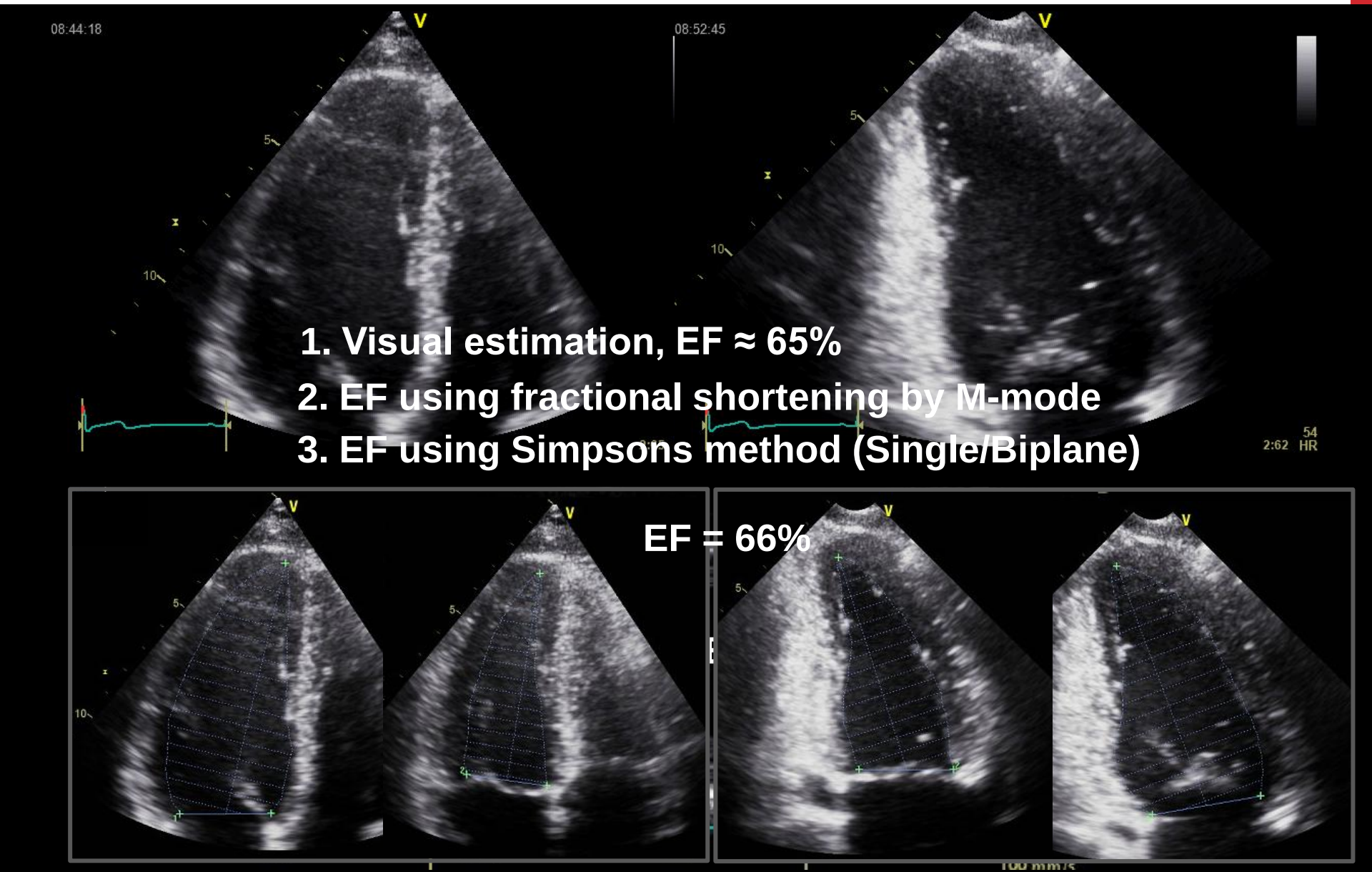
Echocardiography for Coronary Artery disease
-Strain or Not to strain-



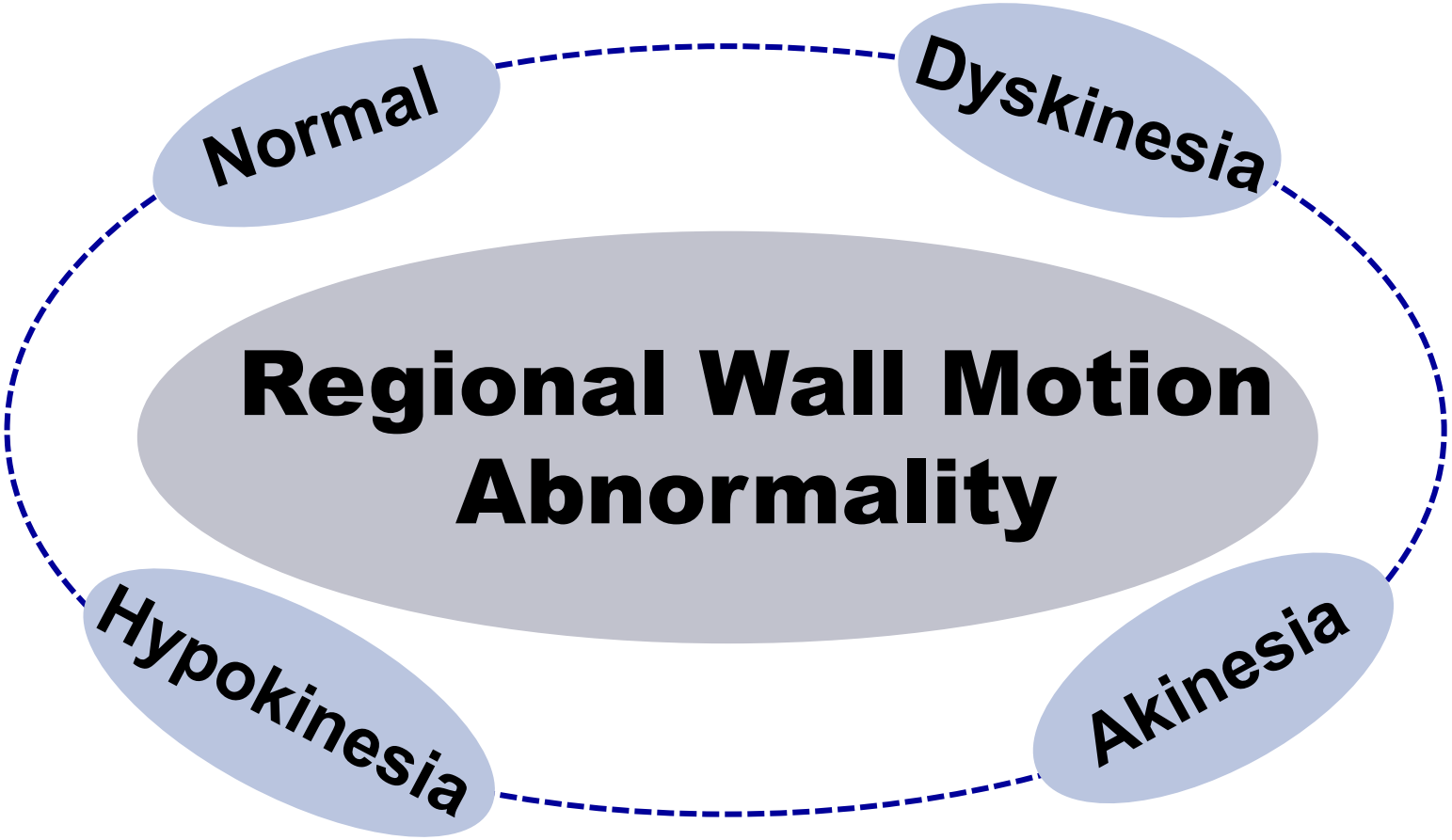

경희의대 강동경희대병원

황희정

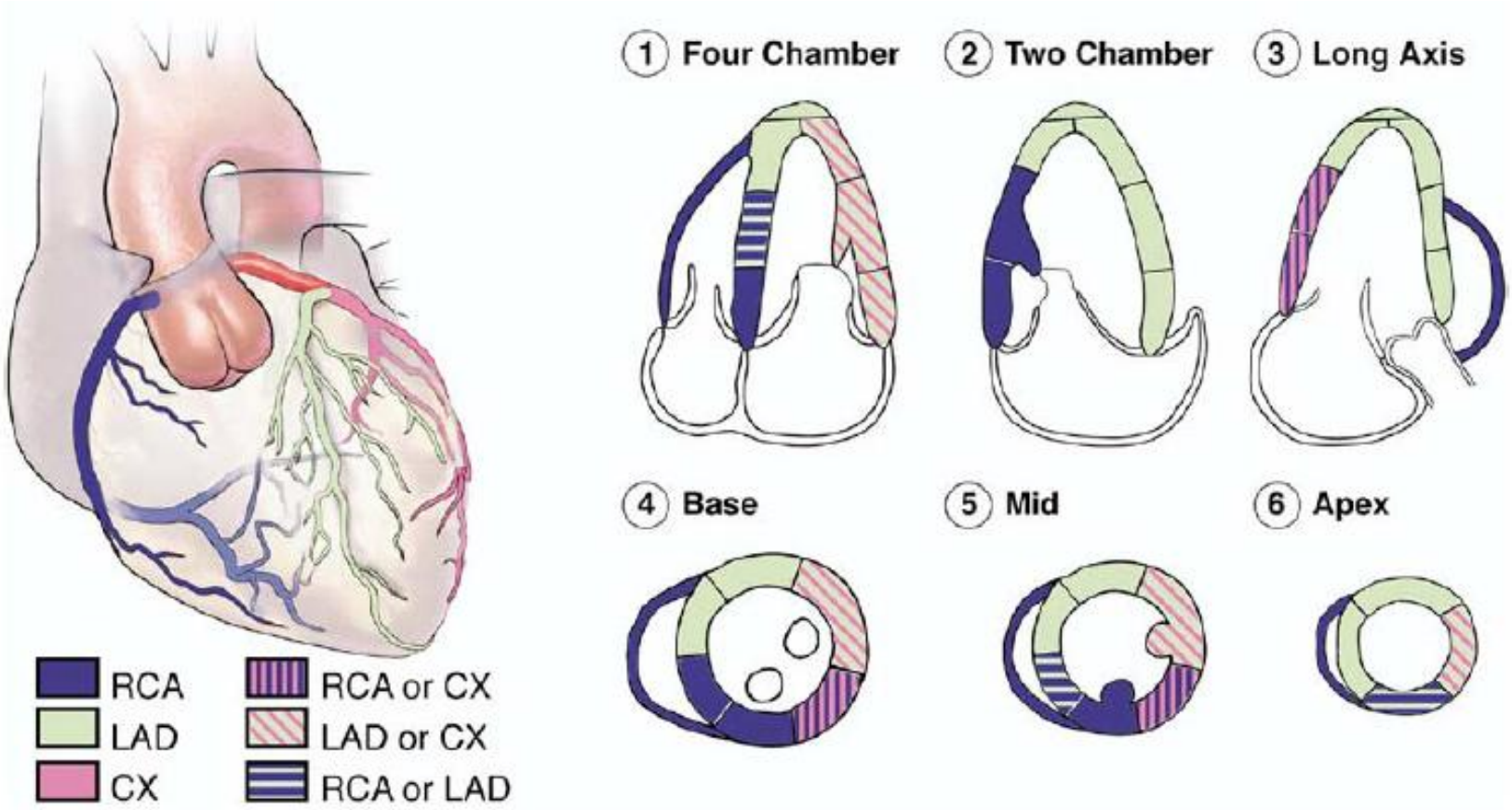
LV Systolic Function



Diagnosis of CAD on Echo



Wall motion abnormality



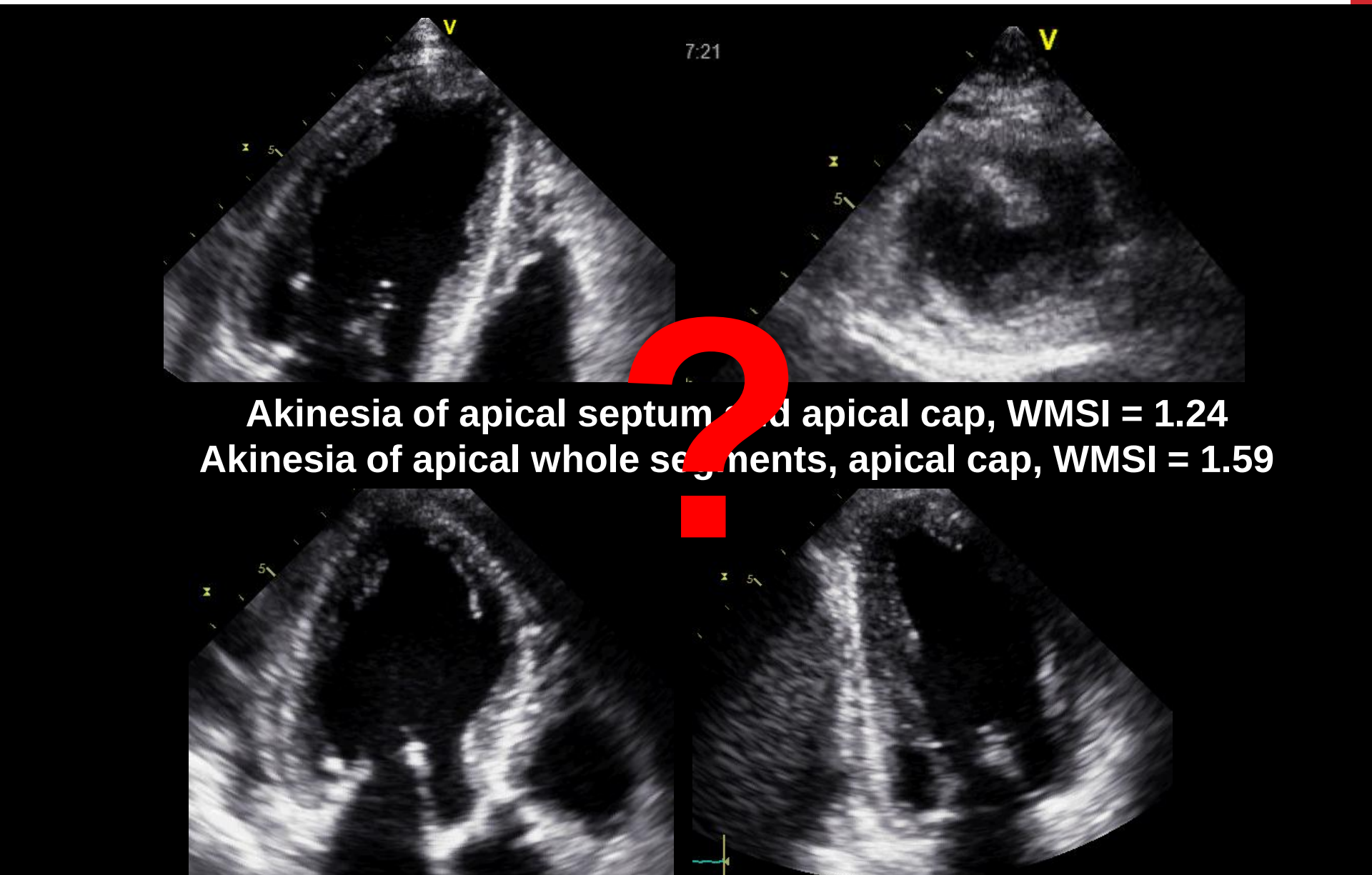
WMSI (wall motion score index)

$$= \frac{\text{Sum of all scores}}{\text{17 seg. (or 16)}}$$

(Normal = 1; Hypokinesia = 2; Akinesia = 3; Dyskinesia = 4; aneurysm = 5)

J Am Soc Echocardiogr 2005;18:1440

Diagnosis of CAD on Echo



Limitations of RWMA

1. **Subjective, Semi-quantitative (operator-dependent)**
2. **Mainly, estimation d/t radial myocardial function (myocardial shortening and thickening)**

   - limited estimation in the longitudinal and circumferential function

3. **Tethering effect**

Strain/Strain Rate Imaging

1. Strain (ε, %)

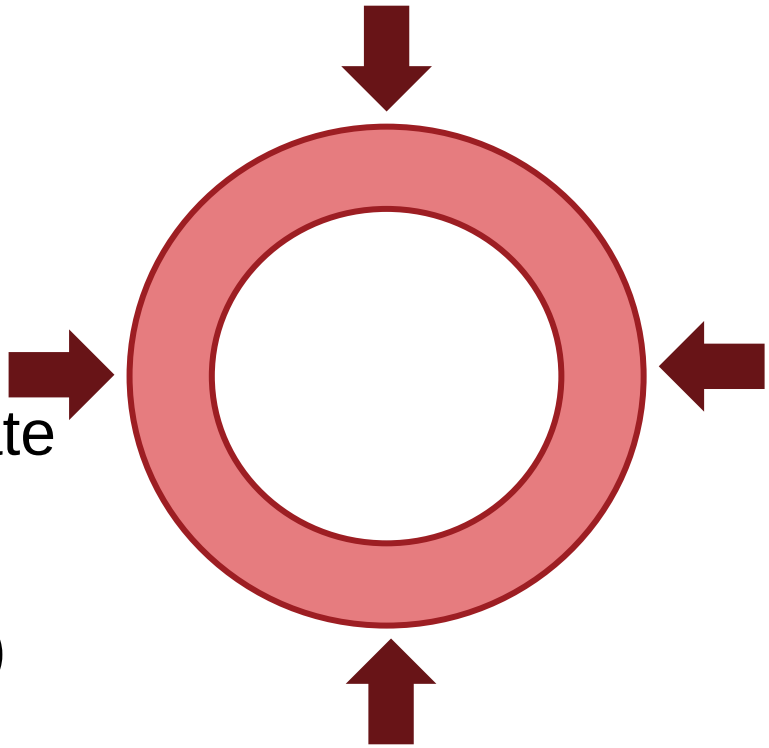
: relative deformation magnitude of tissue from an applied force or stress

2. Strain rate (SR, s^{-1})

- rate of myocardia deformation

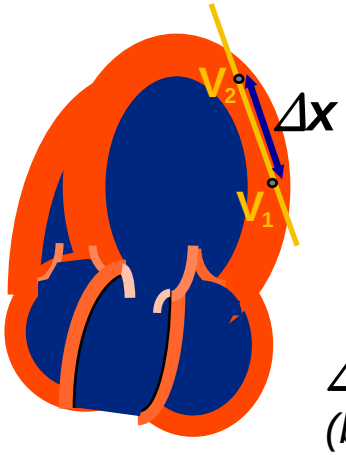
3. Methods

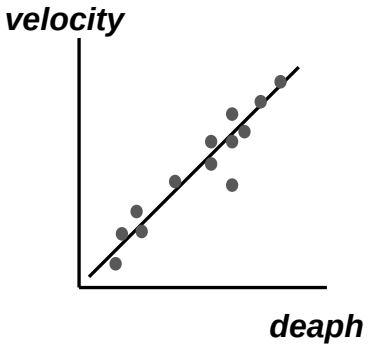
- Tissue Doppler strain/strain rate imaging (TDI)
- Speckle tracking imaging (STI)



Tissue Doppler Imaging (TDI)

Eulerian, Natural strain



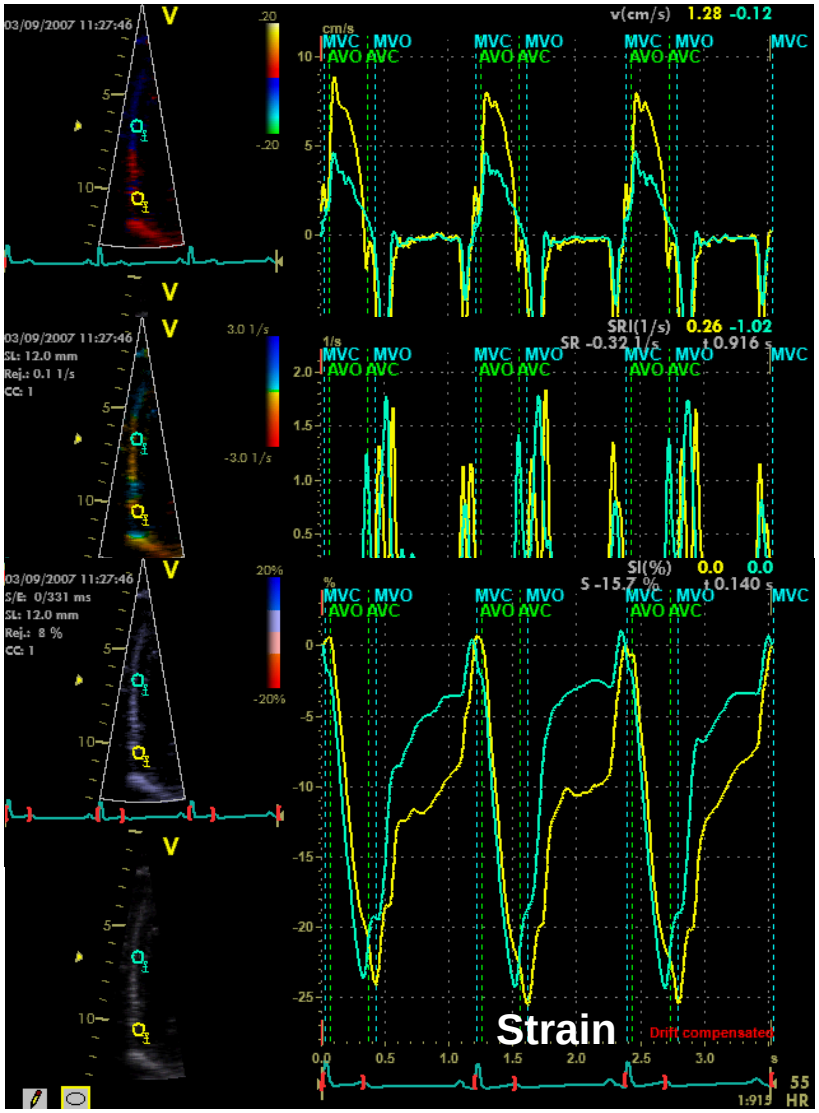


$\Delta\, v/\Delta x = SR$

(by linear regression)

$$SR = \frac{V_2 - V_1}{\Delta x} \quad \Rightarrow \quad Sn = \int_{t_o}^{t} SR\, dt$$

(velocity gradient)



Limitations of TDI

1. Angle dependency
   (limited study in the basal segment
2. High temporal resolution
3. Low signal to
4. One
5. Static
   low lat
   processing

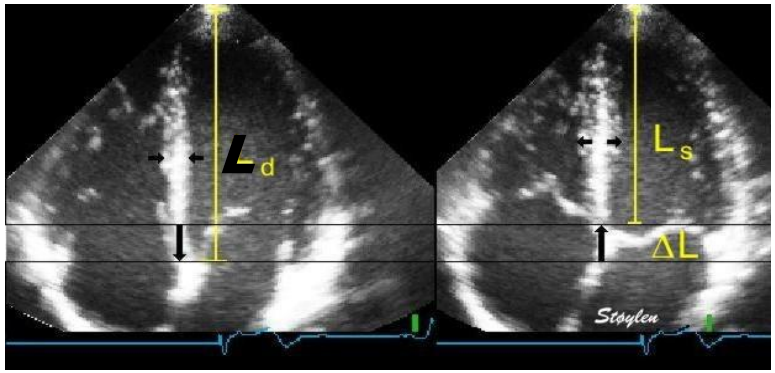
Technical difficulty
&
Time consuming process

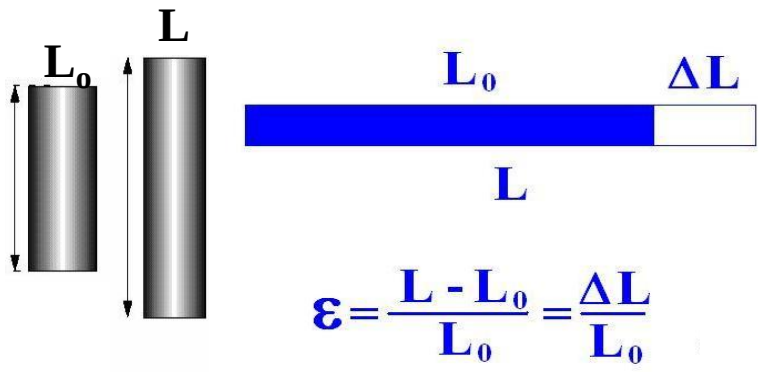
integration drift, aliasing,
ysis
tion, drop outs, biased post

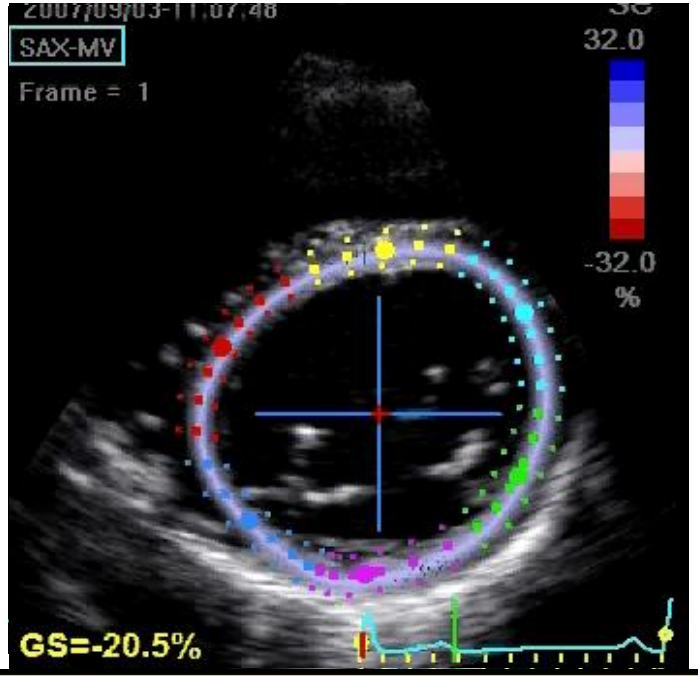
Cir Cardiovasc Imaging 2011;4:179
J Am Soc Echocardiogr 2000;13:1053

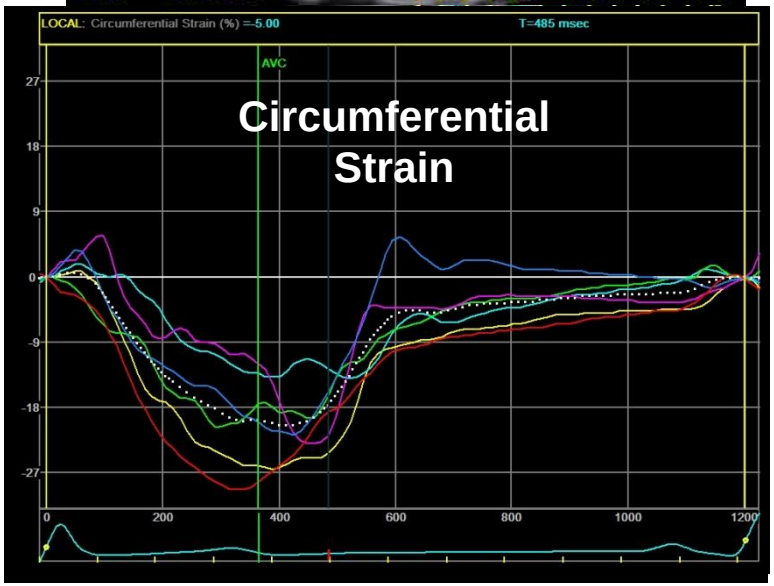
Speckle Tracking Imaging (STI)

Lagrangian strain



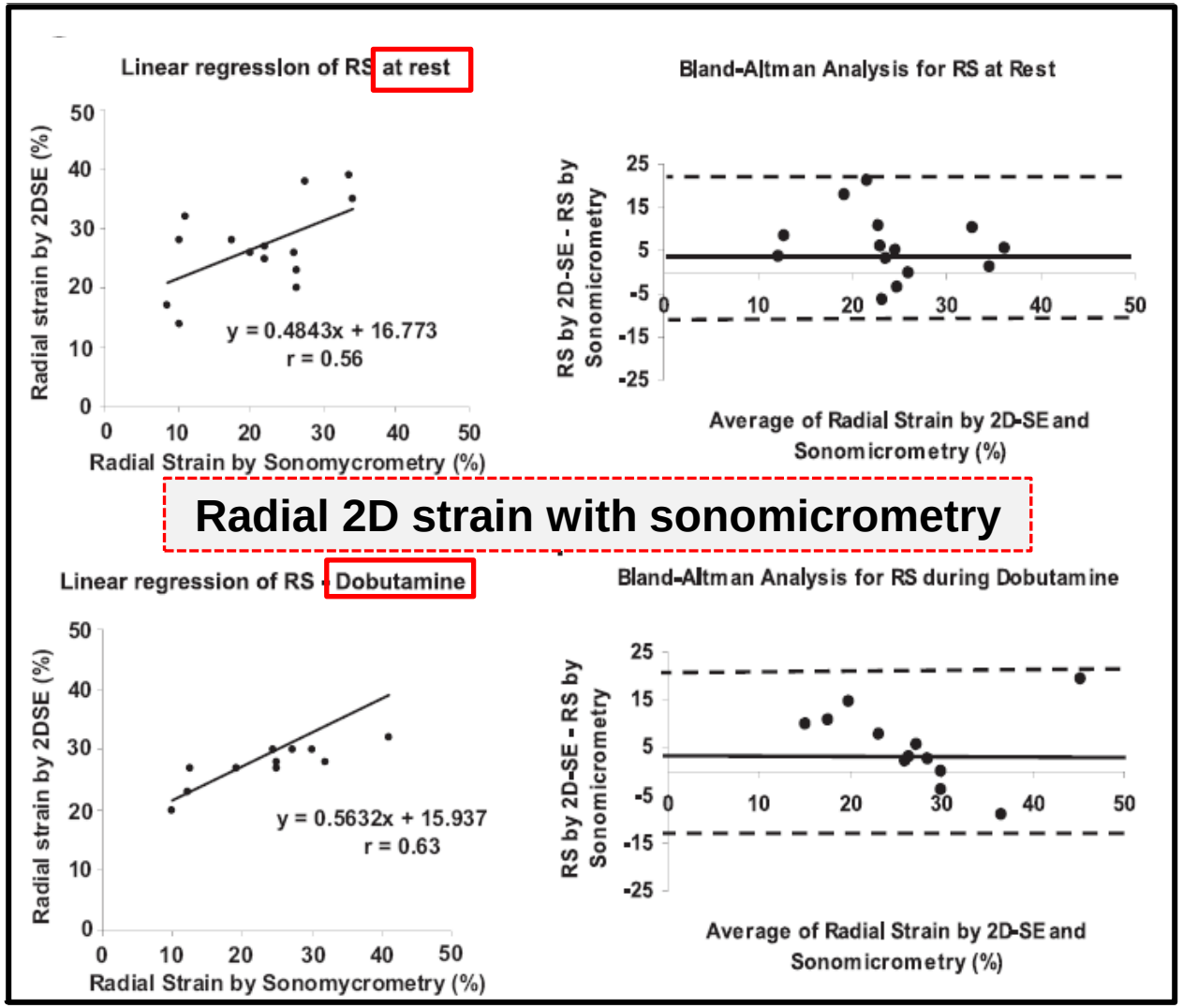






Experimental Validation of 2D Strain using sonomicrometry in ischemic heart

(in 10 open chest pigs)



J Am Coll Cardiol 2008:51:149

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Global Strain in CAD

- **Assessed baseline 2D strain echocardiography retrospectively in patients who underwent exercise echocardiography & CAD**

	No CAD, n=67	CAD (≥ 50%), n=56	P value
WMSI, baseline	1.02 ± 0.07	1.07 ± 0.13	0.0064*
WMSI, peak stress	1.15 ± 0.25	1.32 ± 0.33	0.0012*
GLS, rest (%)	-19.1 ± 3.4	-16.8 ± 3.2	0.0002*

*** ROC for detection of significant CAD**

	AUC	95% CI	P value	Optimal Cutpoint	Sensitivity/ Specificity
WMSI, peak stress	0.69	0.59-0.78	0.0003	≥ 1.13	68/70
GLS, rest (%)	0.72	0.63-0.82	<0.0001	> -17.8	66/76

Eur Heart J Cardiovasc Imaging 2012:13:579

Global Strain in CAD severity

	High risk*, n=38	Low risk, n=28	Normal, n=30	P-value
LV EF (%)	67 ± 5	67 ± 5	68 ± 4	0.804
Global GLS (%)	-18.0 ± 2.3‡§	-19.4 ± 2.4‡	-22.0 ± 1.5	<0.001

*P-values were calculated using the Chi-square test or by one-way analysis of variance with post hoc analysis with Bonferroni's correction. †P , 0.05 and ‡P , 0.001 compared with the normal group, §P , 0.05 compared with the low-risk group.

**High risk: left main, 3 vessel diseases*

Eur J Echocardiogr 2009;10:695

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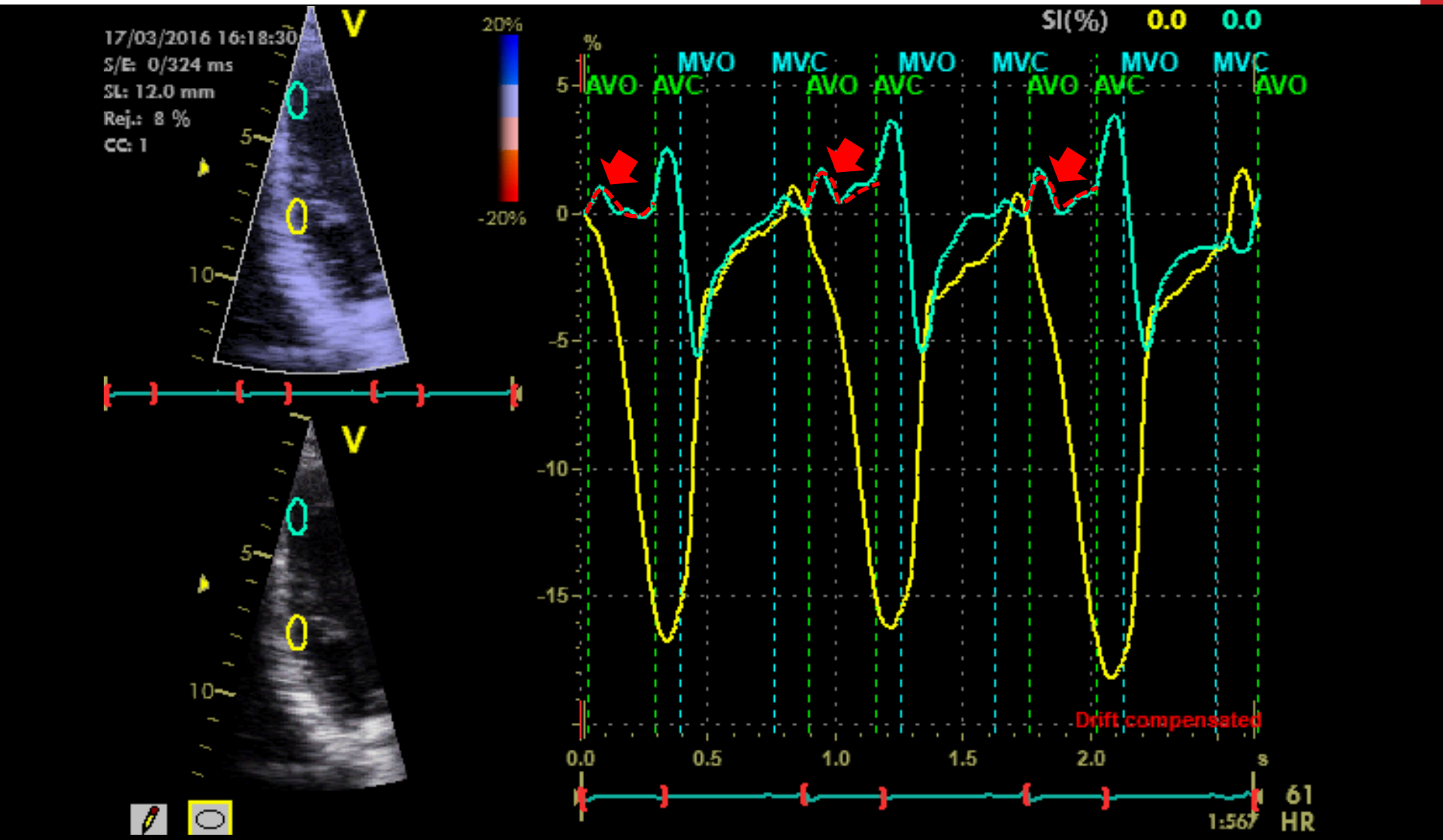
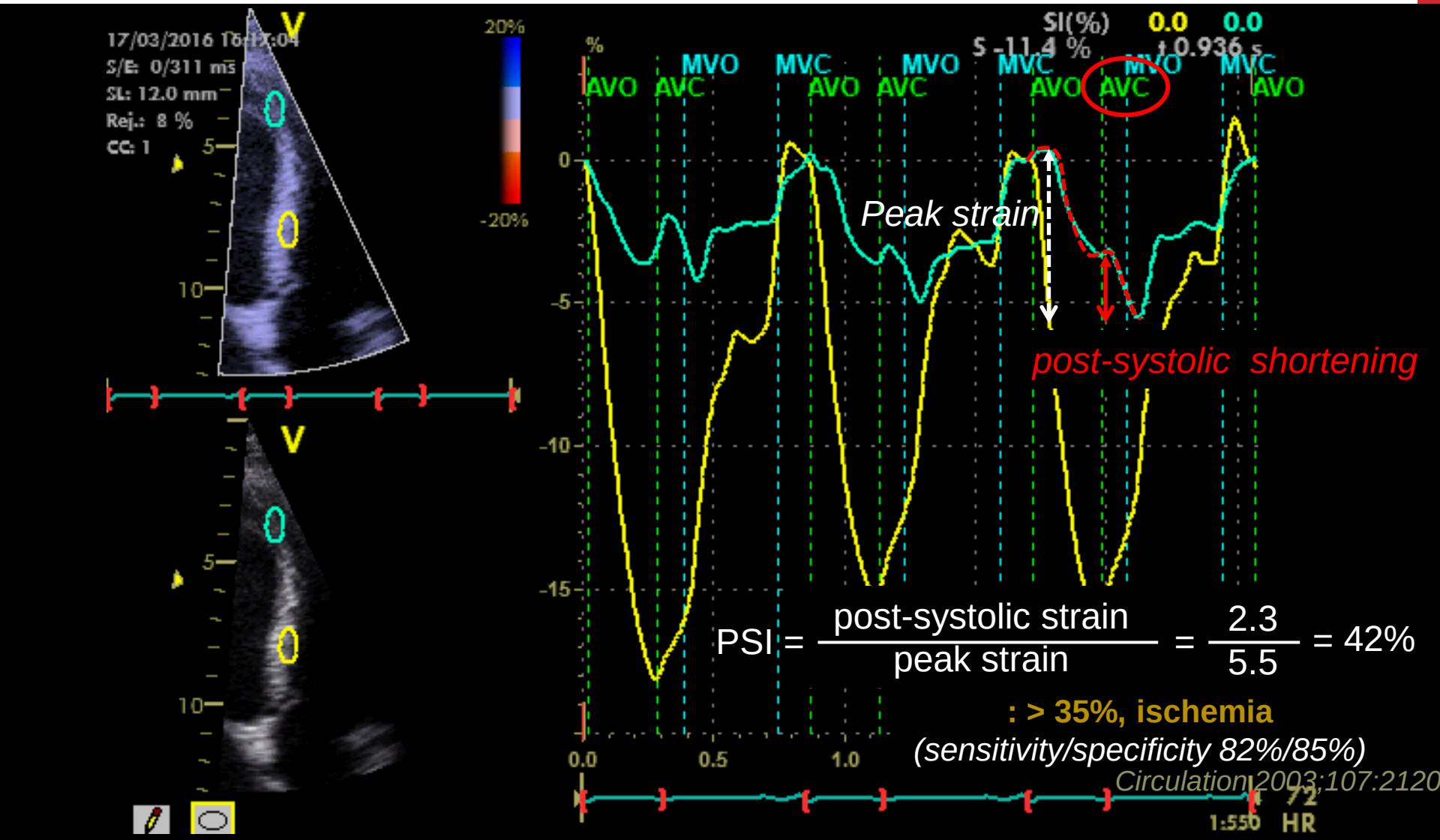
Regional Strain Patterns on Ischemic Myocardium (1)



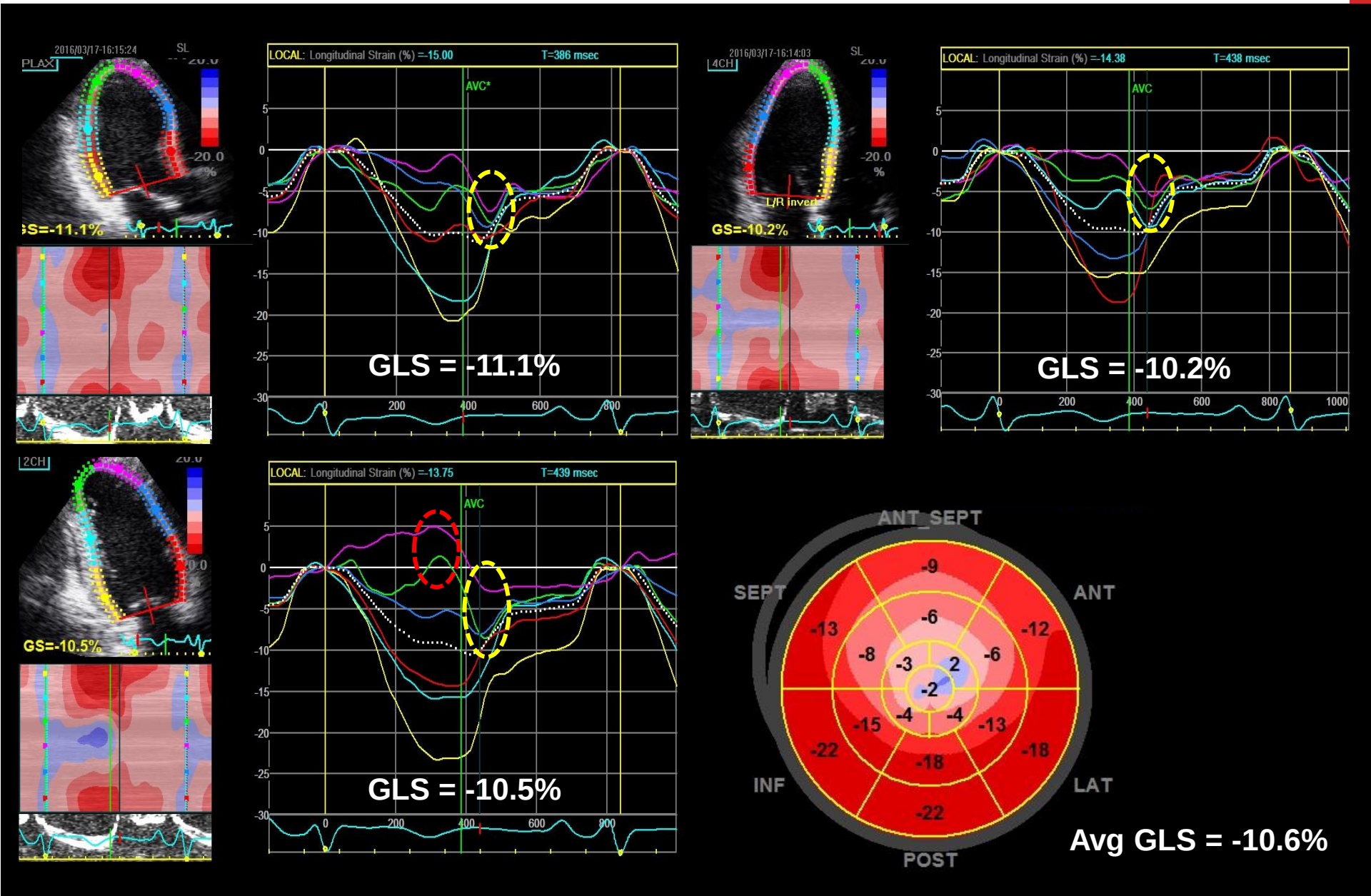
(Early) Systolic Bulging of Apical Post. Wall

Regional Strain Patterns on Ischemic Myocardium (2)

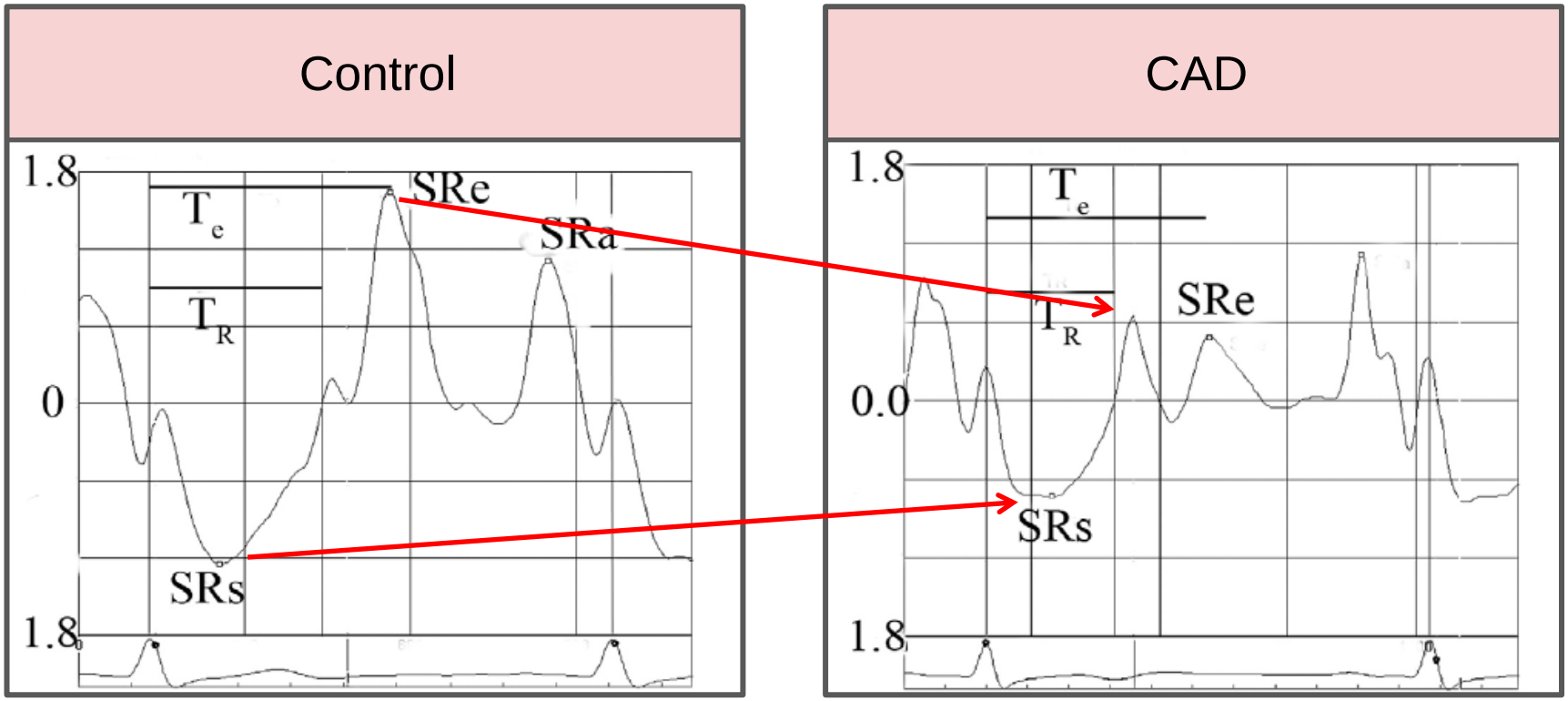


Post-systolic Shortening of Apical Inferoseptum

Example. 47/M, After Revascularization of AMI (pLAD total occlusion)



Strain rate for CAD



**Regional diastolic deformation using 2-D strain echocardiography during/within 24 hrs of CAG; CAD (≥ 70% stenosis) :Control = 39:15*

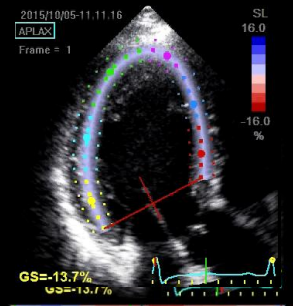
SRs, -0.83 s^{-1} (sensitivity, 85%, specificity, 64%)

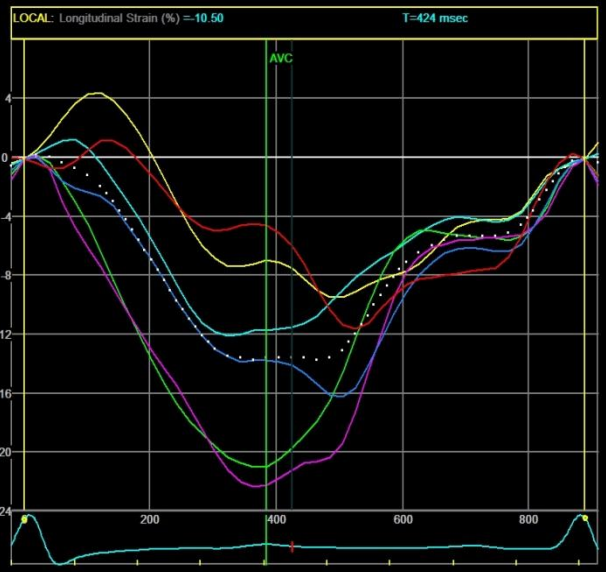
SRe, 0.96 s^{-1} (sensitivity, 77%, specificity, 93%)

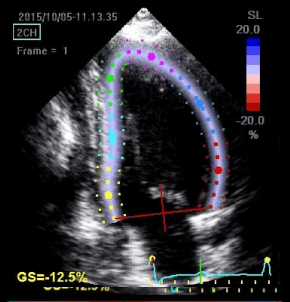
Am J Cardiol 2006;98:1581

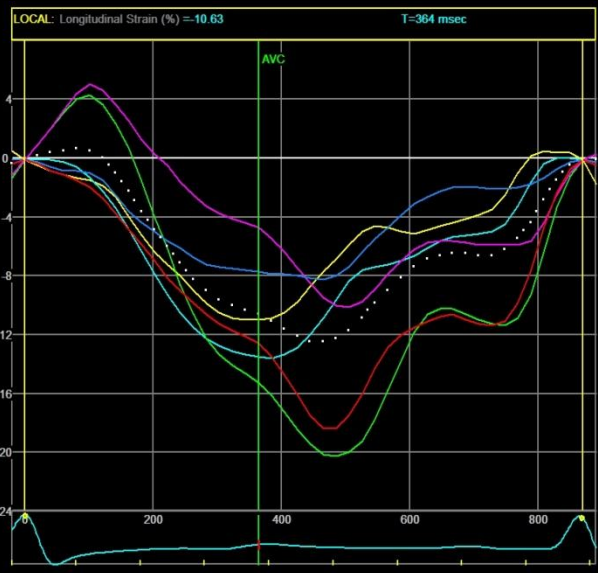
Are There Specific findings to Predict CAD in the Strain/Strain rate Value/Pattern?

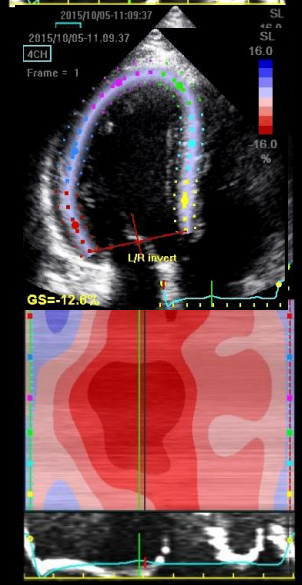
Example. 38/M, Hypertensive ESRD with PD

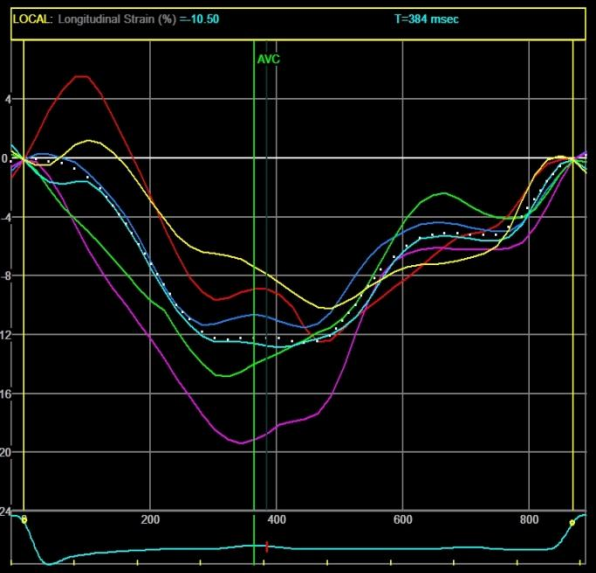


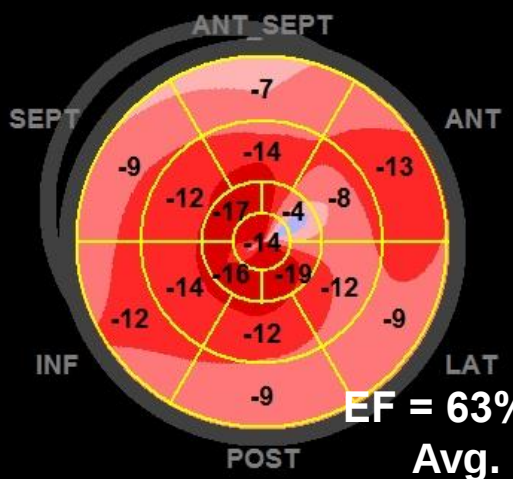








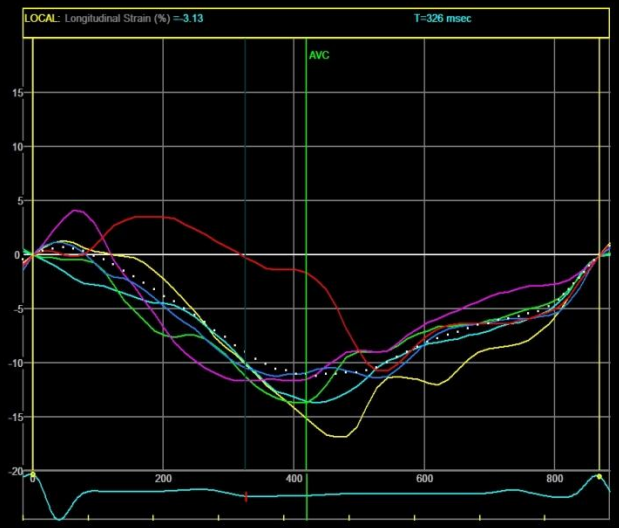


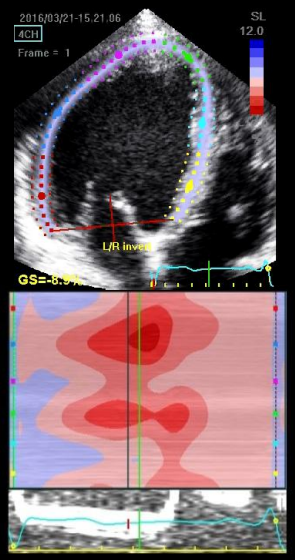


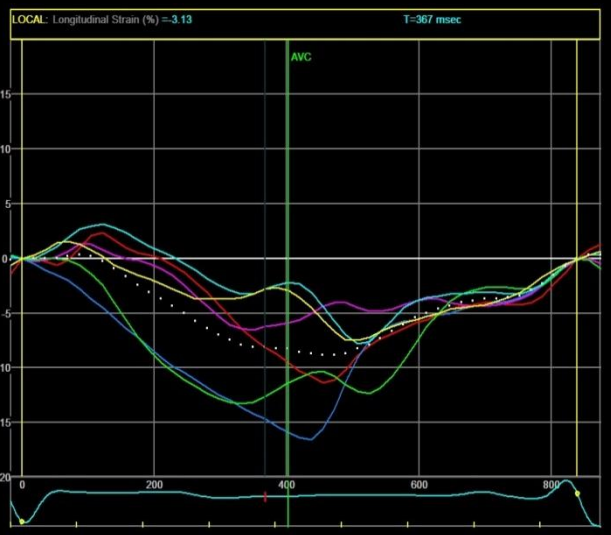
EF = 63% by 2D, E/e' = 12

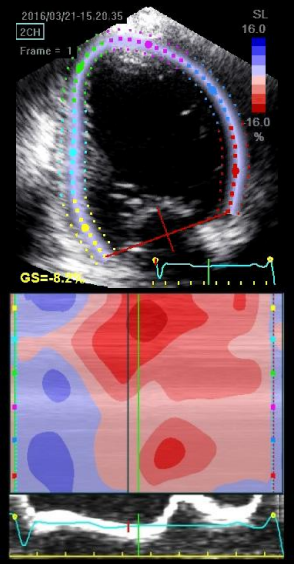
Avg. GLS = -12.9%

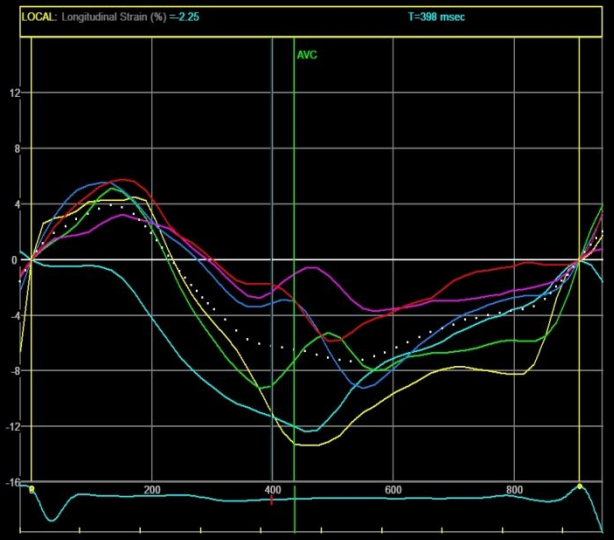
Example. 80/M, DCMP with Normal CAD

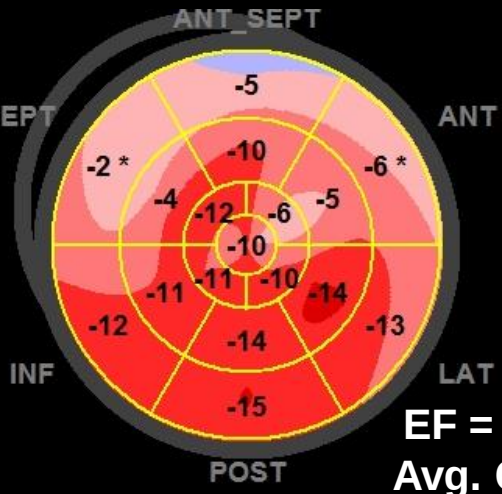








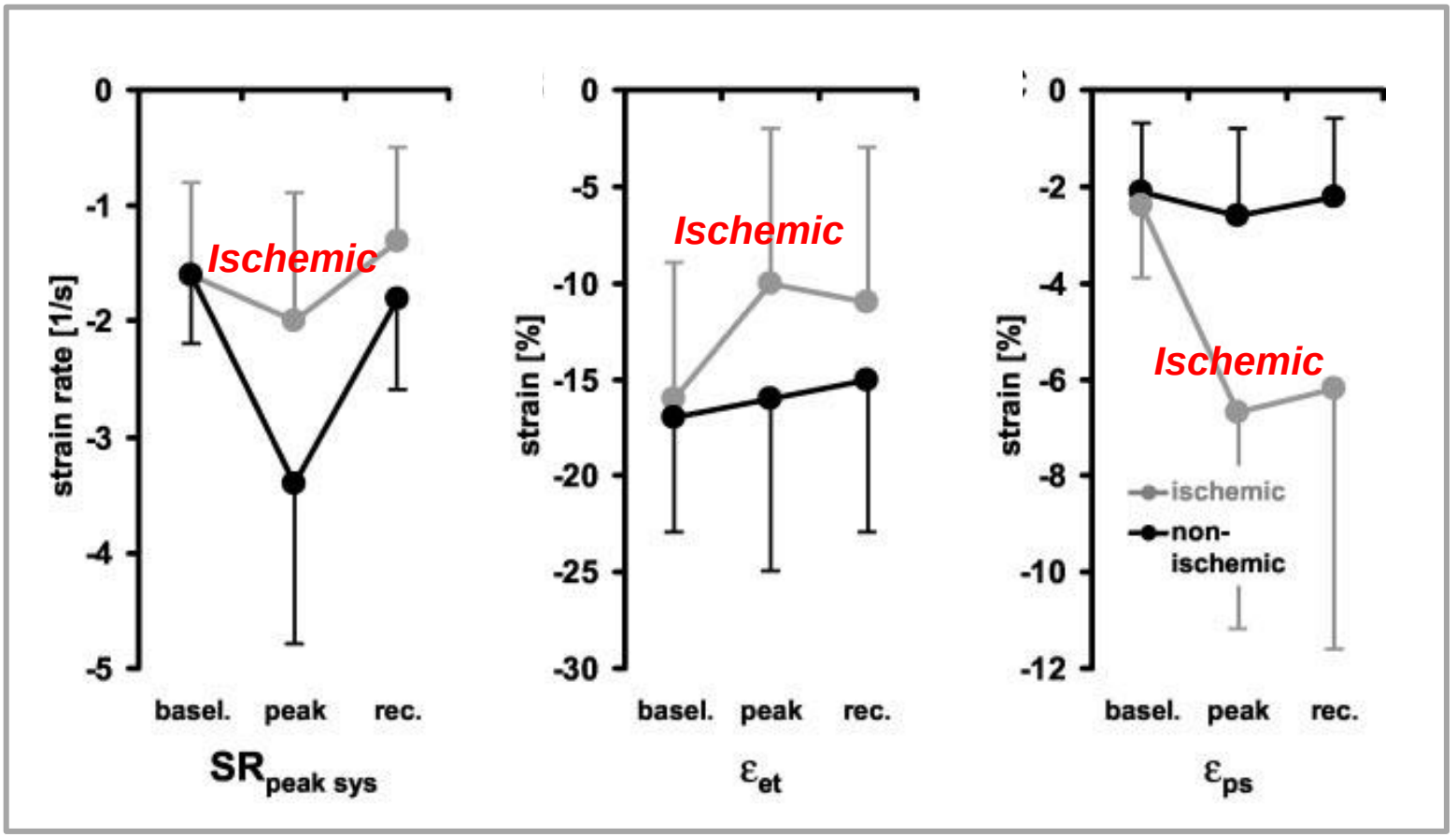




EF = 30 % by 2D

Avg. GLS = -9.4%

Strain Rate Imaging during Dobutamine Stress Echo (DSE)

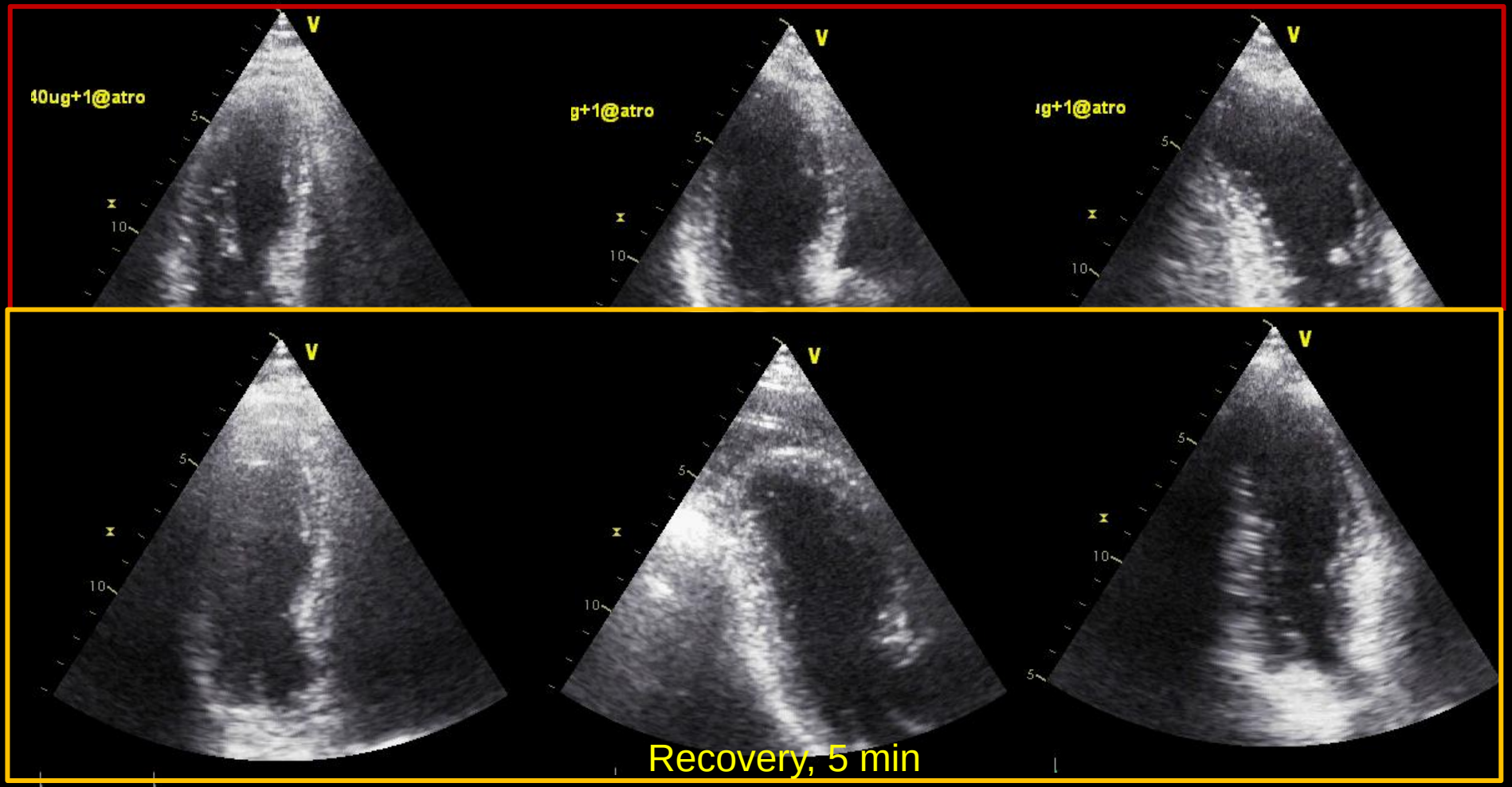


Ischemic myocardium

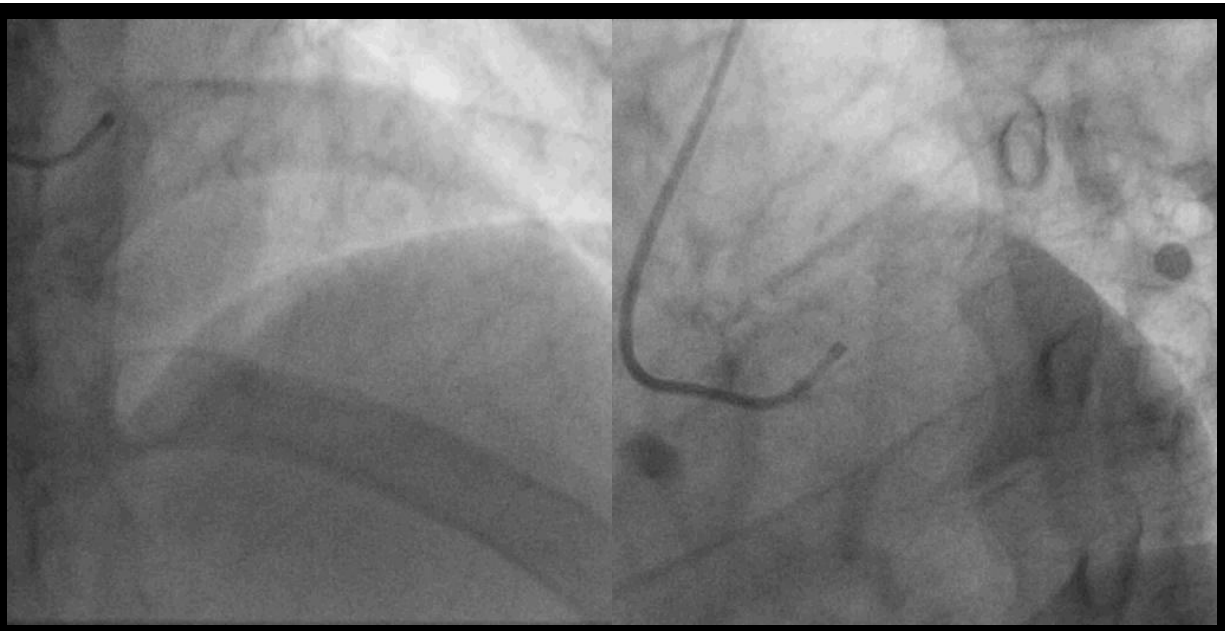
Normal myocardium

Circulation 2003;107:2120

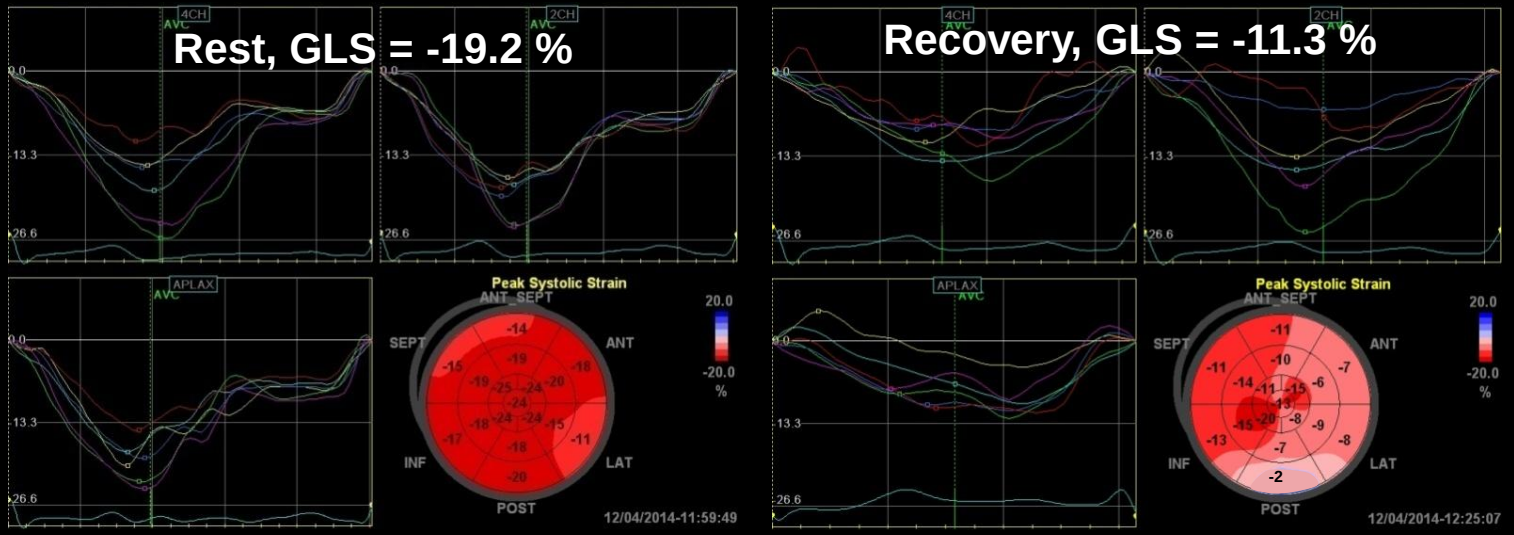
Example. 55 year-old male with CAD (+)



Example. 55/M, Exertional chest pain

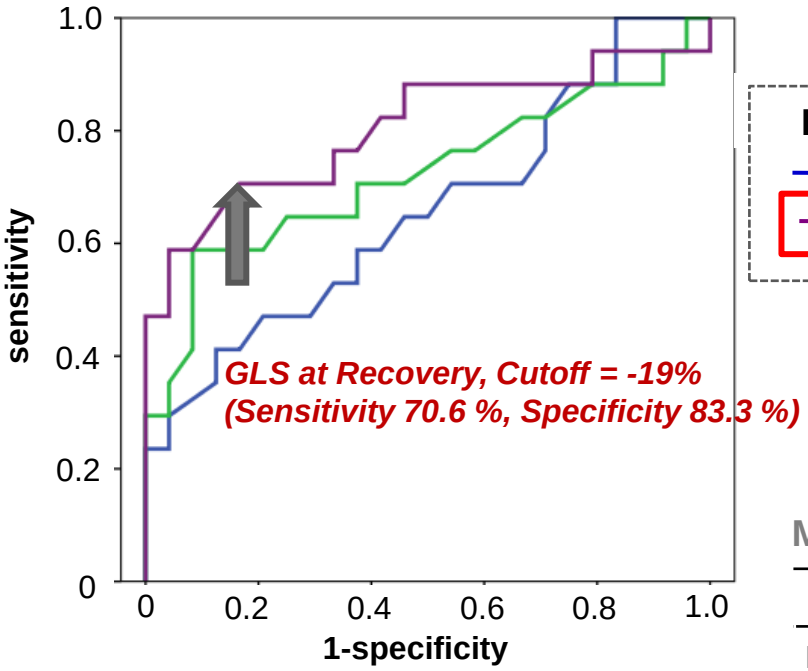


<Dobutamine Stress Echo>



Speckle Tracking after DSE

ROC curves of GLS for detection of significant CAD

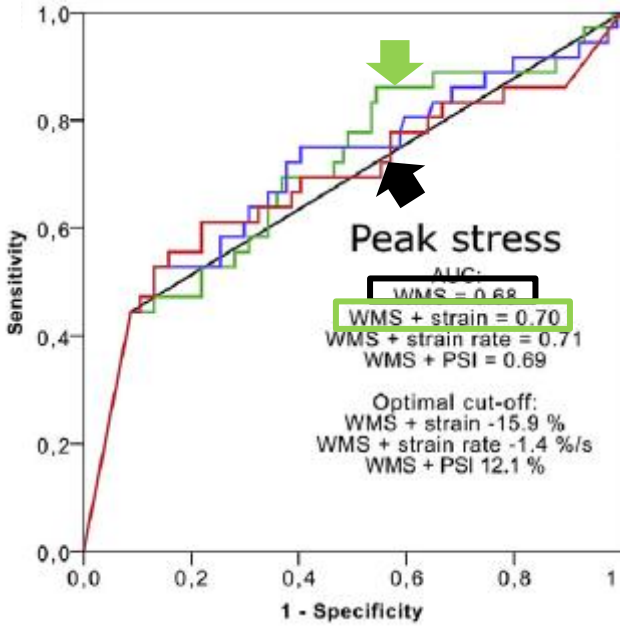


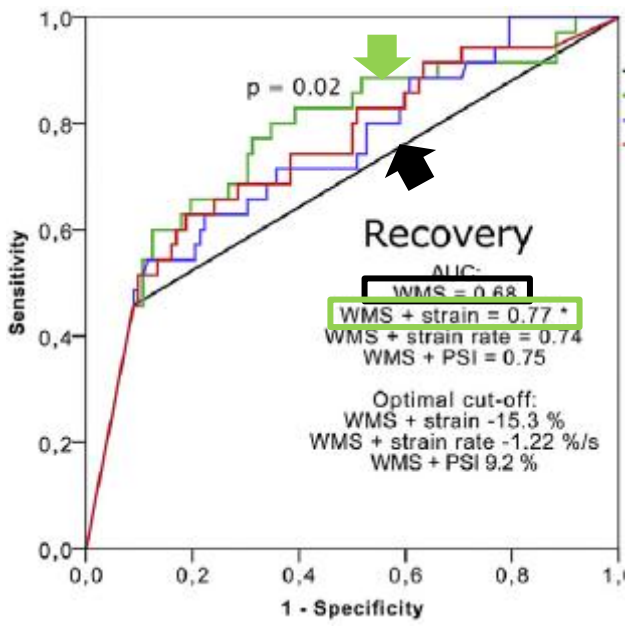
Mean global longitudinal end-systolic strain (GLS,%)

	CAD (-), n=26	CAD (+), n=18	p value
Rest	-20.1 ± 2.8	-19.4 ± 2.2	0.360
Recovery	-21.0 ± 1.9	-18.0 ± 3.4	0.003

J Cardiovasc Ultrasound 2014;22:127

STI during vs. after DSE





ROC curves of speckle tracking variables for detection of significant CAD combined with visual wall motion analysis

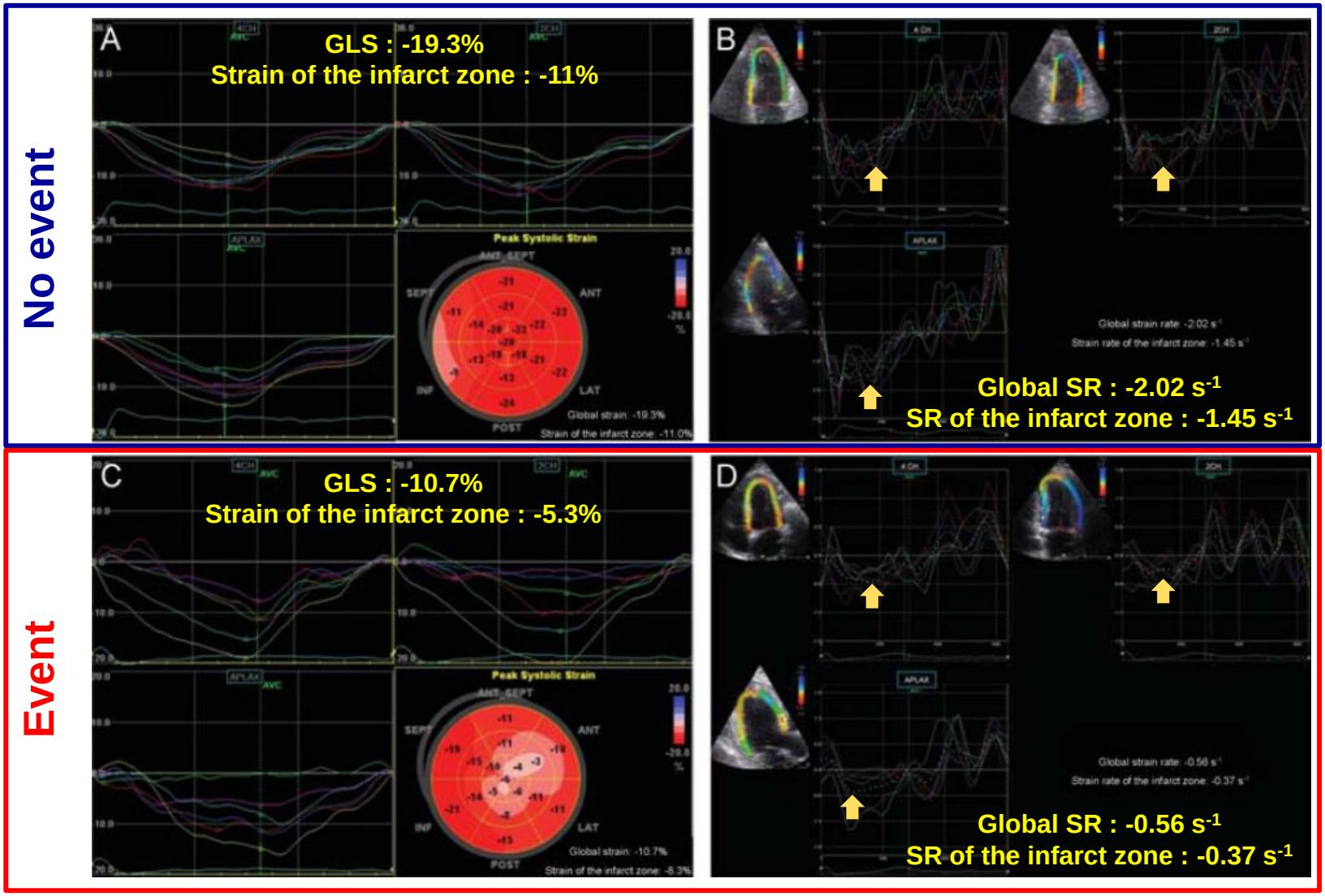
- WMS
- Strain + WMS
- Strain rate + WMS
- Post-systolic index + WMS

P < .05 against WMS alone.

	No CAD	CAD	P value
Regional strain (%)			
Rest	-18.9 ± 3.1	-18.3 ± 3.4	0.31
Peak stress	-18.3 ± 4.7	-17.6 ± 4.7	0.44
Recovery	-19.3 ± 3.9	-16.4 ± 4.8	<0.001
Regional PSI (%)			
Rest	3.0 ± 3.4	5.1 ± 4.6	0.01
Peak stress	4.7 ± 6.7	7.5 ± 8.2	0.02
Recovery	3.8 ± 5.5	9.8 ± 9.6	<0.001

Unsitalo et al. J Am Soc Echocardiogr 2016

Prognostic Importance of Strain/Strain rate after AMI



Eur Heart J 2010;31:1640

Prognostic Importance of Strain/Strain rate after AMI

Correlations with all-cause mortality

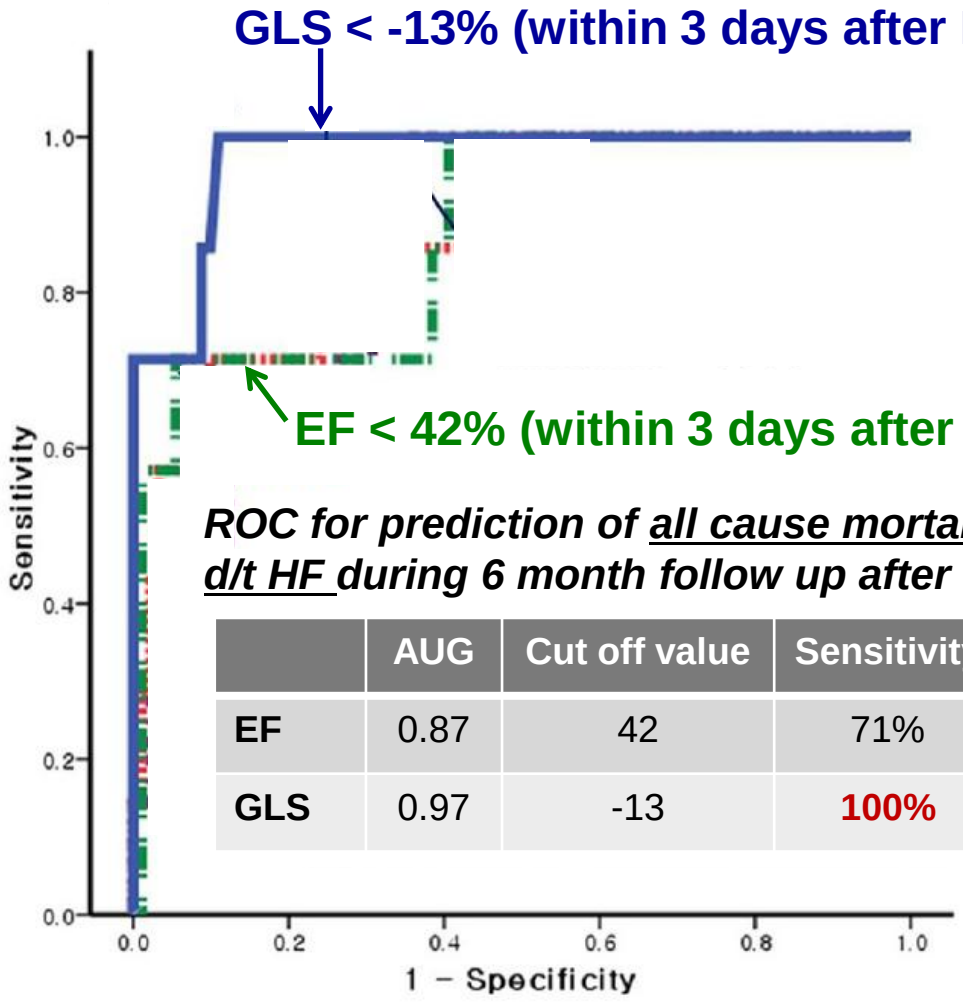
Multivariate	HR	95% CI	P-value
Multi-vessel disease	2.1	1.5-2.9	<0.001
QRS duration (ms)	1.0	1.0-1.0	<0.001
Global strain (%)	1.1	1.0-1.1	0.006
Global strain rate (s^{-1})	18	10-35	<0.001

after adjusting for **clinical and echocardiographic parameters, including **LVEF, WMSI***

Global strain and **strain rate** higher than **-15.1%** and **-1.06 s^{-1}** demonstrated **HRs of 4.5** (95% CI 2.1–9.7) and **4.4** (95% CI 2.0–9.5) ***for all-cause mortality***, respectively.

Eur Heart J 2010;31:1640

Prognostic Importance of Strain/Strain rate after AMI



ROC for prediction of <u>all cause mortality and readmission d/t HF</u> during 6 month follow up after PCI in STEMI

	AUG	Cut off value	Sensitivity	specificity
EF	0.87	42	71%	**94%**
GLS	0.97	-13	**100%**	89%

Am J Cardiol 2011;108:340

Hurdle in Clinical Use of STI

2015 ASE/EACI Cardiac Chamber Quantification Recommendation

Supplemental Table 6 Normal LV strain values from meta-analysis and individual recent publications using specific vendors' equipment and software

vendor	Software	n	Mean	SD	LLN	Reference
Varying	Meta-analysis	2597	−19.7%		NA	26
GE	EchoPAC BT 12	247	−21.5%	2.0%	−18%	31
	EchoPAC BT 12	207	−21.2%	1.6%	−18%	*
	EchoPAC BT 12	131	−21.2%	2.4%	−17%	†
	EchoPAC 110.1.3	333	−21.3%	2.1%	−17%	32
Philips	QLAB 7.1	330	−18.9%	2.5%	−14%	32
Toshiba	Ultra Extend	337	−19.9%	2.4%	−15%	32
Siemens	VVI	116	−19.8	4.6	−11%	197
	VVI	82	−17.3	2.3	−13%	198
Esaote	Mylab 50	30	−19.5	3.1	−13%	199

LLN, Lower limit of normal range.
*T. Kouznetsova and J. Staessen, Department of Cardiology, Catholic University Leuven, personal communication.
†P. Barbier, University Milano, personal communication.

J Am Soc Echocardiogr 2015;28:1

Summaries

1. **Limitations of CAD assessment by WMA**
   - subjective, radial myocardial function, tethering effect
   → strain/strain rate imaging analysis
2. **STI : relatively lesser time-consuming and technically easier process than TDI**
3. **Global/Regional strain/strain rate at rest and during stress test in the detection of CAD**
   - incremental benefit to WMA
4. **Strain/strain rate to predict the prognosis after PCI in AMI**
   - incremental benefit to clinical data and traditional echo parameters (ex. EF, LV remodeling)