Echo is Still Strong in Myocardial Viability

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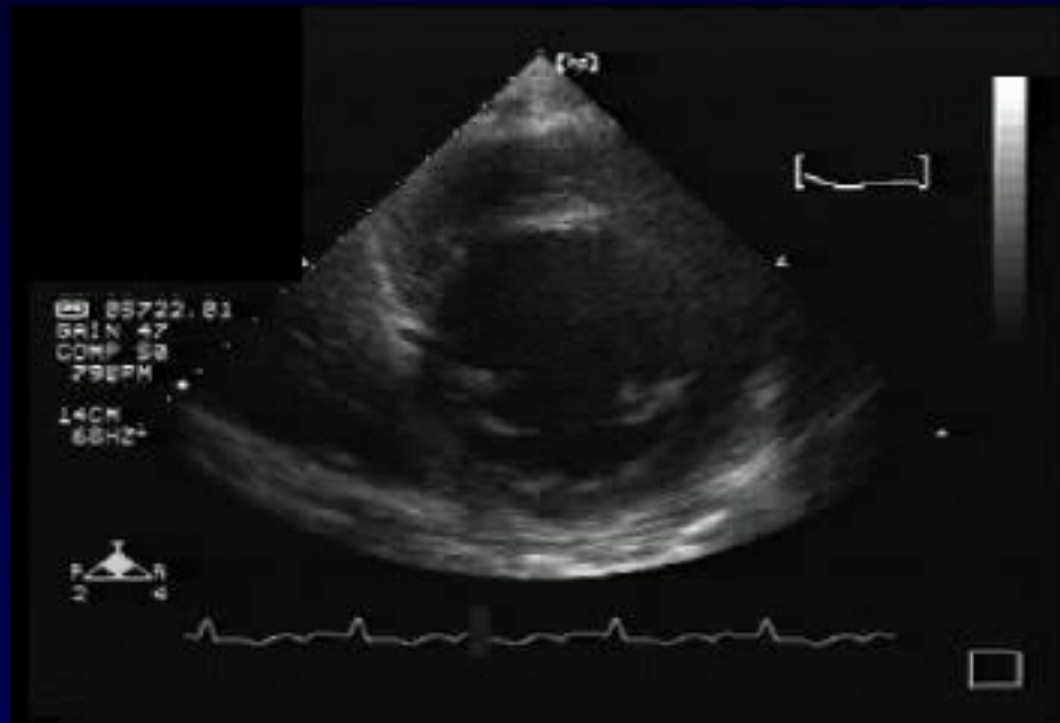
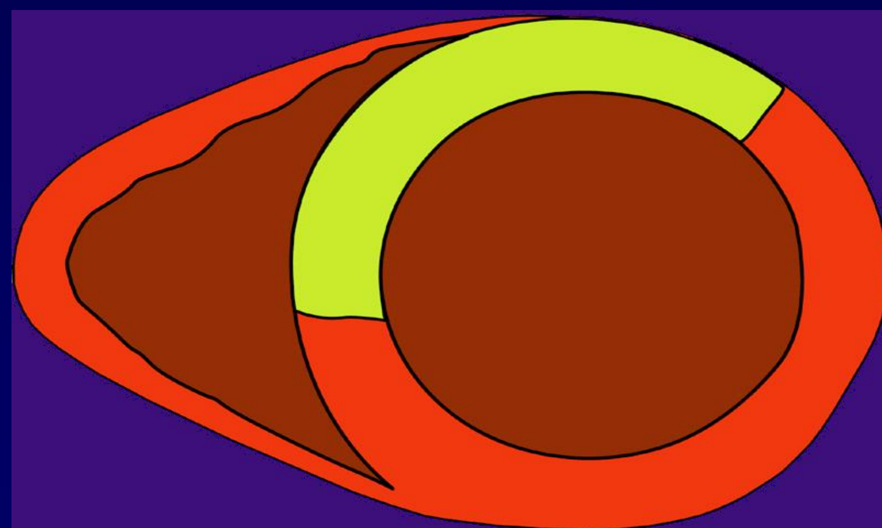


LV dysfunction

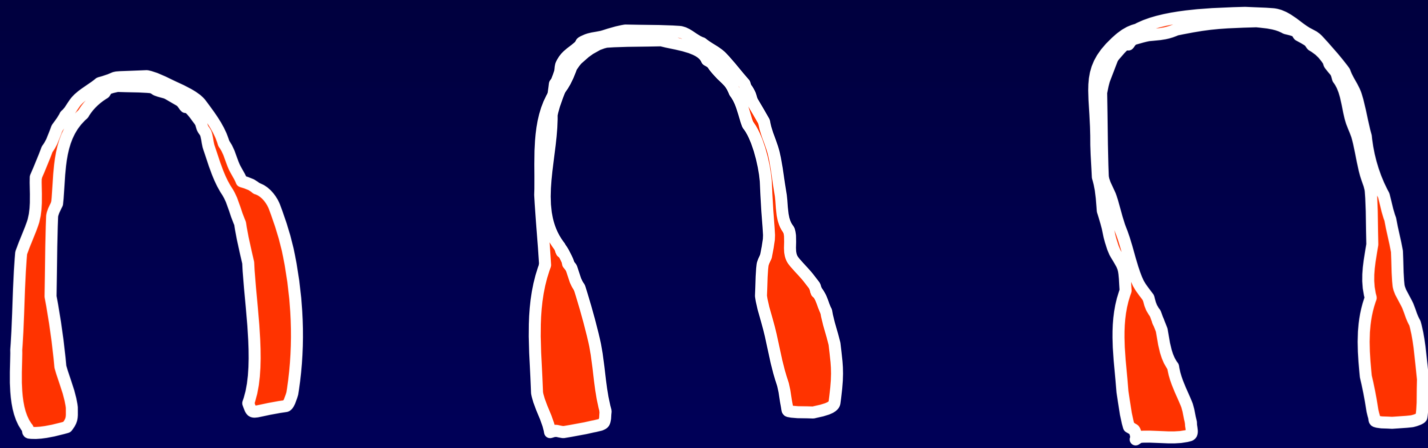
- **Necrosis**
- **Ischemia**
- **Stunned**
- **Hibernating**



Viable ?

Remodeling

Necrotic tissue- replaced by fibrotic and scar tissue



Stage I. For hours to a few days

Stage 2. Three weeks

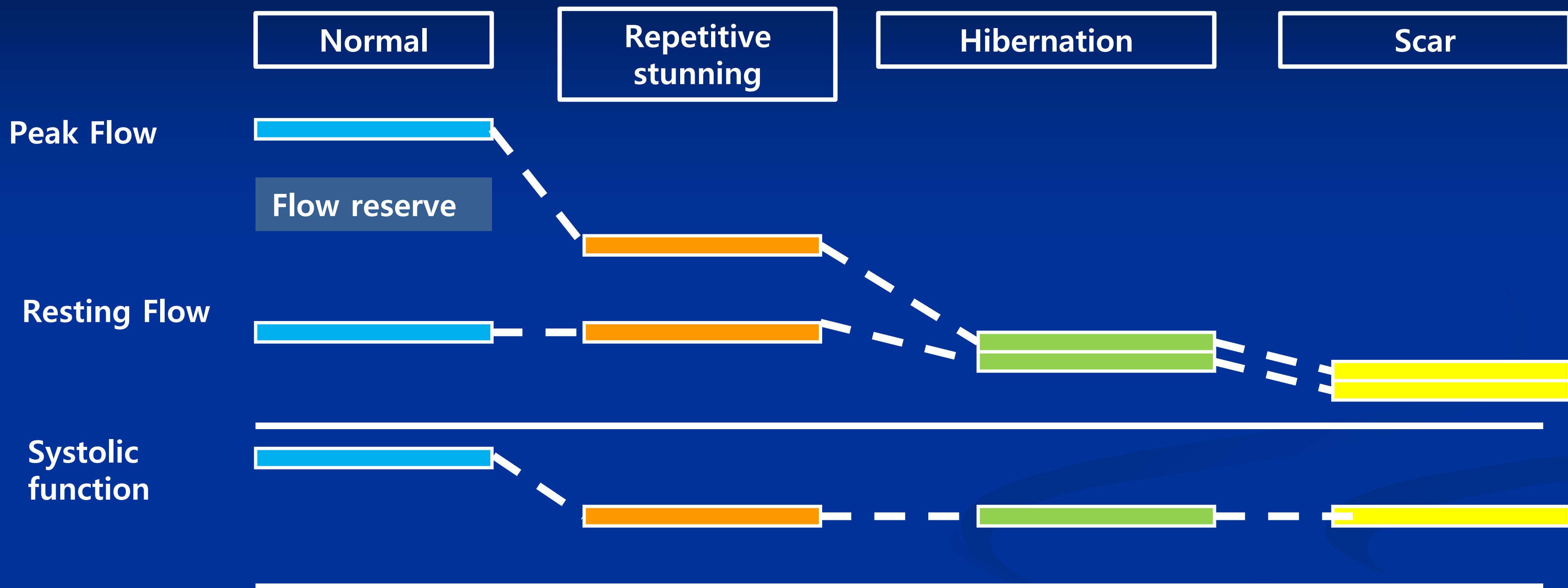
Stage 3. Three or four weeks later

Techniques to Detect Viable Myocardium

Characteristics of viable myocardium	Technique	Signs of viability
Contractile reserve	Dobutame Echo Dobutamine MRI	Improved contraction during infusion of low-dose dobutamine
Intact cell membrane	Thallium-201 SPECT	Tracer activity >50% Redistribution (>10%)
Intact mitochondria	Technetium-99m SPECT	Tracer activity >50% Improved tracer uptake after nitrates
Glucose metabolism	18F-FDG imaging	Tracer activity >50% Preserved perfusion/18F-FDG uptake Perfusion-metabolism mismatch

Schinkel AFL, et al. Heart 2005;91:111-7.

Spectrum of myocardial dysfunction in ICM



CFR	V
CR	V
PERF	V
MET	V

CFR	↓
CR	V
PERF	V
MET	V

CFR	↓↓
CR	↔
PERF	↔
MET	V

CFR	X
CR	X
PERF	X
MET	X

Courtesy of DH Kim, AMC.

아름다운 인재의 샘 가천대학교

Myocardial Viability

Myocardial Contrast Echo

TABLE 3-4 Predictive Value of MCE for Detection of Myocardial Viability within 7 Days After Acute Myocardial Infarction, and for Identification of Hibernating Myocardium

Study	*N*	*Follow-up (months)*	*Sensitivity*	*Specificity*	*Reference Standard*
Detection of Myocardial Viability Post Myocardial Infarction					
Swinburn et al[a]	96	3-6	59%	76%	RF
Main et al[b]	34	2	77%	83%	RF
Hillis et al[c]	37	2	80%	67%	RF
Janardhana et al[d]	50	3	87%	78%	RF
Korosoglou et al[e]	32	1	81%	88%	RF
Huang et al[f]	34	4	83%	82%	RF
Nunes Sbano et al[g]	50	6	95%	52%	RF
Abe et al[h]	21	6	98%	32%	RF
Dwivedi et al[i]	95	46	80%	76%	CO
Galiuto L et al[j]	110	6	70%	74%	RF
Detection of Hibernating Myocardium					
Korosoglou et al[k]	43	3	86%	64%	RF
Chelliah et al[l]	39	3	88%	61%	RF
Korosoglou et al[m]	34	3-6	88%	66%	RF
Shimoni et al[n]	20	3-4	82%	69%	RF

The reference standard was either recovery of regional function (RF) or clinical outcome (CO, defined as death or nonfatal myocardial in farction).
References:

Otto. Practice of Clinical Echocardiography, 4th ed, 2012. p54

Myocardial Viability
Dobutamine Stress Echo

TABLE 16-8 Comparison of Nuclear and Stress Echocardiographic Techniques for Prediction of Viability (Evidenced by Improvement of Regional LV Function)*

			Sensitivity, %		Specificity	
Study	*Thallium Technique*	*Dobutamine Protocol, mcg/kg/min*	*Thallium SPECT*	*Dobutamine Echocardiography*	*Thallium SPECT*	*Dobutamine Echocardiography*
Marzullo[163]	Rest-redistribution	Low-dose, 10	86	82	92	92
Charney[164]	Rest-redistribution	Low-dose, 10	95	71	85	93
Kostopoulos[165]	Rest-redistribution	Low-dose, 10	90	87	69	94
Qureshi[166]	Rest-redistribution	High-dose, 40	90	74	56	89
Nagueh[167]	Rest-redistribution	High-dose, 40	91	68	43	83
Senior[168]	Stress (dobutamine)-rest/NTG	Low-dose, 10	92	87	78	82
Arnese[169]	Stress (dobutamine) reinjection	Low-dose, 10	89	74	48	95
Perrone-Filardi[170]	Stress (dobutamine) reinjection	Low-dose, 10	100	79	22	83
Bax[171]	Stress (dobutamine) reinjection	Low-dose, 10	93	85	43	63
Haque[172]	Stress (exercise) reinjection	Low-dose, 20	100	94	40	80
Vanoverschelde[173]	Stress (exercise) reinjection	High-dose, 40	72	88	73	77
Elsasser[174]	Stress (dobutamine) reinjection	High-dose, 40	87	95	98	80

NTG, Nitroglycerin; *SPECT*, single photon emission computed tomography.
*Average ejection fraction 38%.

Otto. Practice of Clinical Echocardiography, 4th ed, 2012. p313

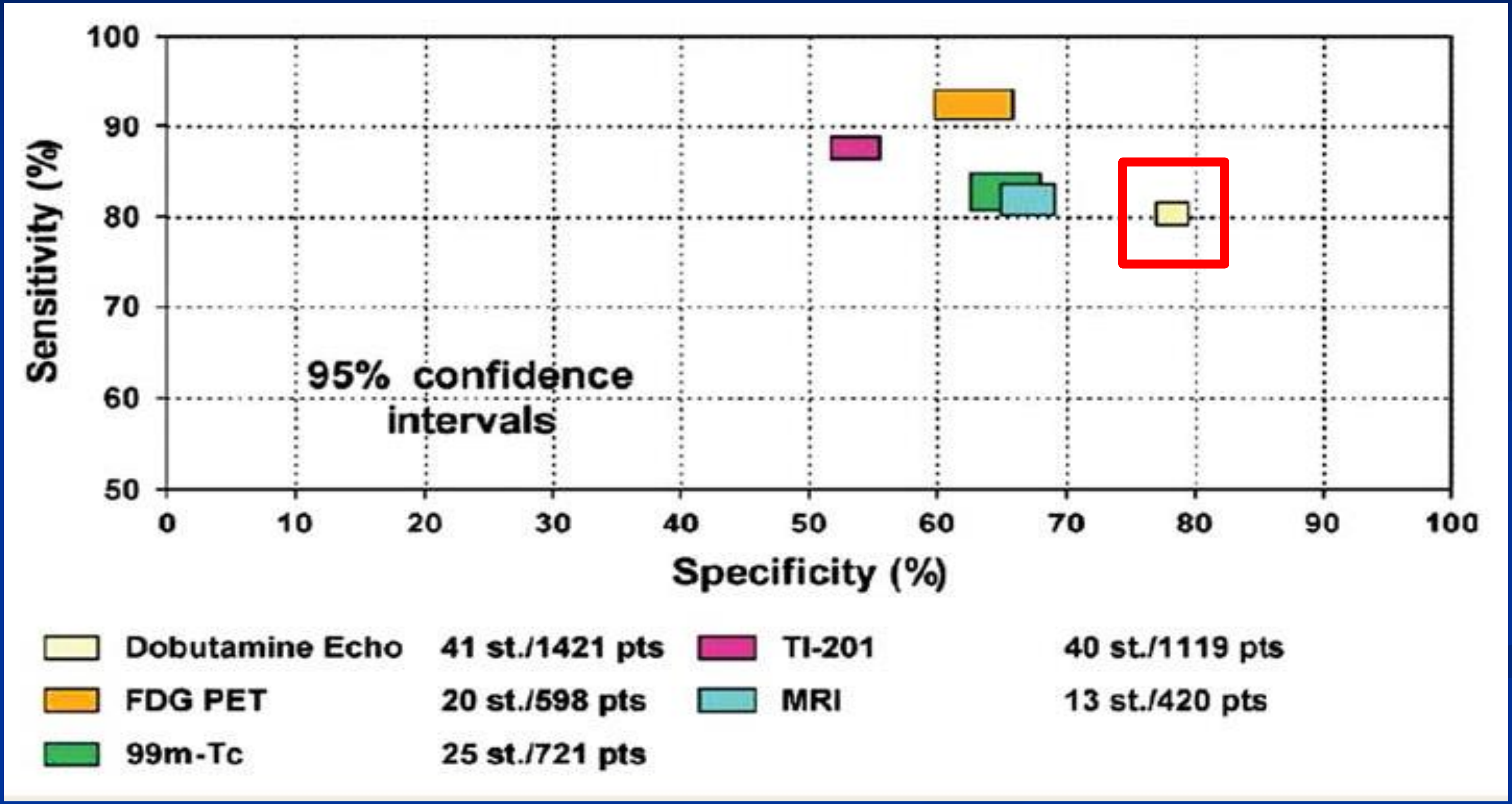
Comparison of the various imaging techniques for detecting Hibernating Myocardium

Technique	No. of studies	No. of patients	Mean EF (%)	Sensitivity (%)	Specificity (%)
Dobutamine echocardiography.total	41	1421	25.48	80	78
Low-dose DbE	33	1121	25.48	79	78
High-dose DbE	8	290	29.38	83	79
Myocardial contrast echocardiography. total	10	268	29.38	87	50
Thallium scintigraphy. total	40	1119	23.45	87	54
Tl-201 rest-redistribution	28	776	23.45	87	56
Tl-201 re-injection	12	343	31.49	87	50
Technetium scintigraphy.Total	25	721	23.54	83	65
Without nitrates protocol	17	516	23.52	83	57
With nitrates protocol	8	205	35.54	81	69
Positron emission tomography.total	24	756	23.53	92	63
Cardiovascular magnetic resonance. total	14	450	24.53	80	70
Low-dose dobutamine protocol	9	272	24.53	74	82
Late gadolinium-enhancement protocol	5	178	32.52	84	63

Shah et al. EHJ 2013 review

Detection of Myocardial Viability

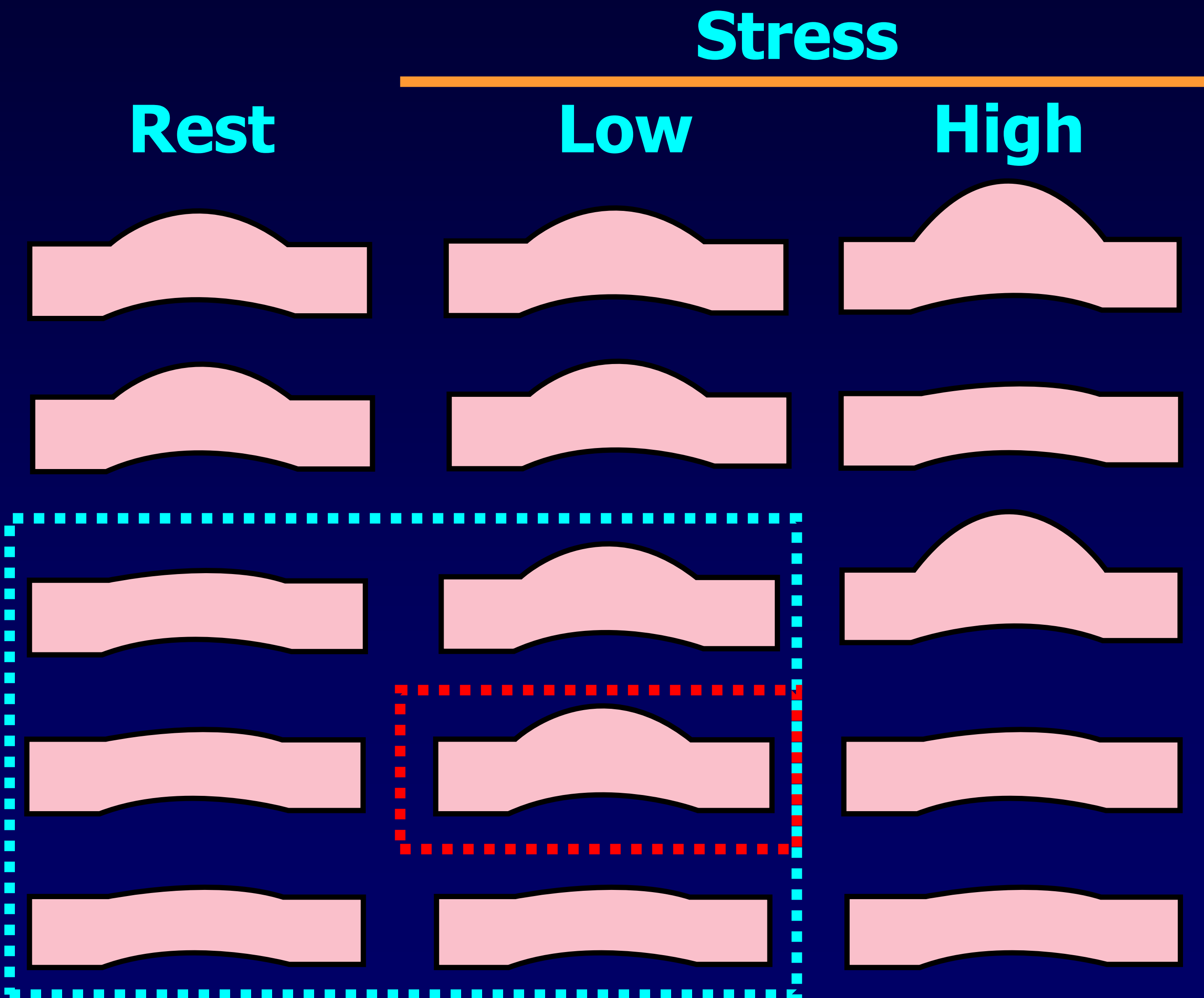
Functional Recovery After Revascularization



European Heart Journal (2010) 31, 2984–2995

Dobutamine Stress Echocardiography

Detection of Mycardial Viability



Hyperkinetic
Normal

Worsening
Ischemic

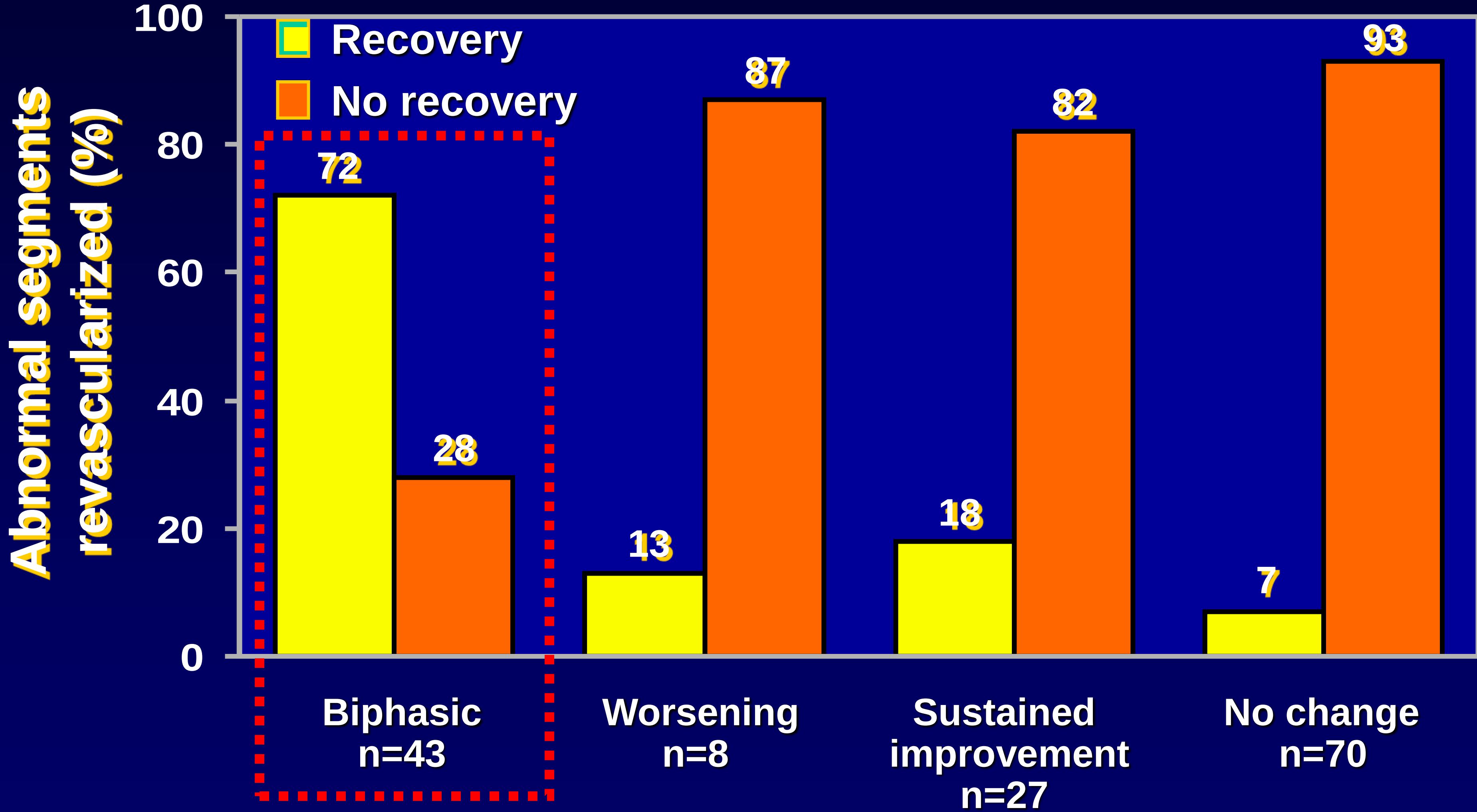
Sustained Improvement
Viable, patent IRA

Biphasic
Viable, stenosed IRA

No Change
Infarction

Dobutamine Stress Echocardiography

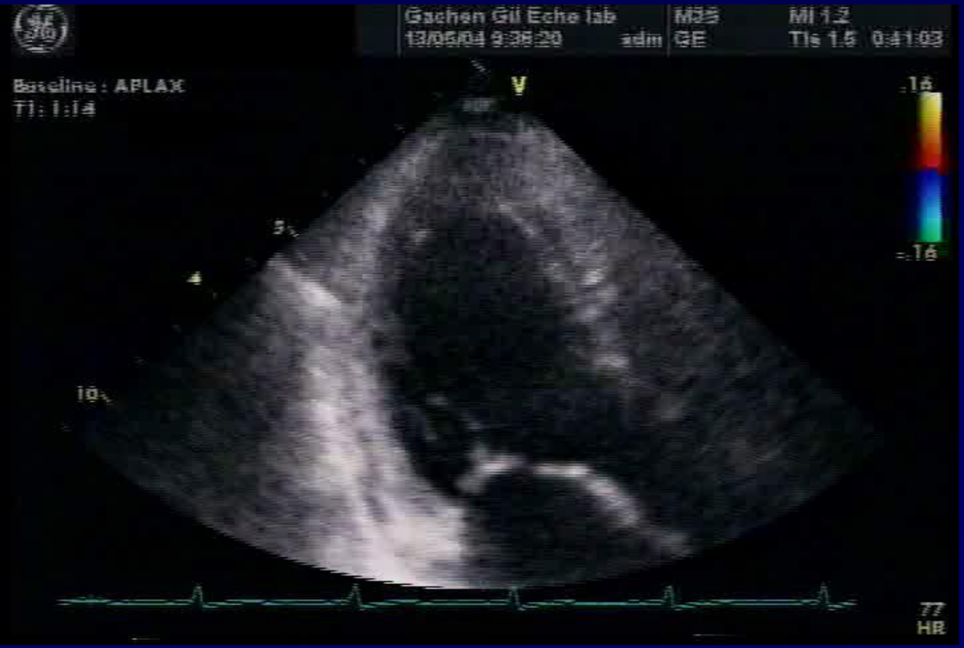
Detection of Mycardial Viability



Qureshi U et al, Circ 95:626, 1997

가천대학교


Gachen Gil Echo lab
13/05/04 9:51:58
adm
M3S
GE
MI 1.2
TIs 1.5
0:43:00
Baseline : APLAX
10ug : APLAX
HR


Gachen Gil Echo lab
13/05/04 9:36:20
adm
M3S
GE
MI 1.2
TIs 1.5
0:41:03
Baseline : APLAX
T1: 1:14
77
HR


Gachen Gil Echo lab
16/08/05 17:02:37
adm
M3S
GE
MI 1.3
TIs 0.8
1:49:06
64
HR

Regional Wall Motion in 2D Echo

- Wall thickening
- Endocardial motion
- Synchronicity

Regional Wall Motion in 2D Echo

Problems of `Eye Ball` Assessment

1. Limited temporal resolution
2. Only radial motion
3. Interobserver variability
4. Long learning curve

Need Quantitative Measurements !

Importance of **Quantification**

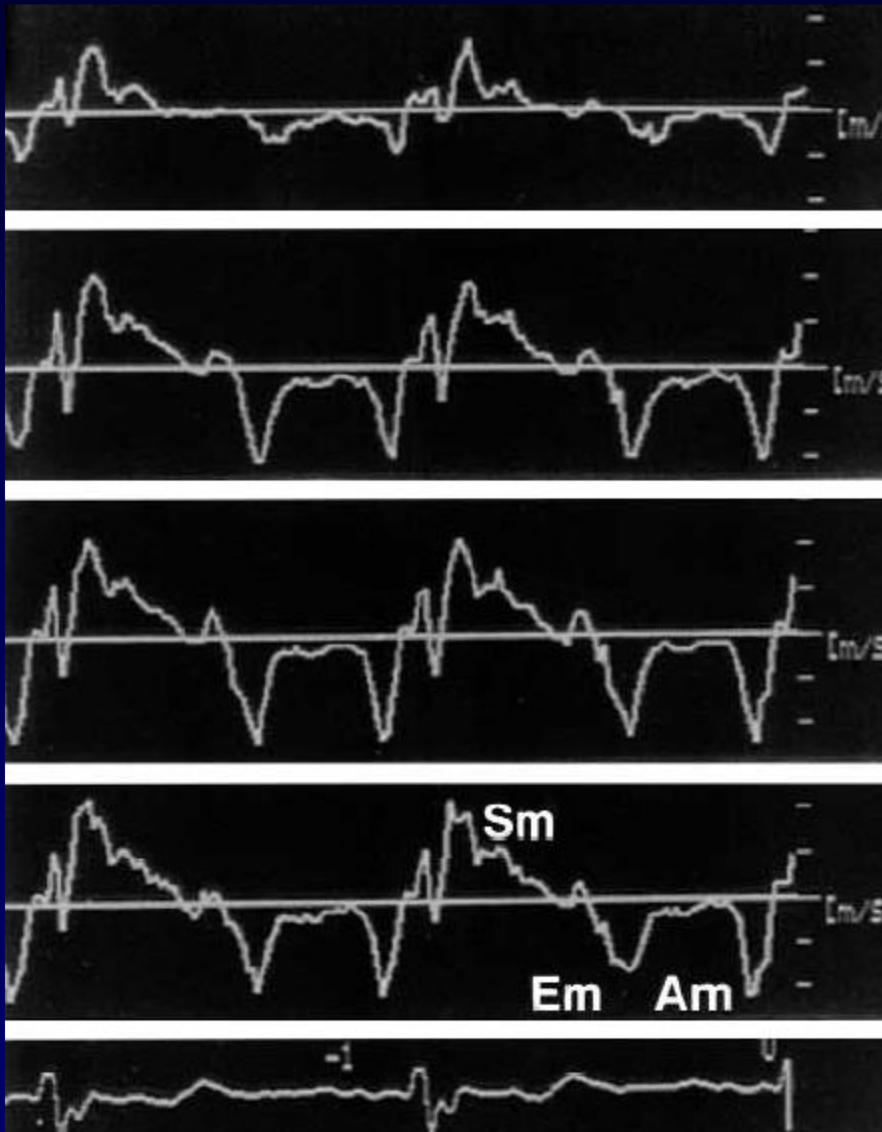
" If you can't measure it, you can't manage it. "

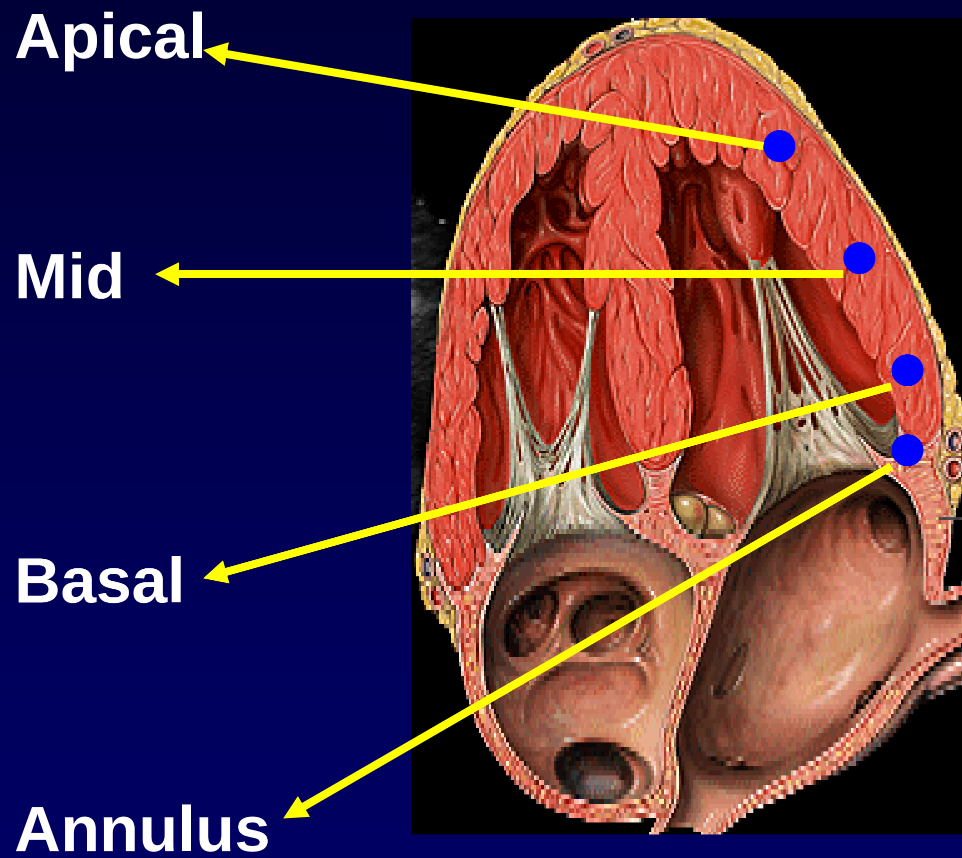
Peter F. Drucker (1909-2005)

Quantification of Wall Motion

Tissue Doppler Imaging
Deformation Imaging

Longitudinal Myocardial Velocity

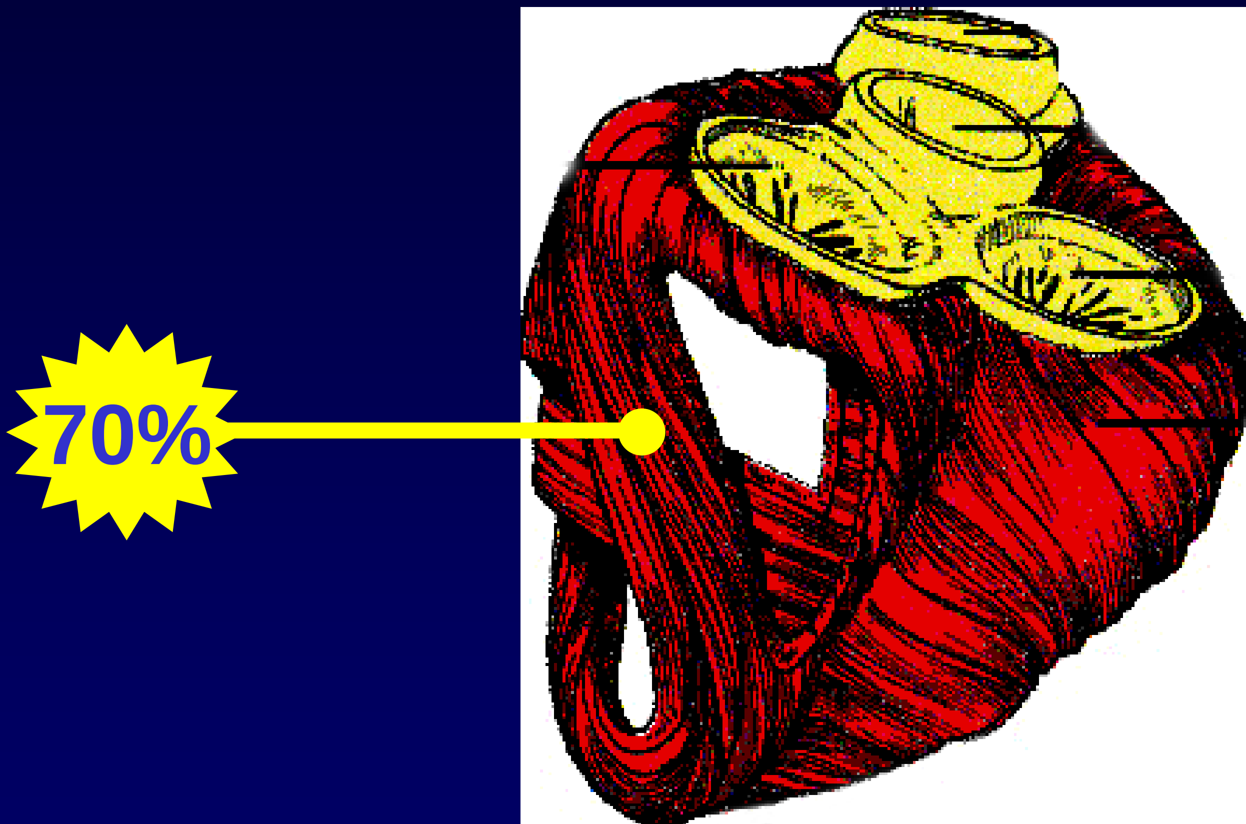




Palmes et *al., J Am Soc Echocardiogr, 2001*

아름다운 인재의 샘 가천대학교

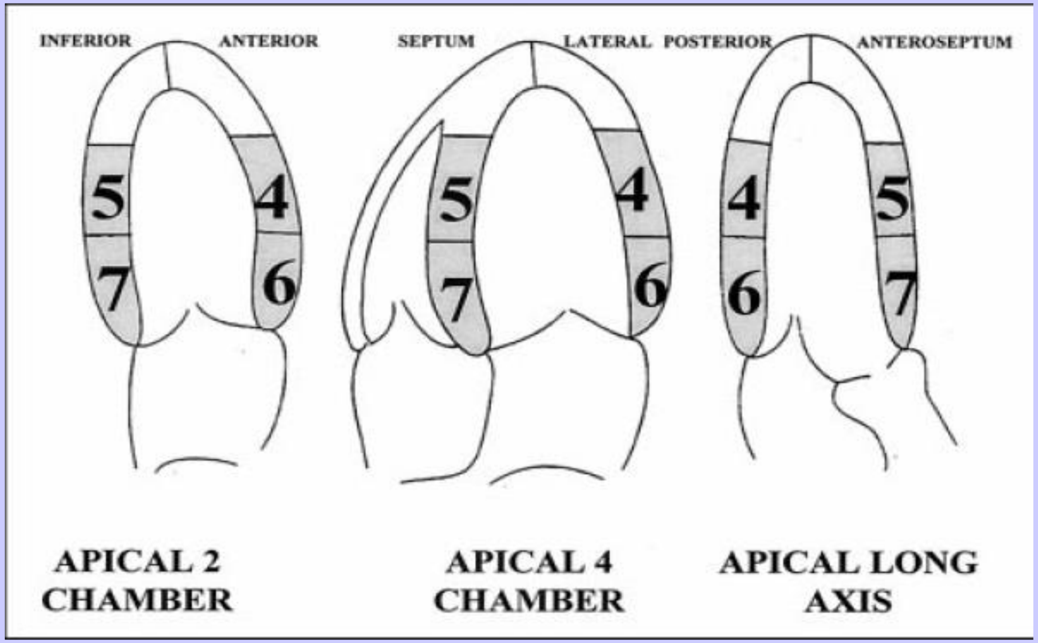
“The Left Ventricle is ”…

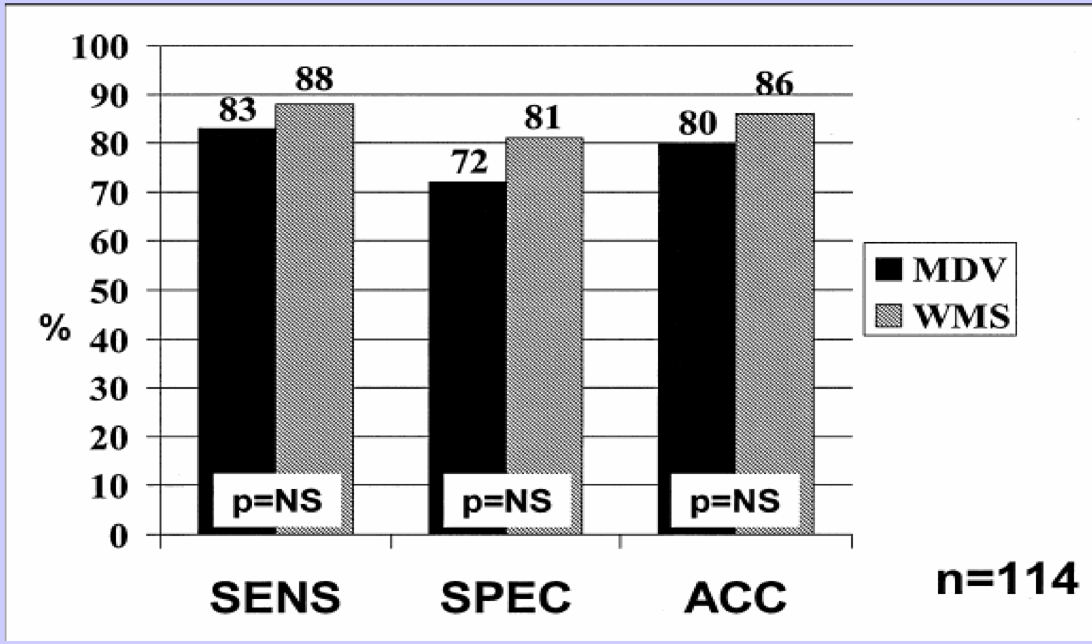


Isaac K, et al., J Am Soc Echocardiogr, 1993

70% of the muscle fibers are longitudinal!

Segmental TDI (S’) for IHD during Dobutamine Stress Echo

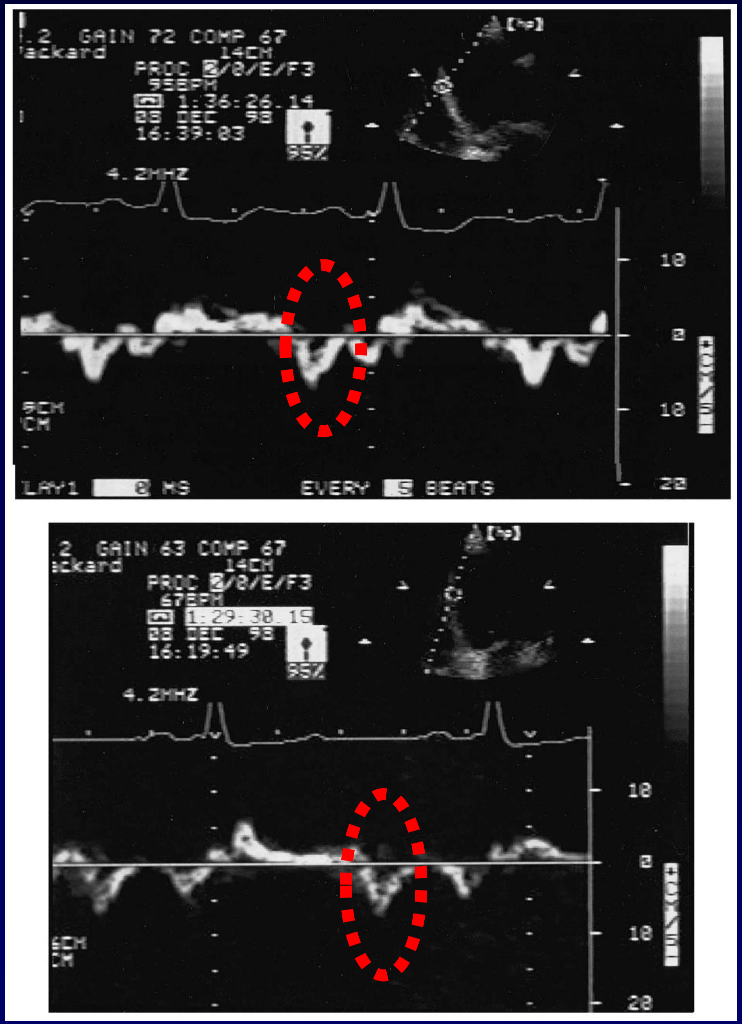


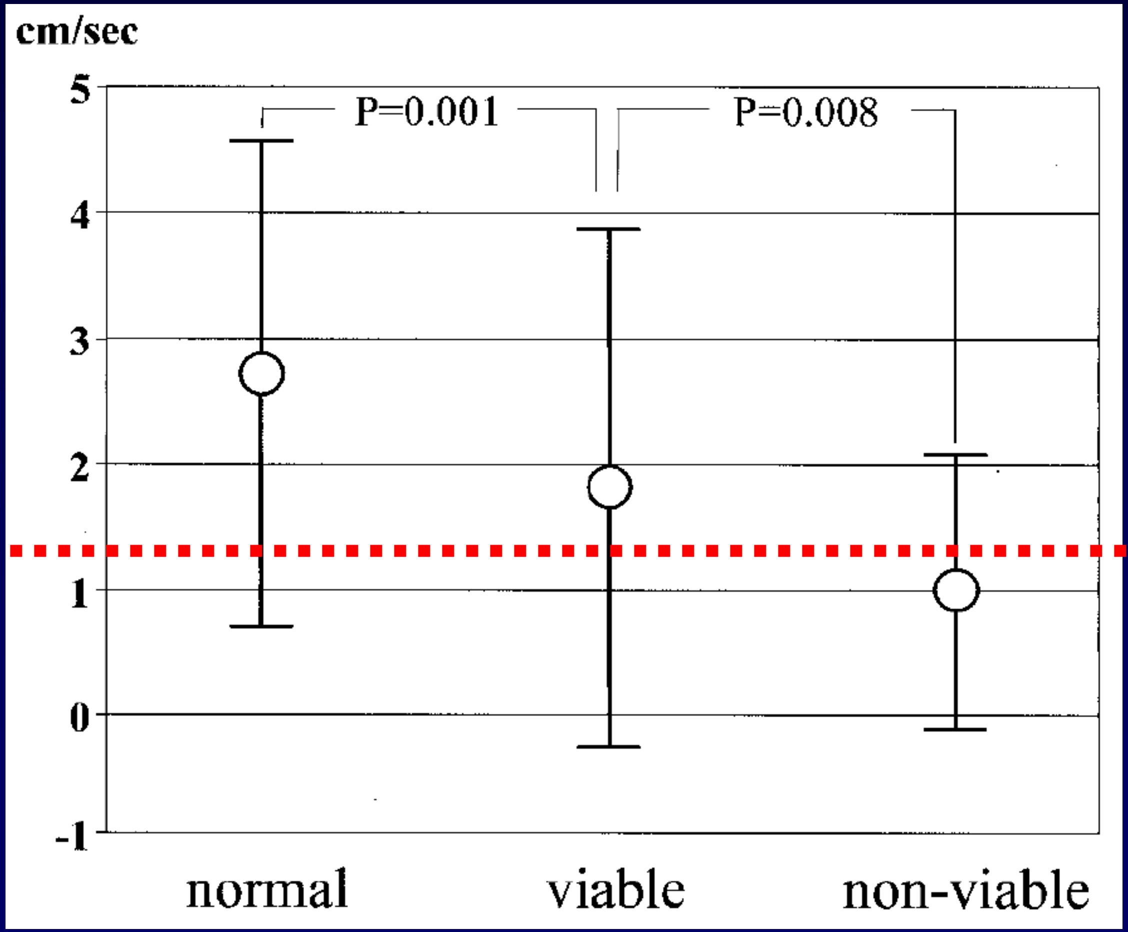


Marwick T. Am J Cardiol 2001;87:525–31.

Change of S' during LD-Dobutamine Stress Echocardiography

c/w PET, n=36

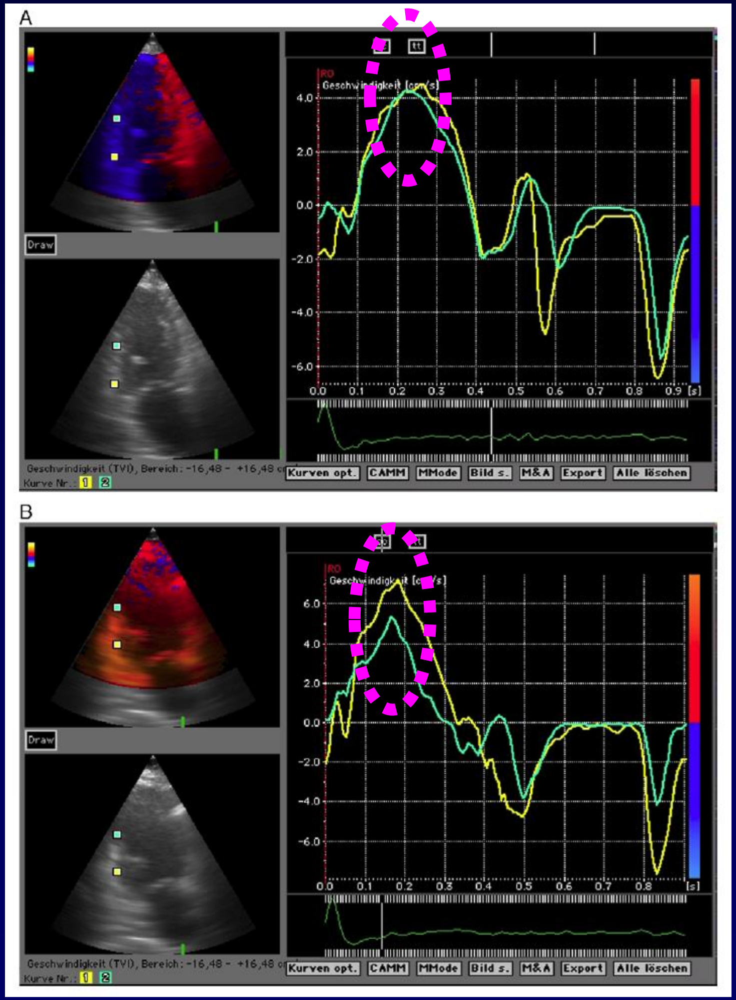




Yuan D,,Hoffmann R. Echocardiogr 2001;18(8):657-64.

Change of S' during LD-Dobutamine Stress Echocardiography

c/w 3M F/U Echo, n=56

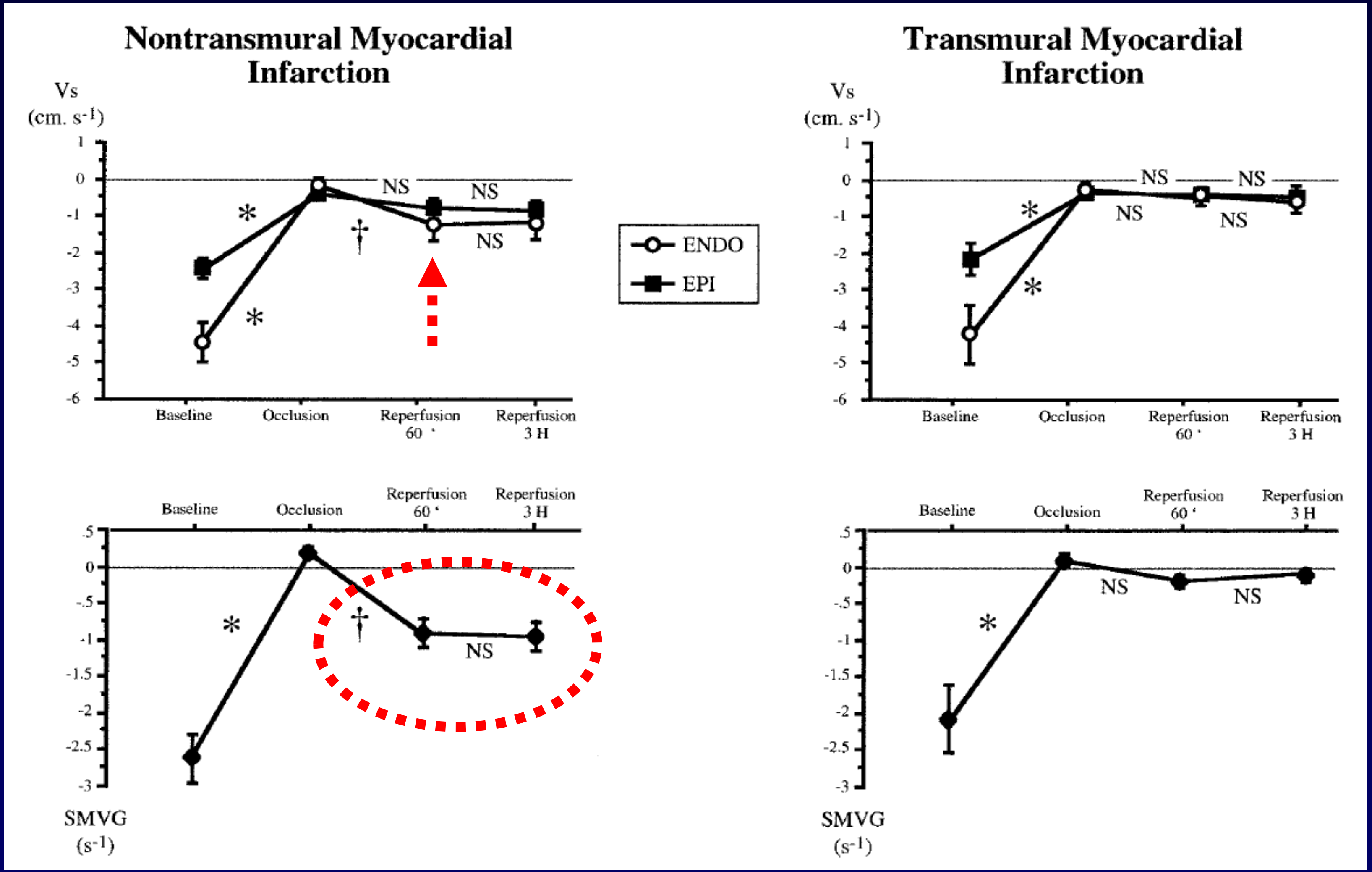


	Basal	Midventricular	Apical	p
Viable				
Rest V_{peak}	5.1	4.6	4.2	0.23
Stress V_{peak}	7.7	7.2	6.8	0.61
Increase in V_{peak}	1.6	2.6	2.6	0.14
Increase in %	31.4	56.5	61.9	0.69
Nonviable				
Rest V_{peak}	5.7	3.3	2.9	0.0012
Stress V_{peak}	6.4	3.8	3.6	0.002
Increase in V_{peak}	0.7	0.5	0.7	0.81
Increase in %	12.3	15.1	24.1	0.27

By ROC analysis, a cut-off value of 1.0 cm/s was the best parameter to differ viable from nonviable myocardium (area under the curve 0.85; p <0.01; 95% CI 0.79 to 0.90).

Schneider C,et al. Int J cardiol 2006;110:15-21.

TDI Strain Differentiates Transmurality in AMI After Reperfusion

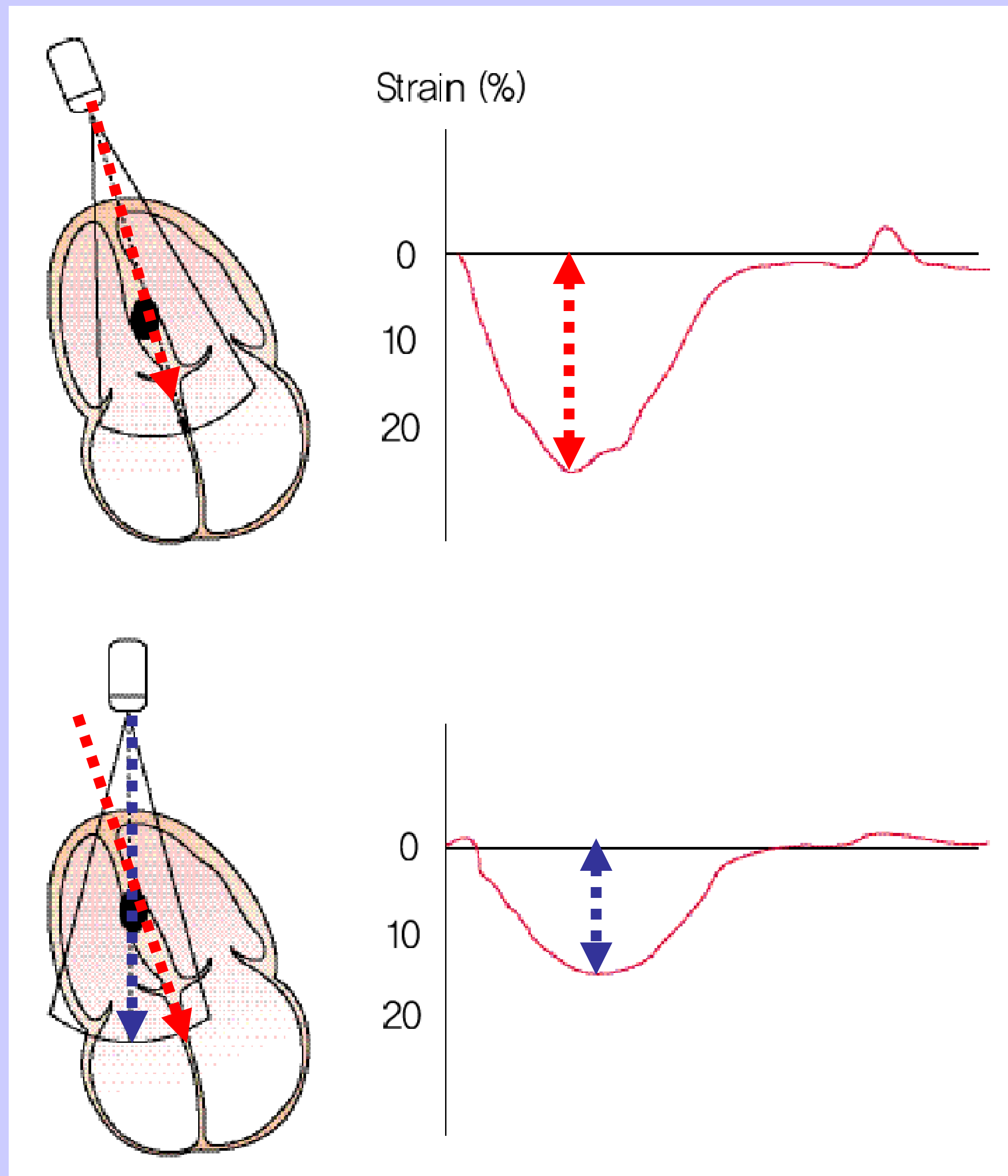


Derumeaux G et al. Circulation 2001;103:589-96

Limitations of TDI

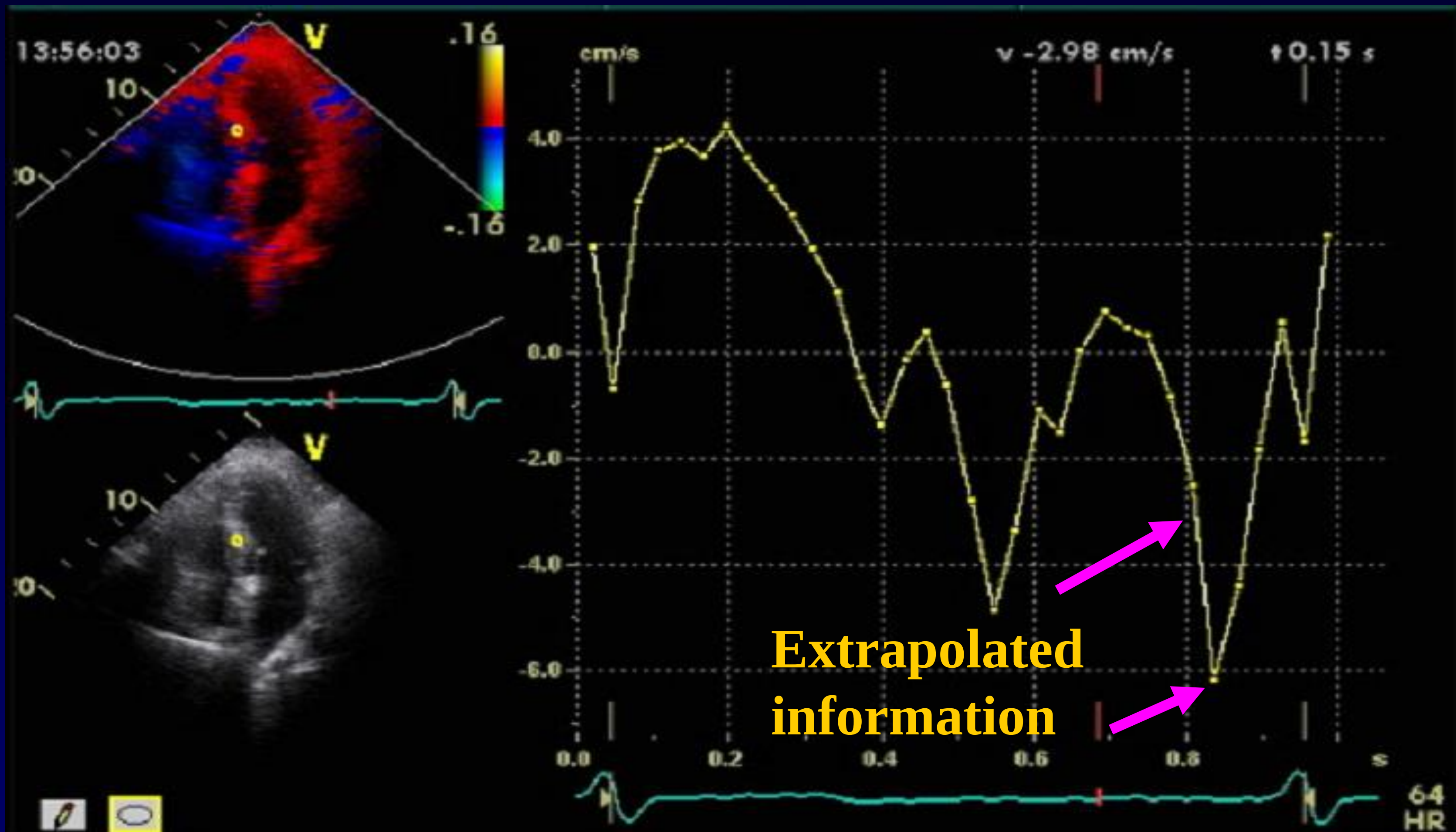
- ✓Angle dependency
- ✓Frame rate dependency
- ✓ 'Tethering' (묶임현상)

Angle Dependency of TDI



임상 심초음파학 제2판 p187

Low Frame Rate TDI Data



More data points, More accurate waveforms!

' Tethering(묶임현상)' of TDI

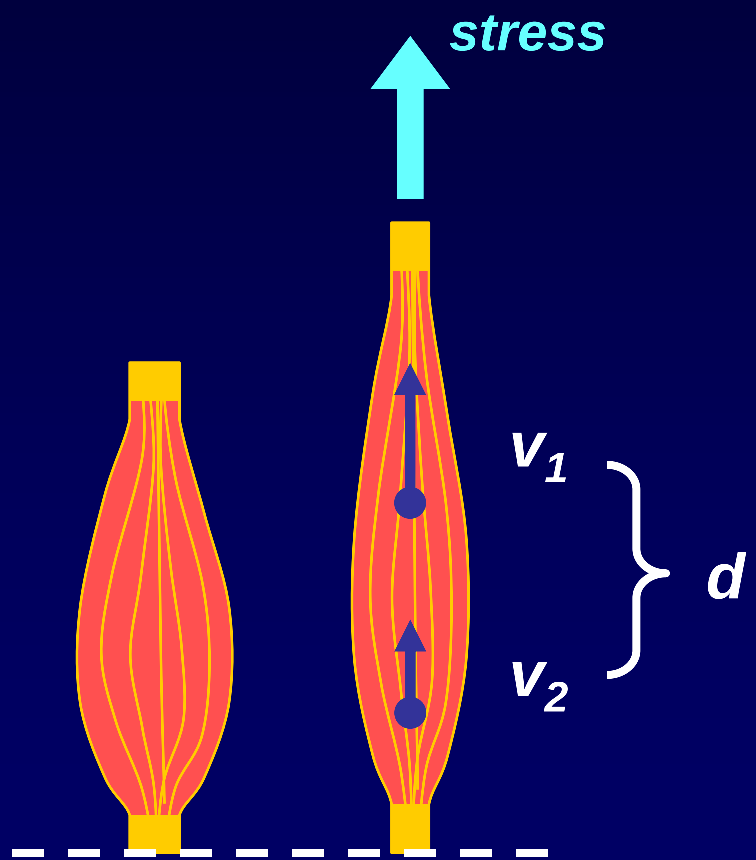
Limitations of TDI Stress Echo

- ✓ Angle dependent
  -> Need of 'Narrow angle'

- ✓ Not simultaneous assessment
  -> Color spectral TDI
  (frame rate dependent)

- ✓ 'Tethering'

"Strain Rate": *Rate of Deformation*
(Spatial velocity gradient)



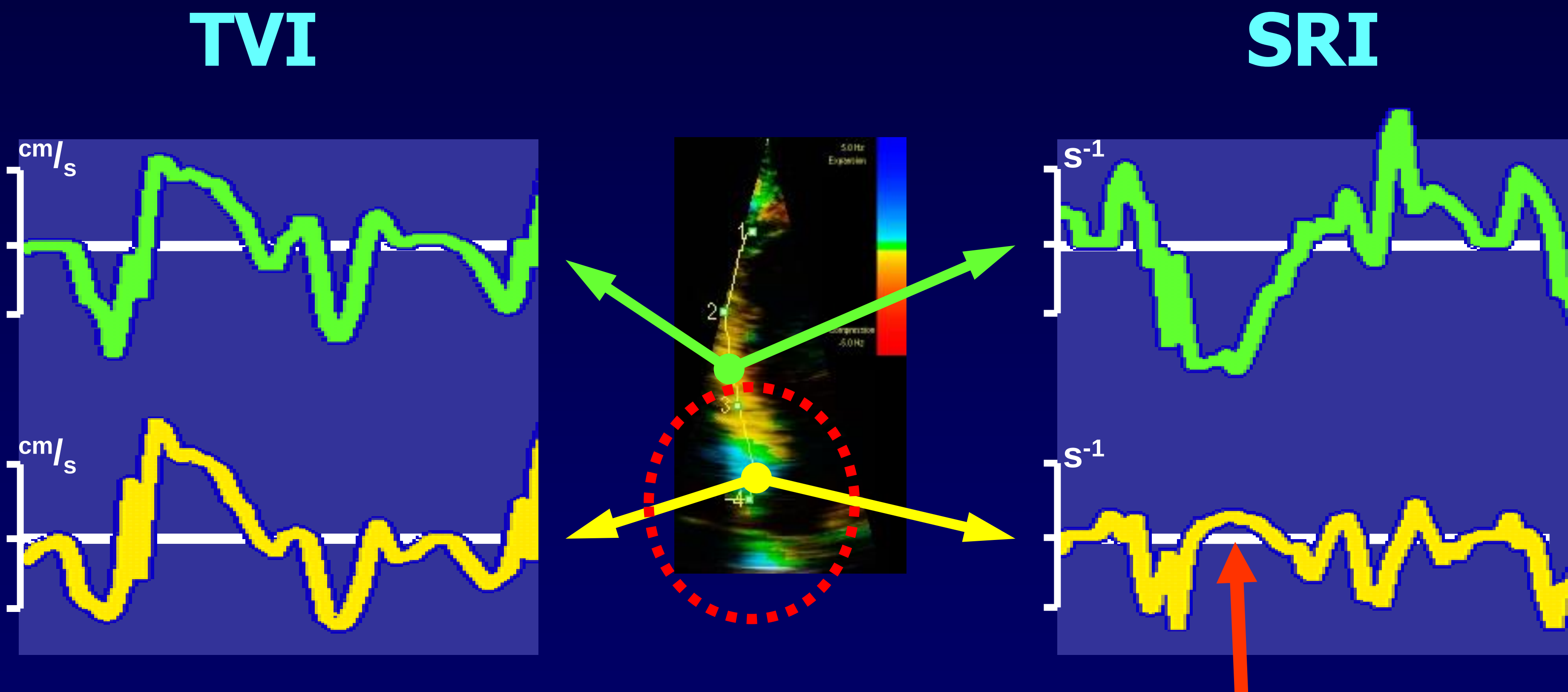
$$Strain\ Rate = \frac{V_1 - V_2}{d}$$

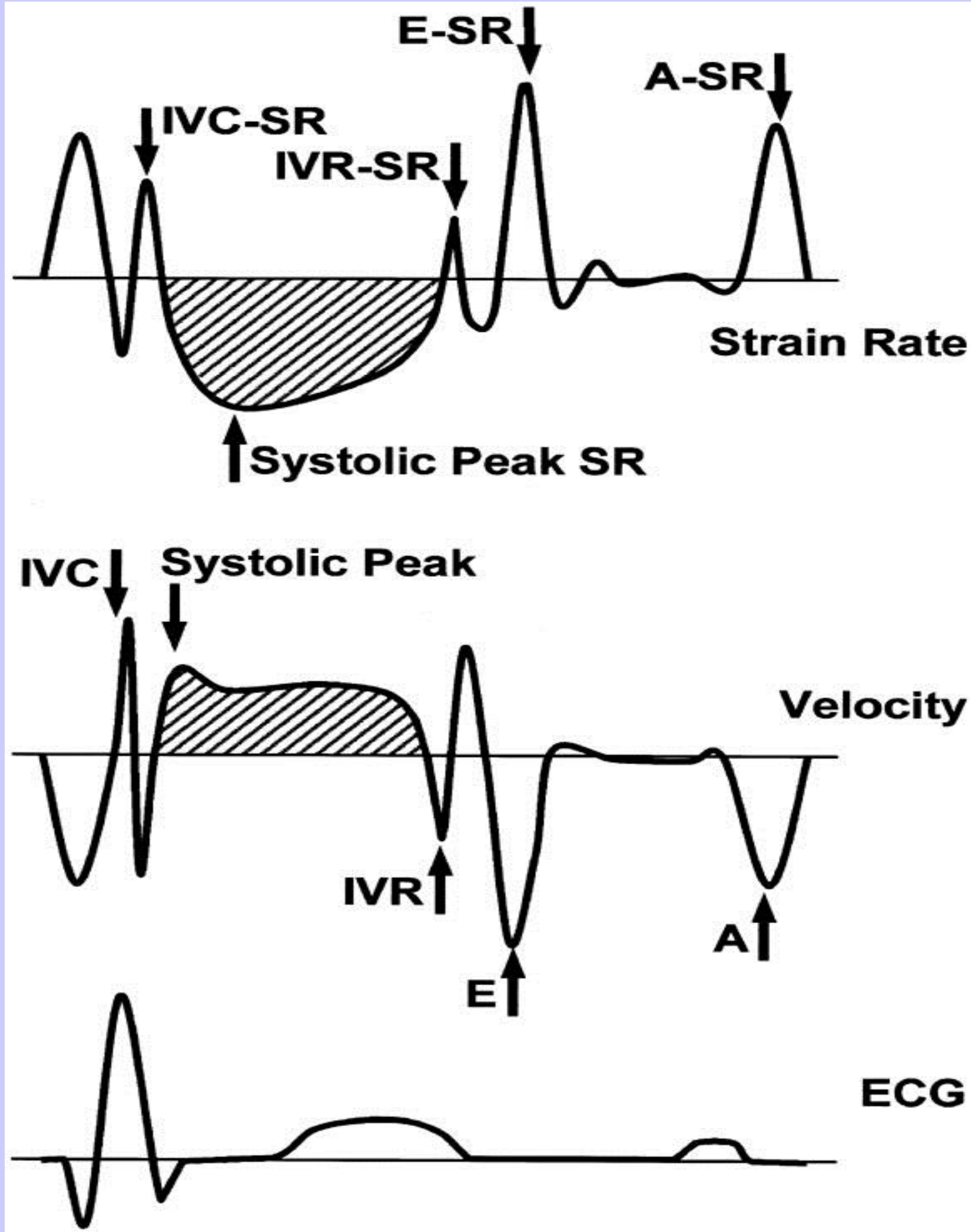
No influence of translation

Really local information

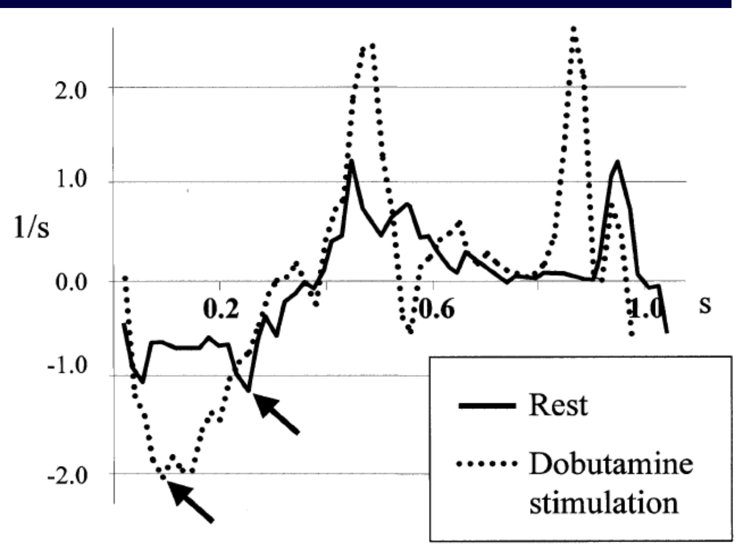
Advantage of Strain Rate Imaging vs TDI

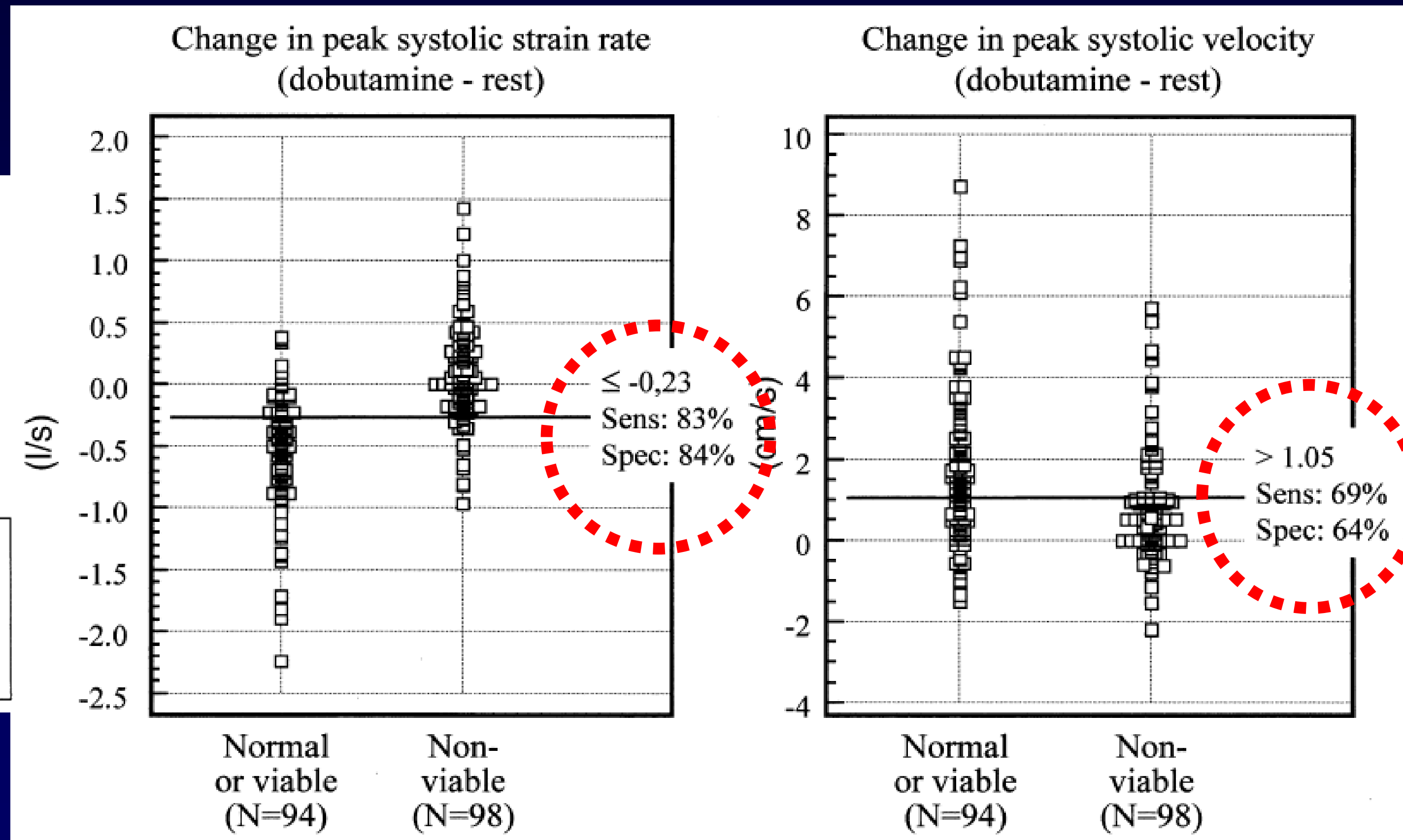
Basal septal akinesia




E-SR
A-SR
IVC-SR
IVR-SR
Strain Rate
Systolic Peak SR
IVC
Systolic Peak
Velocity
IVR
E
A
ECG

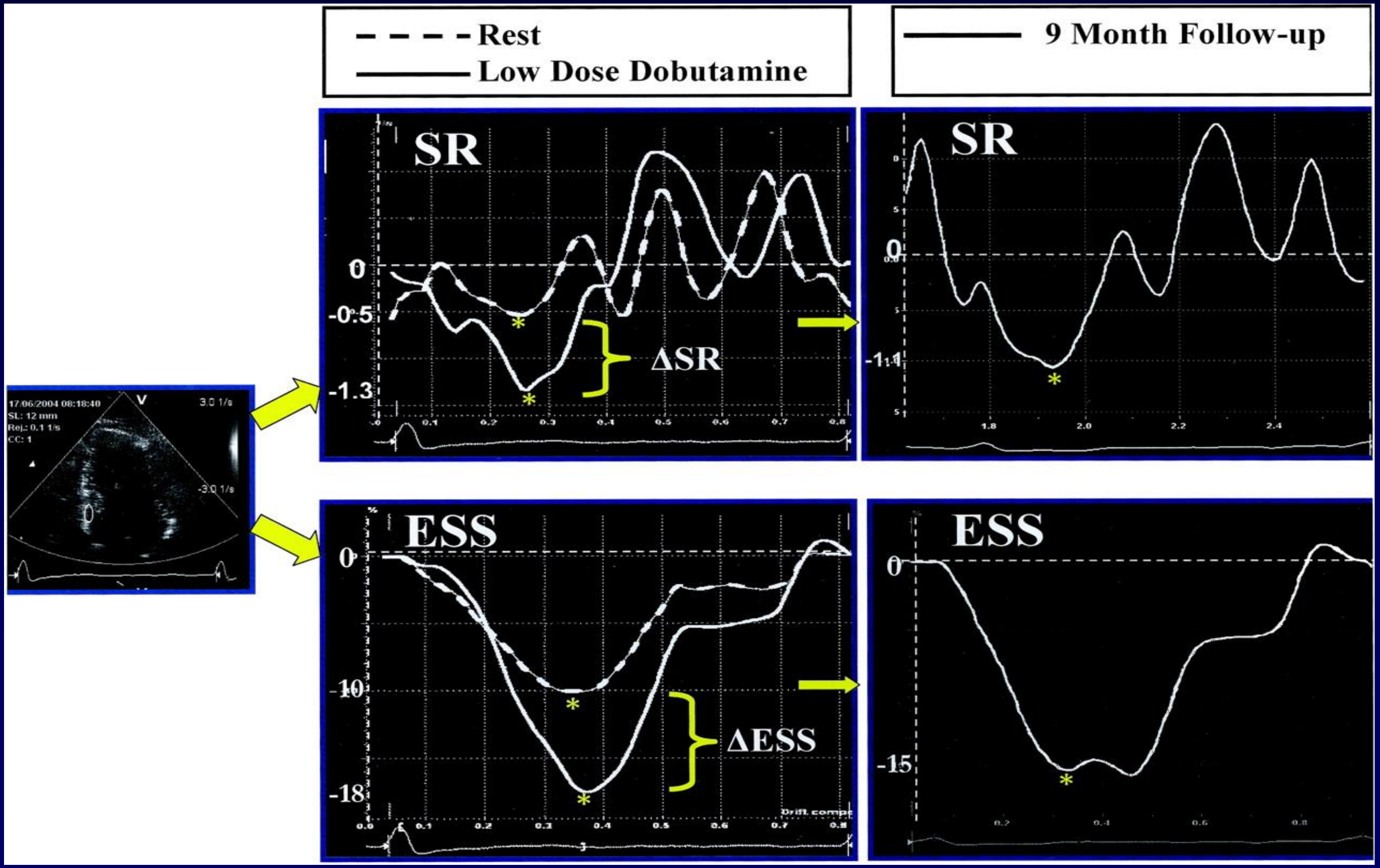
Peak Systolic Strain Rate during Dobutamine Stress Echocardiography



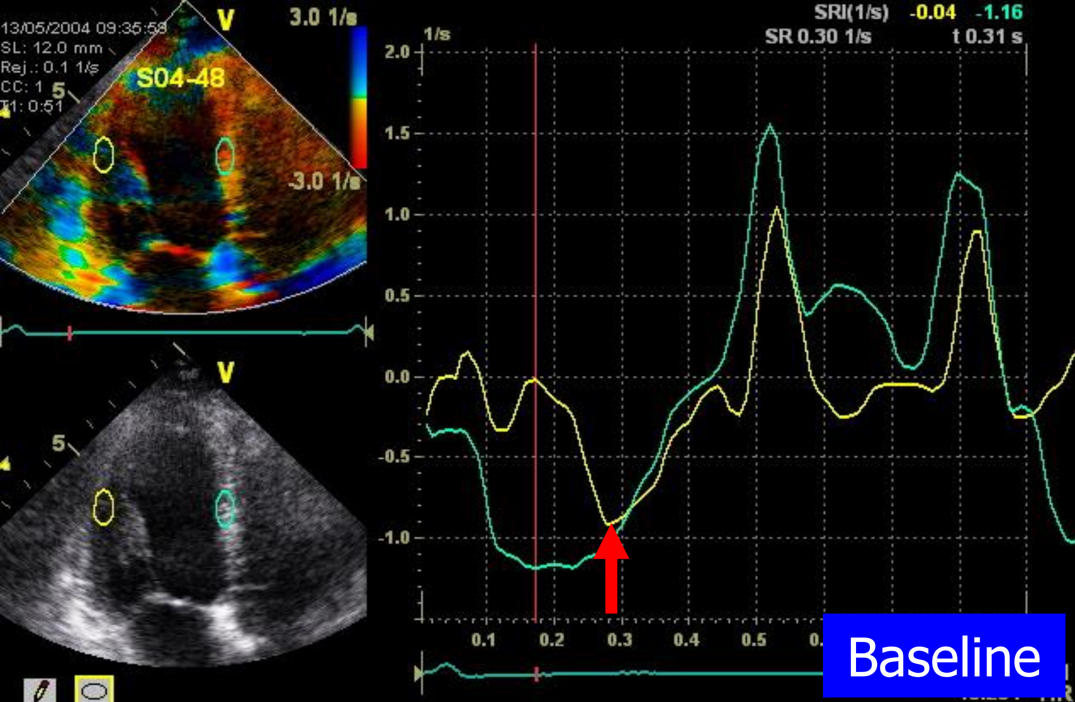


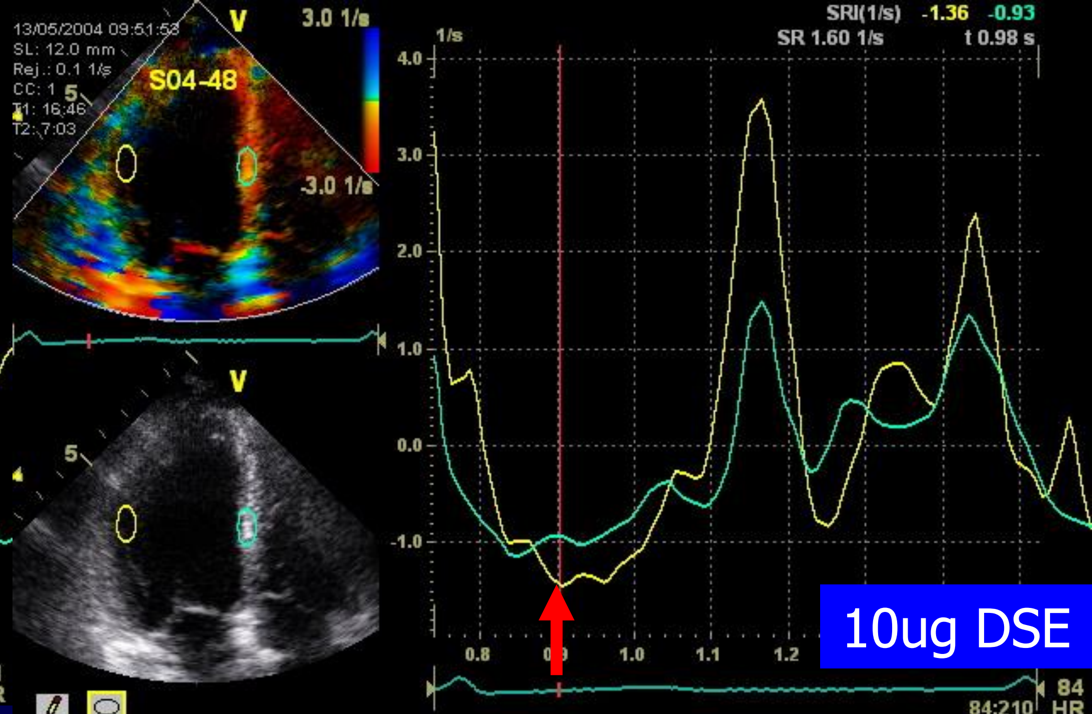
Hoffmann et al. JACC 2002;39:443-9.

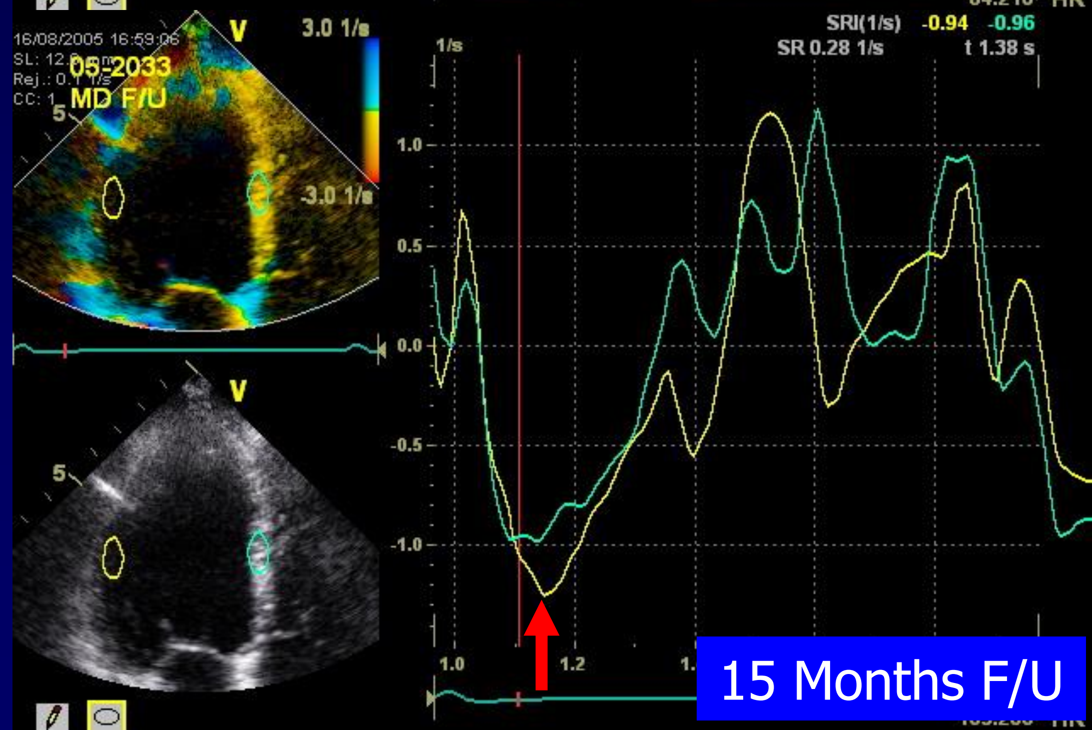
Incremental Value of SRI Assessment of Myocardial Viability after Revascularization



Hanecom et al. Circulation 2005;20;112(25):3892-900.





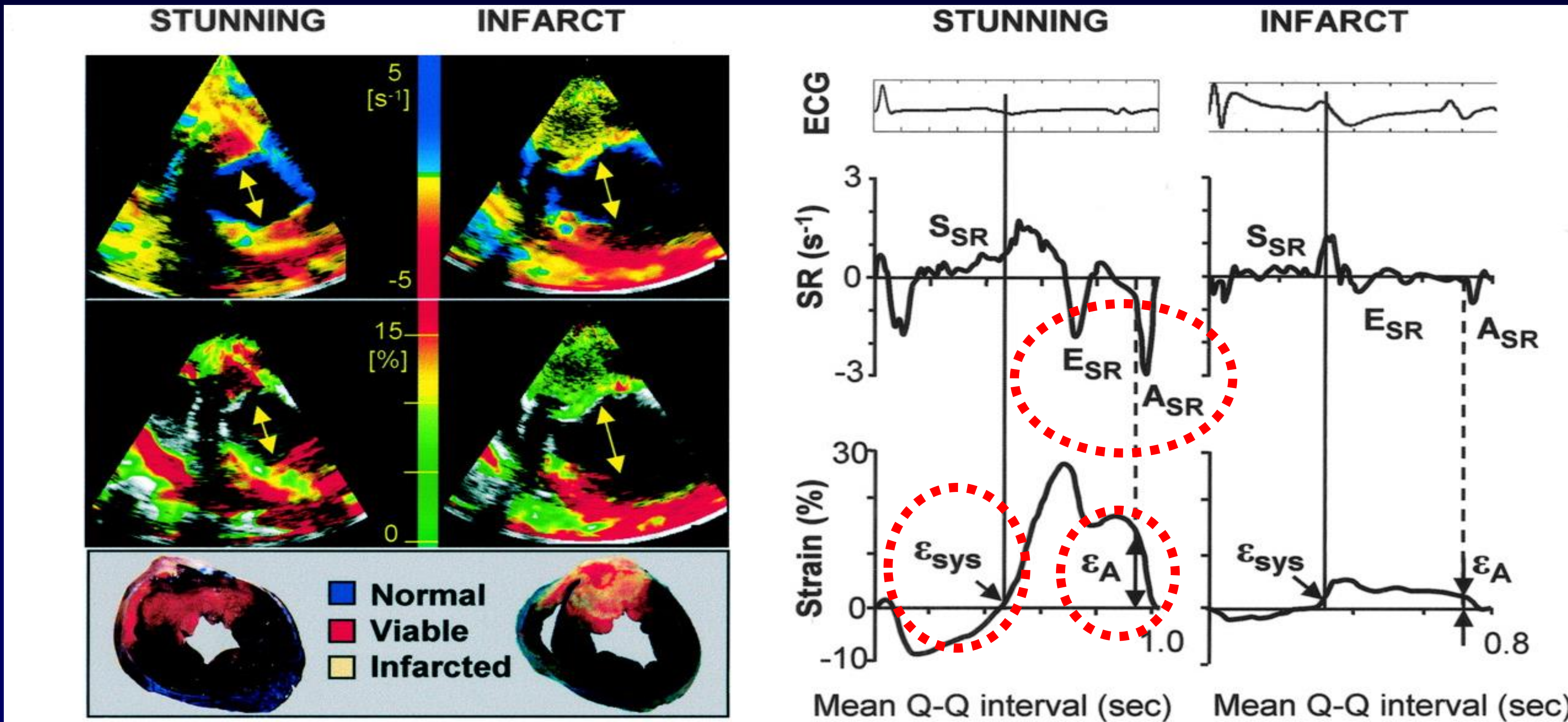


F/60, NSTEMI s/p tirofiban
EF=53% (LVEDV/ESV=80.5/37.8ml)
E/E'=9.38
NT-proBNP=476ng/L
Lt main and 2VD,
LVEDP=9mmHg, PCWP=5mmHg

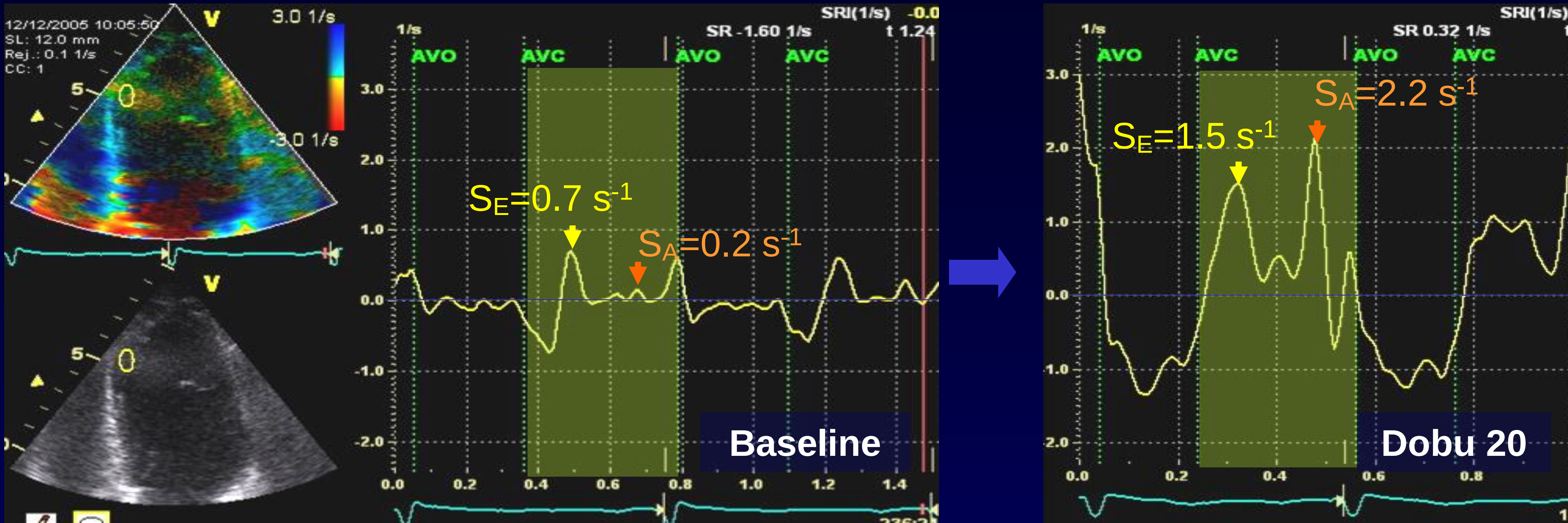
20466383 (MD#97)

Altered Myocardial Stiffness

Stunned Vs. Transmural Infarct



Pislaru et al. Circulation 2004;109:2905-10.



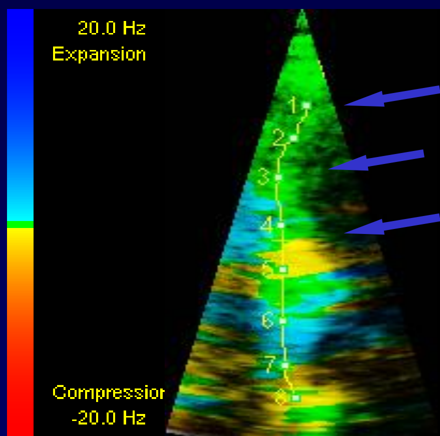
	Normal	Viable by PET	Nonviable by PET	*Viable & nonviab*
Peak SR_E at rest	1.13±0.58	0.89±0.51	0.77±0.49	0.103
Peak SR_E with dob	1.30±0.61	1.06±0.51	0.78±0.48	<.001
ΔPeak SR_E with dob	0.17±0.58	0.17±0.59	0.01±0.60	0.049
Peak SR_A at rest	0.98±0.61	0.71±0.55	0.57±0.47	0.055
Peak SR_A with dob	1.24±0.64	1.00±0.56	0.71±0.58	<.001

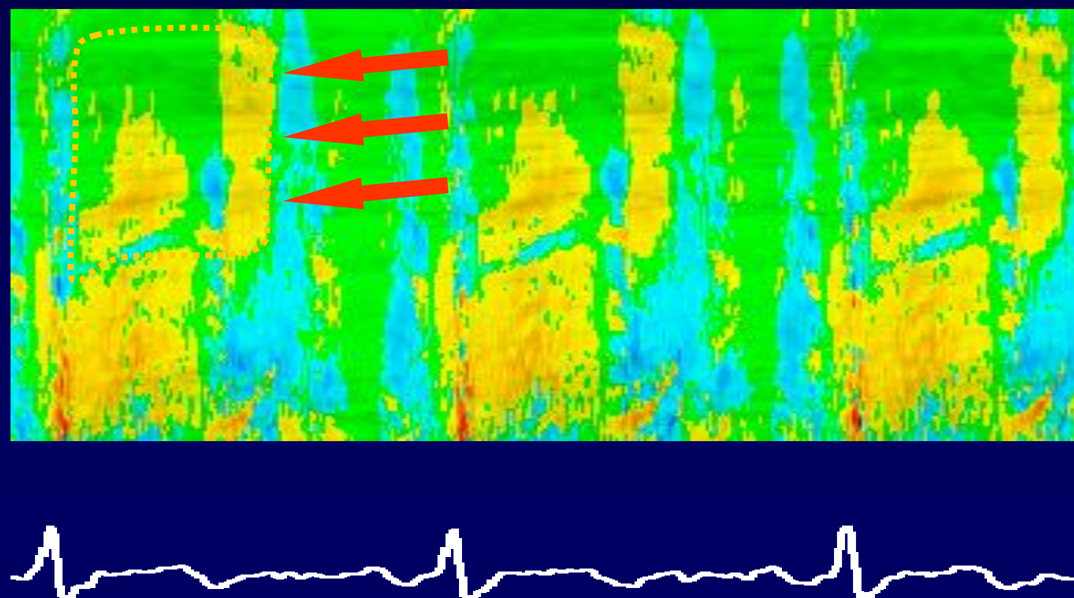
n=37

Hoffmann R, et al. Am Soc Echocardiogr 2005;18(4):330-5.

Strain Rate for Assessing Viability

Acute myocardial infarction in man
(LAD occlusion)

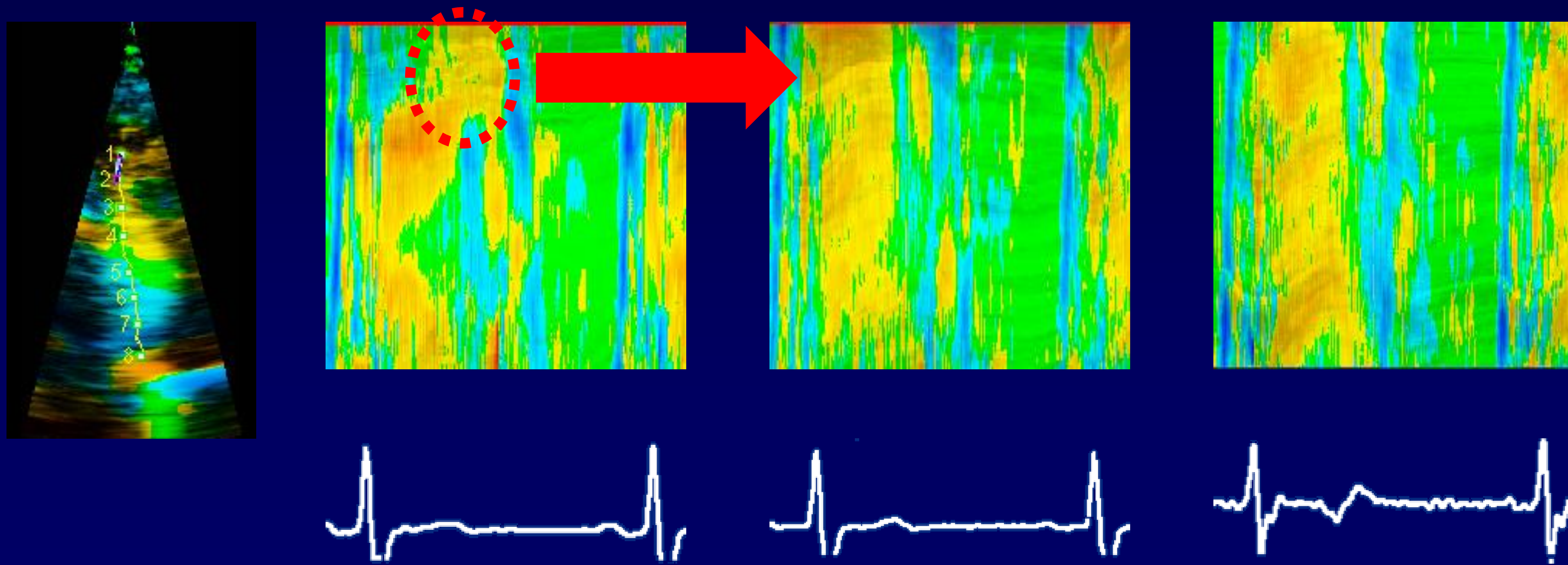


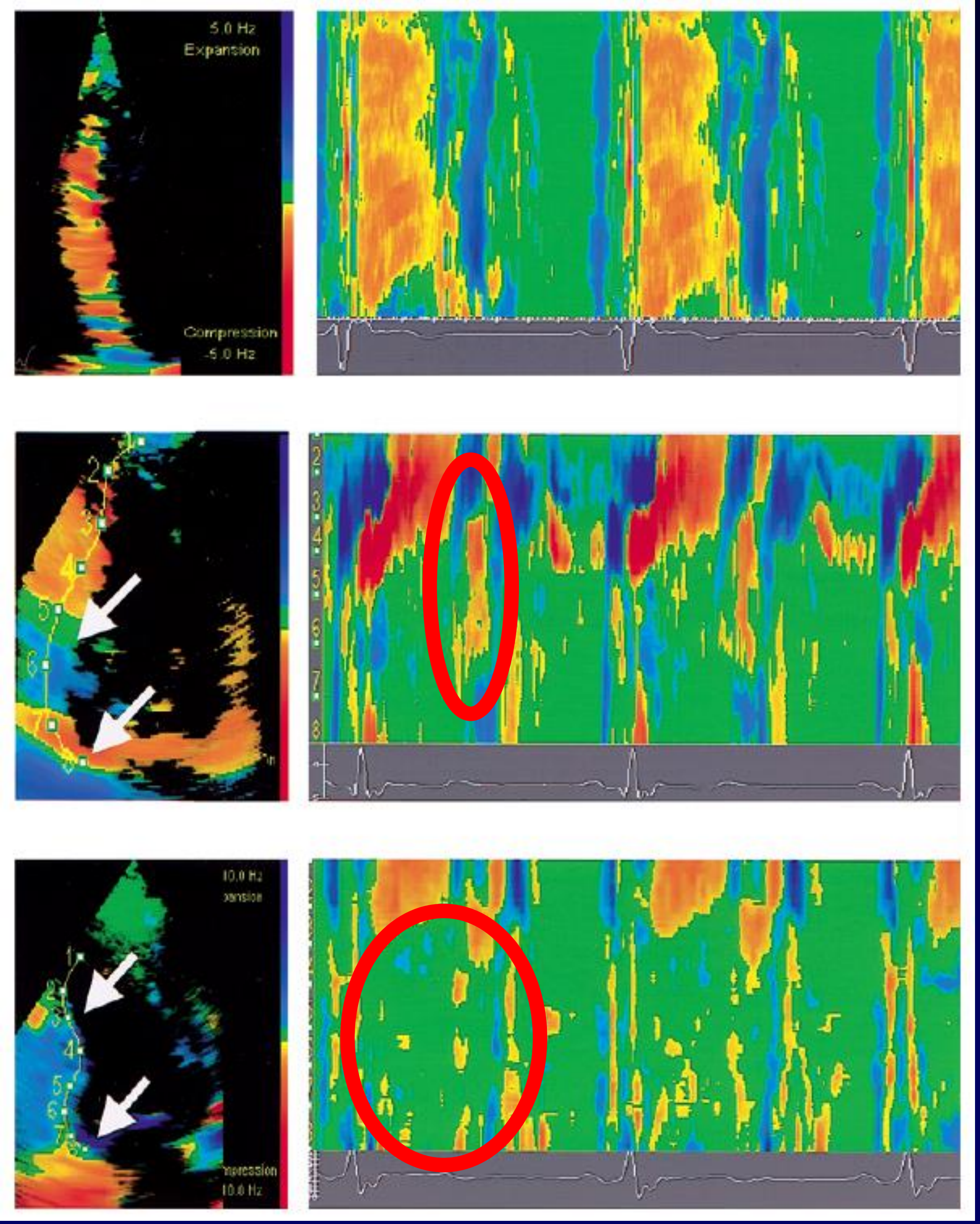


Strain Rate for Assessing Viability

Recovery

acute MI | 1 day | 2 weeks





Apex

Normal

Base

Apex

Acute Inferior MI

Base

Apex

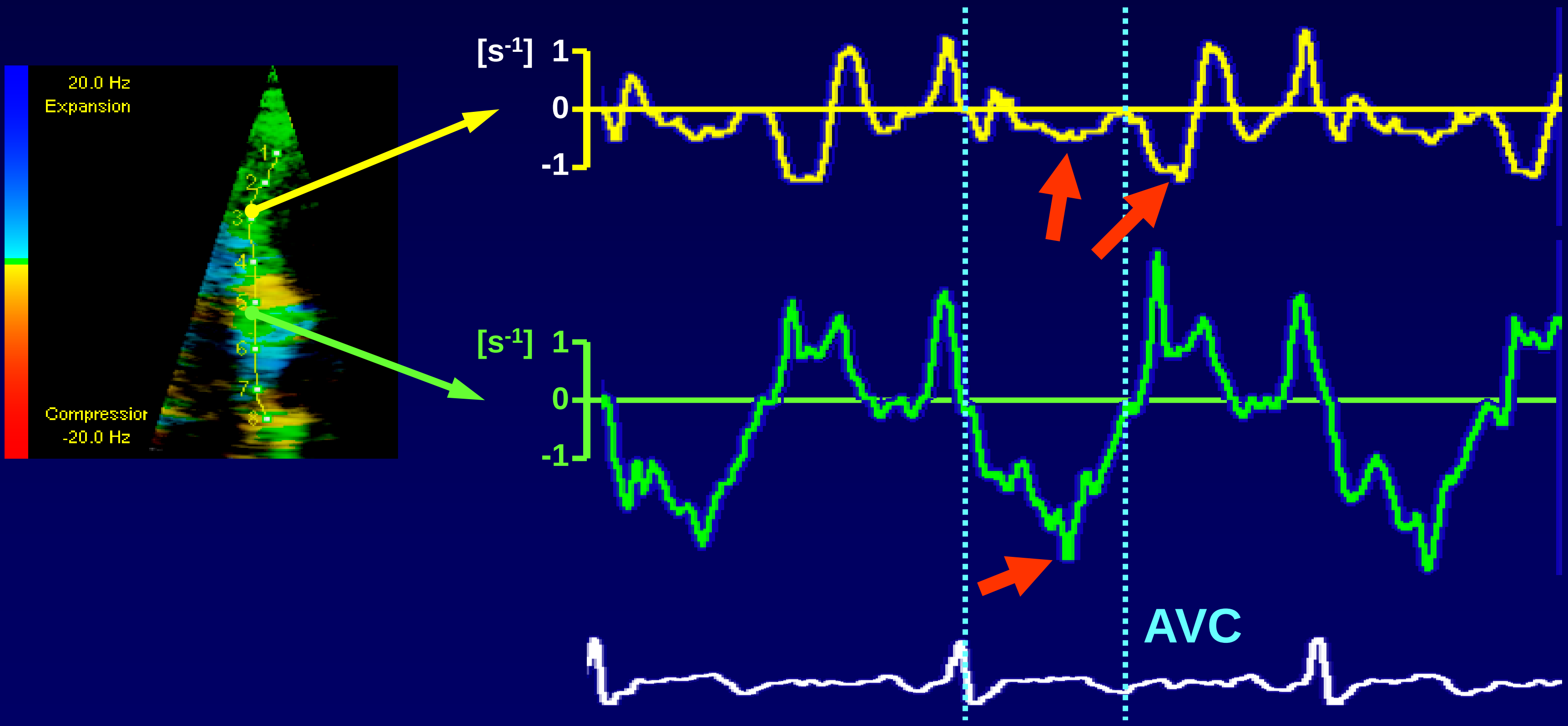
Chronic Inferior MI

Base

Hatle L, et al, Eur Heart J, 2000

Strain Rate for Assessing Viability

Acute myocardial infarction in man (LAD occlusion)



Tennant R and Wiggers CJ. Am J Physiol. 1935;112:351-61.

THE EFFECT OF CORONARY OCCLUSION ON MYOCARDIAL CONTRACTION[1]

ROBERT TENNANT[2] AND CARL J. WIGGERS

From the Department of Physiology, Western Reserve University Medical School, Cleveland, O.

Received for publication March 22, 1935

Many students of the coronary circulation must have noted that the ventricular zone affected by ligating a large coronary branch not only appears cyanotic and dilated, but that it seems to alter in its mode of contraction. The detailed and sequential changes in contraction are not easily followed by the unaided eye and so far have not been recorded myographically. The reasons for this were the lack of an adequate and suitable myograph and a technic for the application of one to a limited ventricular surface so that records obtained represent, at least reasonably well, changes in muscle length and not predominantly artefacts due to position changes, thrusts and vibrations of the vigorously beating ventricle.

This communication concerns itself with descriptions of a technique and of a type of optical myograph suitable for such studies and an analysis of the changes in optical myograms which follow clamping of a large coronary vessel.

Apparatus. After preliminary efforts to obtain satisfactory ventricular myograms with the segment myograph used by one of us (Wiggers, 1916) to study auricular contraction, it became obvious that in order to overcome the distortions produced by twists and thrusts of the beating ventricle an instrument was needed in which the movable lever arm operates in fixed bearings. A suitable myograph which retains the compactness, lightness and efficiency of the earlier form is illustrated in figure 1. The body of the instrument consists of a small receiving tambour, *E*, (2.5 cm. in diameter) from which a tube leads off at right angles for connection with an optical segment capsule. The lever arms which are of aluminum are spaced 1.5 cm. apart. The rigid arm, *A*, is attached solidly to the back of the tambour and the movable one, *B*, is pivoted in jewel bearings, *C*, as indicated in the insert sketch. The total weight of the myograph is only

[1] The expenses of this investigation were defrayed partly from a grant to one of us (C. J. W.) by the Ella Sachs Plotz Foundation, and partly from a grant to the other (R. T.) by the Josiah Macy, Jr. Foundation.

[2] Fellow of the National Research Council.

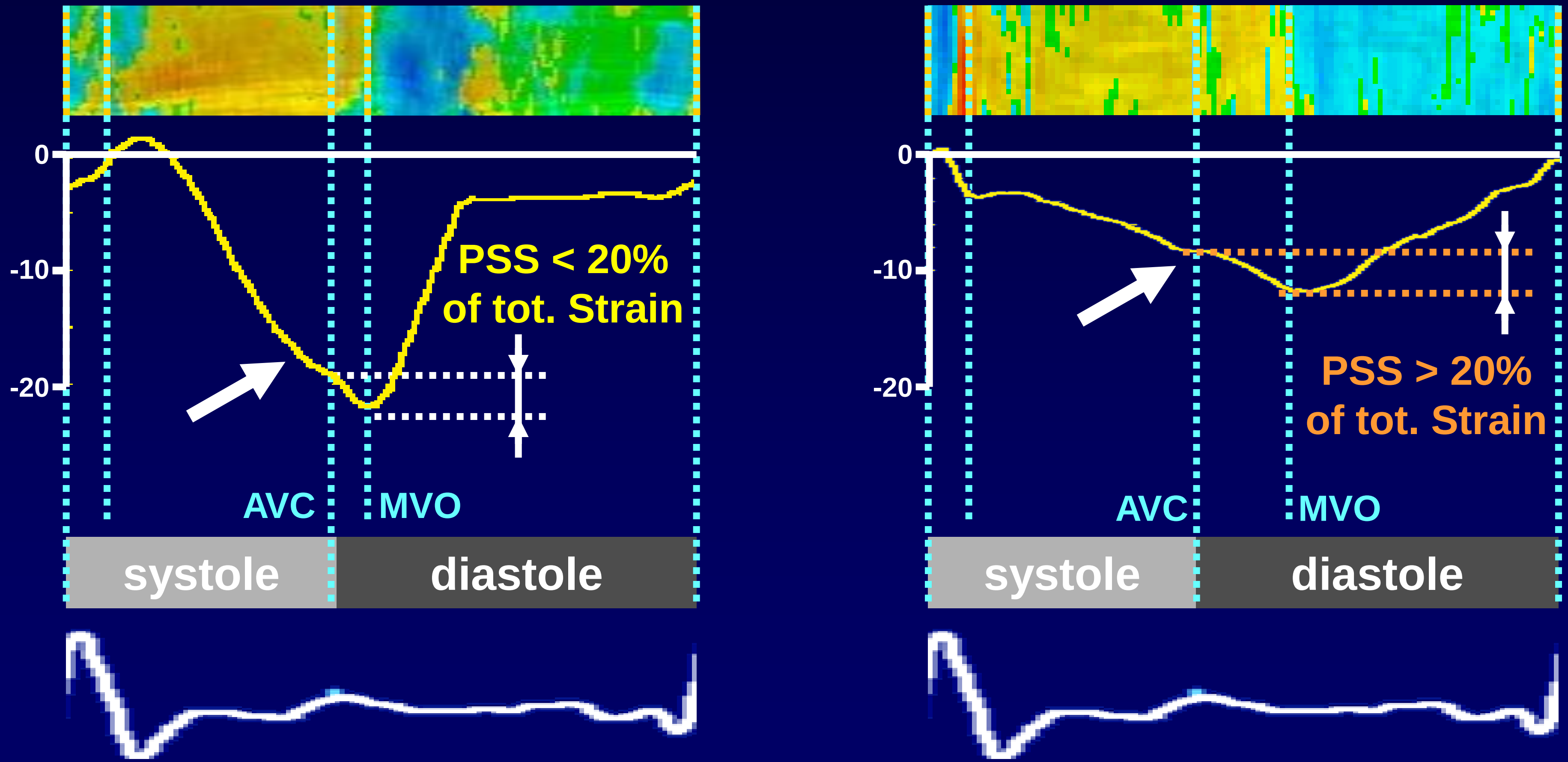
Post Systolic Thickening

- First described by Tennant and Wiggers.
- ***Common finding in myocardial infarction***.
- Small area of contraction interspersed by akinetic and hypokinetic segment after MI.
- ***Good predictor of viable myocardium.***
- ***Underlying mechanisms are unclear.***

  (Active fiber shortening or passive thickening)

Post Systolic Shortening

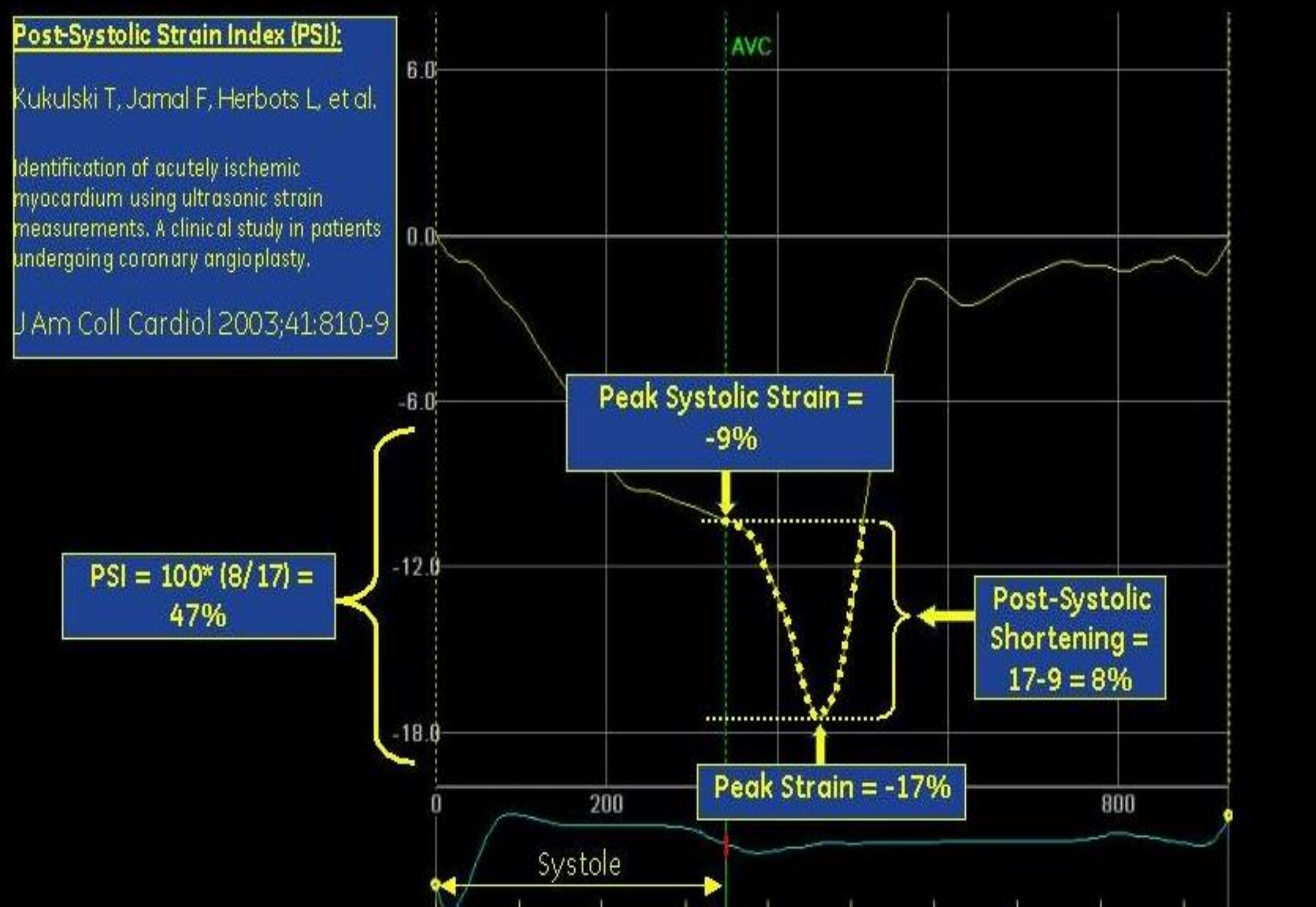
Defined as predominantly negative Strain between AVC and E-wave (MVO)



Post Systolic Strain Index

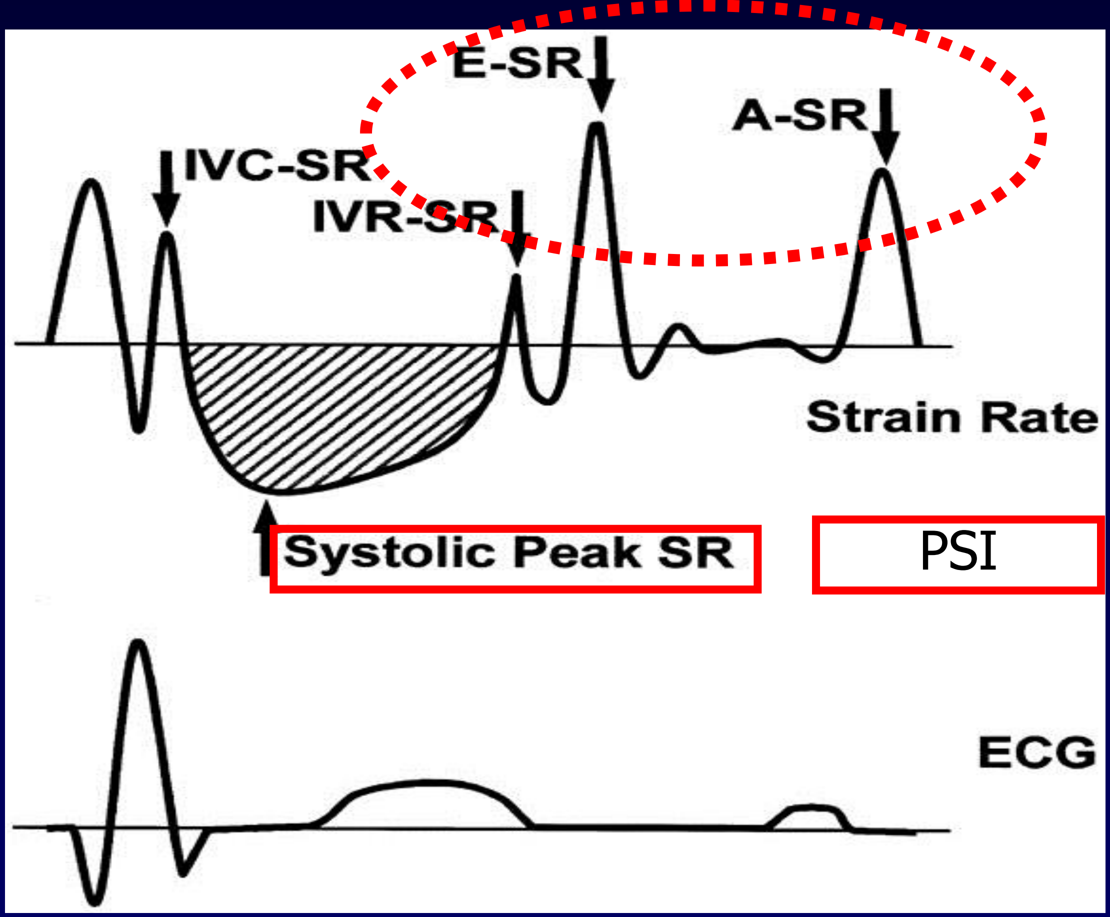
- PSS Bulls Eye
- PSI Bulls Eye
- Post Systolic Index
- PSS manual correction
- Pre-stretch definition
- Trace Analysis

Post Systolic Index

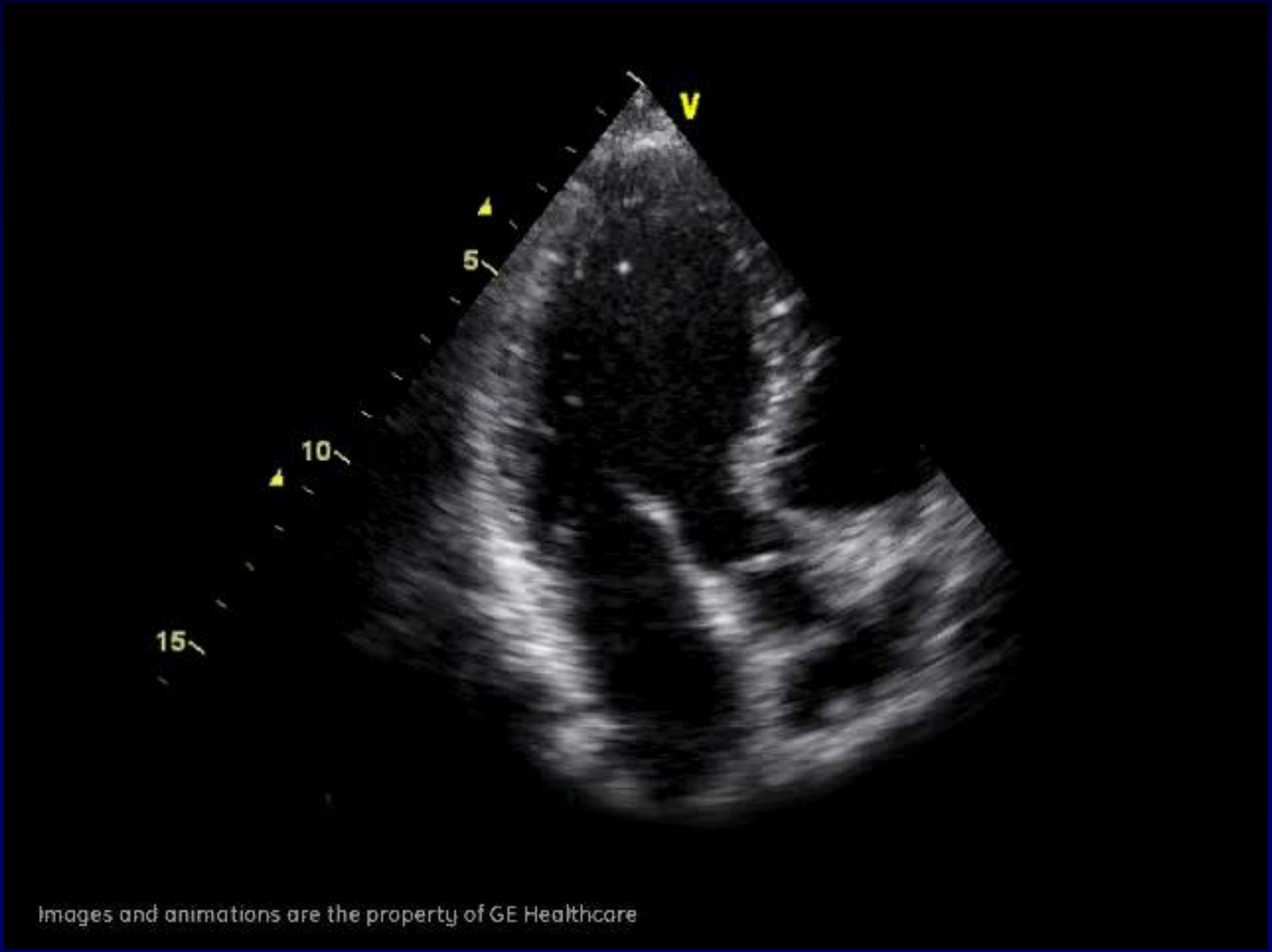


	Rest			Dobutamine Stress		
	SR_{SYS}	ε_{SYS}	PSI	SR_{SYS}	ε_{SYS}	PSI
Control	5/s	60 %	2 %	↗	↗↘	→
Stunning	↓	↓	↑	↗	↗	↘
Acute ischemia	↓	↓	↑	↘	↘	↗
Nontransmural MI	↓	↓	↑	↗↘	→	↗
Transmural MI	↓ ↓	↓ ↓	↑ ↑	→	→	→

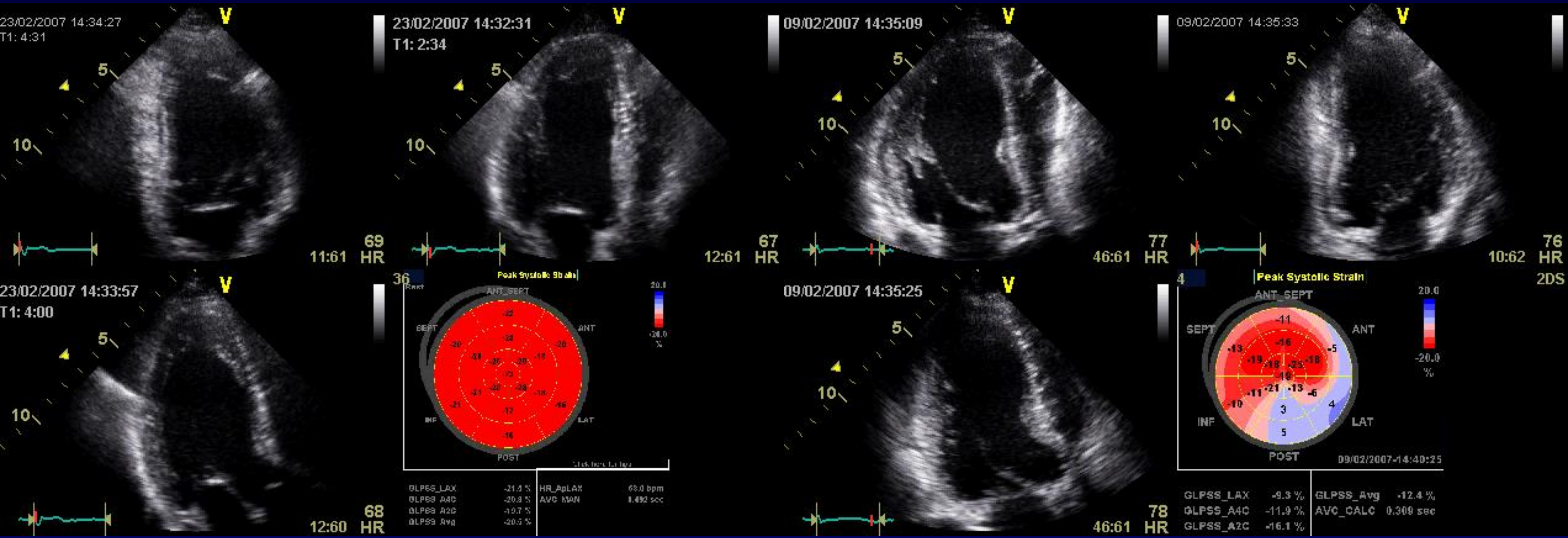
Weidemann et al. Circulation 2003;107(6):883-8.


E-SR
A-SR
IVC-SR
IVR-SR
Strain Rate
Systolic Peak SR
PSI
ECG

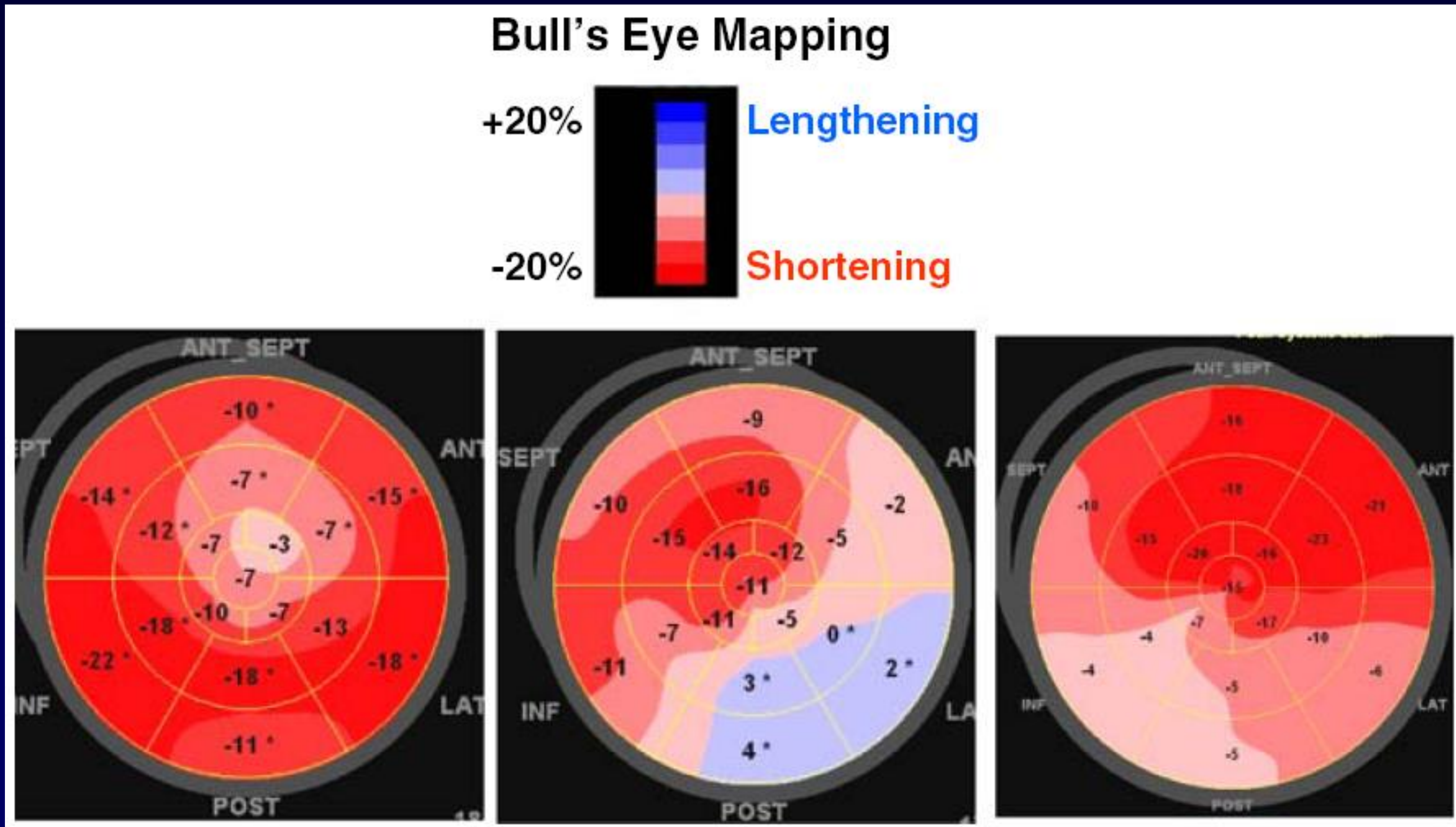
Automated Functional Imaging



Automated Functional Imaging

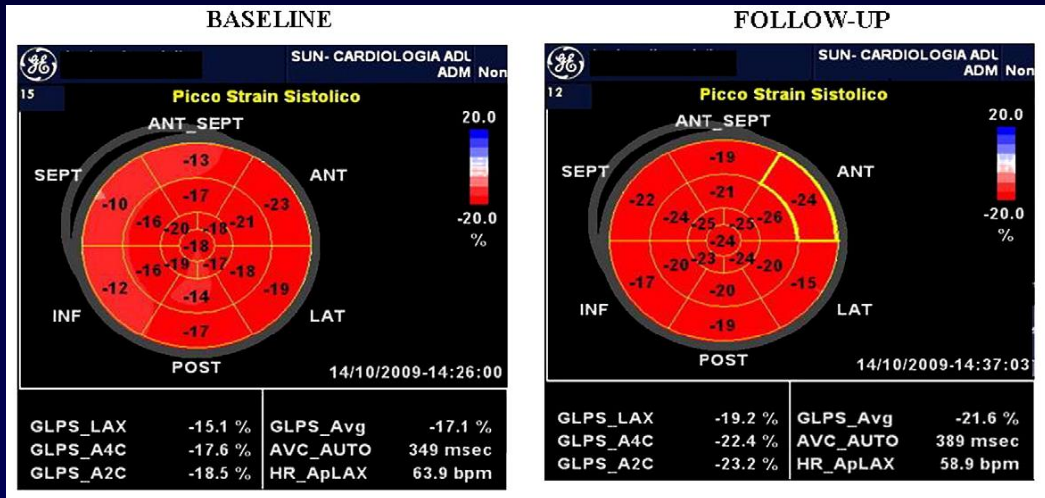


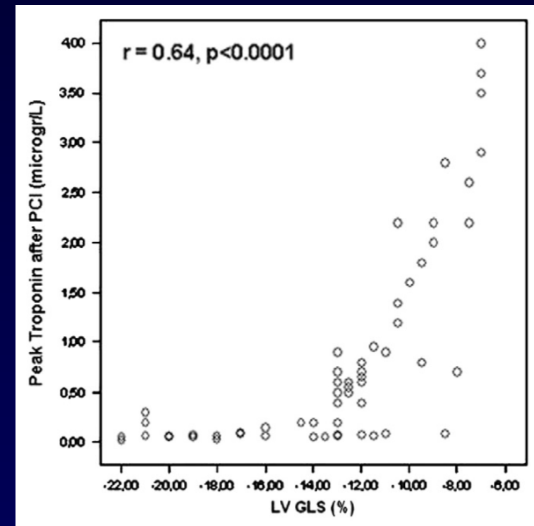
Automated Functional Imaging

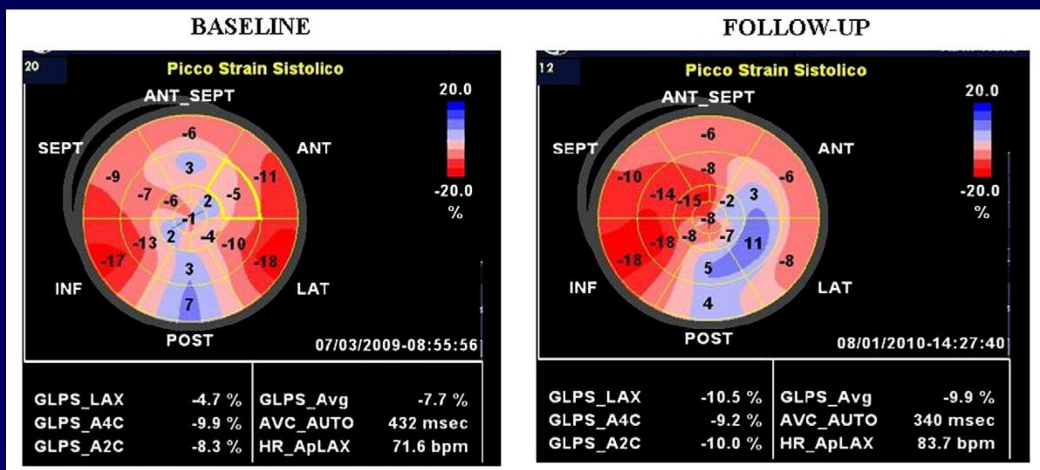


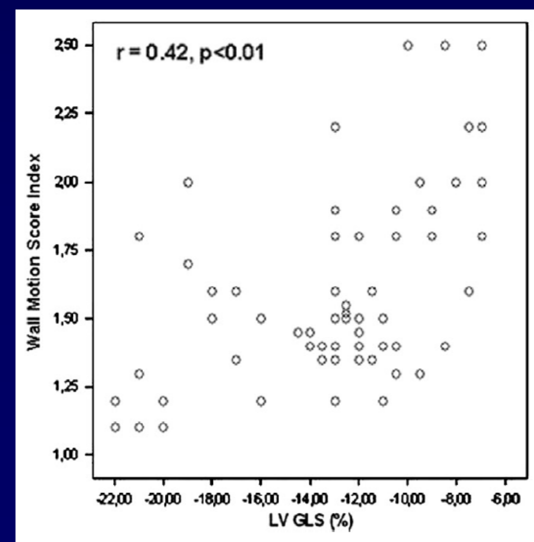
Anteroseptal MI (LAD) Inferolateral MI (LCX) Inferior MI (RCA)

Gobal Longitudinal Strain predicts LV remodeling in recent NSTEMI





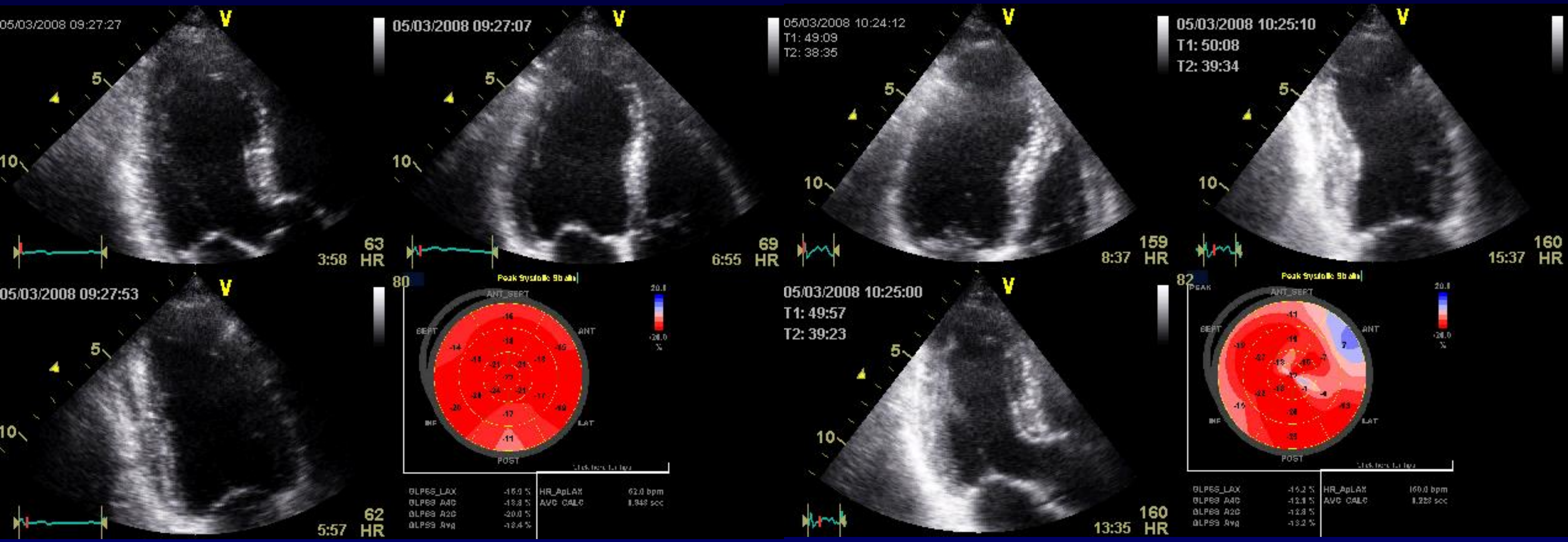




D'Andrea A, et al. Int J Cardiol. 2011;153:185-191.

Automated Functional Imaging

Exercise Echo



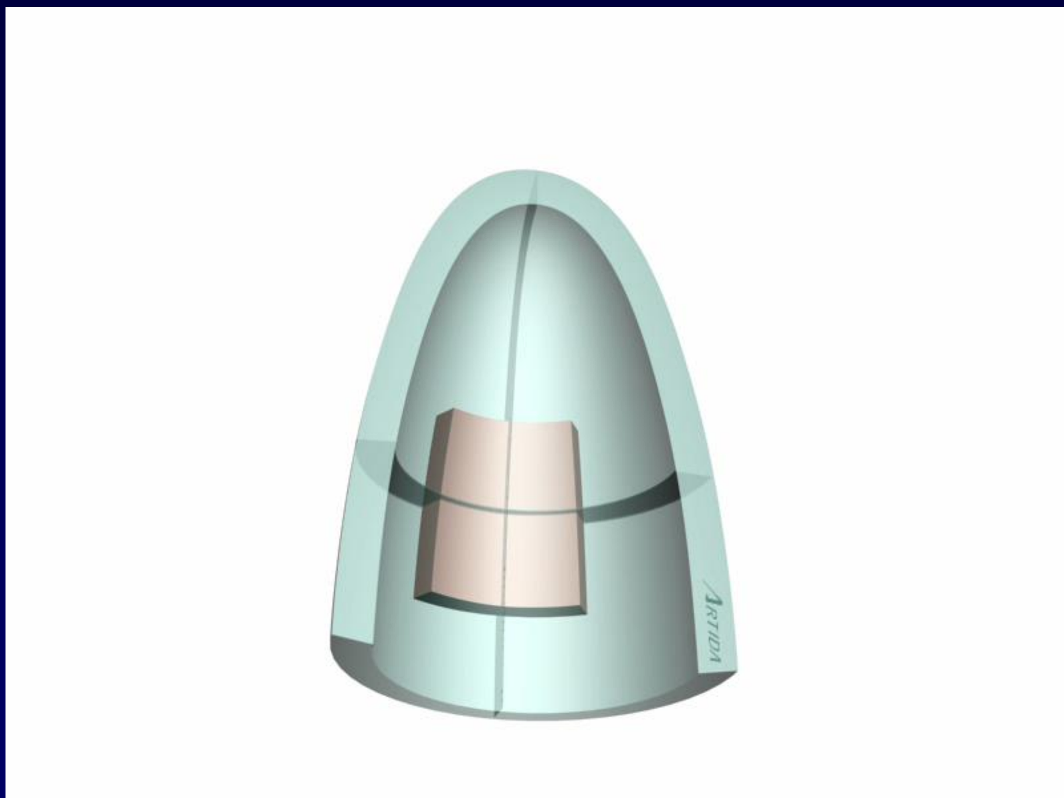
baseline

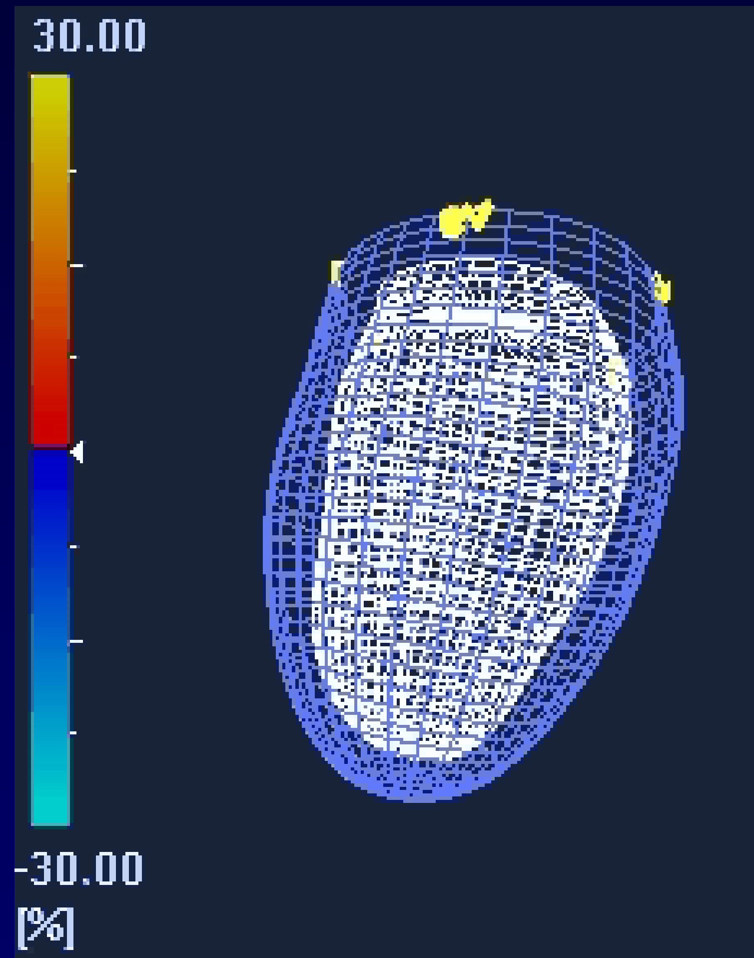
peak

LAD os 70% LN

가천대학교

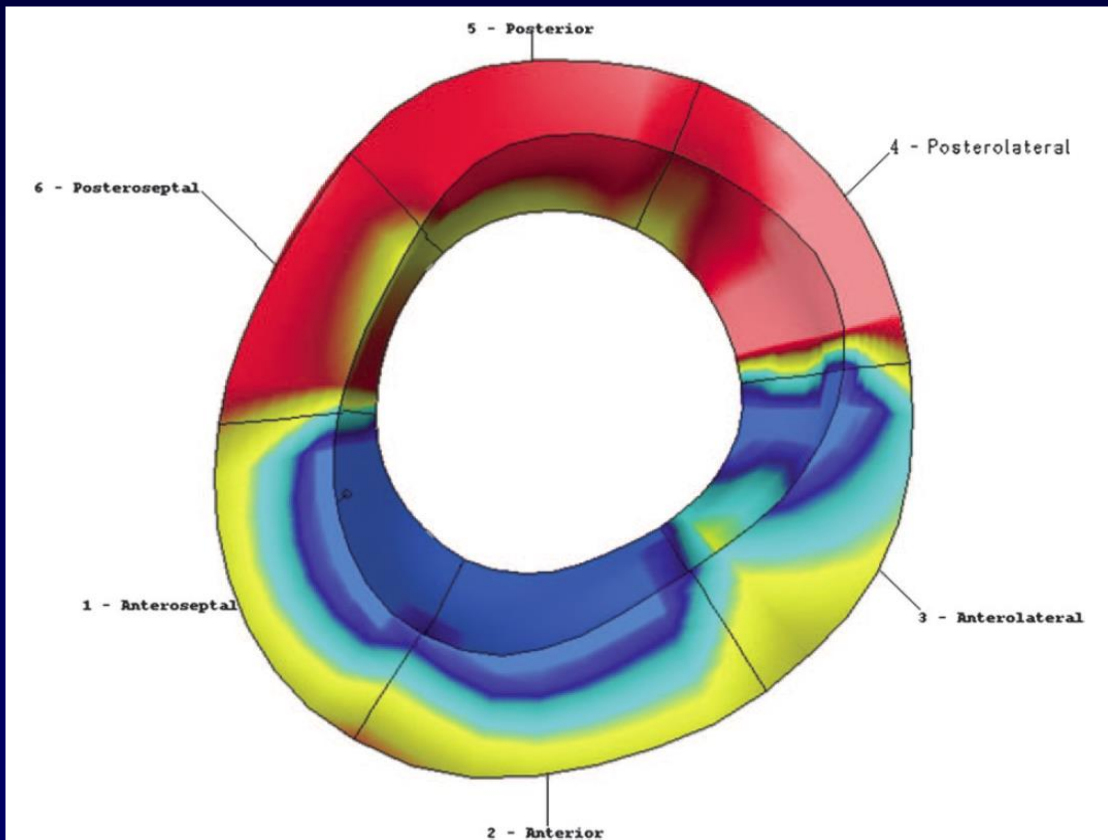
3D Strain





3D LV Strain in LD Dobutamine MR

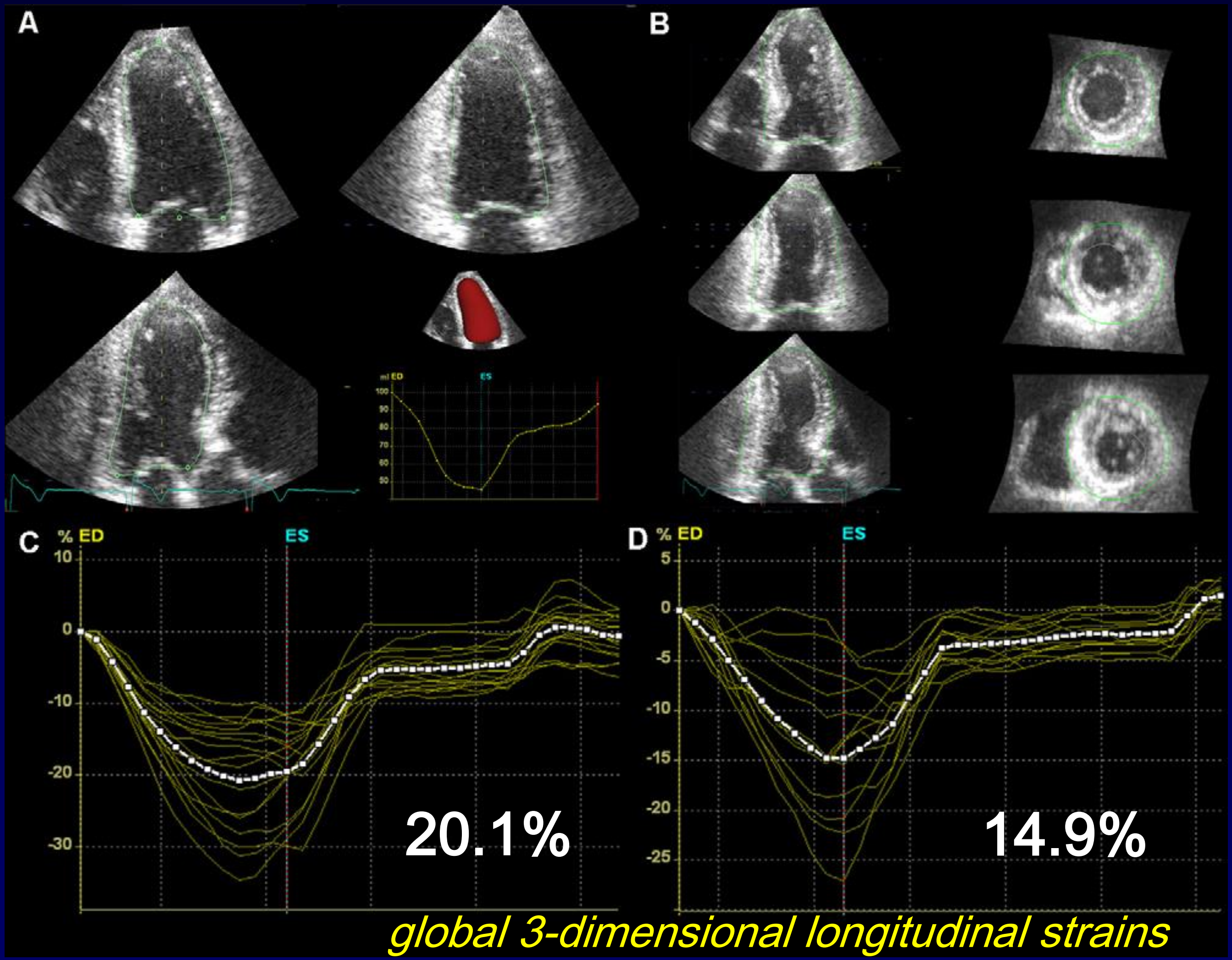
Circumferential strain in mid-ventricle



- Compared with normal volunteers, global left ventricular Ecc was significantly decreased in patients with ICM at rest (0.150.06 versus 0.270.03; *P*<0.001) and with dobutamine (0.170.08 versus 0.370.10; *P*<0.001).
- Ecc was significantly decreased in nonviable regions compared with viable segments at rest (0.080.06 versus 0.170.10; *P*<0.001) and with dobutamine (0.070.06 versus 0.210.11; *P*<0.001).

Bree et al. Circulation 2006;114(suppl I):I-33-6.

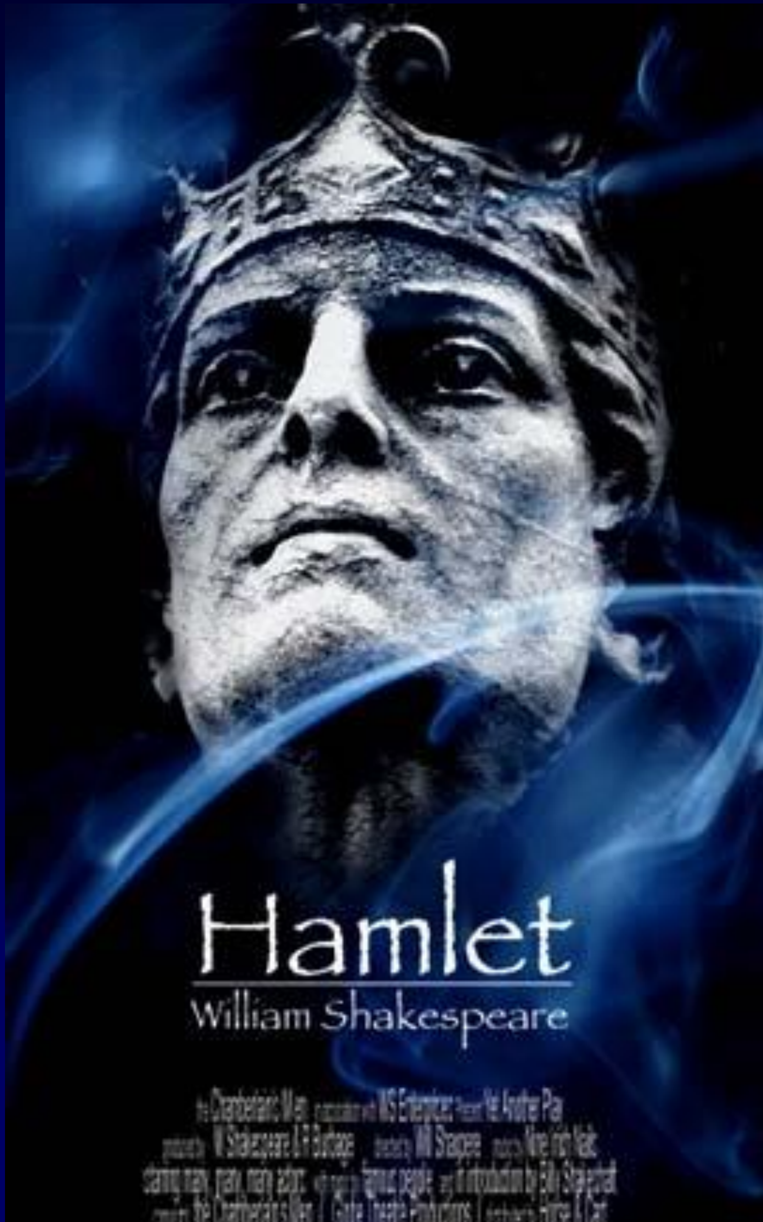
3D Speckle Tracking Longtudinal Strain Strain



Abate E, et al. Am J Cardiol. 2012;110:961-967.

Take Home Message

1. **Low dose dobutamine stress echocardiography** showed **high specificity** and comparable sensitivity with other imaging modalities
2. Measurement of both **systolic and post-systolic deformation** both at rest and during a graded dobutamine infusion may provide prognostic information about myocardial viability.
3. Implement of these new indices in the routine clinical practice will need **additional clinical and large-scale studies.**



"To be, or not to be, that is the question !"

Shakespeare, Hamlet, 1601

"To be, or not to be, that is on your hands !"

Special thanks to

Hye-Jin Kim (GE Health Korea), Eun Ok Shim, Kyeong Soon Kim, Ok Ryun Kim, Eun Ju You, Jung Geun Moon, Mi-Seung Shin (Gachon Gil Echo Lab), Dae Hee Kim, Soo-Jin Kang (Ulsan Univ.) and Goo-Yeong Cho (Hallym Univ.)

for this slide.

Thank you for your attention !!!

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