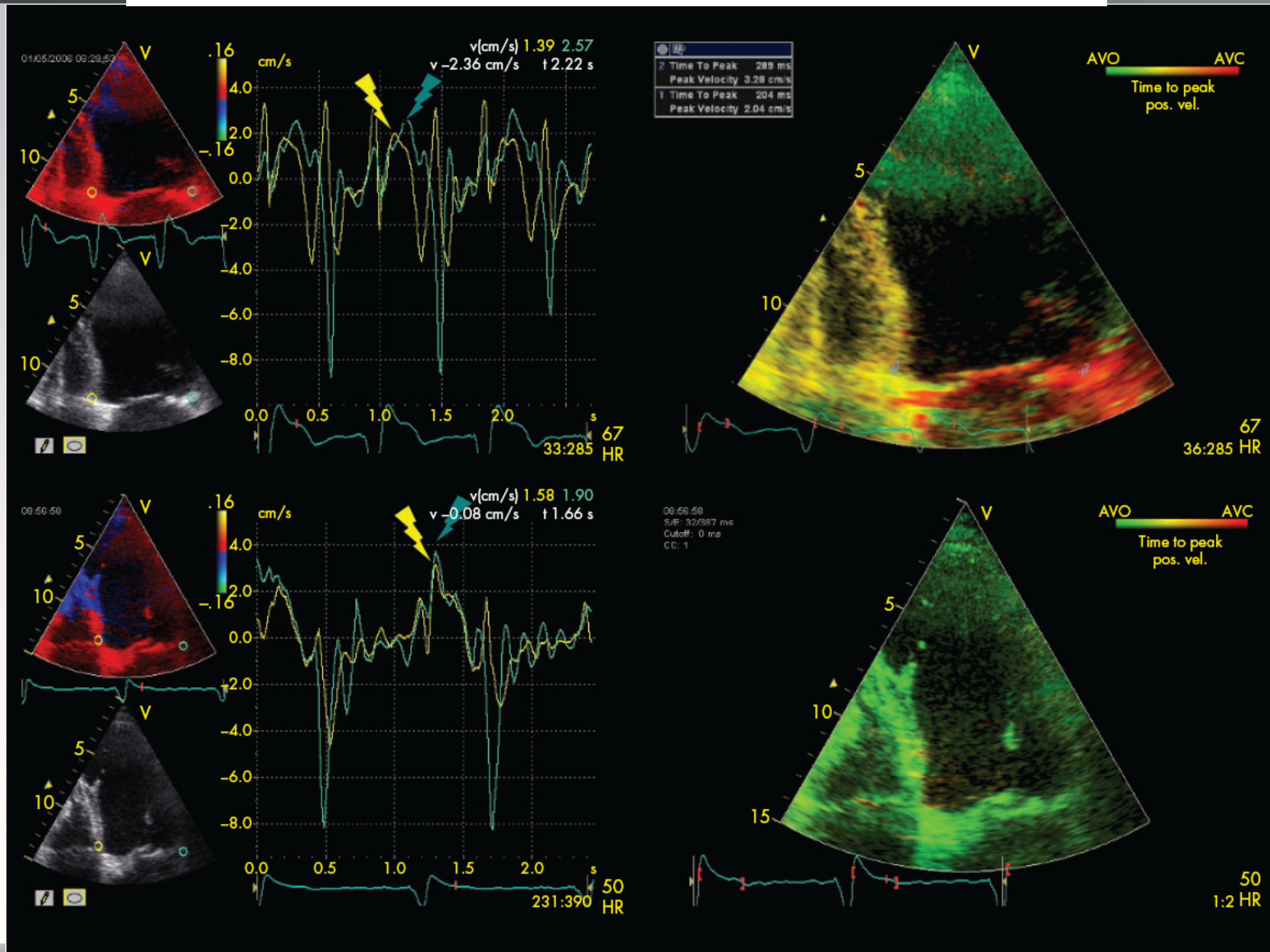
Archives of Cardiovascular Disease (2009) **102**, 65–74



Tissue synchronisation imaging accurately measures left ventricular dyssynchrony and predicts response to cardiac resynchronisation therapy

Nico R Van de Veire, Gabe B Bleeker, Johan De Sutter, Claudia Ypenburg, Eduard R Holman, Ernst E van der Wal, Martin J Schalij, Jeroen J Bax

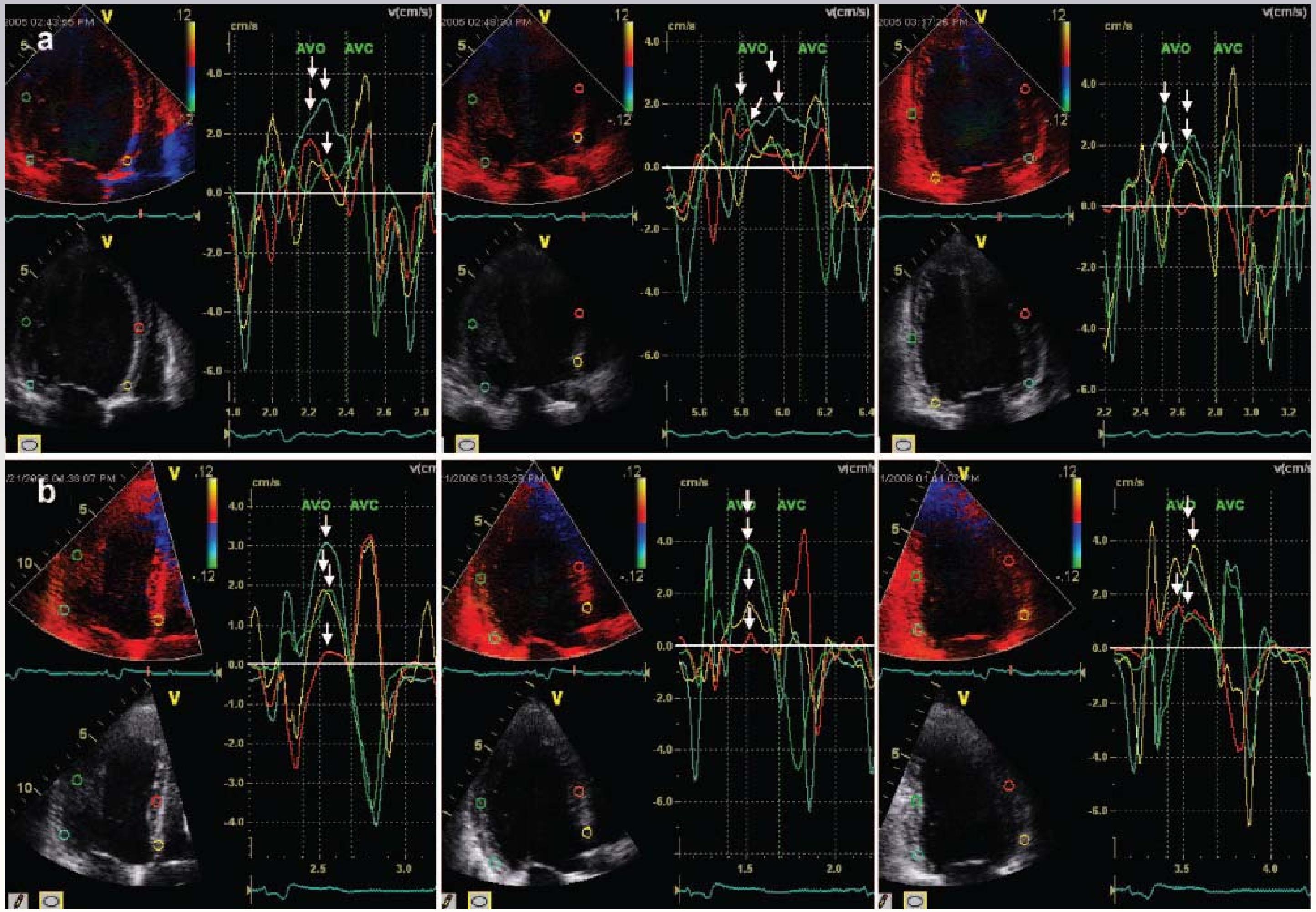
Heart 2007;**93**:1034–1039. doi: 10.1136/hrt.2006.099424



Patient Selection and Echocardiographic Assessment of Dyssynchrony in Cardiac Resynchronization Therapy

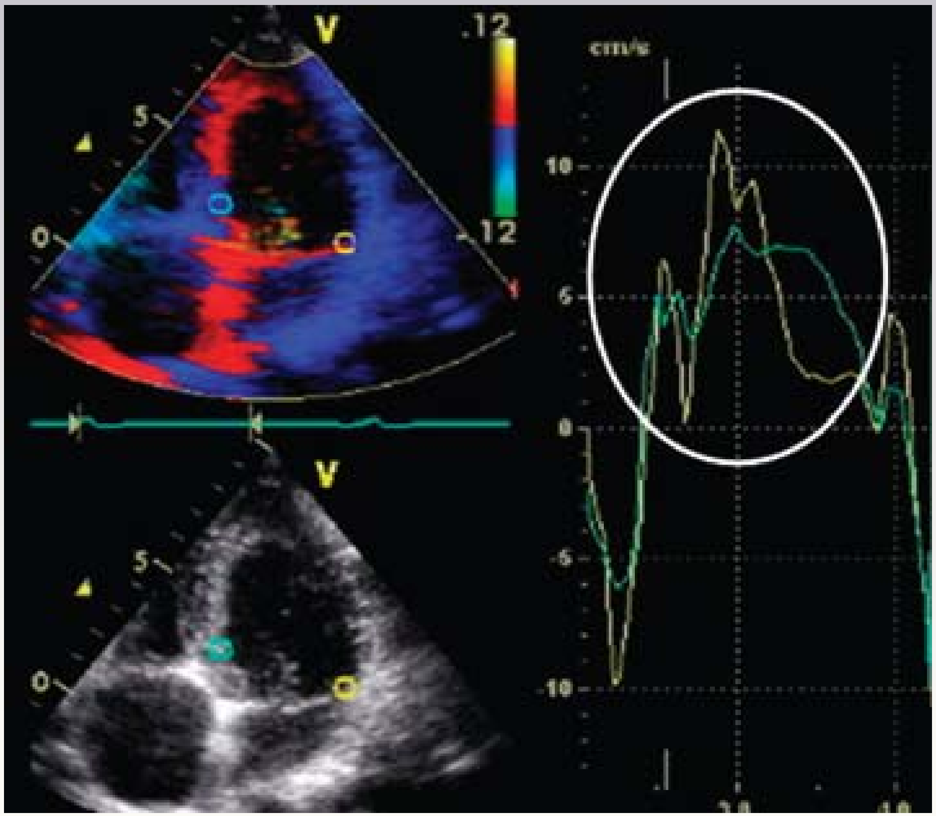
Lisa J. Anderson, Chinami Miyazaki, George R. Sutherland and Jae K. Oh

Circulation 2008;117;2009-2023



Echocardiographic Algorithm for Cardiac Resynchronization

Stéphane Lafitte, M.D., Ph.D., Patricia Reant, M.D., Karim Serri, M.D., and Raymond Roudaut, M.D.

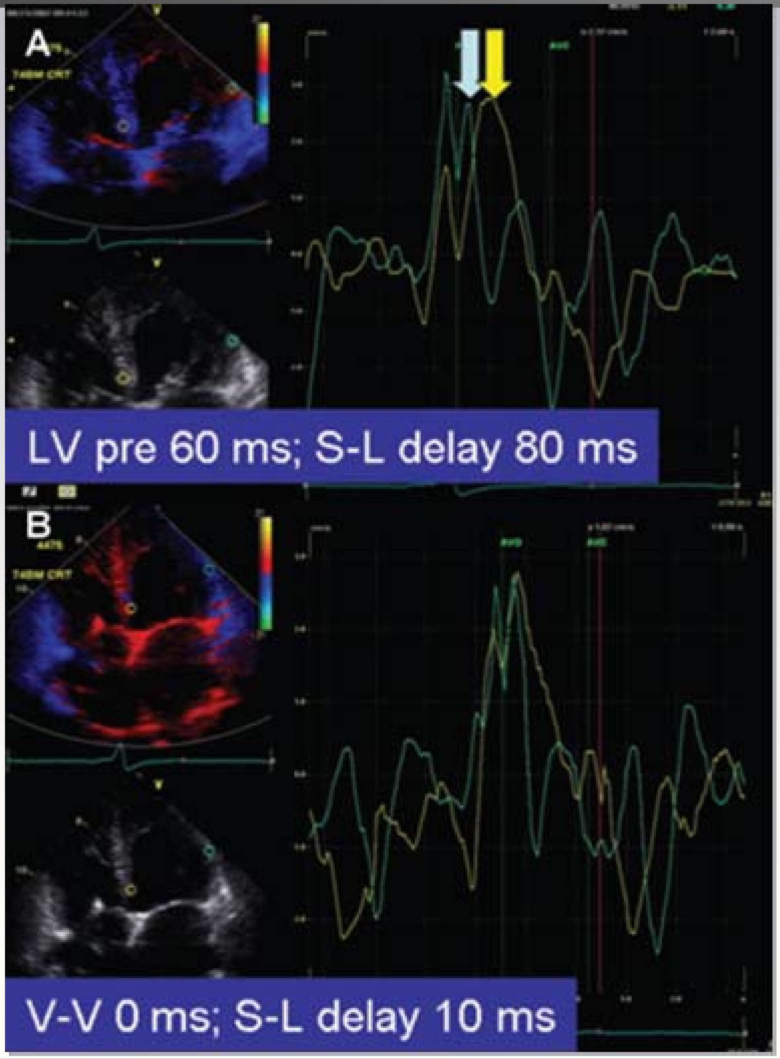


Echocardiograrhy 2008

Noninvasive Imaging in Cardiac Resynchronization Therapy—Part 2: Follow-up and Optimization of Settings

CLAUDIA YPENBURG, M.D.,* NICO VAN DE VEIRE, PH.D.,* JOS J. WESTENBERG,* GABE B. BLEEKER, M.D.,* NINA AJMONE MARSAN, M.D.,* MAUREEN M. HENNEMAN, M.D.,* ERNST E. VAN DER WALL, PH.D.,* MARTIN J. SCHALIJ, PH.D.,* THEODORE P. ABRAHAM, PH.D.,† S. SERGE BAROLD, M.D.,‡ and JEROEN J. BAX, M.D.*

PACE 2008



Practical and conceptual limitations of tissue Doppler imaging to predict reverse remodelling in cardiac resynchronisation therapy

Bart W.L. De Boeck [a,*], Mathias Meine [a], Geert E. Leenders [a], Arco J. Teske [a], Harry van Wessel [a], J. Hans Kirkels [a], Frits W. Prinzen [b], Pieter A. Doevendans [a], Maarten J. Cramer [a]

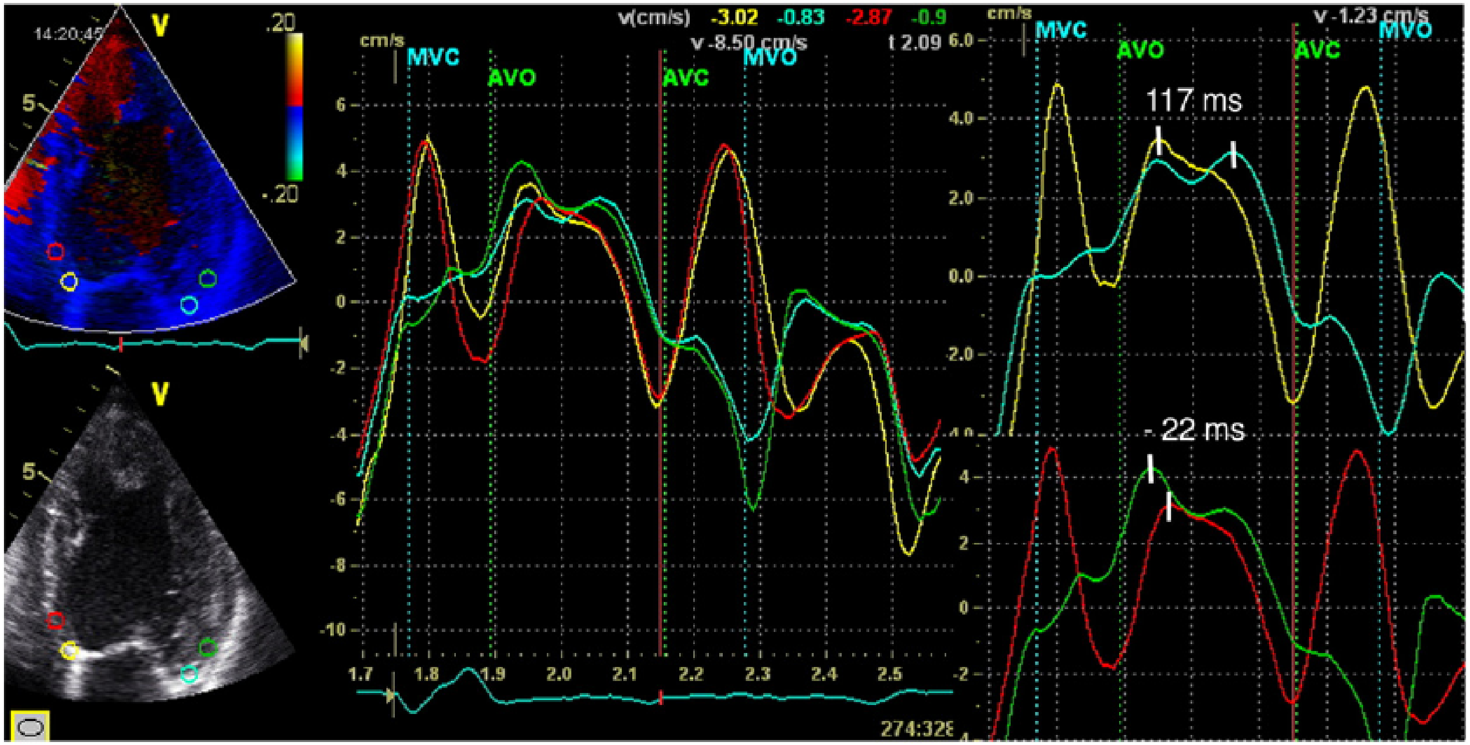
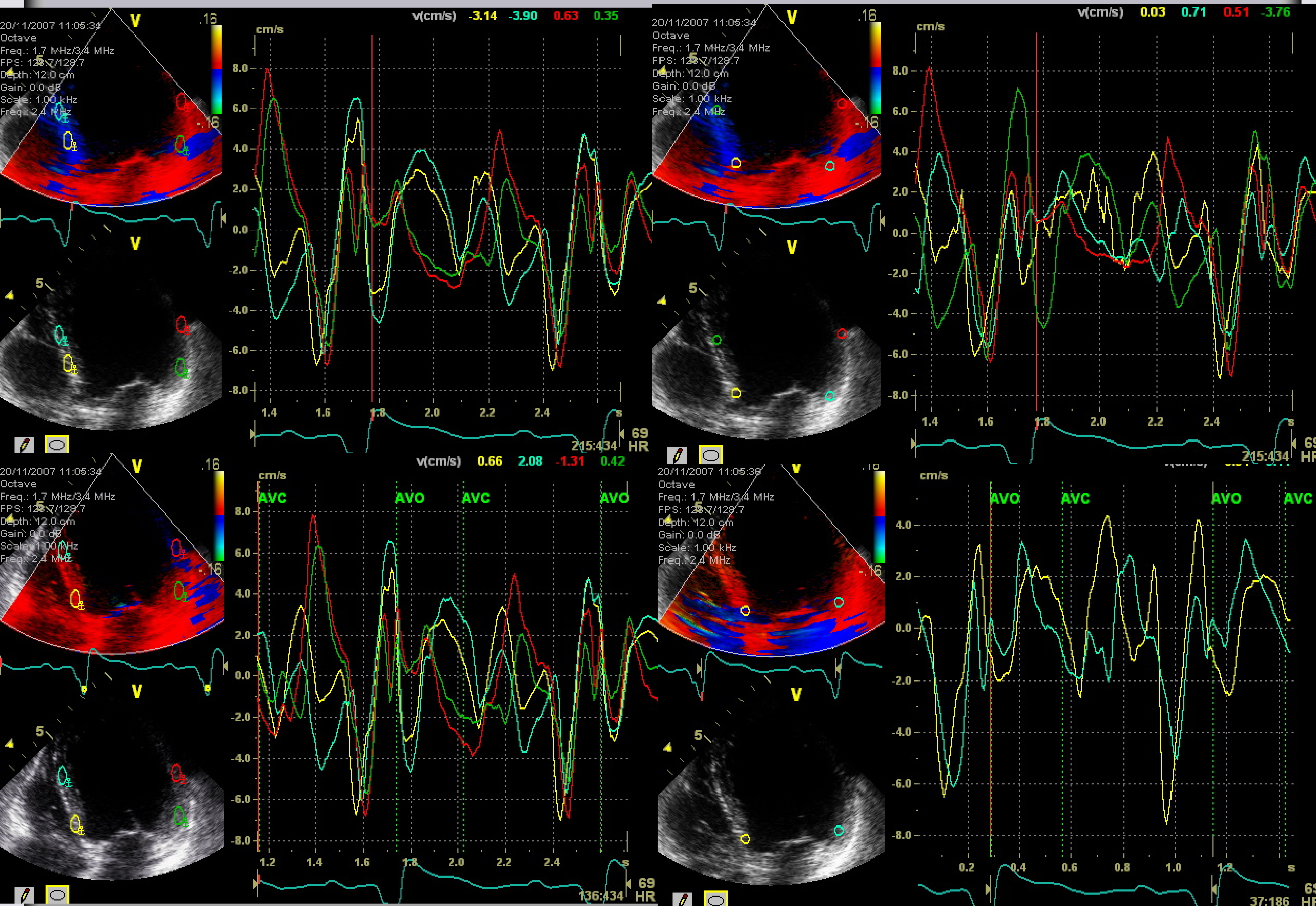


Fig. 1. Sample position within the basal segment can affect the measured TDI-SL. Left panel shows the basal and midbasal position of ROI's as defined in the study, with the corresponding traces (see text). A biphasic systolic signal with a late peak is seen in the basal lateral wall (top right, cyan curve), resulting in a TDI-SL of 117 ms. At the midbasal level, the velocity pattern at the lateral wall is less biphasic and displays an early peak (bottom right, green curve); a TDI-SL of −22 ms is measured. The patient responded to CRT.

European Journal of Heart Failure 10 (2008) 281 – 290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cm/s
215:434
69 HR
v(cm/s) 0.03 0.71 0.51 -3.76
v(cm/s) 0.66 2.08 -1.31 0.42
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AVO
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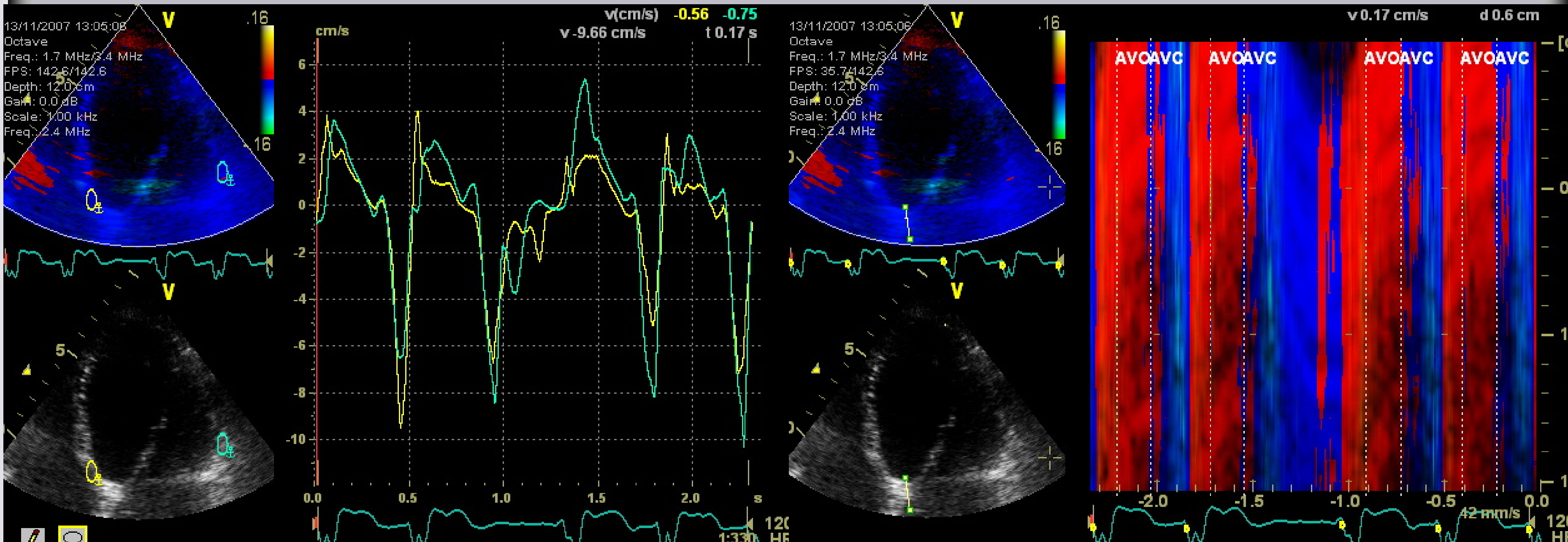
37:186



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v -9.66 cm/s
t 0.17 s
cm/s
FPS: 35.7/142.6
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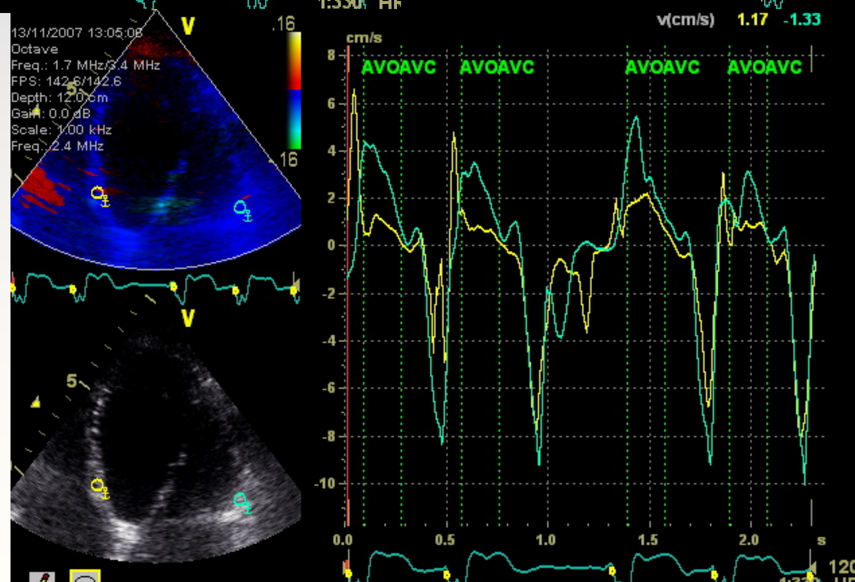
d 0.6 cm
AVOAVC AVOAVC AVOAVC AVOAVC
42 mm/s
120 HR
1:33



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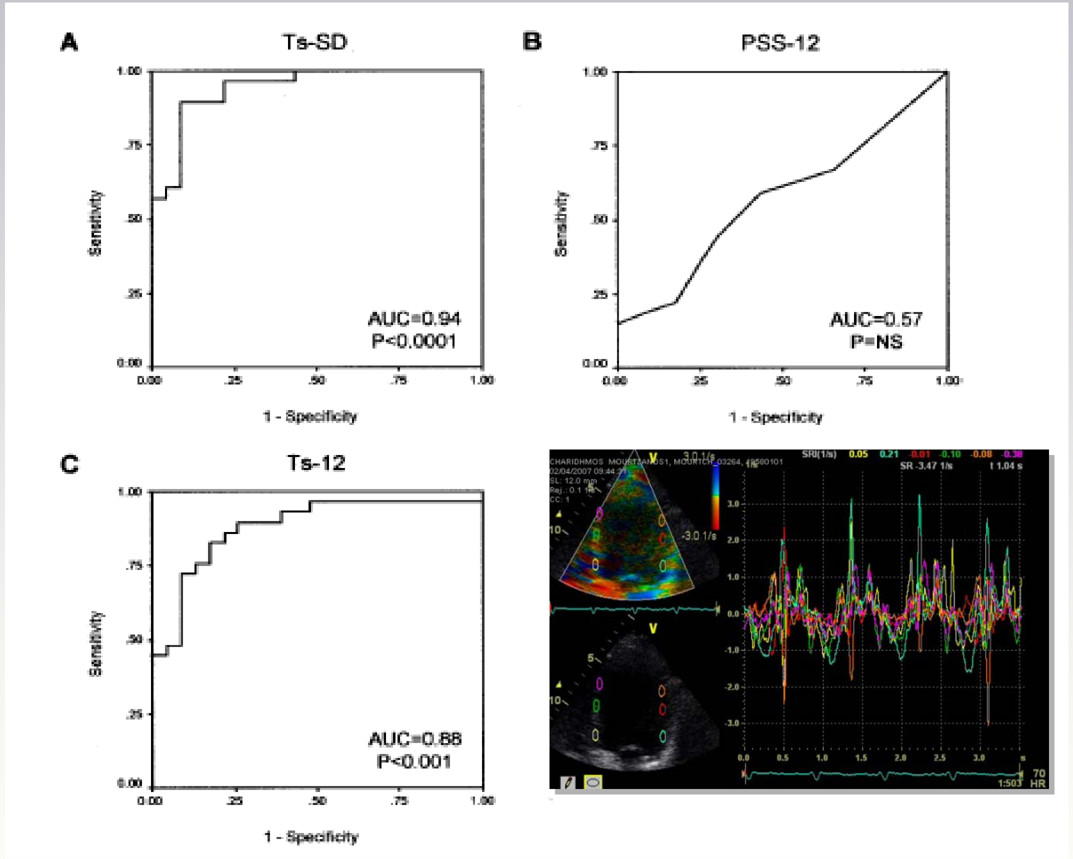
Scale: 1.00 kHz
Freq.: 2.4 MHz
v(cm/s) 1.17 -1.33
cm/s
AVOAVC AVOAVC AVOAVC AVOAVC
120 HR
1:33

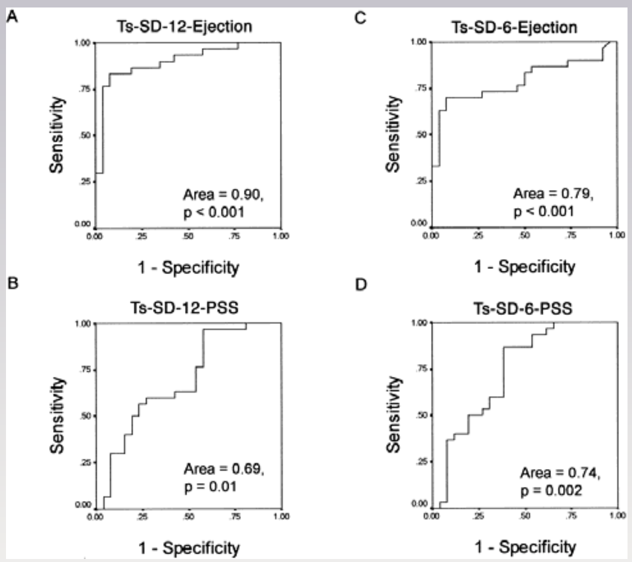
Tissue Doppler Imaging Is Superior to Strain Rate Imaging and Postsystolic Shortening on the Prediction of Reverse Remodeling in Both Ischemic and Nonischemic Heart Failure After Cardiac Resynchronization Therapy

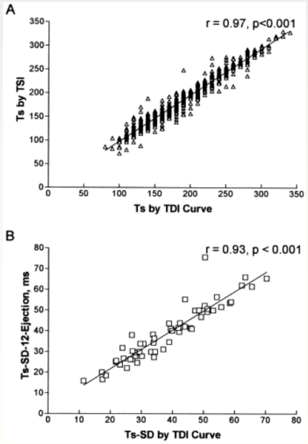
Yu et al Circ 2004

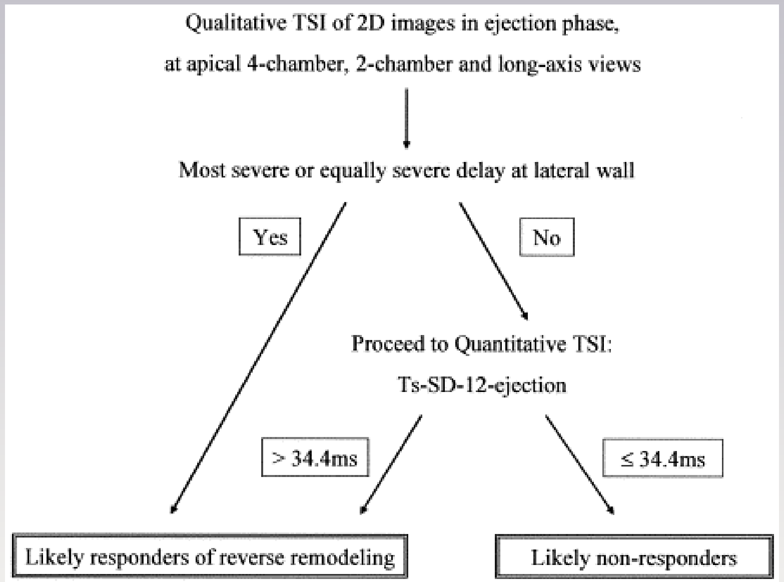


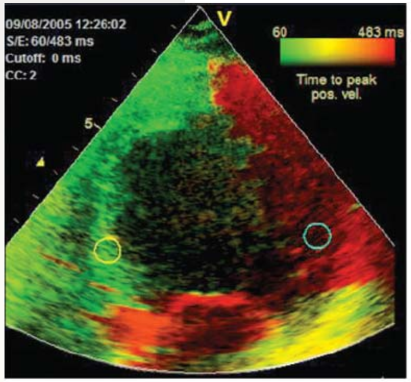
A novel tool to assess systolic asynchrony and identify responders of CRT by TSI

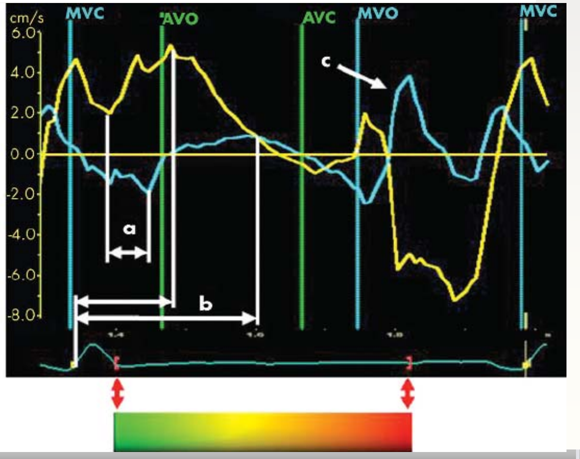
(Yu et al JACC 2005)



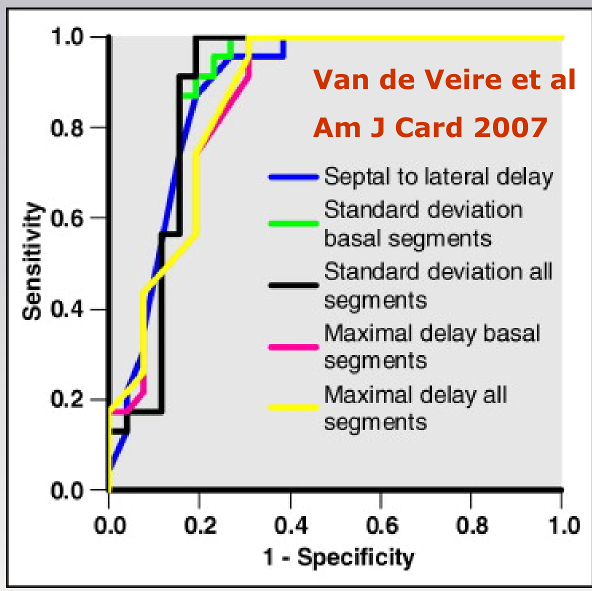


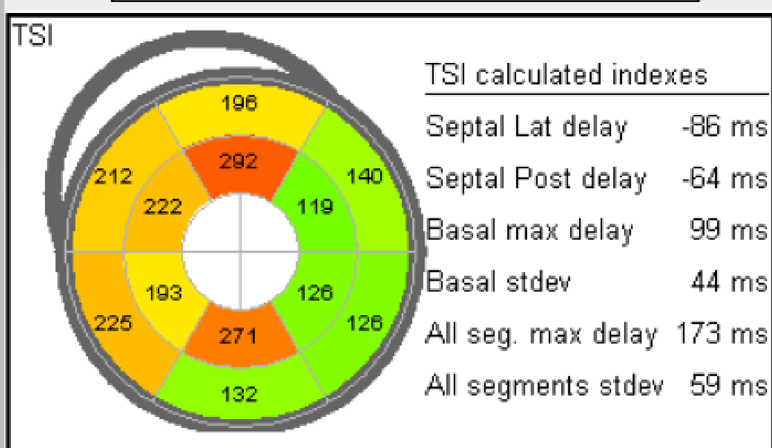


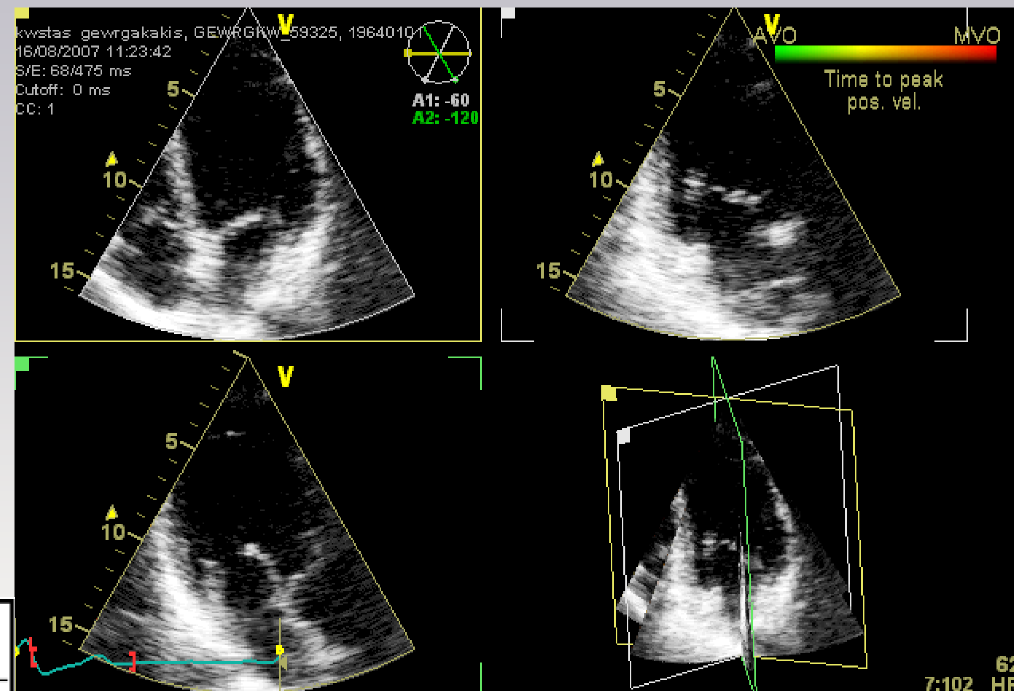




TSI in CRT



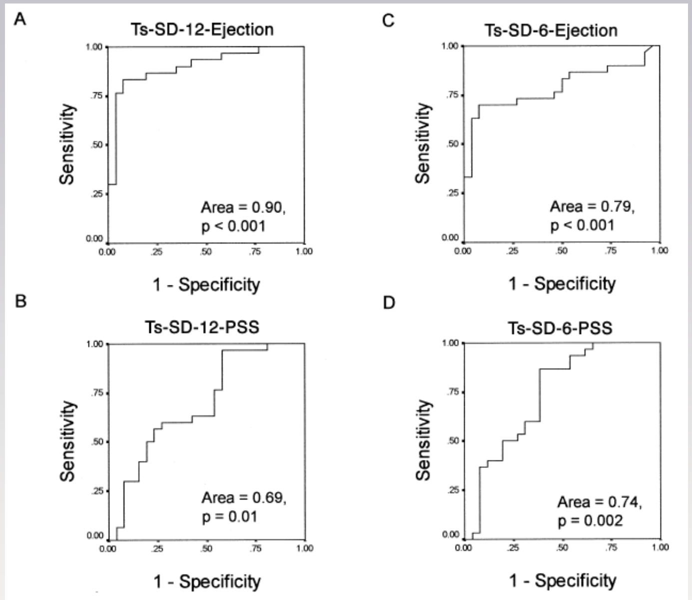




	ROC Curve Area (95% CI)	p Value	Cutoff (ms)	Sensitivity (%)	Specificity (%)
Septal-to-lateral delay	0.882 (0.782–0.983)	<0.0001	65	87	81
SD of basal segments	0.876 (0.767–0.985)	<0.0001	36.5	91	81
SD of all segments	0.883 (0.774–0.992)	<0.0001	35.8	91	85
Maximal delay in basal segments	0.860 (0.753–0.967)	<0.0001	95	74	81
Maximal delay in all segments	0.865 (0.760–0.969)	<0.0001	95	74	81

TSI & CRT

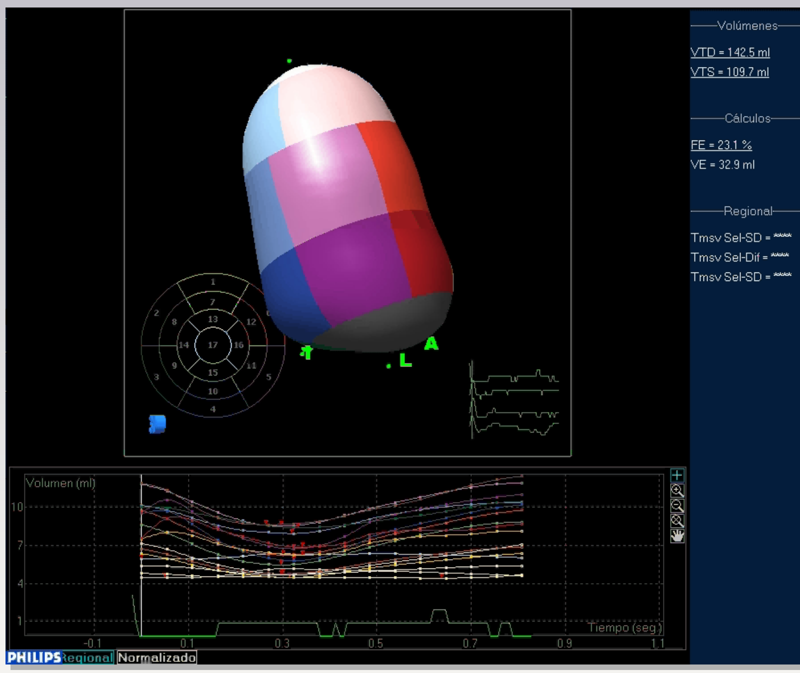
	Cutoff (ms)	Sensitivity (%)	Specificity (%)
Ts-SD-12-ejection	34.4	87	81
Ts-SD-6-ejection	34.5	70	92
Ts-12-ejection	105	83	85
Ts-6-ejection	78	73	77
Ts-SD-12-PSS	70	70	46
Ts-SD-6-PSS	40	87	61
Ts-12-PSS	250	70	50
Ts-6-PSS	102	87	61
Ts-SD-12-ejection AND Ts-12-ejection	34.4 AND 105	83	89
Ts-SD-12-ejection OR Ts-12-ejection	34.4 OR 105	87	77
Ts-SD-12-ejection AND Ts-6-PSS	34.4 AND 102	77	89
Ts-SD-12-ejection OR Ts-6-PSS	34.4 OR 102	93	69
Lateral wall delay	Yes or no	47	89
Lateral wall delay, then Ts-SD-12-ejection	Yes or no, THEN 34.4	82	87

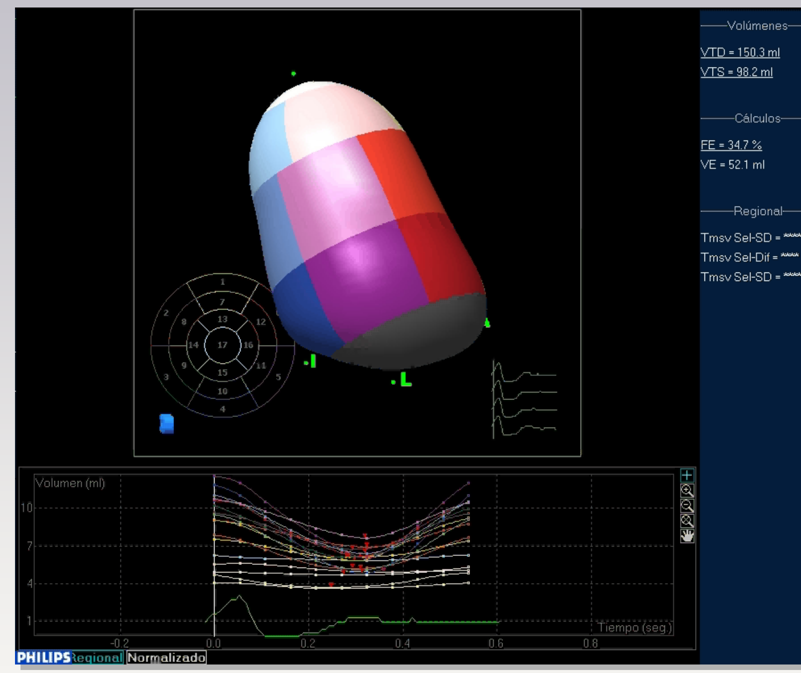


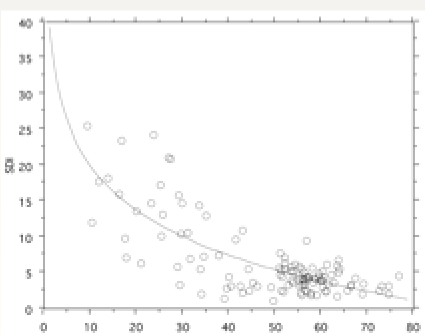
	TSI (Ejection Phase)		TSI (PSS)	
	ROC Area	p Value	ROC Area	p Value
Ts-SD-12	0.90 (0.82–0.99)	<0.001	0.69 (0.55–0.83)	0.01
Ts-SD-6	0.79 (0.67–0.91)	<0.001	0.74 (0.61–0.88)	0.002
Ts-12	0.91 (0.84–0.99)	<0.001	0.70 (0.57–0.84)	0.01
Ts-6	0.80 (0.68–0.92)	<0.001	0.75 (0.62–0.88)	0.002

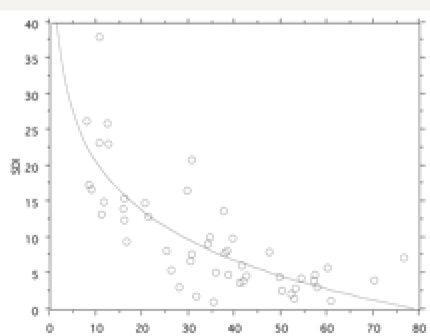
Yu et al JACC 2005

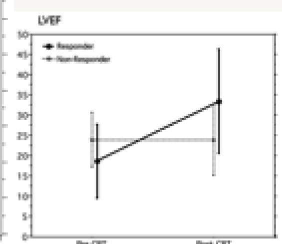
Real-Time Three-Dimensional Echocardiography
A Novel Technique to Quantify Global Left Ventricular Mechanical Dyssynchrony
(Kapetanakis et al Circ. 2005)

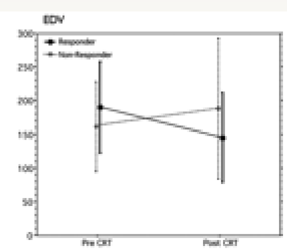


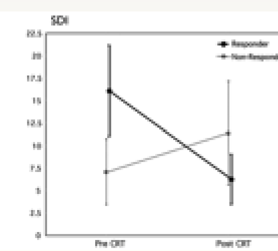












A cut-off value for SDI C 5.6% has been

found as evidence of intraventricular dyssynchrony

predicting CRT response

3D/4D

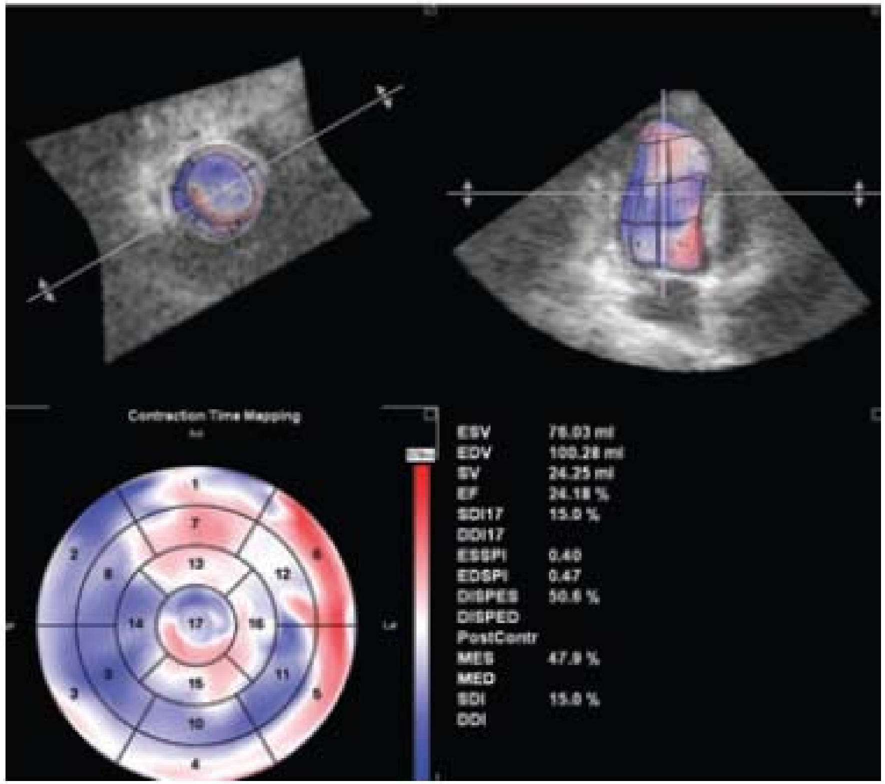
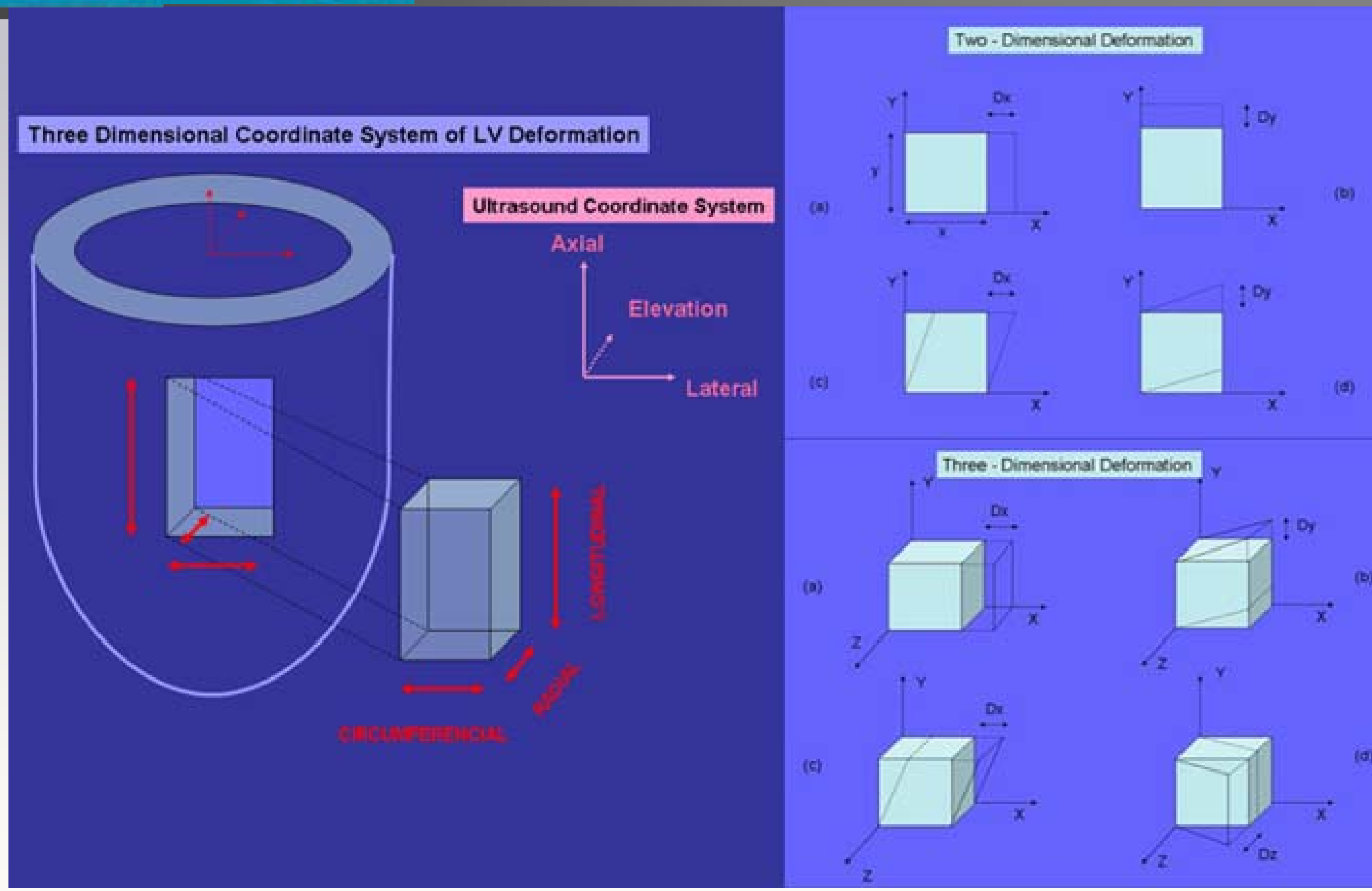


Figure 9. *"Bull's-eye" representation of the end-systolic times of each wall in the 17-segment models following volumetric 3D acquisition. In blue, the walls whose end systoles are the earliest; in red, the latest. Contrary to the tissue tracking method, which evaluates the displacement of the myocardial wall, 3D/4D imaging is based on the displacement motion of the endocardium. The limits are similar to the TM mode.*

LV deformation



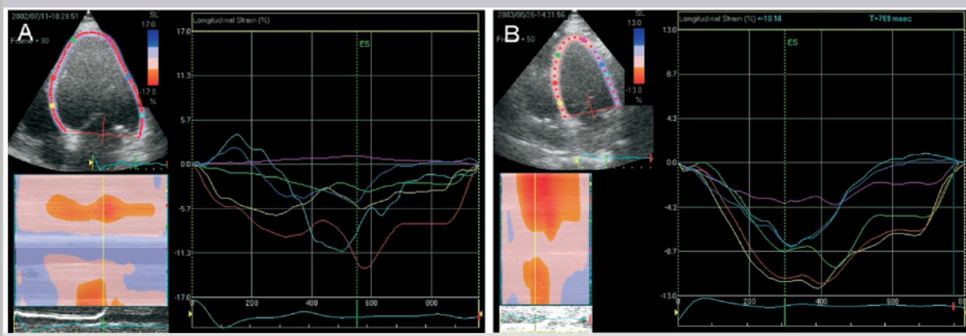
(1) Longitudinal deformation: From base to apex.

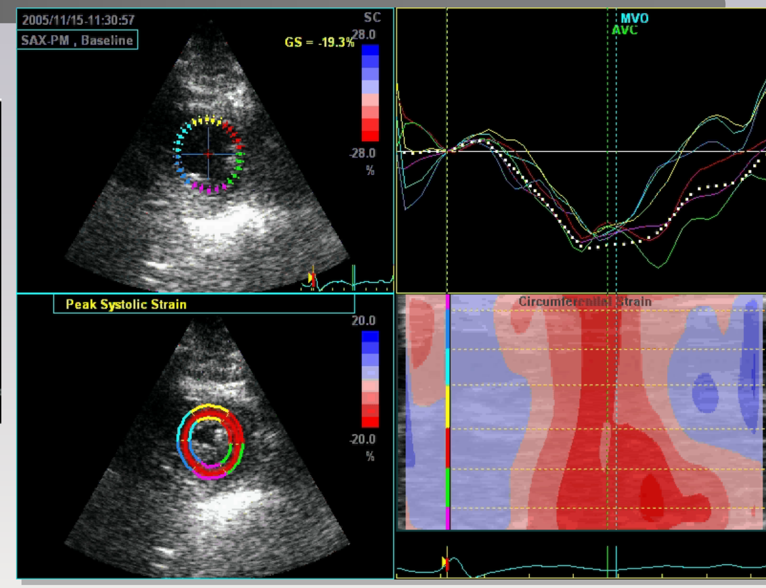
(2) Radial deformation: Perpendicular to epicardium and to the longitudinal axis.

(3) Circumferential deformation: Perpendicular to radial and longitudinal axes.

Evaluation of Longitudinal and Radial 2D- Strain Imaging Versus TDI in Predicting Long-term Response to CRT

(Knebel et al JASE 2007)





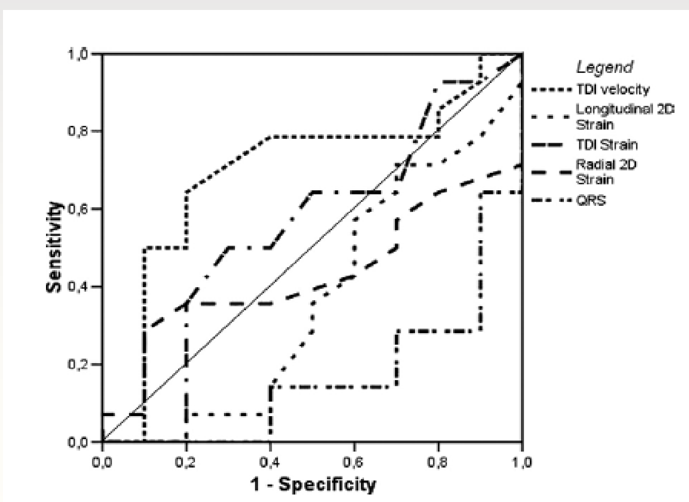
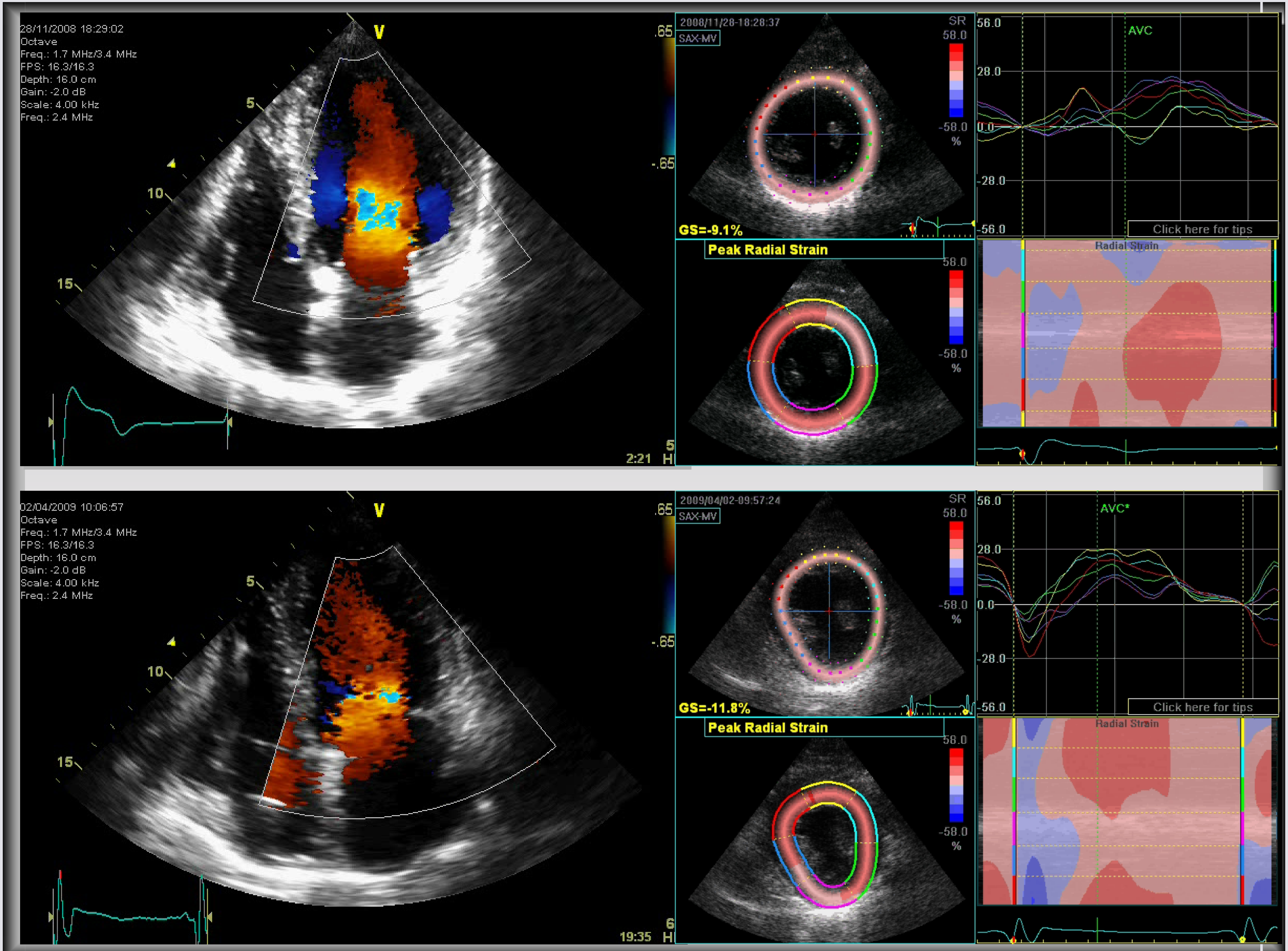


Table 5 Area under the curve in receiver operating characteristic analysis for the prediction of benefit from cardiac resynchronization therapy

	AUC (±SD)
DTI velocity	0.696 (0.116)
DTI strain	0.546 (0.126)
2D Radial strain	0.432 (0.119)
2D Longitudinal strain	0.368 (0.121)
QRS width	0.341 (0.092)



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FPS: 16.3/16.3
Depth: 16.0 cm
Gain: -2.0 dB
Scale: 4.00 kHz
Freq.: 2.4 MHz
2008/11/28-18:28:37
SAX-MV
SR
GS=-9.1%
Peak Radial Strain
AVC
Click here for tips
Radial Strain
2:21
02/04/2009 10:06:57
Octave
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FPS: 16.3/16.3
Depth: 16.0 cm
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Freq.: 2.4 MHz
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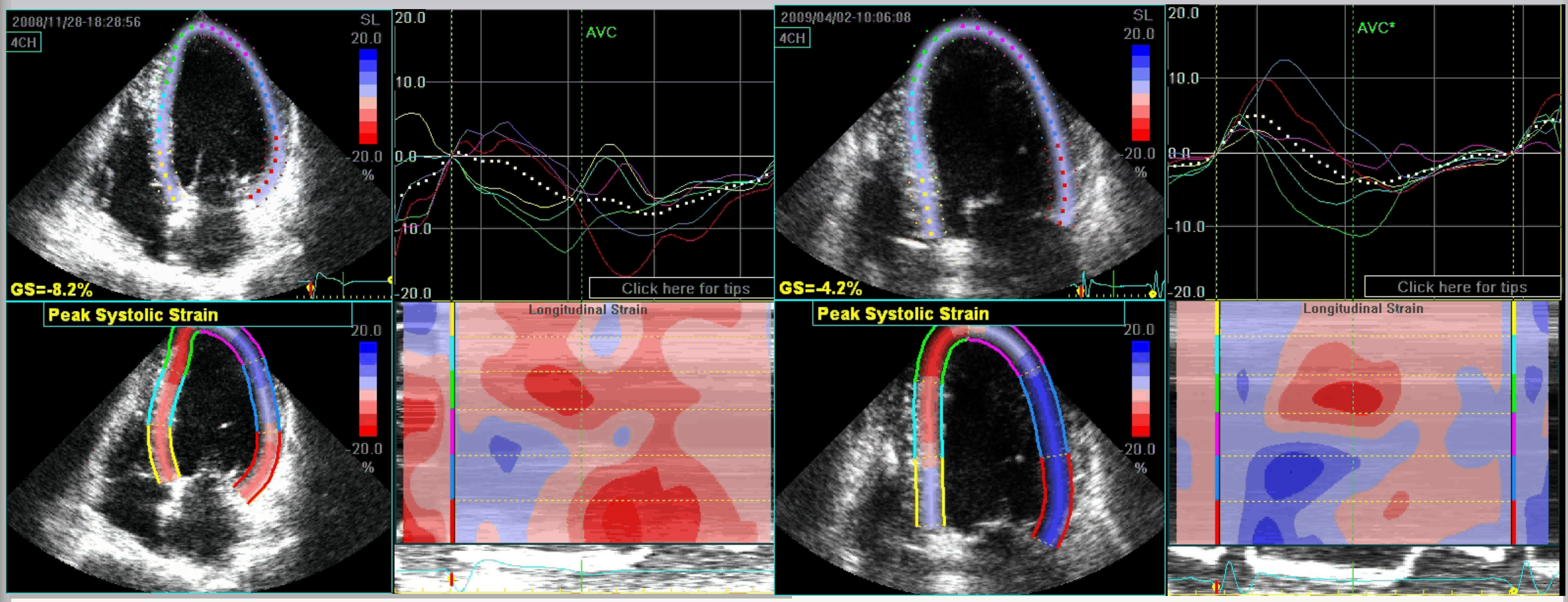
SR
GS=-11.8%
Peak Radial Strain
AVC*
Click here for tips
Radial Strain
19:35

Longitudinal 2D-Strain



Assessment of Left Ventricular Dyssynchrony by Speckle Tracking Strain Imaging

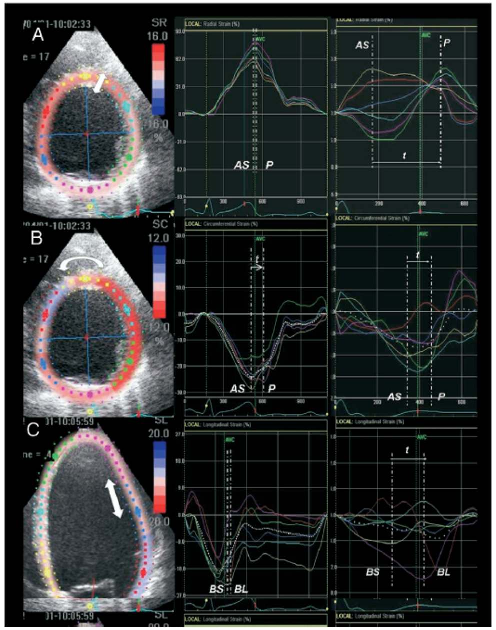


Figure 1 Two-Dimensional Strain Imaging

In the **left panels**, the 2-dimensional strain images are represented. The arrows depict the type of deformation assessed in each view: radial thickening **(A)**, circumferential shortening **(B)**, and longitudinal shortening **(C)**. The **middle and right panels** demonstrate the segmental time-strain curves for a synchronous **(middle panels)** and dyssynchronous **(right panels)** left ventricle for each view. Time differences in peak-systolic strain (*t*) between anteroseptal (AS) and posterior (P) segments, in short-axis view, and between basal-septal (BS) and basal-lateral (BL) segments, in 4-chamber view, can be obtained from these curves.

In the midventricular short-axis images, RS by speckle tracking was possible in 90% of 1,896 attempted segments. The lesser feasibility for assessment of LS

was due to nonvalid tracking at the apical segments,where 30% of the segments had to be discarded.

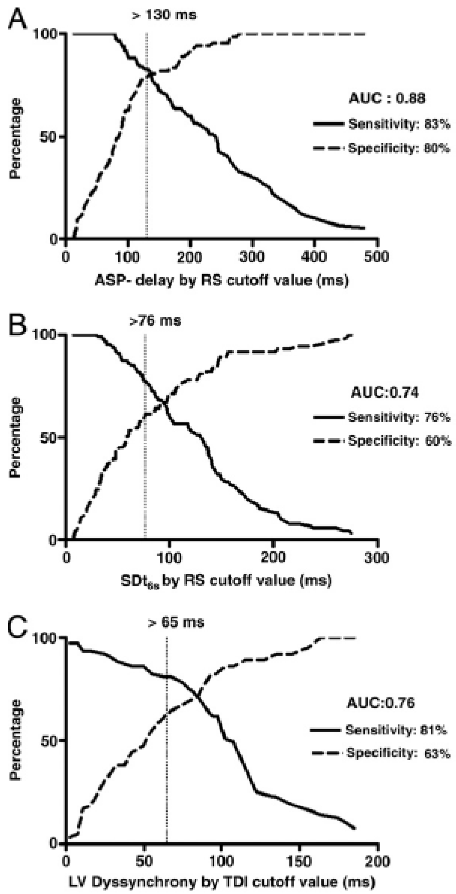


Figure 5 Receiver-Operating Characteristic Curves for AS-P Delay and SDt_{65} by RS and LV Dyssynchrony by TDI

(A) AS-P delay; **(B)** SDt_{65}; **(C)** assessed by RS and LV dyssynchrony. AUC = area under the curve; TDI = tissue Doppler imaging; other abbreviations as in Figures 3 and 4.

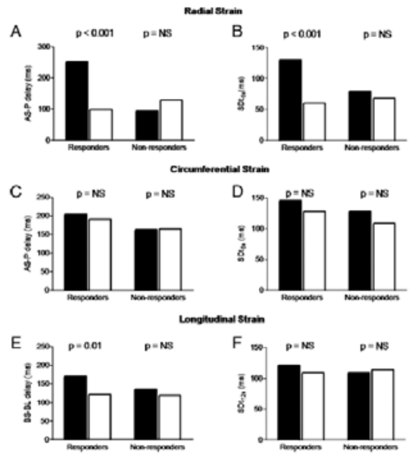


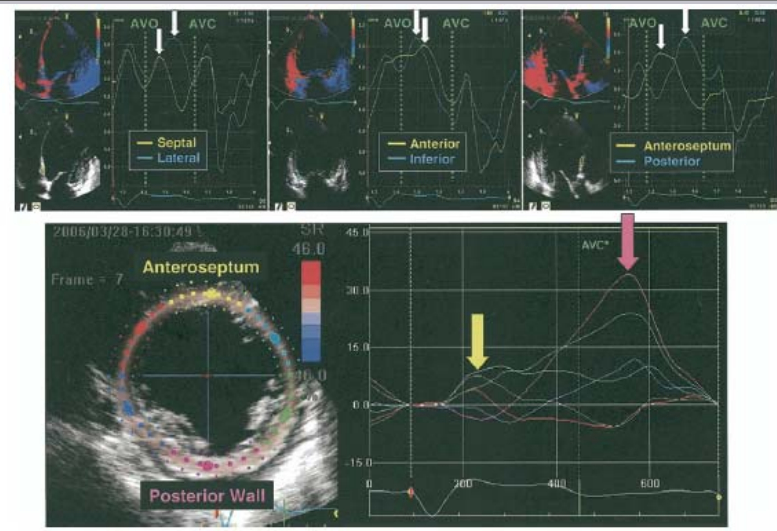
Figure 4 Changes in LV Dyssynchrony as Assessed With RS, CS, and LS After Cardiac Resynchronization Therapy in Responders and Nonresponders

(A and B) RS; **(C and D)** circumferential strain (CS); **(E, F)** longitudinal strain (LS). **Solid bars** = baseline values, **open bars** = values at 6-month follow-up. BS-BL delay = difference between time to peak systolic strain of the basal-septal and basal-lateral segments; SDt_{12S} = standard deviation of the time to peak systolic strain of 12 segments; other abbreviations as in Figure 3.

Delgado et al JACC 2008

Combined Longitudinal and Radial Dyssynchrony Predicts Ventricular Response After CRT

Gorscan III et al Jacc 2007



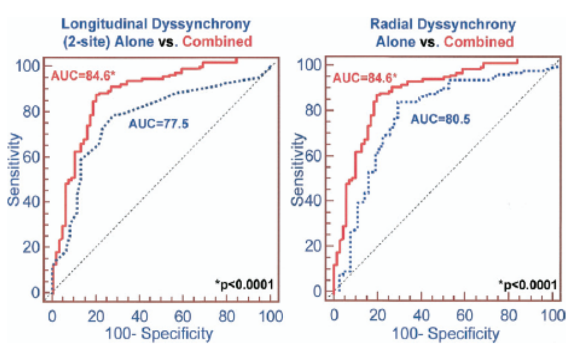


Figure 3 Receiver-Operating Characteristic Curves for Individual Dyssynchrony Methods and the Combined Method

The comparison with the 2-site tissue Doppler longitudinal dyssynchrony data appears on the **left**, and the comparison with radial dyssynchrony by speckle-tracking radial strain appears on the **right**. The areas under the curves (AUCs) were significantly greater with the combined approach than with either individual approach and support its favorable ability to predict ejection fraction response to cardiac resynchronization therapy. Sensitivities and specificities were 72% and 77% for the 2-site tissue Doppler method, 84% and 73% for the radial strain method, and 88% and 80% for the combined method. **Blue dashed lines** = individual dyssynchrony methods; **red solid lines** = combined method.

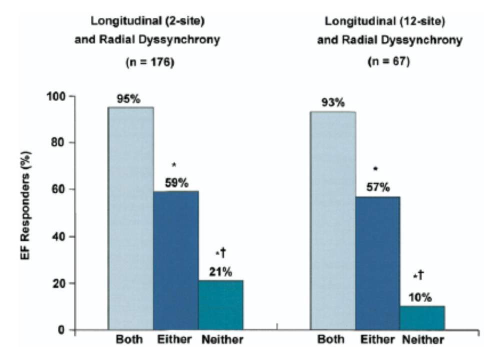


Figure 4 Proportion of Patients Who Were EF Responders to Resynchronization Therapy

All patients had 2-site tissue Doppler measures of longitudinal dyssynchrony along with radial strain dyssynchrony **(left)**, and a subgroup of 67 patients had 12-site tissue Doppler measures of longitudinal dyssynchrony along with radial strain dyssynchrony **(right)**. A pattern of both longitudinal and radial dyssynchrony was associated with ejection fraction (EF) response, whereas a pattern of neither longitudinal nor radial dyssynchrony was associated with EF nonresponse, particularly when the 12-site tissue Doppler method excluded dyssynchrony. A heterogeneous pattern of either longitudinal or radial dyssynchrony (but not both) had an intermediate proportion of responders. *p $<$ 0.05 versus both groups; †p $<$ 0.05 versus either group.

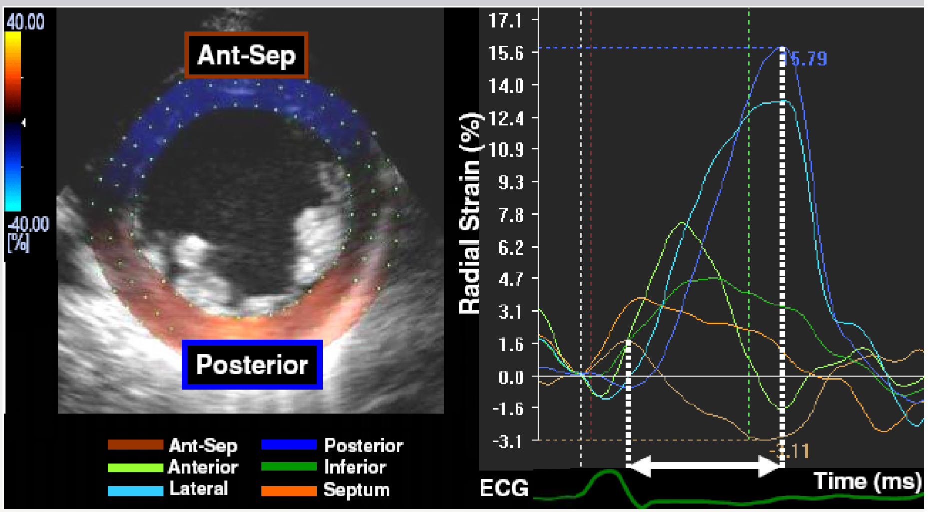
Recent advances in CRT: echocardiographic modalities, patient selection, optimization, non responders—all you need to know for more efficient CRT

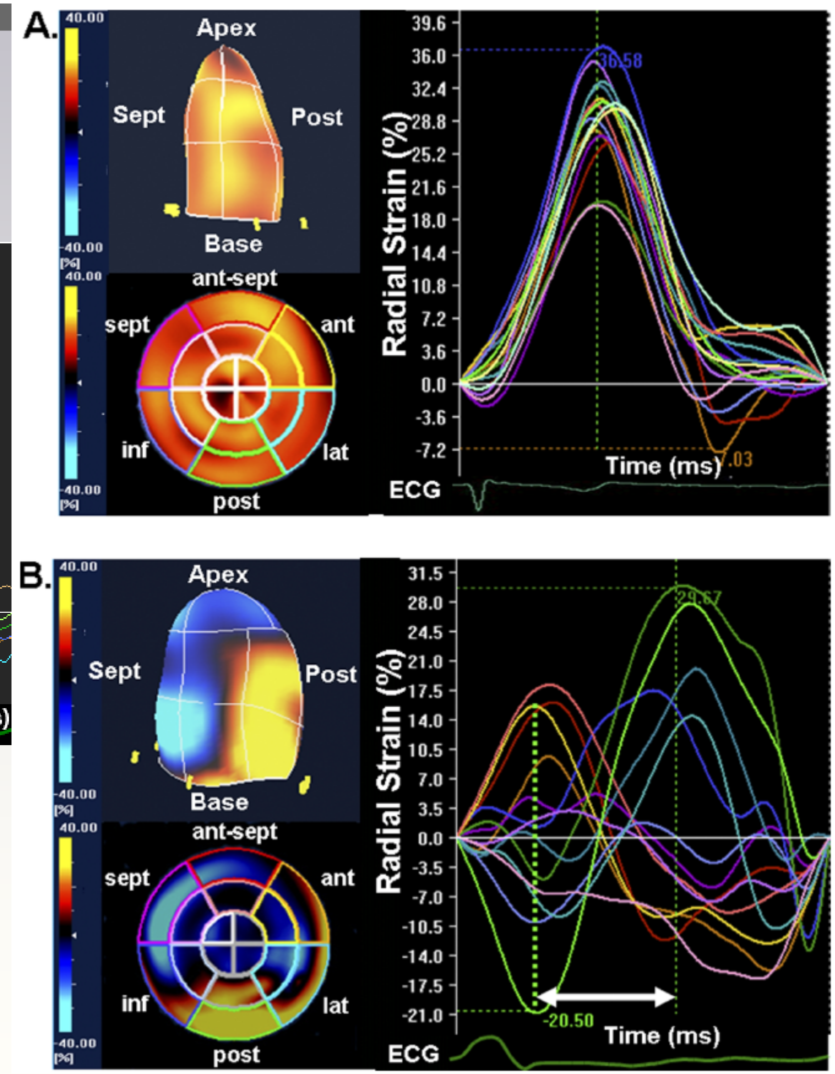
Harry Pavlopoulos • Petros Nihoyannopoulos Int.J .Card. Imaging 11/09

Dyssynchrony imaging map by 3D speckle tracking. Parametric Imaging (lower left) and polar map (centre) displaying regional colour coded time delays of displacement of the entire left ventricle based on 3D speckle tracking, identifying a post systolic shortening (PSS) event located at inferior septal and inferior wall. End-systolic and end-diastolic volumes, as well as ejection fraction based on 3D measurements are also presented at the same time. Regional curves of longitudinal displacement can also be seen

Usefulness of Three-Dimensional Speckle Tracking Strain to Quantify Dyssynchrony and the Site of Latest Mechanical Activation

Hidekazu Tanaka, MD, Hideyuki Hara, MD, Samir Saba, MD, and John Gorcsan III, MD*





Am J Cardiol 2010;xx:xxx

Article in press

Usefulness of Three-Dimensional Speckle Tracking Strain to Quantify Dyssynchrony and the Site of Latest Mechanical Activation

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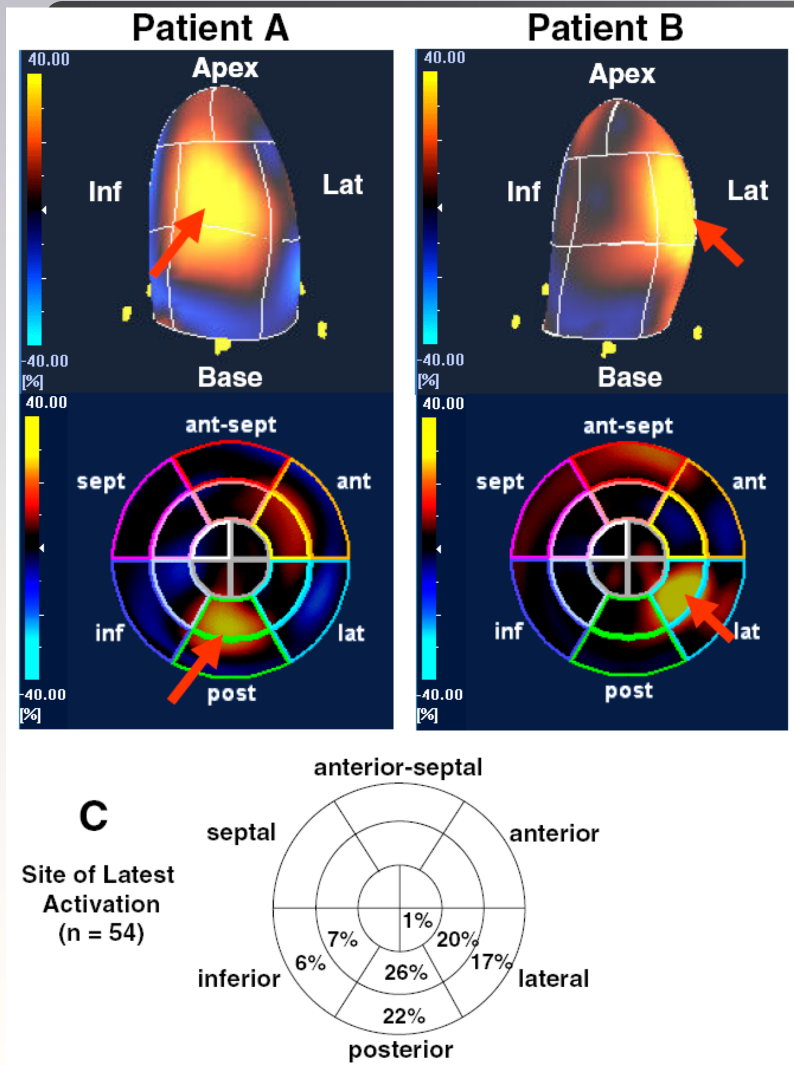
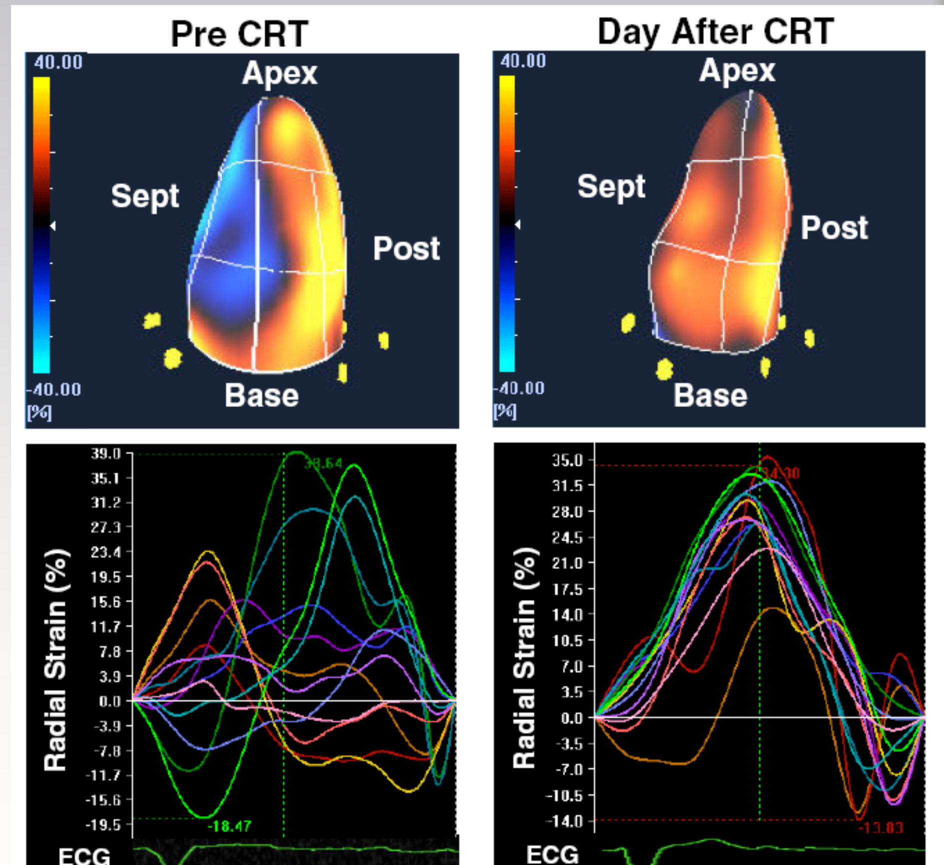
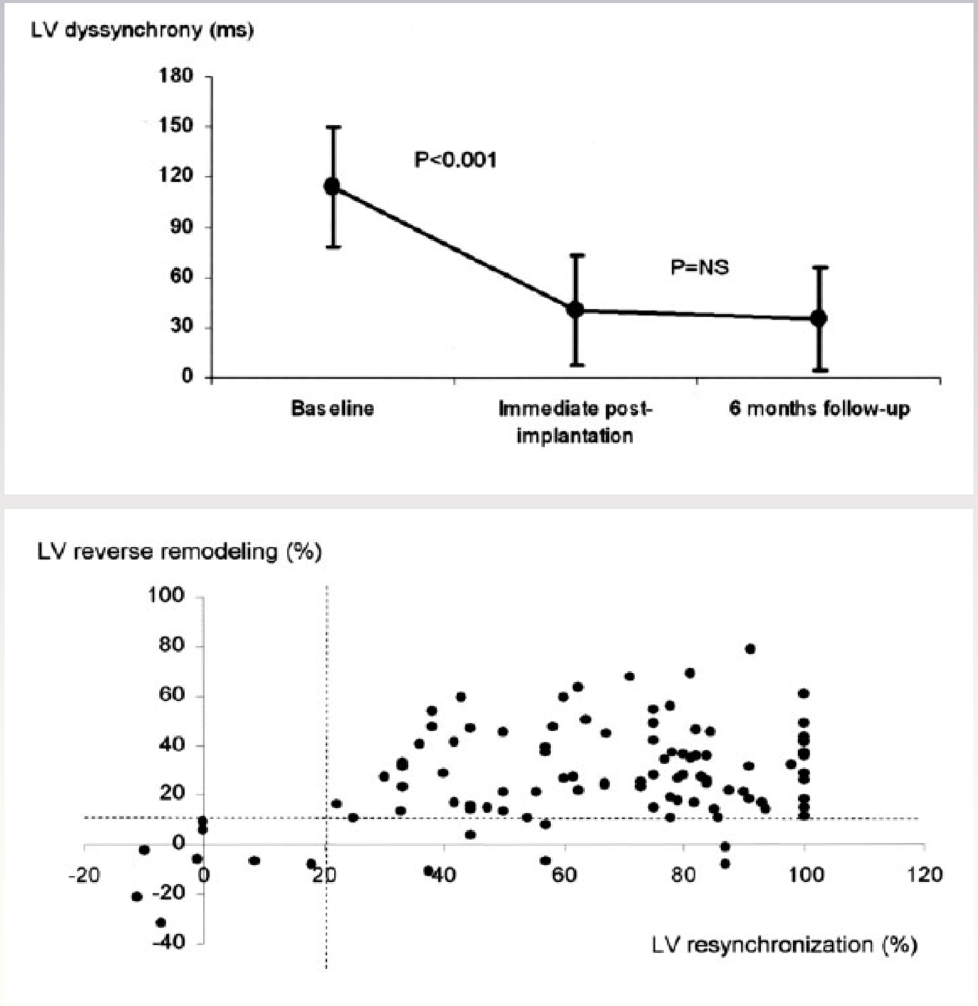
Am J Cardiol 2010





Left Ventricular Resynchronization Is Mandatory for Response to CRT

Bleeker et al Circulation Sep. 2007



Insights From a CRT Optimization Clinic as Part of a Heart Failure Disease Management Program

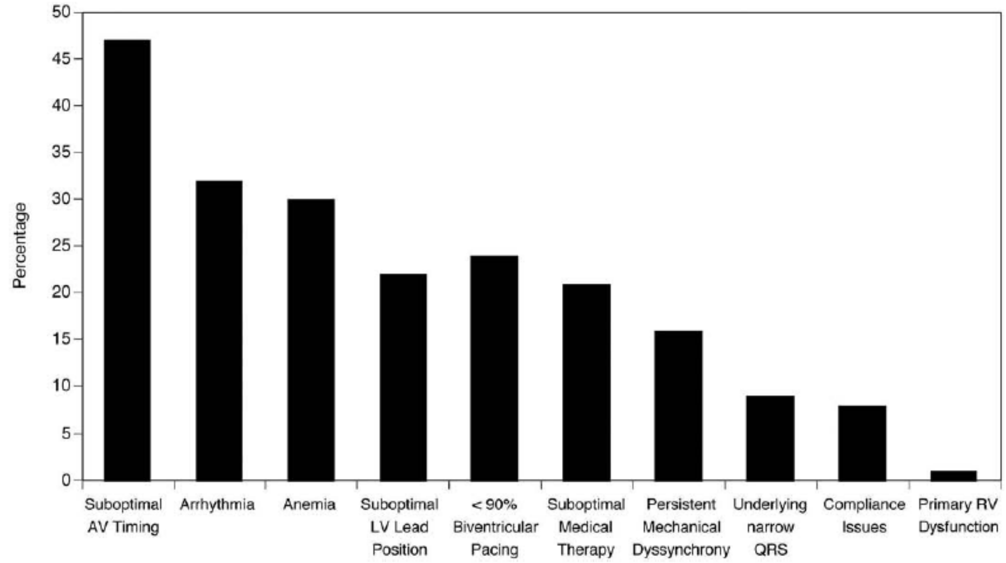


Figure 2 Potential Reasons for Suboptimal Response

AV = atrioventricular; LV = left ventricular; RV = right ventricular.

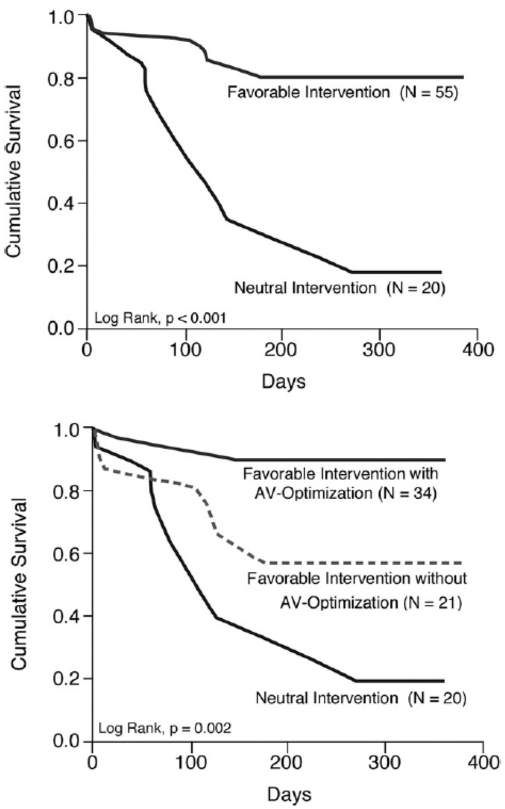
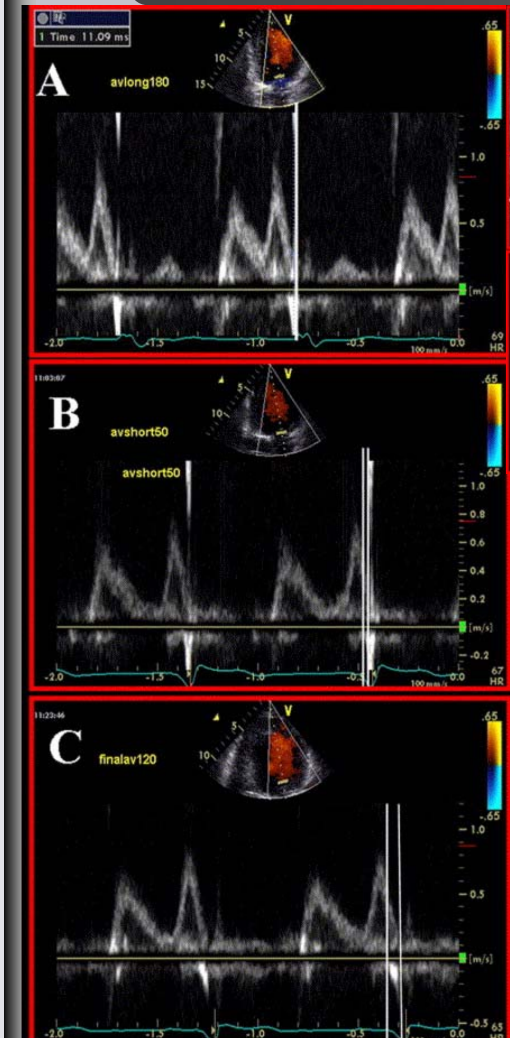


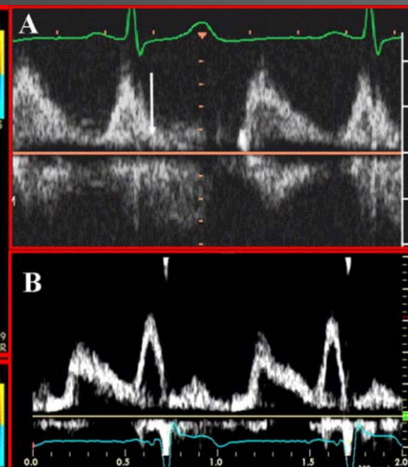
Figure 4 Clinical Outcomes of "Favorable" Versus "Neutral" Interventions With or Without AV Optimization

Kaplan-Meier curves for patients deemed to be successfully optimized ("favorable" intervention) with/without atrioventricular (AV) optimization versus those that could not be significantly optimized ("neutral" intervention) after the cardiac resynchronization therapy optimization clinic.

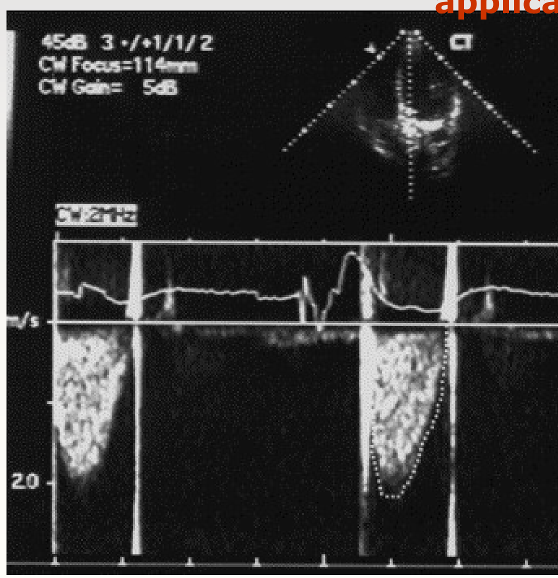
Mullens et al JACC 2009

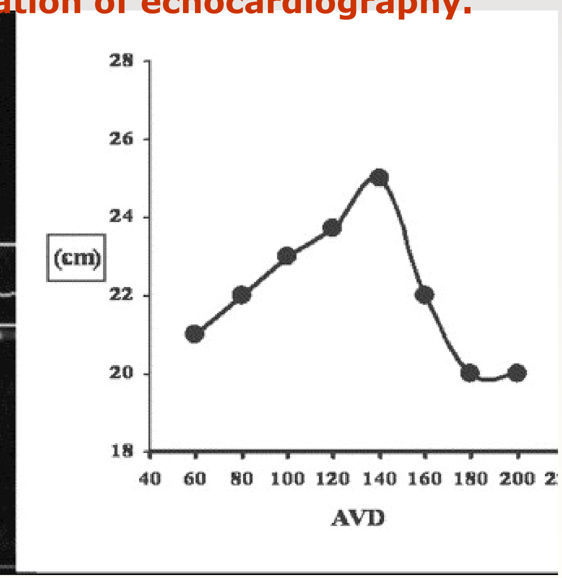
Optimization of AV and VV- delay





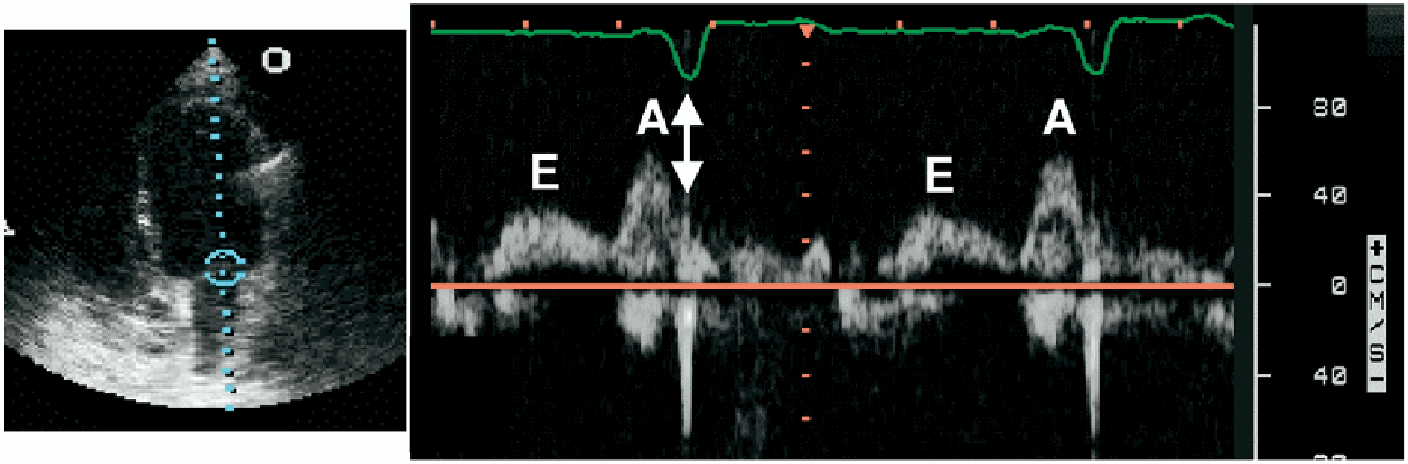
(1) the AVD is programmed before V-V delay
(2) the optimal V-V delay that results in maximal hemodynamic improvement is likely LV before RV pacing and at an average interval of 20 to 40 milliseconds;
(3) V-V delays greater than 40 milliseconds are uncommon regardless of the ventricular pacing sequence; and
(4) simultaneous BIV pacing may be the best mode in some patients.
Thus, optimal V-V delay programming of CRT devices represents another emerging application of echocardiography.





AV optimization

Simplified AV Delay Screening



Satisfactory AV Delay

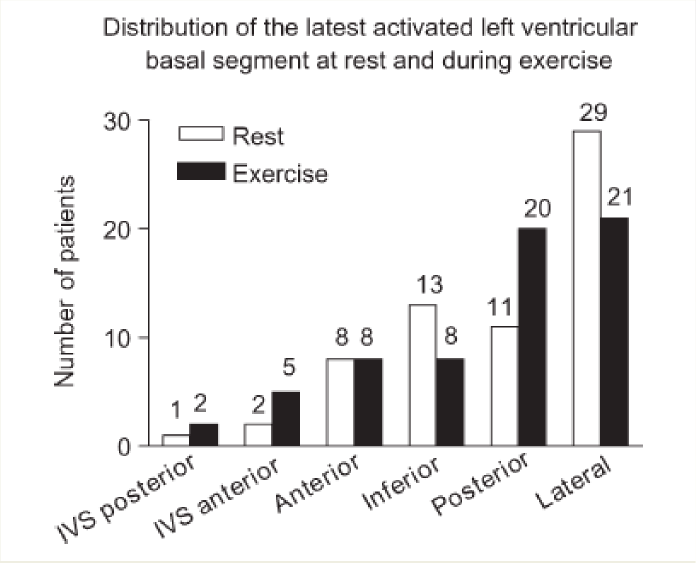
1. E and A Waves Separated
2. Termination of A after QRS onset or Mitral Closure Click Aligned With End of A and QRS Complex.

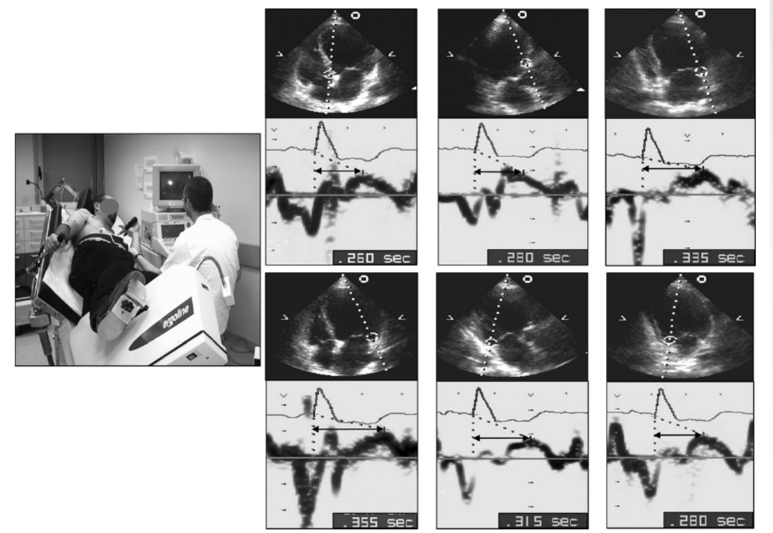
Exercise stress echocardiography is superior to rest echocardiography in predicting LV reverse remodelling and functional improvement after CRT (Rochi et al EHJ 2009)

Table 2 Predictive value of rest and exercise TDI to identify CRT responders

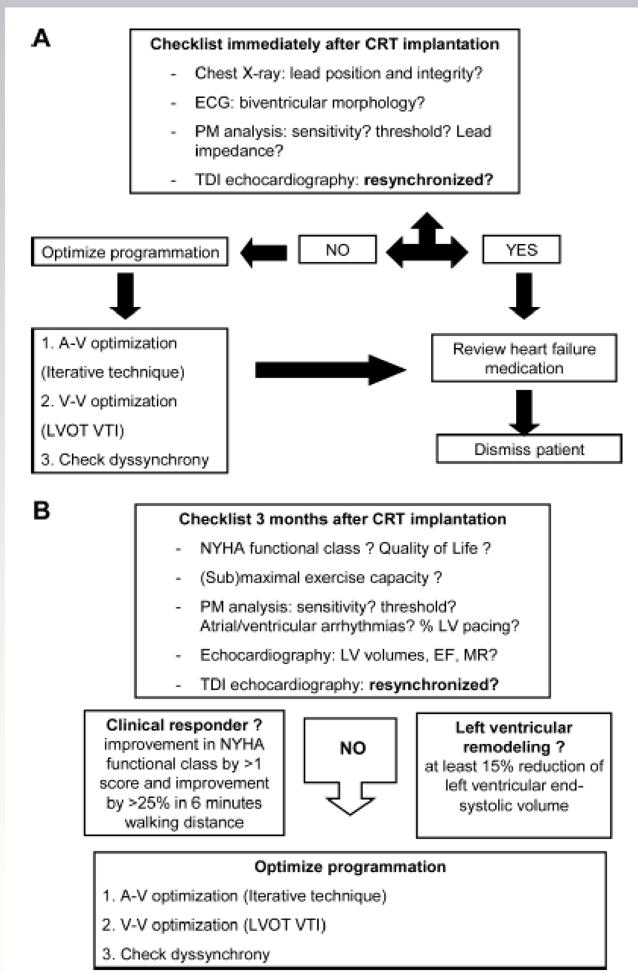
	Rest TDI dyssynchrony	95% CI	Exercise TDI dyssynchrony	95% CI	P-value
Sensitivity	74% (32/43)	60.9–87.1	95% (41/43)	88.5–100	0.01
Specificity	62% (13/21)	41.2–82.7	76% (16/21)	57.7–94.3	0.51
Positive PV	80% (32/40)	67.6–92.4	89% (41/46)	80.0–98.0	0.41
Negative PV	54% (13/24)	34.0–74.0	89% (16/18)	74.5–100	0.03
Overall PV	70% (45/64)	58.8–81.2	89% (57/64)	81.3–96.7	0.01

TDI, tissue Doppler imaging; CRT, cardiac resynchronization therapy; PV, predictive value.



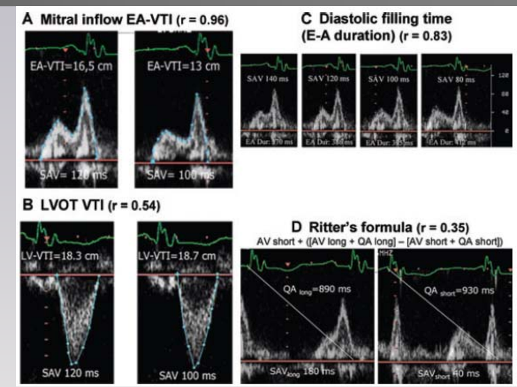


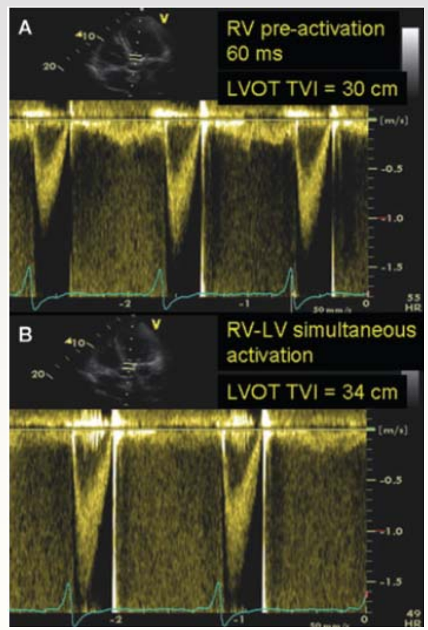
Noninvasive Imaging in CRT—Part 2: Follow-up and Optimization of Settings

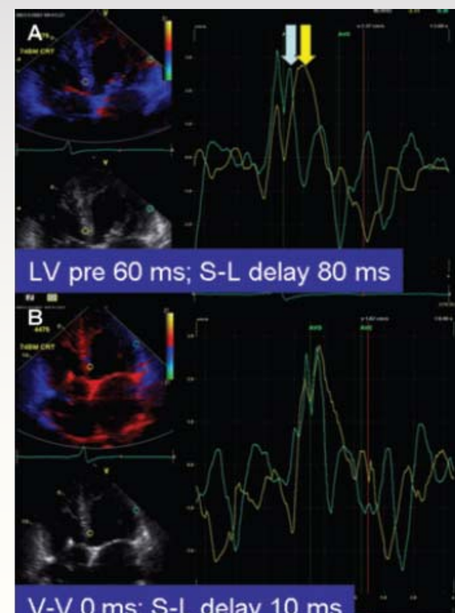


Ypenburg et al

PACE 2008







ΣΥΜΠΕΡΑΣΜΑΤΑ

Echocardiography for CRT Selection:Fatally Misjudged!

- **Επιβεβλημένη η ανάγκη για σωστή επιλογή ασθενών που θα υποβληθούν σε θεραπεία καρδιακού επανασυγχρονισμού**
- **Η υπερηχοκαρδιογραφία ασφαλώς και κατέχει τον πρωτεύοντα ρόλο στην εκτίμηση του *ΑΛΛΑ: ΑΠΟ ΕΞΙΔΕΙΚΕΥΜΕΝΟΥΣ ΧΕΙΡΙΣΤΕΣ ΚΑΙ ΜΕ ΣΥΓΚΕΚΡΙΜΕΝΟ ΠΡΩΤΟΚΟΛΛΟ***
- **Ωστόσο δεν πρέπει να ξεχνάμε την τρισδιάστατη κίνηση της καρδιάς**
- **Συνδυασμός δεικτών της επιμήκους και ακτινικής κίνησης και σύσπασης της καρδιάς μάλλον χρειάζεται για την σωστή επιλογή των ασθενών**
- **Στο μέλλον η εξέλιξη της τρισδιάστατης υπερηχοκαρδιογραφίας (υψηλότερο volume rate , αξιολόγηση software) και του 3D- strain ίσως είναι η λύση**