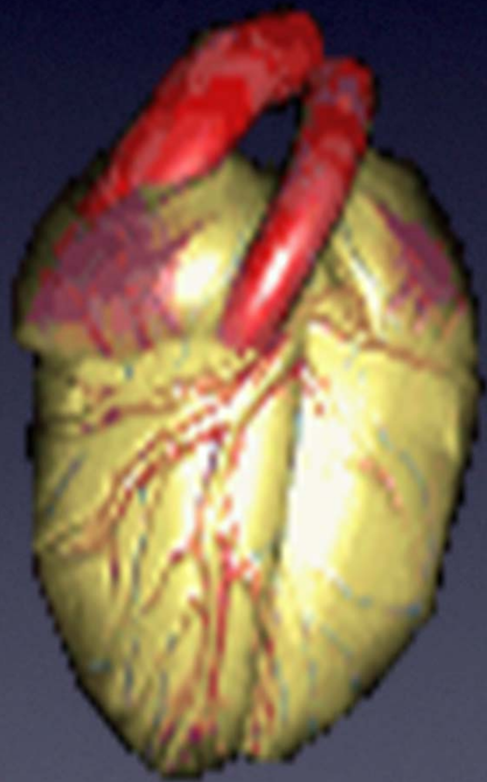
Tissue Doppler and myocardial strain
: a new prognostic parameter?

Kyoung Im Cho

linical evaluation of cardiovascular diseases

Echocardiography

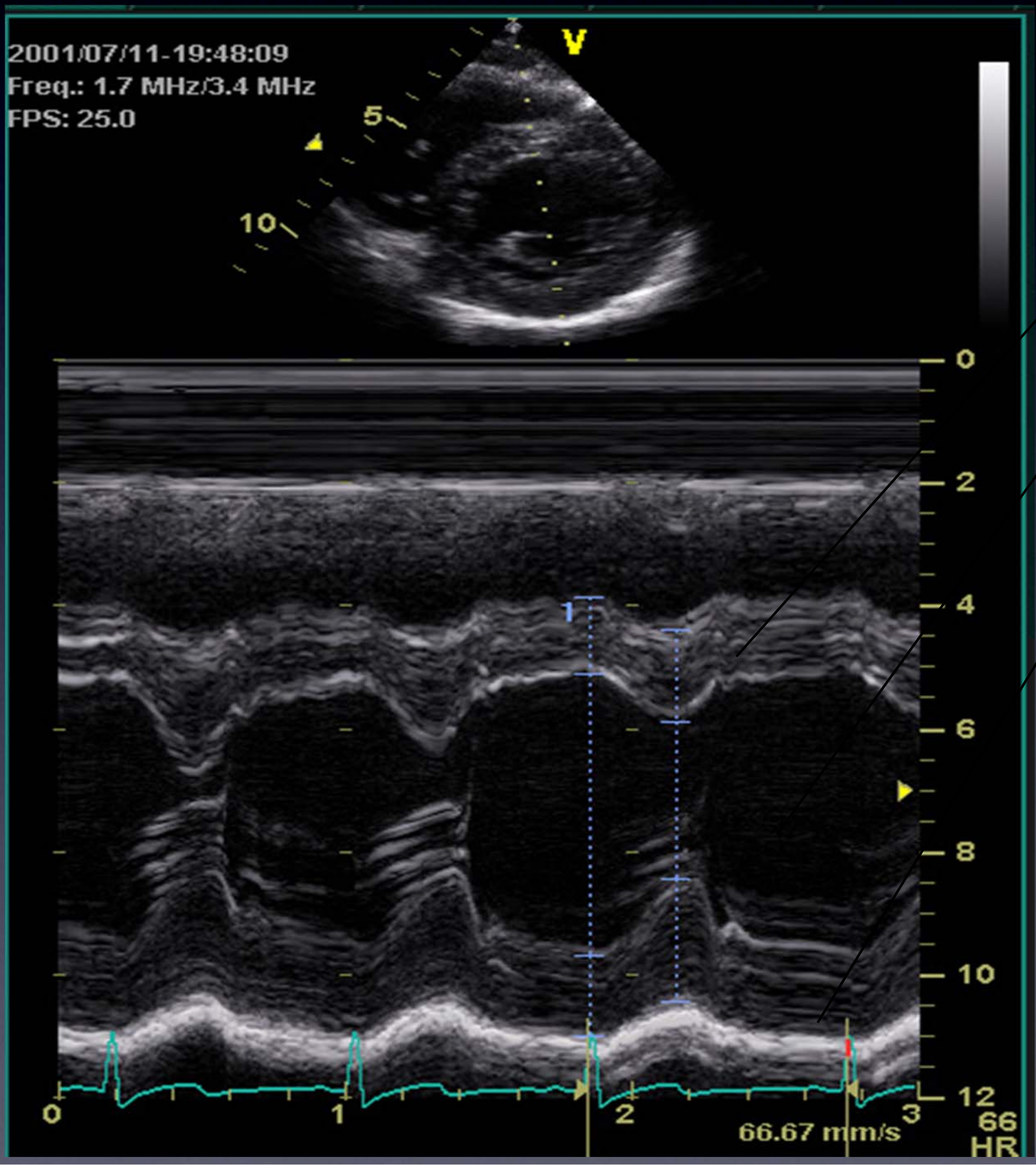
Systolic dysfunction



Diastolic dysfunction

Assessment of LV Systolic function

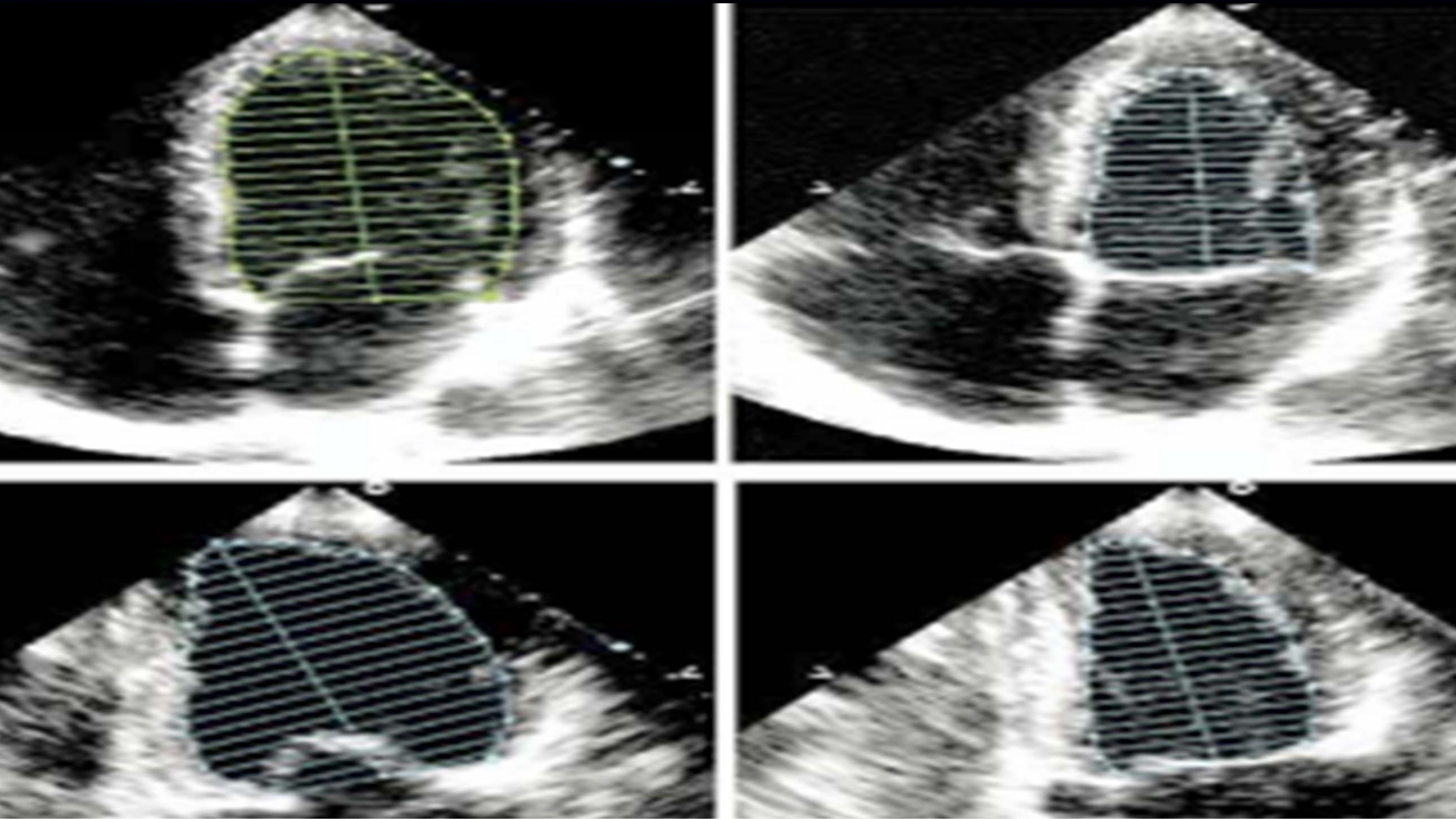
Linear measurement from M-mode



1	IVSd	1.24 cm
	LVIDd	4.57 cm
	LVPWd	1.31 cm
	IVSs	1.49 cm
	LVIDs	2.55 cm
	LVPWs	1.99 cm
	EDV(Teich)	95.9 ml
	ESV(Teich)	23.4 ml
	EF(Teich)	75.6 %
	%FS	44.2 %
	SV(Teich)	72.4 ml

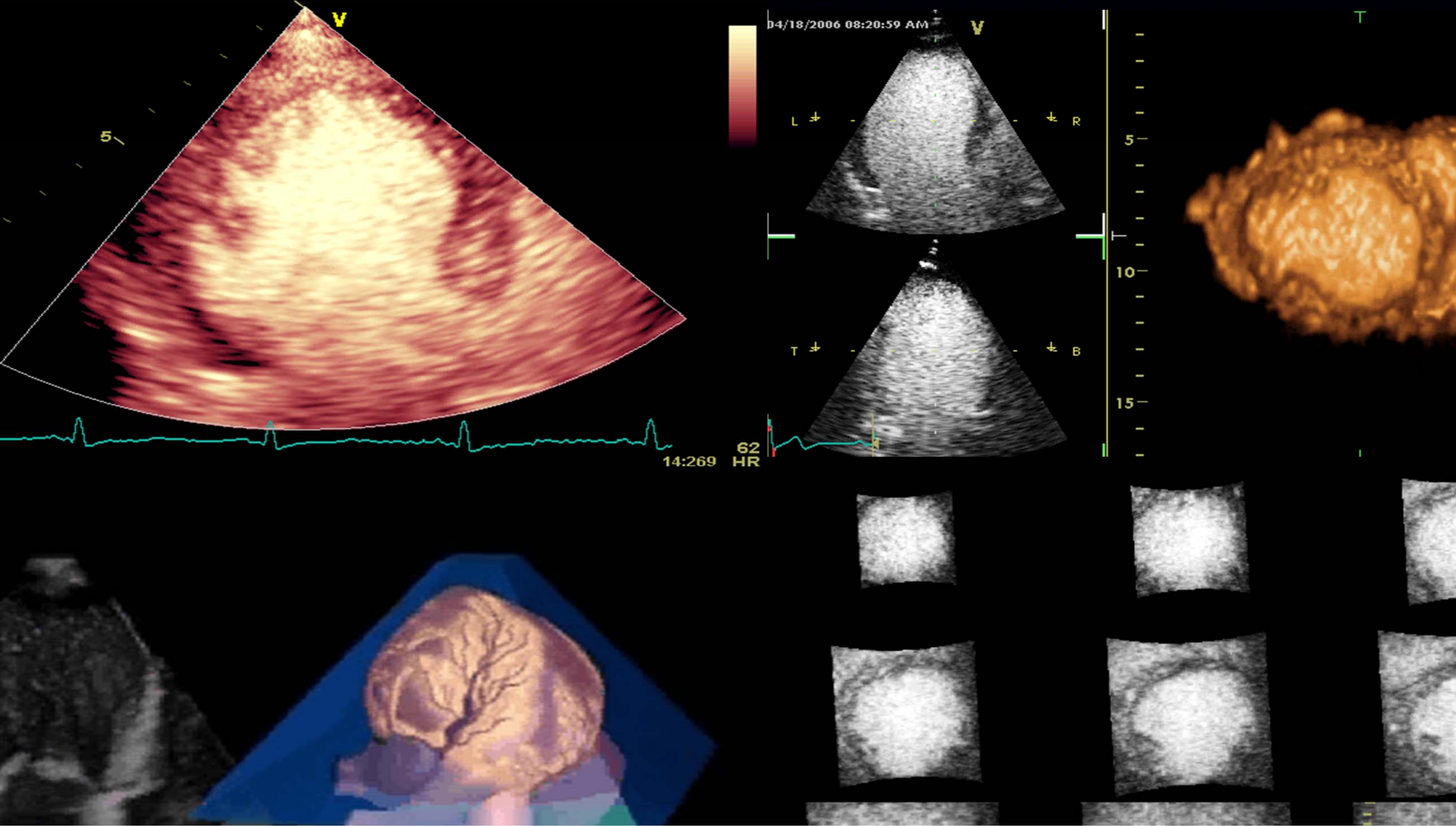
Assessment of LV Systolic function

Volumetric measurements- modified Simpson's rule



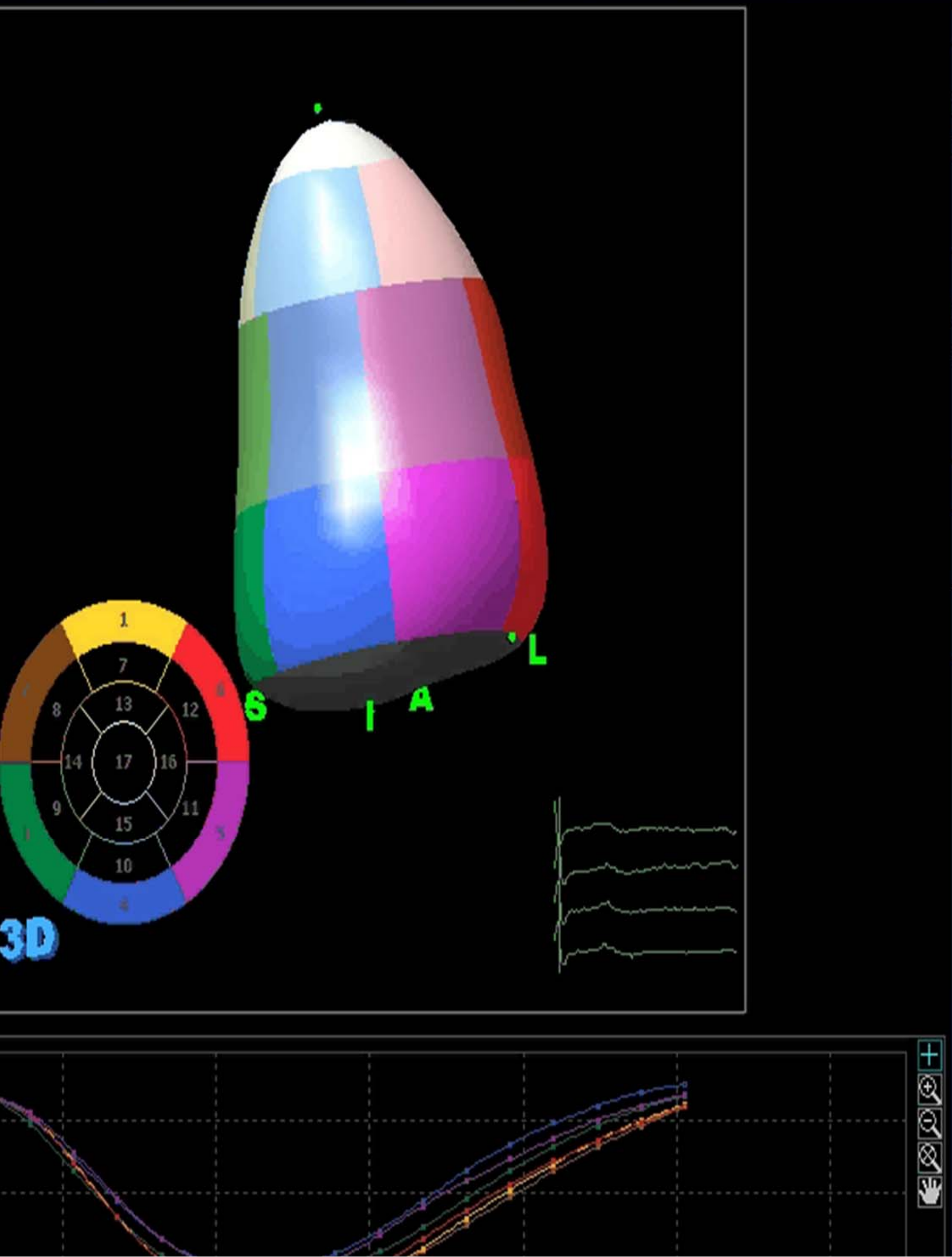
Assessment of LV systolic function

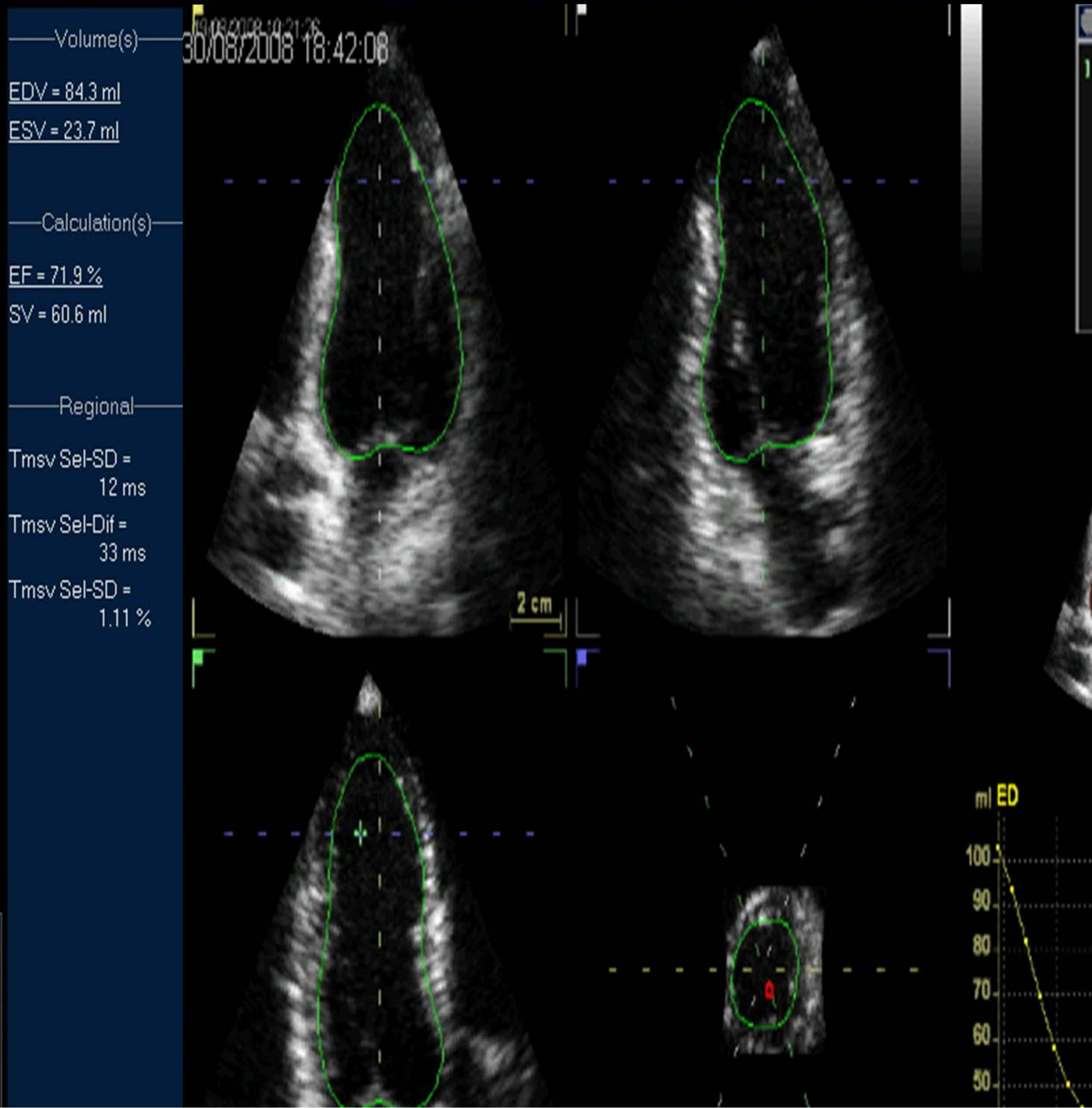
Contrast echocardiography



Assessment of LV Systolic function

3 D and 4D LV Volume...for global EF

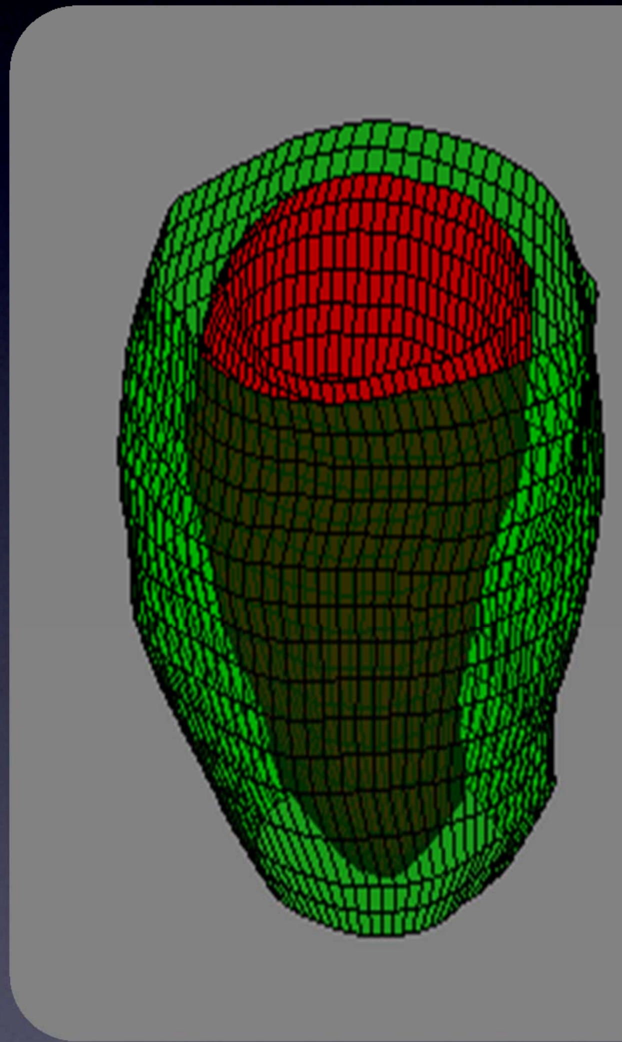




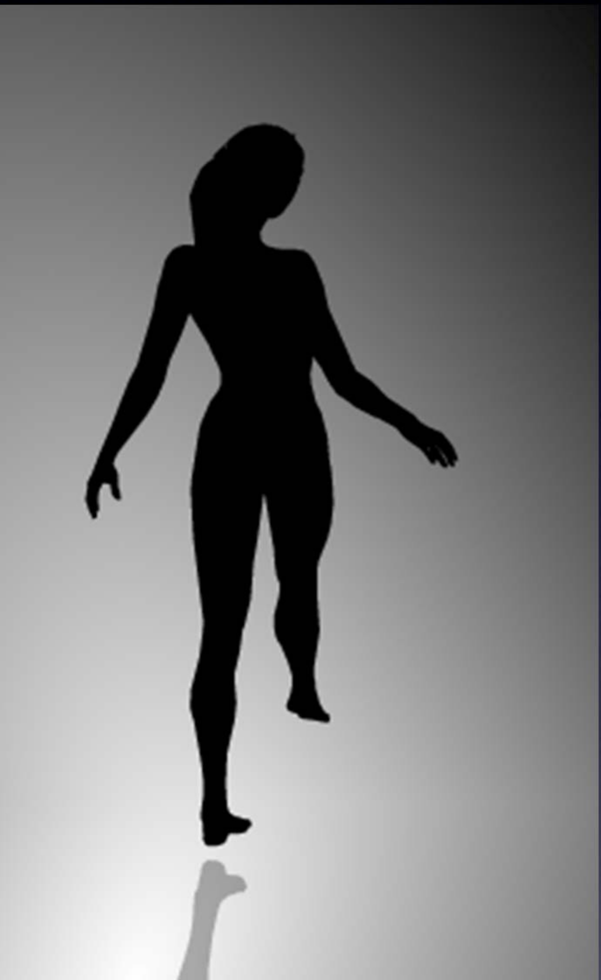
Assessment of LV Systolic function

Standard echocardiographic measurements, such as ejection fraction and endocardial fractional shortening reflect ***chamber dynamics***

Not direct measurements of the longitudinal fiber function



However, heart is complex fiber structure
3-dinesional movement

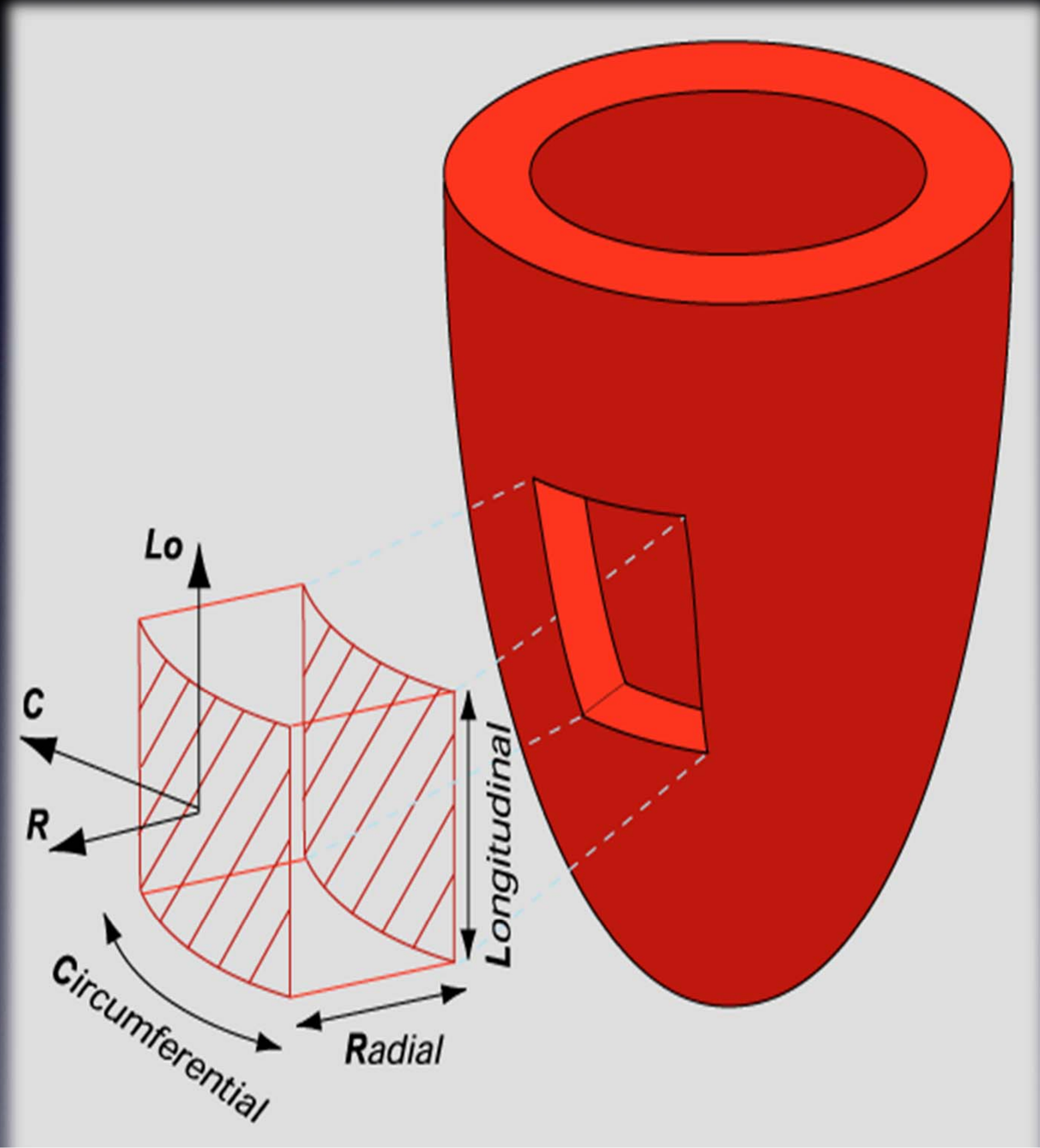


Components of Regional function

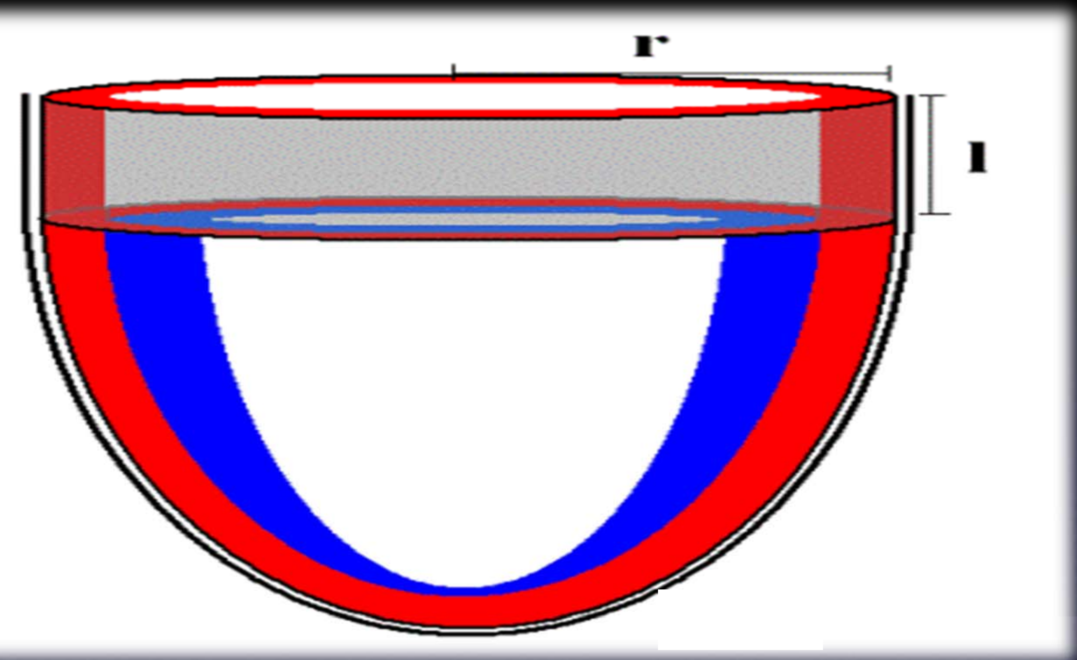
- Radial function
- Longitudinal
- Circumferential

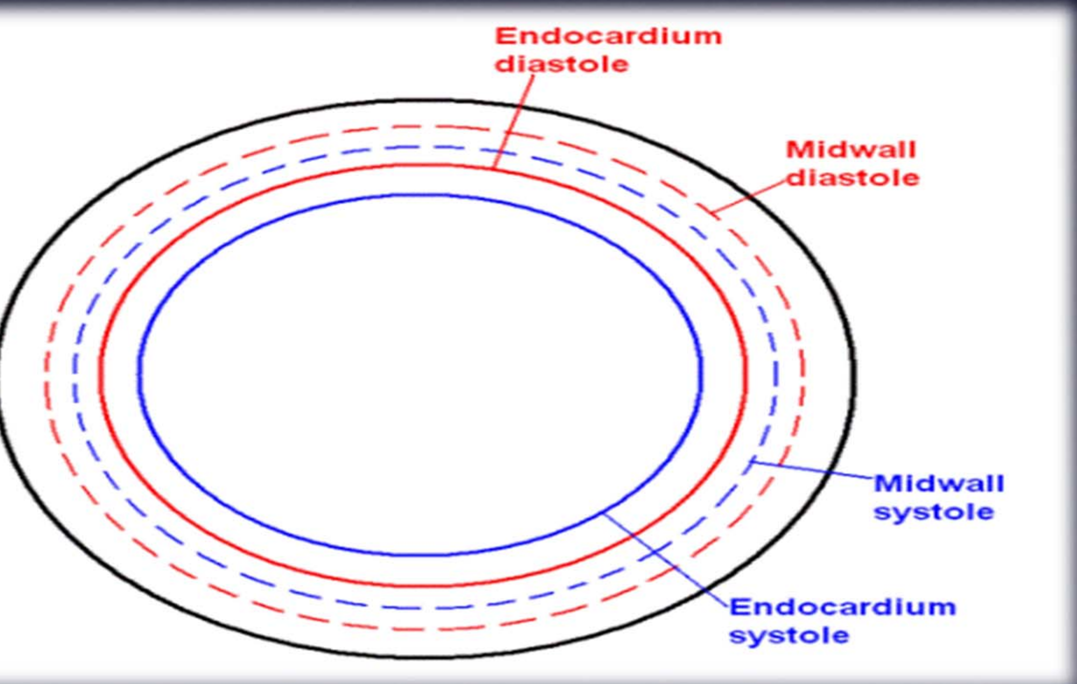
⇩

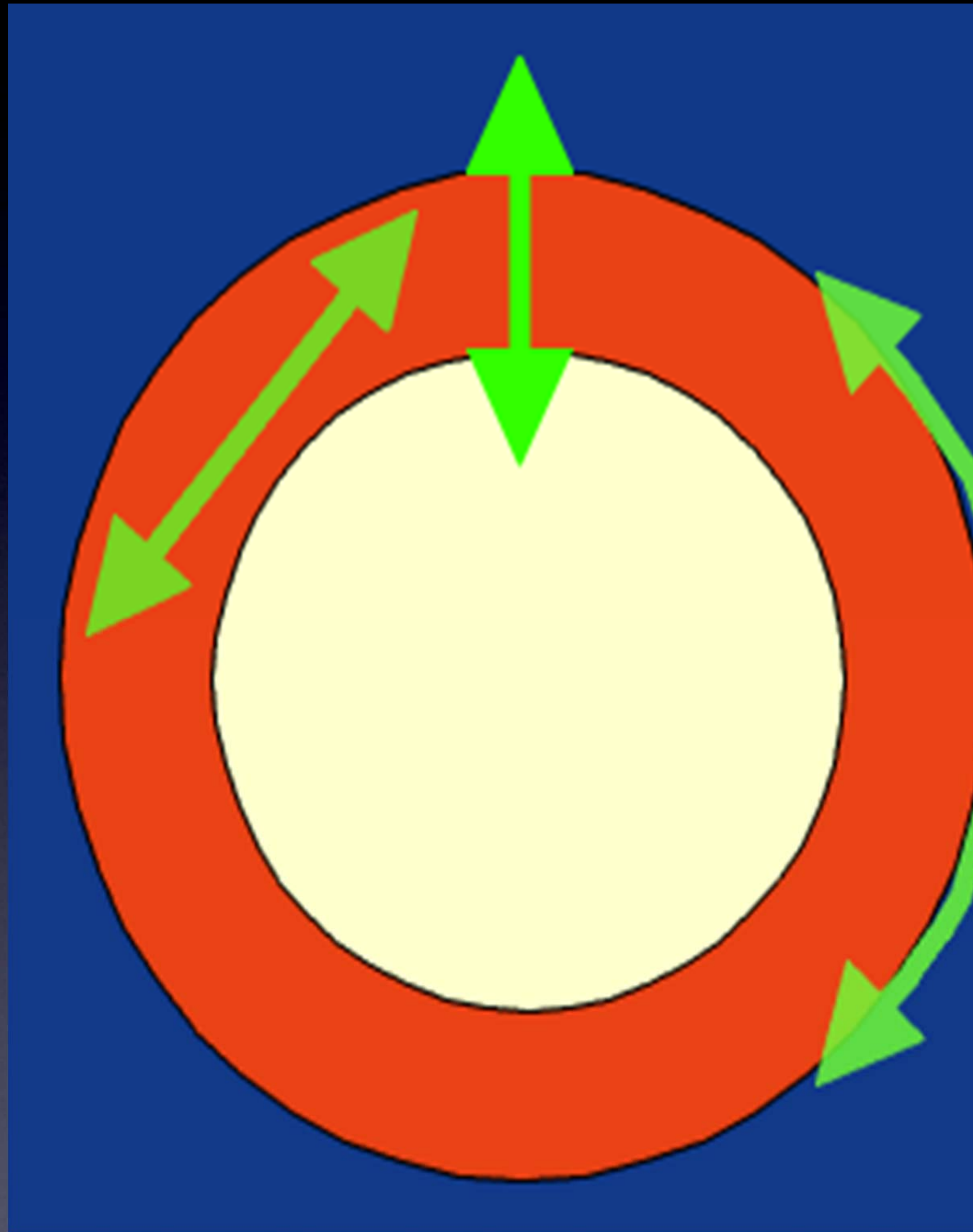
Without the longitudinal component, sarcomere shortening would lead to an EF < 30%.



Components of Regional function







the wall shortens in the longitudinal and circumferential

Assessment of LV systolic function

D and M-mode measurements, fractional shortening, longitudinal shortenin
myocardial velocities 2D volumes and EF are all related to myocardial motio

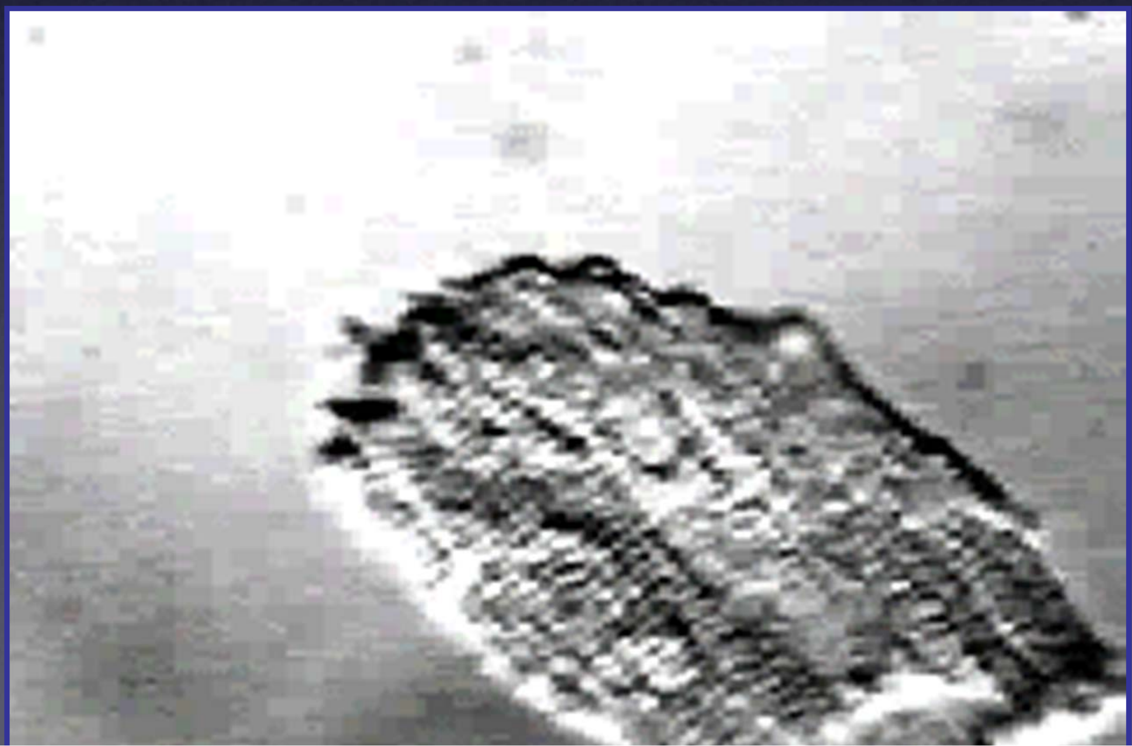
The importance of normal long axis function in maintaining a coordinated ventricular contraction

Strain imaging, compared with conventional echocardiography is a more sensitive method for the detection of LV systolic dysfunction, particularly in subjects with LV remodelling and normal EF

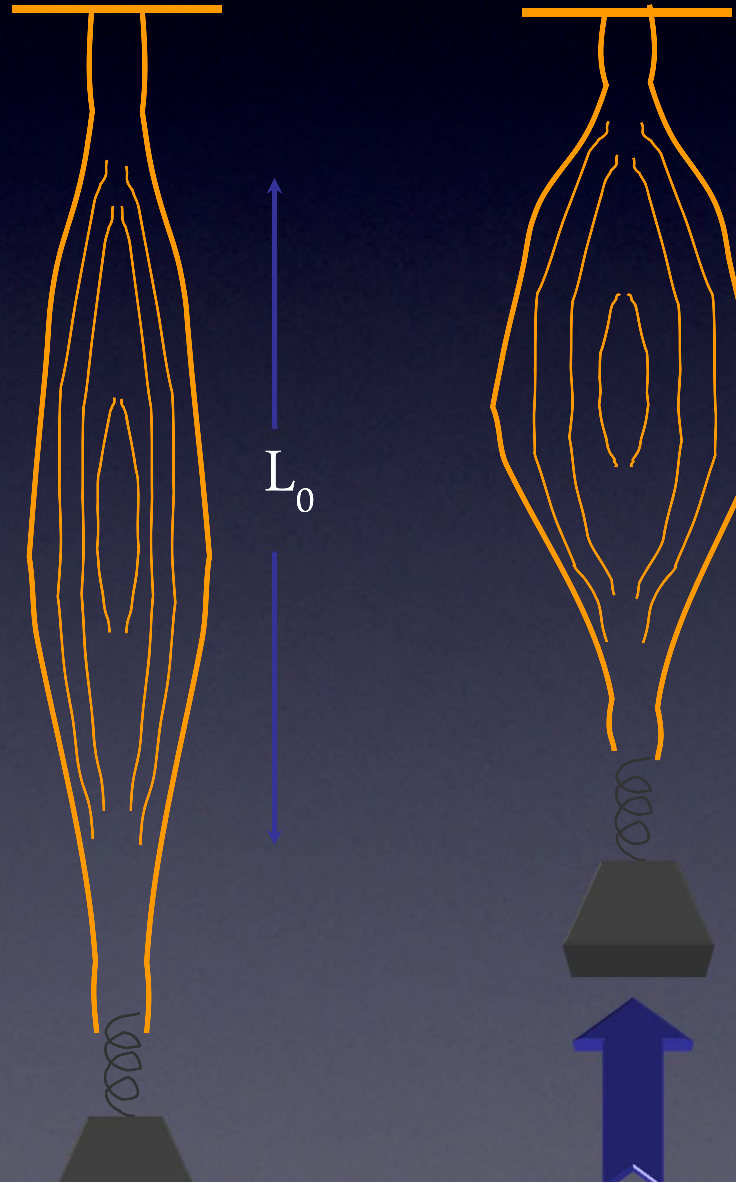
What is Strain?

Strain:

- Is a measure of the *deformation or change in shape* of the myocardium between two points
- Is the percent (%) of deformation or change in shape

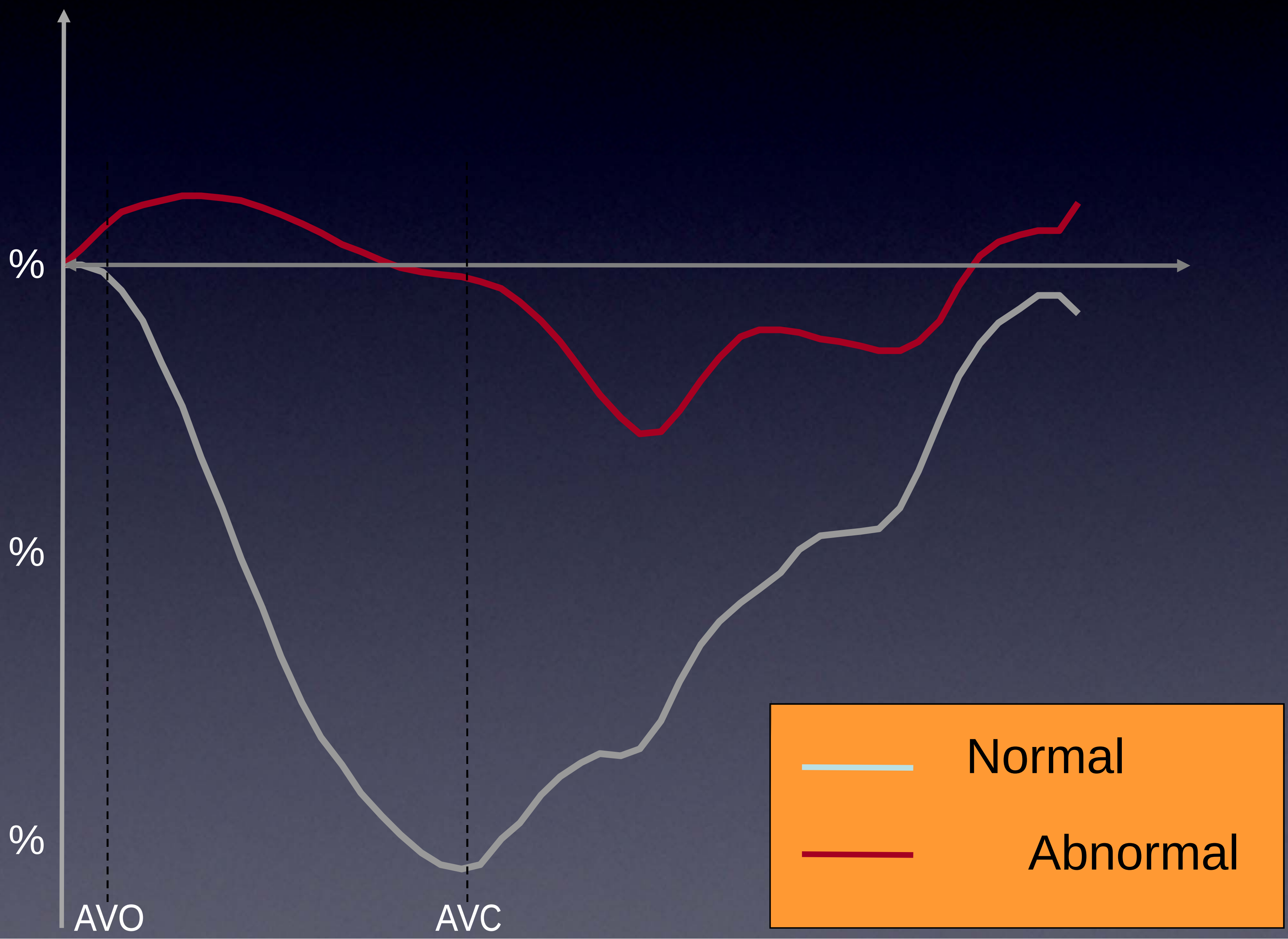


Strain (ε) = $(L-L_0)/L_0$



:tissue deformation imaging

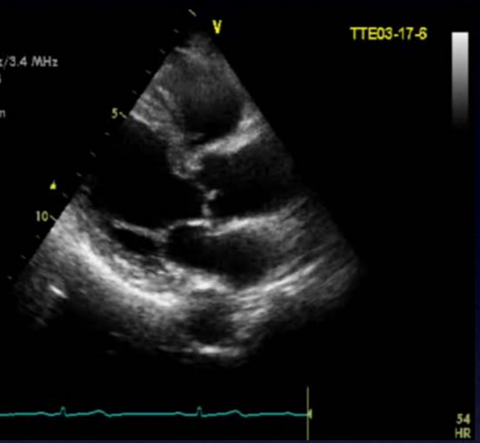
Strain



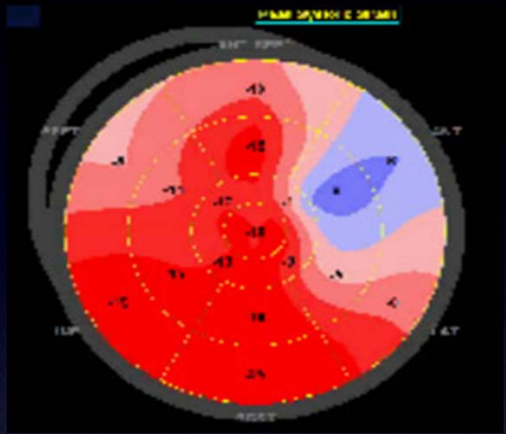
issue Doppler imaging?

Speckle tracking strain ?

Quantification Roadmap



Eye-balling

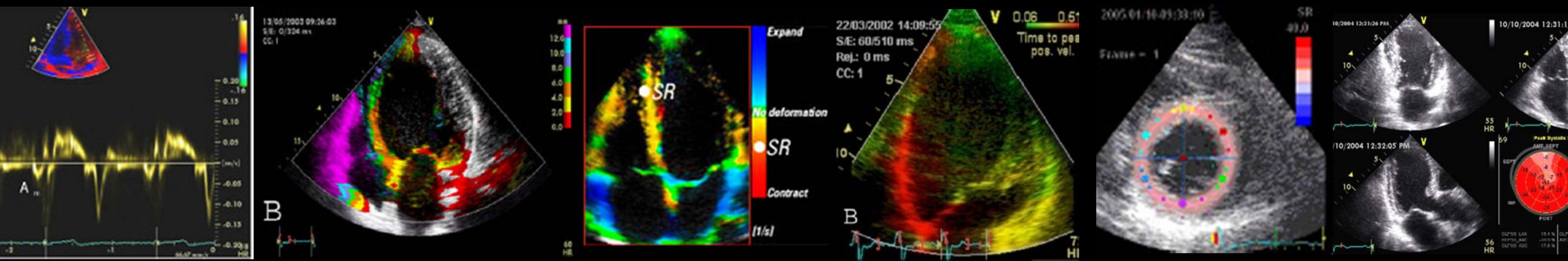


Quantification

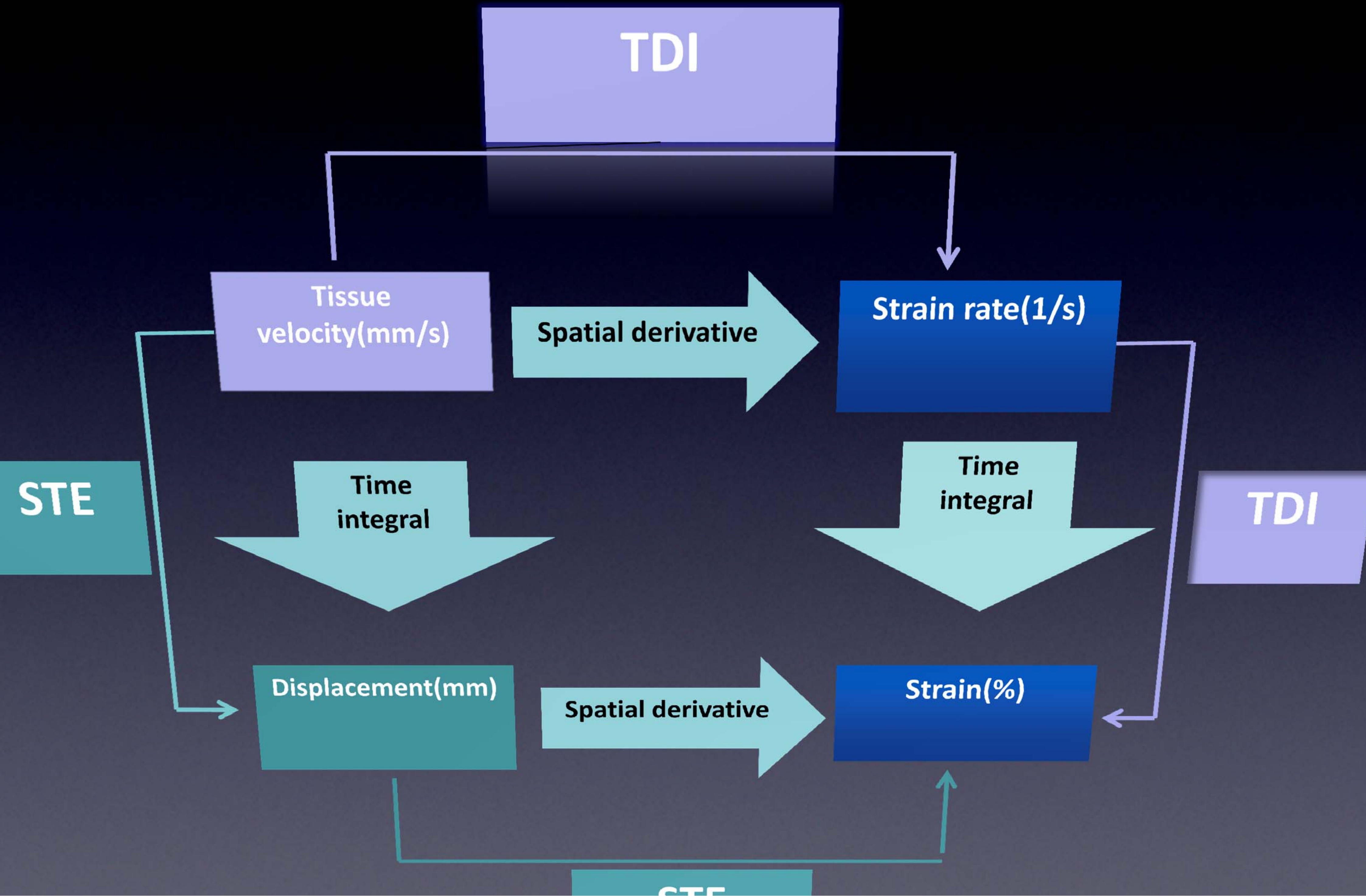
Early quantitative detection is ke

Evolve eye-balling to better tools

Raw Data is enabler for development of ever better quantitative tools.



e Doppler ***Tissue Tracking*** ***Strain*** ***TSI*** ***2D Strain*** ***AF***



TDI
Tissue velocity(mm/s)
Spatial derivative
Strain rate(1/s)
STE
Time integral
Time integral
TDI
Displacement(mm)
Spatial derivative
Strain(%)

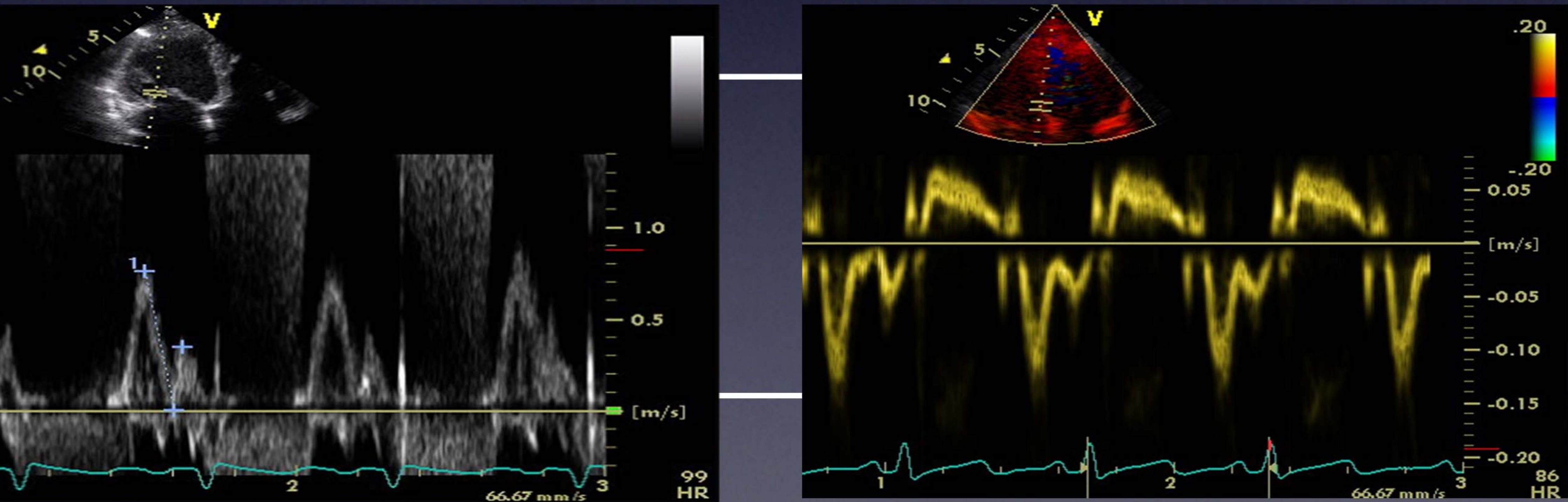
Conventional Doppler and TDI

Conventional Doppler

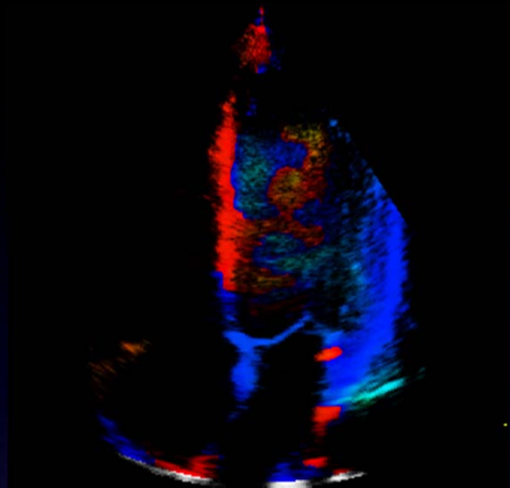
- Measure velocity and direction of blood flow(RBC)

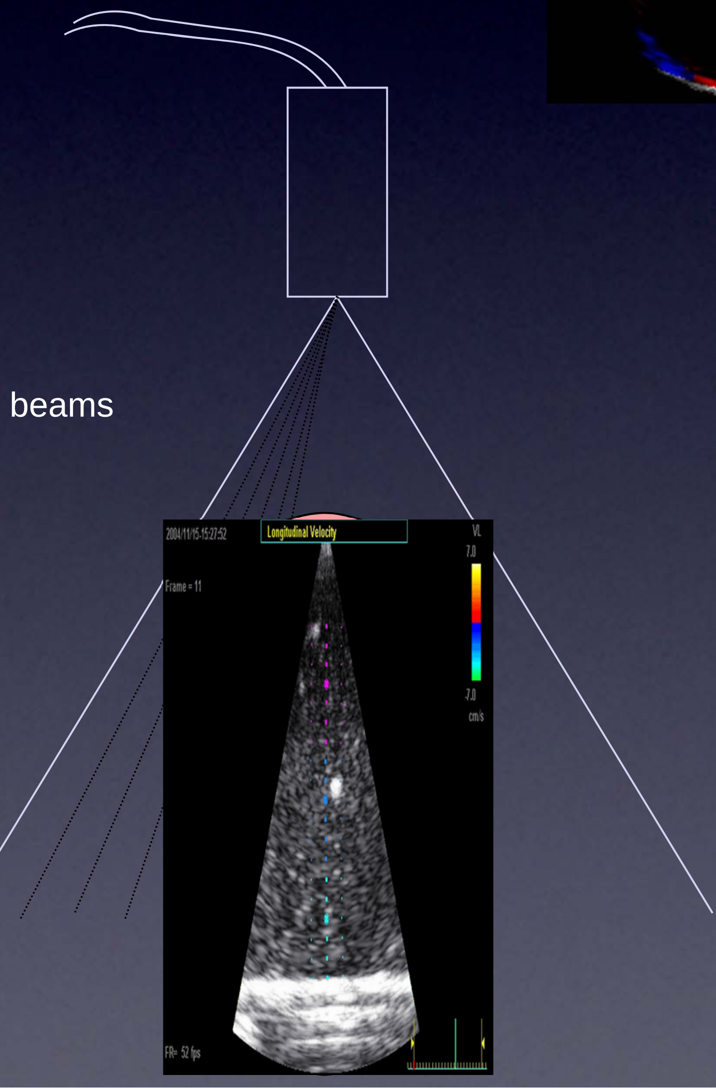
Tissue Velocity(Doppler) Imaging

- Measure *velocity of myocardial tissue*



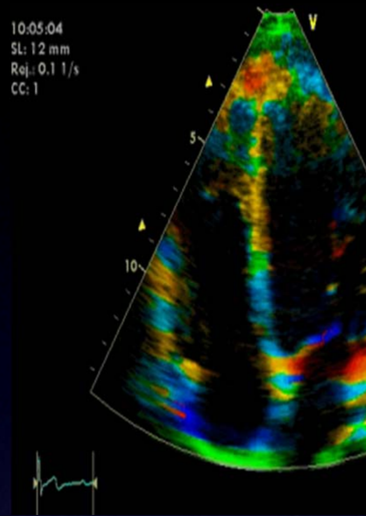
TVI

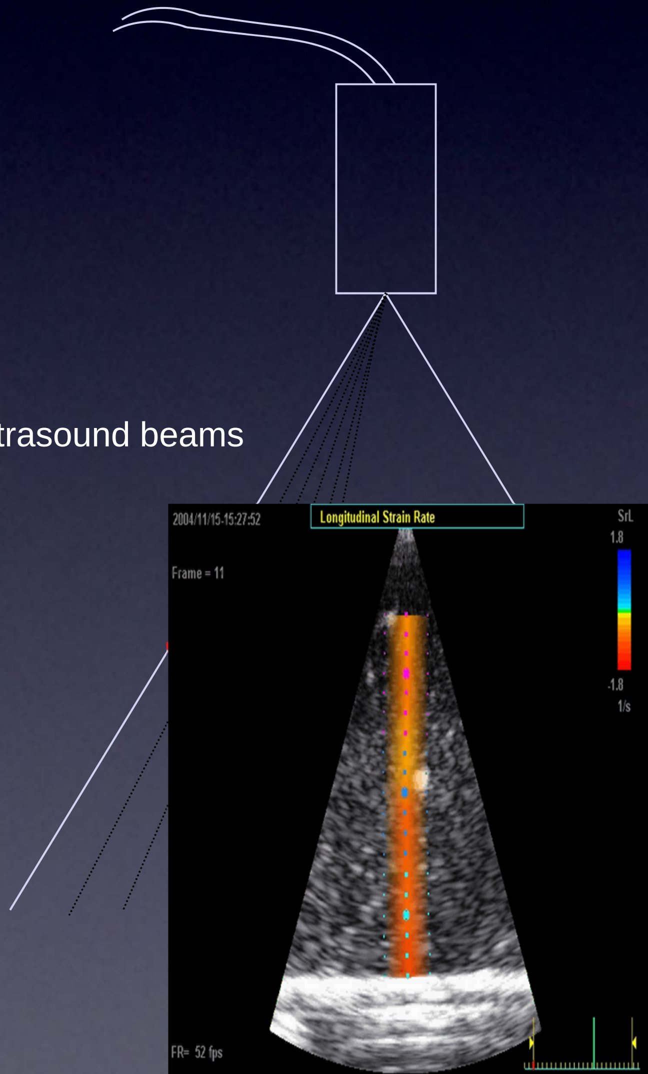




[m/s]

STRAIN





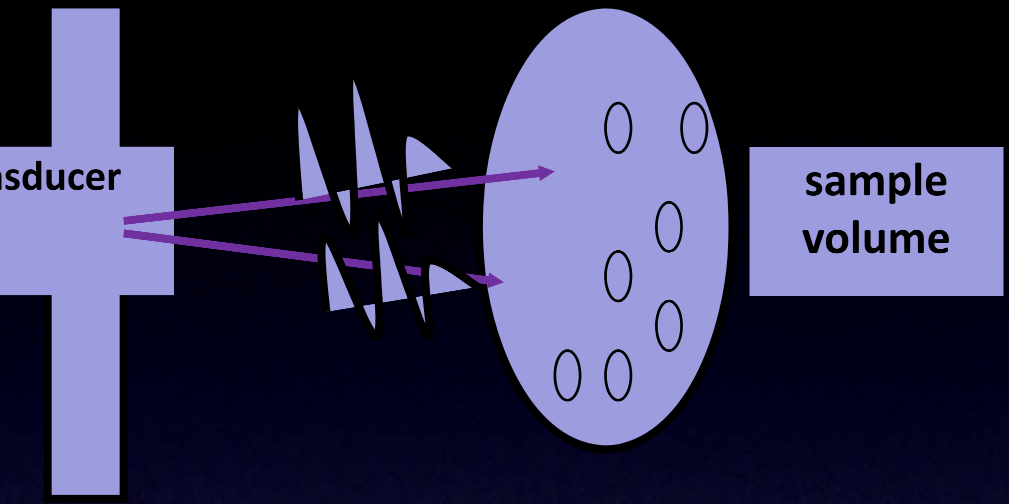
[1/s]

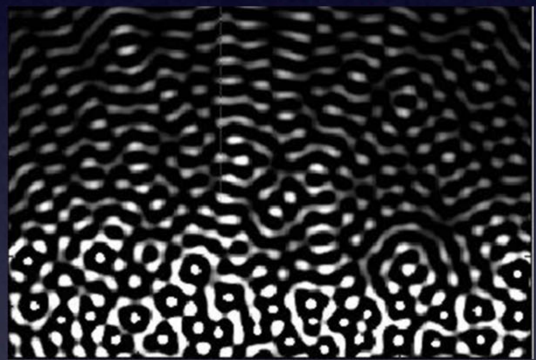
BLUE
above ba
expa

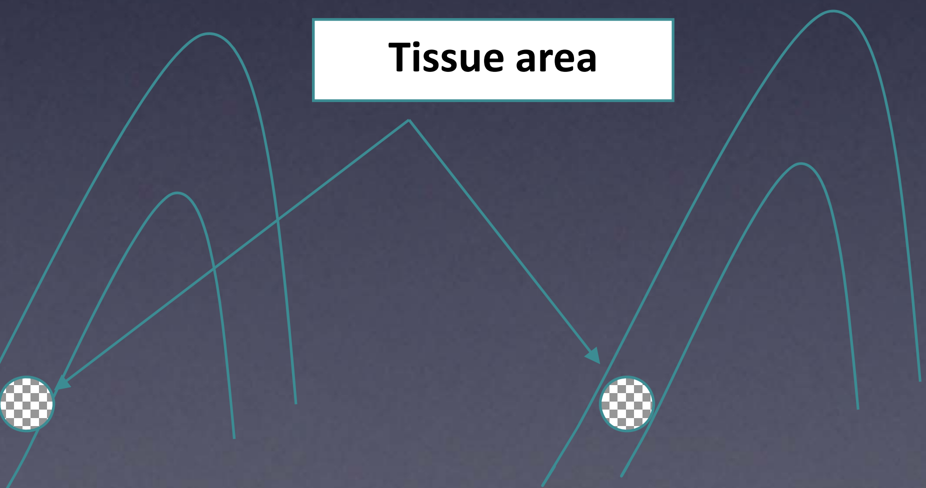
GREE
deform

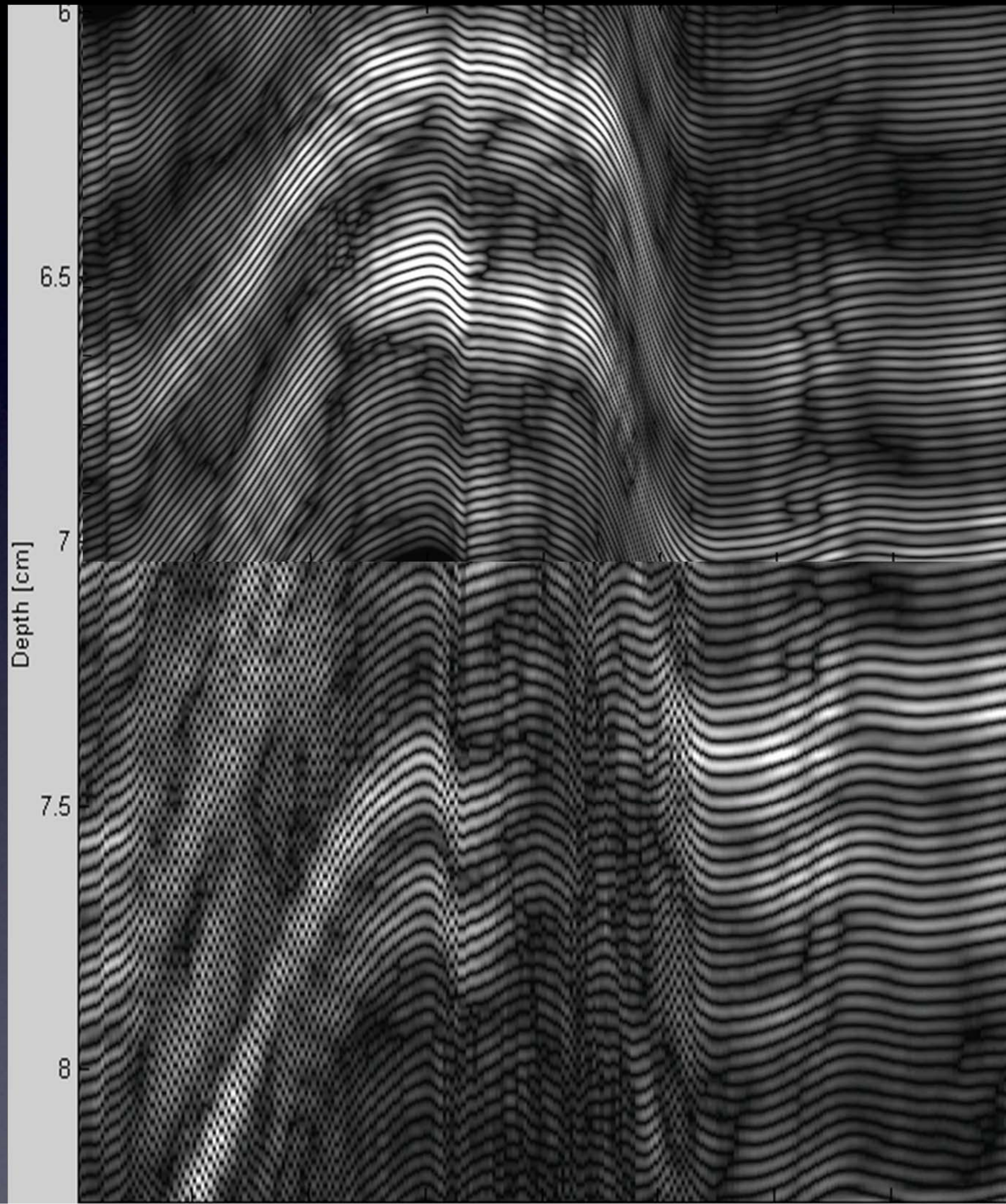
RED (
below ba
contra

V


sducer
sample
volume



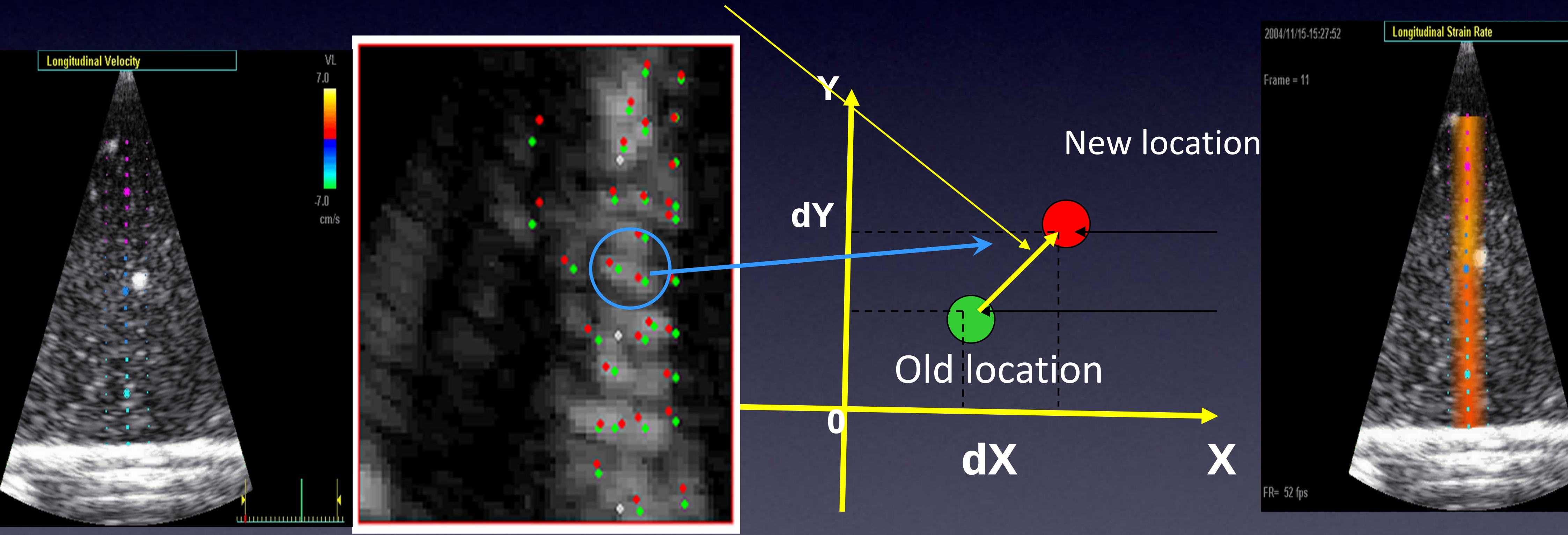

Tissue area


6
6.5
7
7.5
8
Depth [cm]

Estimation of local tissue velocities.

Velocity is estimated as a shift of each object divided by time between successive frames (or multiplied by Frame Rate)-->

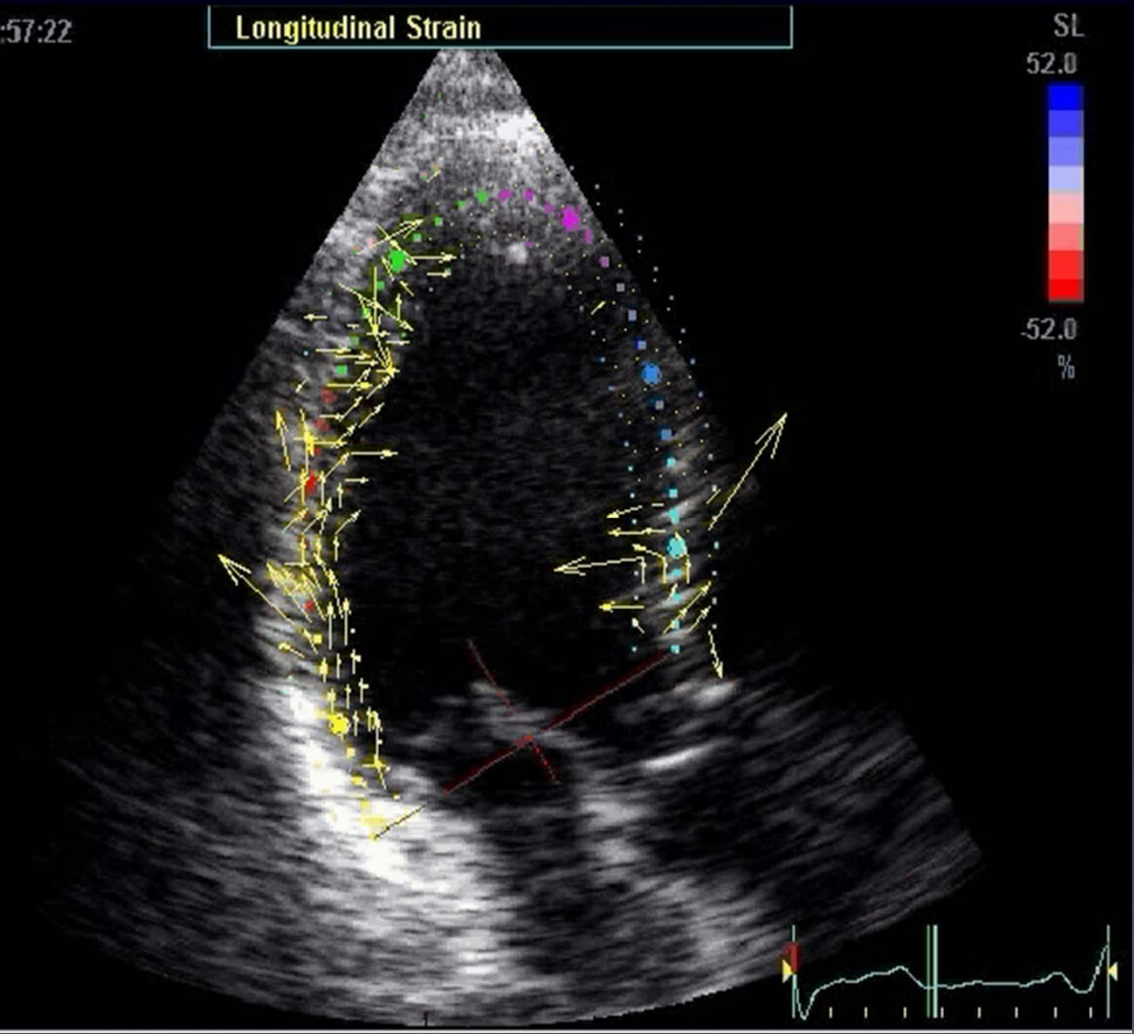
<u>2D velocity vector</u>: (Vx, Vy) = (dX, dY) * FR

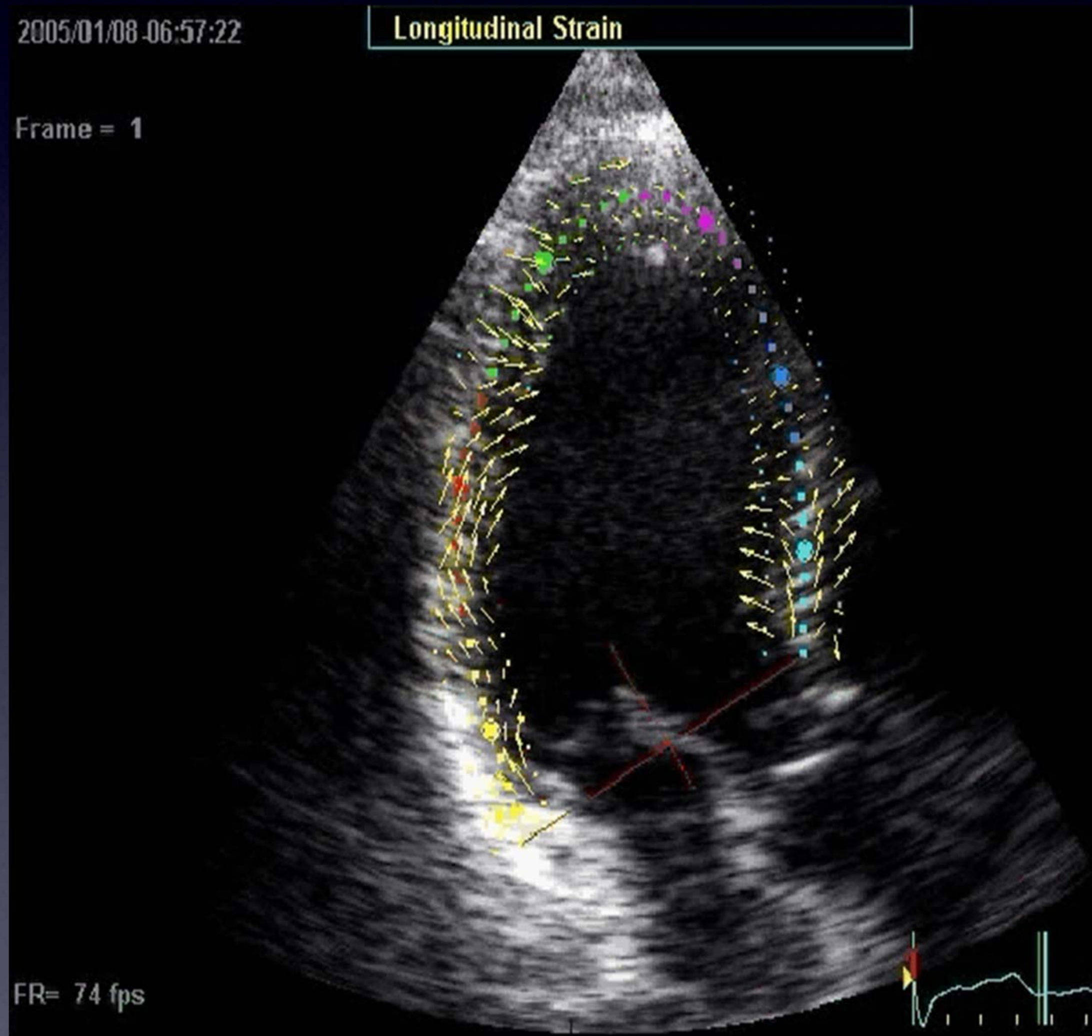


Relative changes of the mutual distance between neighboring elements reflect the tissue's contraction/relaxation dimentional Strain Rate and Strain).

Reconstruction of continuous spatial velocity distribution

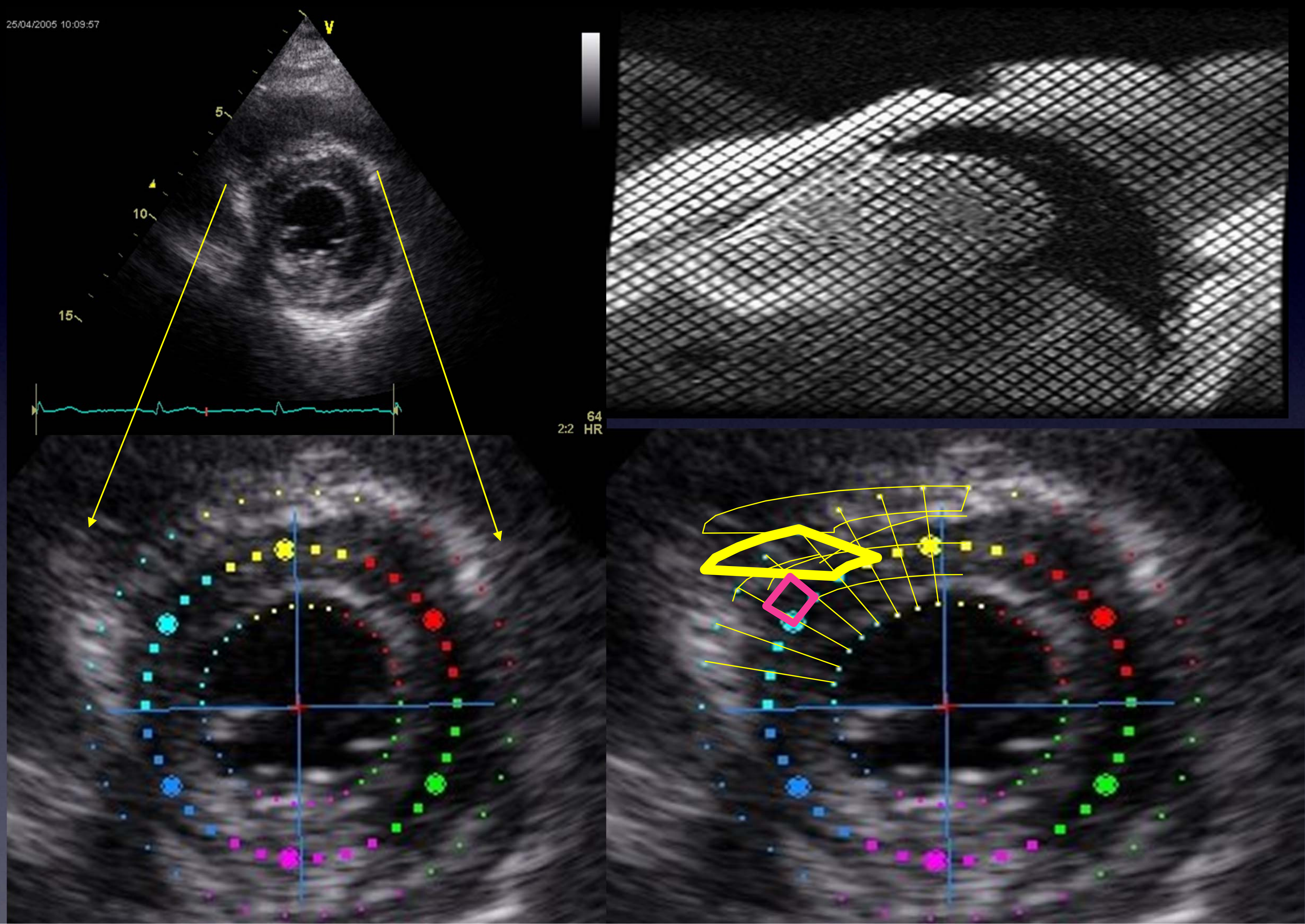
The randomly distributed tissue velocities were approximated by a smooth function.





“Raw” velocity field

Filtered velocity fi


25/04/2005 10:09:57
V
5
10
15
64
2:2 HR

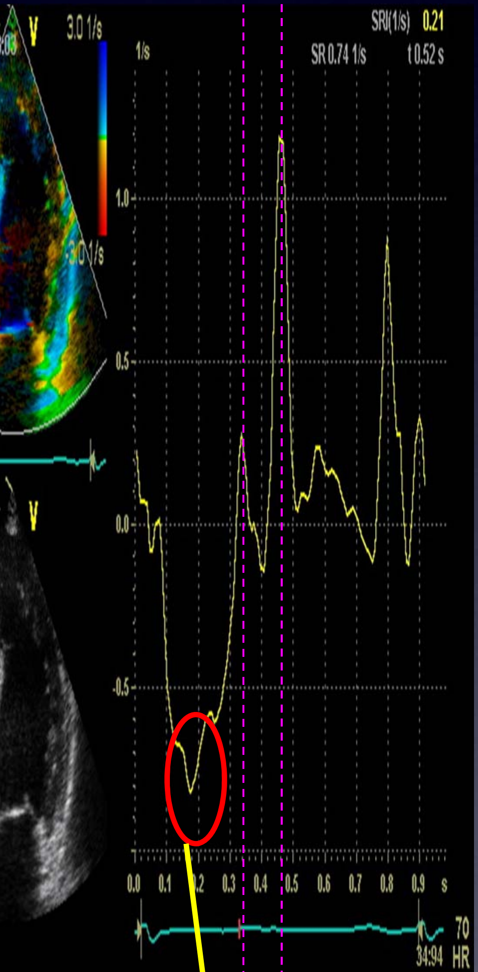
Strain!... TDI vs. STE

	Tissue Doppler imaging	Speckle tracking imaging
ages	**High frame rates** give good temporal resolution Readily available on most modern echo machines Analysis can be done online or offline	**Angle independent** Deformation can be assessed **in two dimensio** Can measure **both regional and global strain** Less influenced by artefacts than TDI More reproducible than TDI Semi-automated processing
antages	**Highly angle dependent** Can assess deformation in only **one dimension** Size and placement of sample volumes done **manually variation** significantly affects results Strain data derived from tissue velocity data—**prone to noise** **Apical segments** particularly difficult to interpret	**Lower frame rates** give lower temporal resolu Need excellent image quality for adequate tra **Lower spatial resolution** than TDI as region of interest determined automatically Tracking affected by out of plane cardiac mot **Lateral resolution** more limited than axial res Automatic tracking must be manually confirm each segment

ain as Parameters of Systolic function

Strain rate

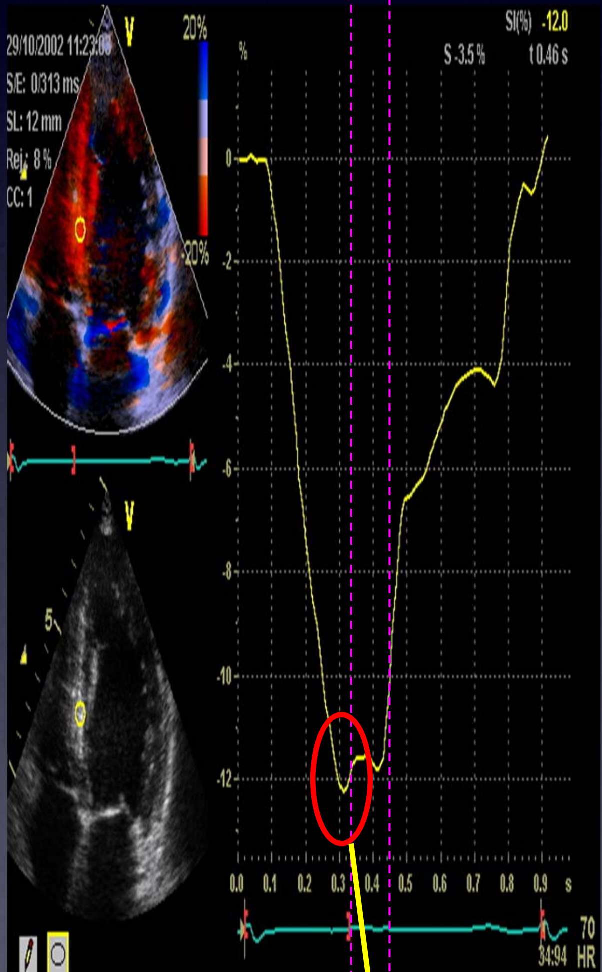
AVC MVO



Peak systolic SR

Strain

AVC MVO



End- systolic S

- ***End systolic strain estimates EF peak systolic SR is a measure of contractility.***

- *When driving a car both the tota distance of the journey as well as t speed of the car during the journe provide valuable information.*

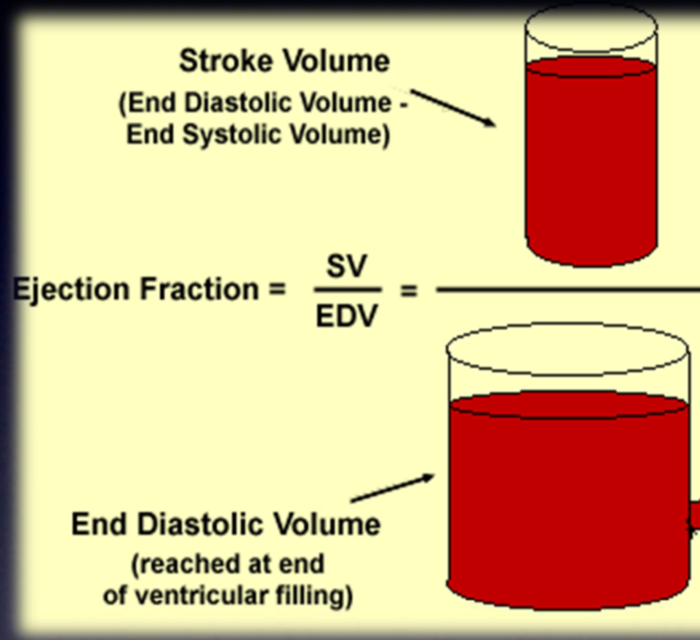
Measurement of LV Strain is superior to EF?

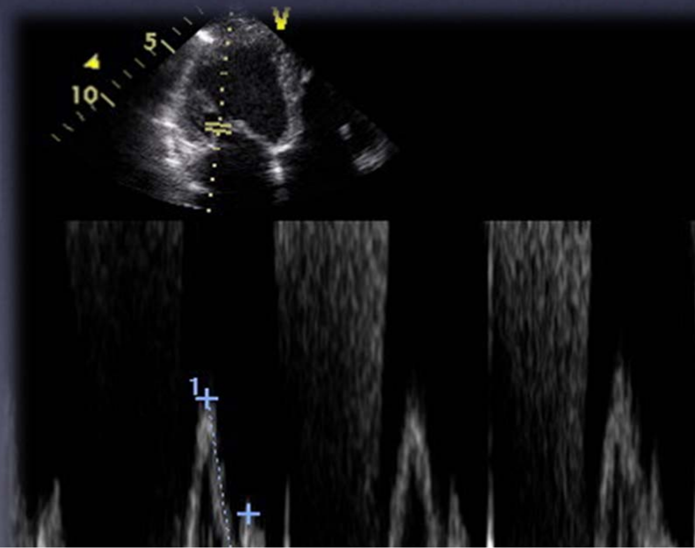
fraction(HFNEF)

Systolic function has been measured by EF

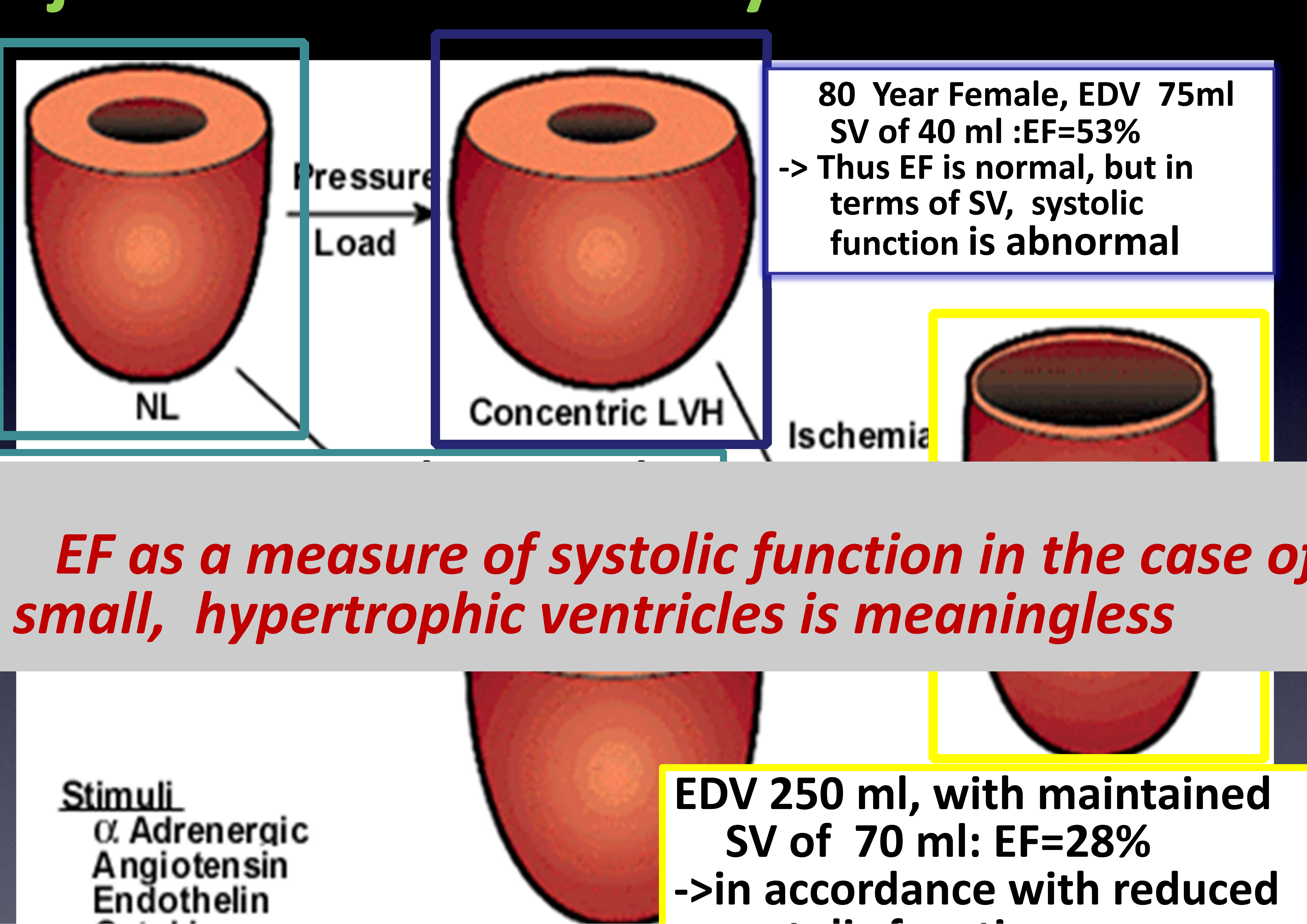
Diastolic function with mitral flow parameters,

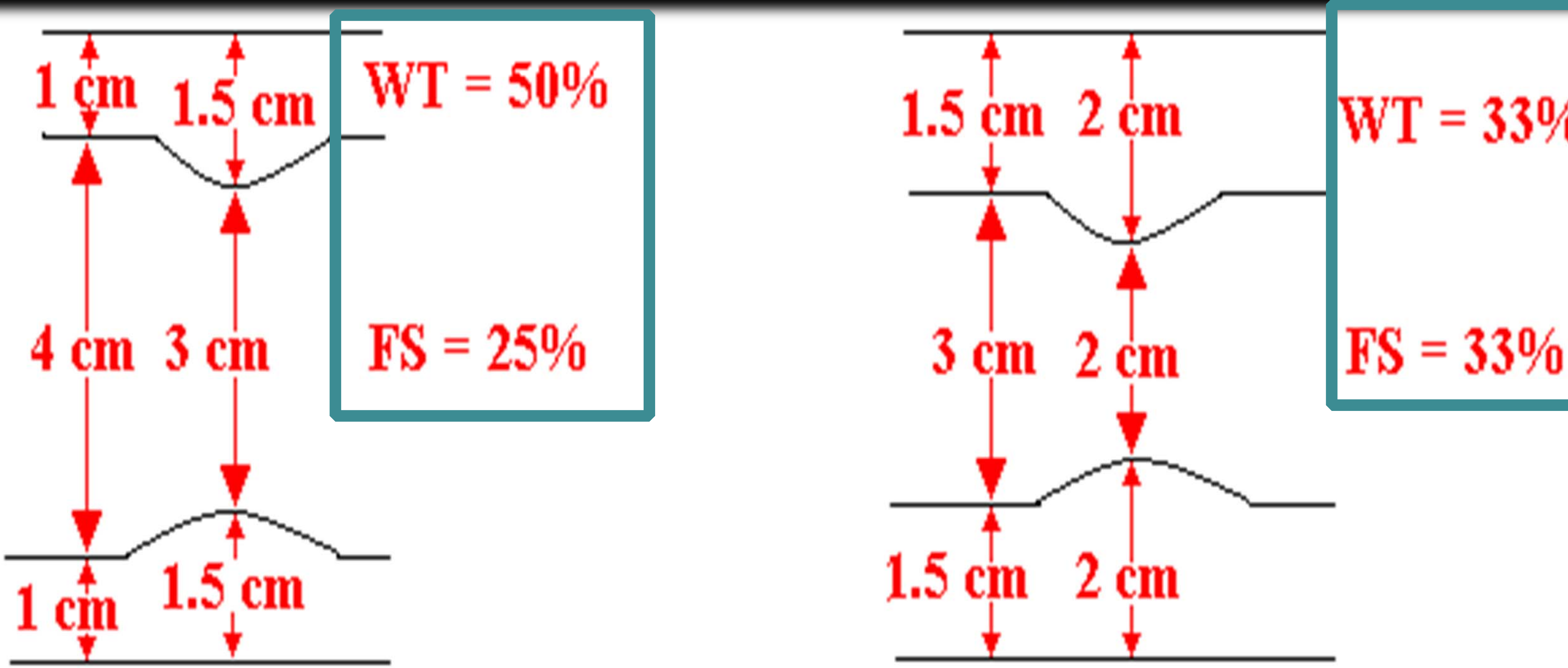
- **Isolated diastolic heart failure**



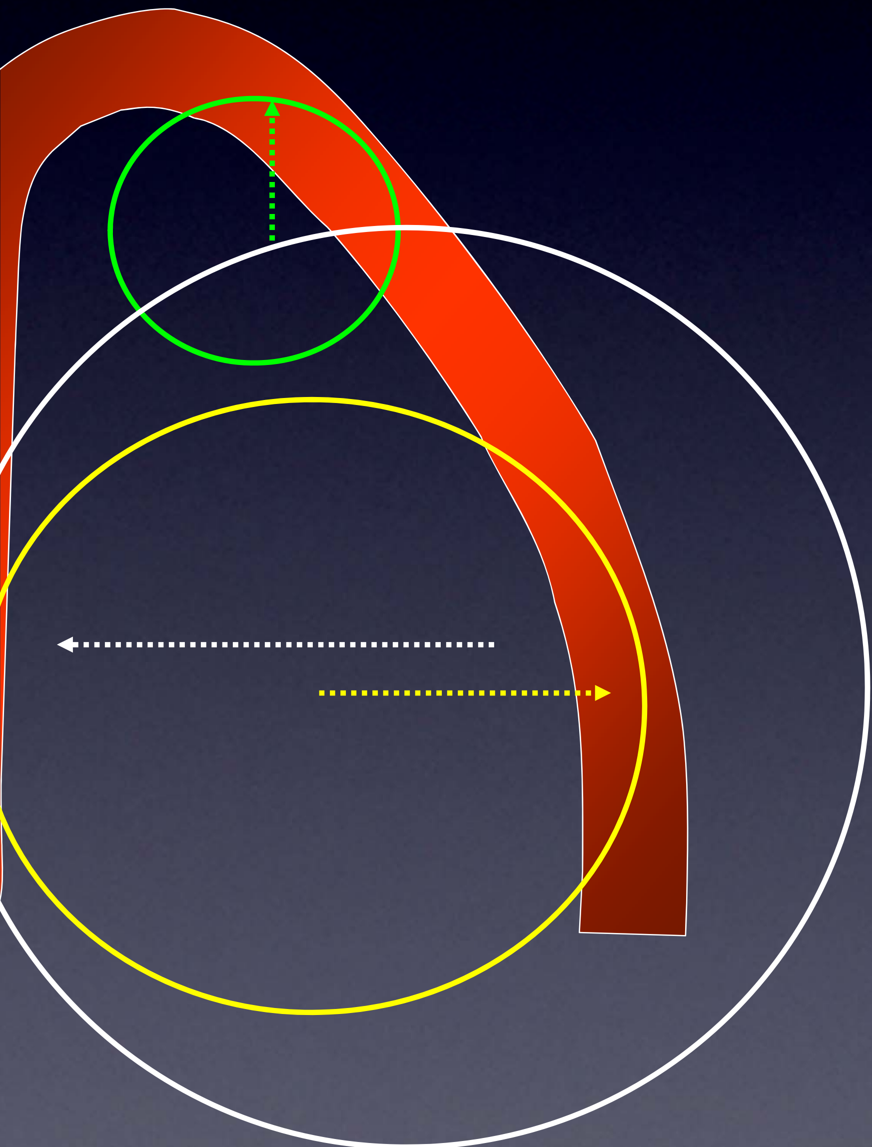


At the outset, measuring systolic and diastolic function by different measures with different sensitivity, is methodological nonsense in any


Pressure
Load
NL
Concentric LVH
Ischemia
80 Year Female, EDV 75ml
SV of 40 ml :EF=53%
-> Thus EF is normal, but in terms of SV, systolic function is abnormal
EF as a measure of systolic function in the case of small, hypertrophic ventricles is meaningless
Stimuli
α Adrenergic
Angiotensin
Endothelin
EDV 250 ml, with maintained
SV of 70 ml: EF=28%
->in accordance with reduced



- *Any conclusions about radial function based on fractional shortening in the presence of hypertrophy may be erroneous, and the term radial function needs to be defined.*
- *Endocardial fractional shortening, which measures circumferential functio*



Wall stress related to:

- Pressure ↑ → σ ↑
- Shape, cavity size ↑ → σ ↑
- Wall thickness ↑ → σ ↓

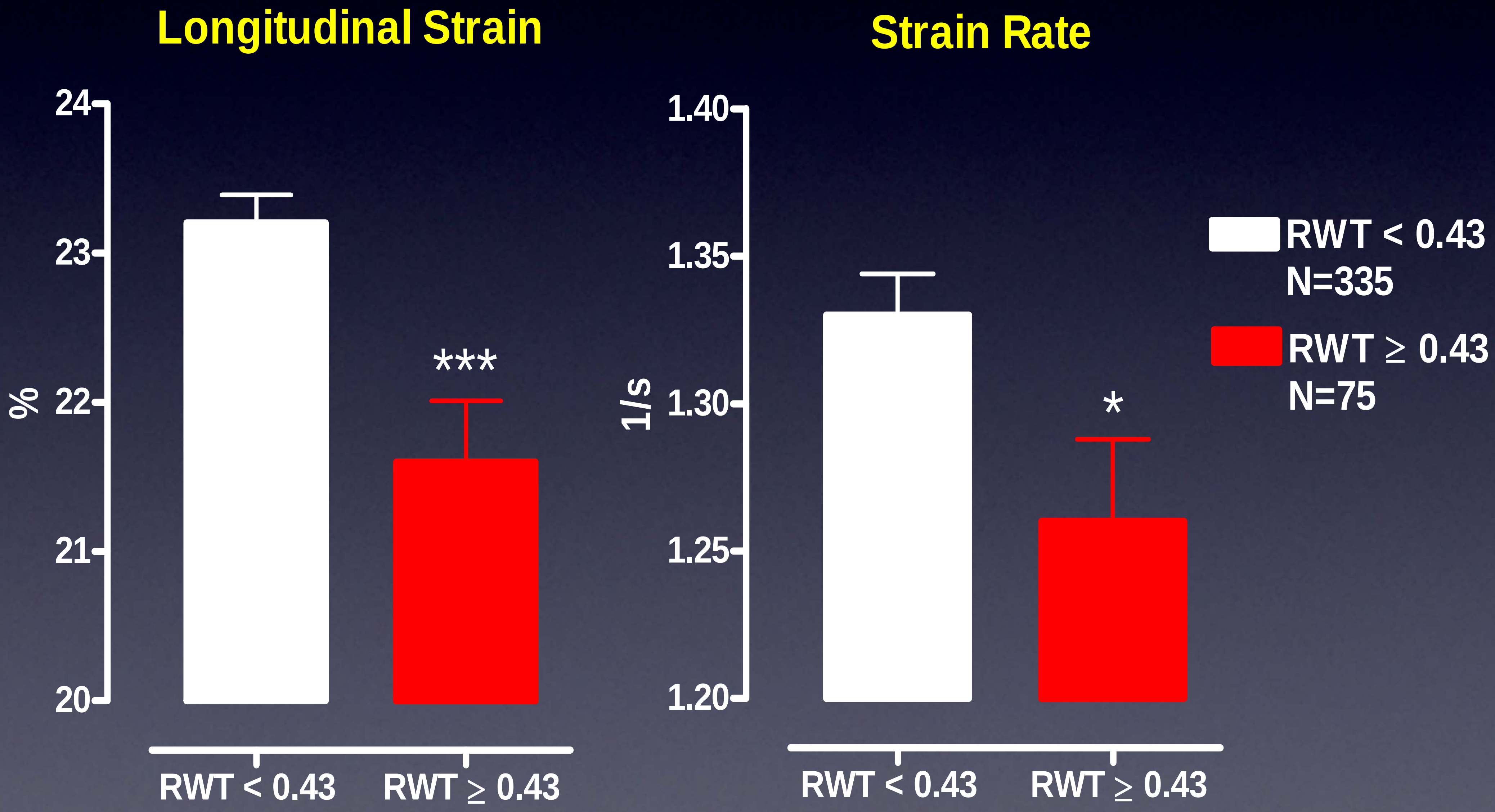
↓

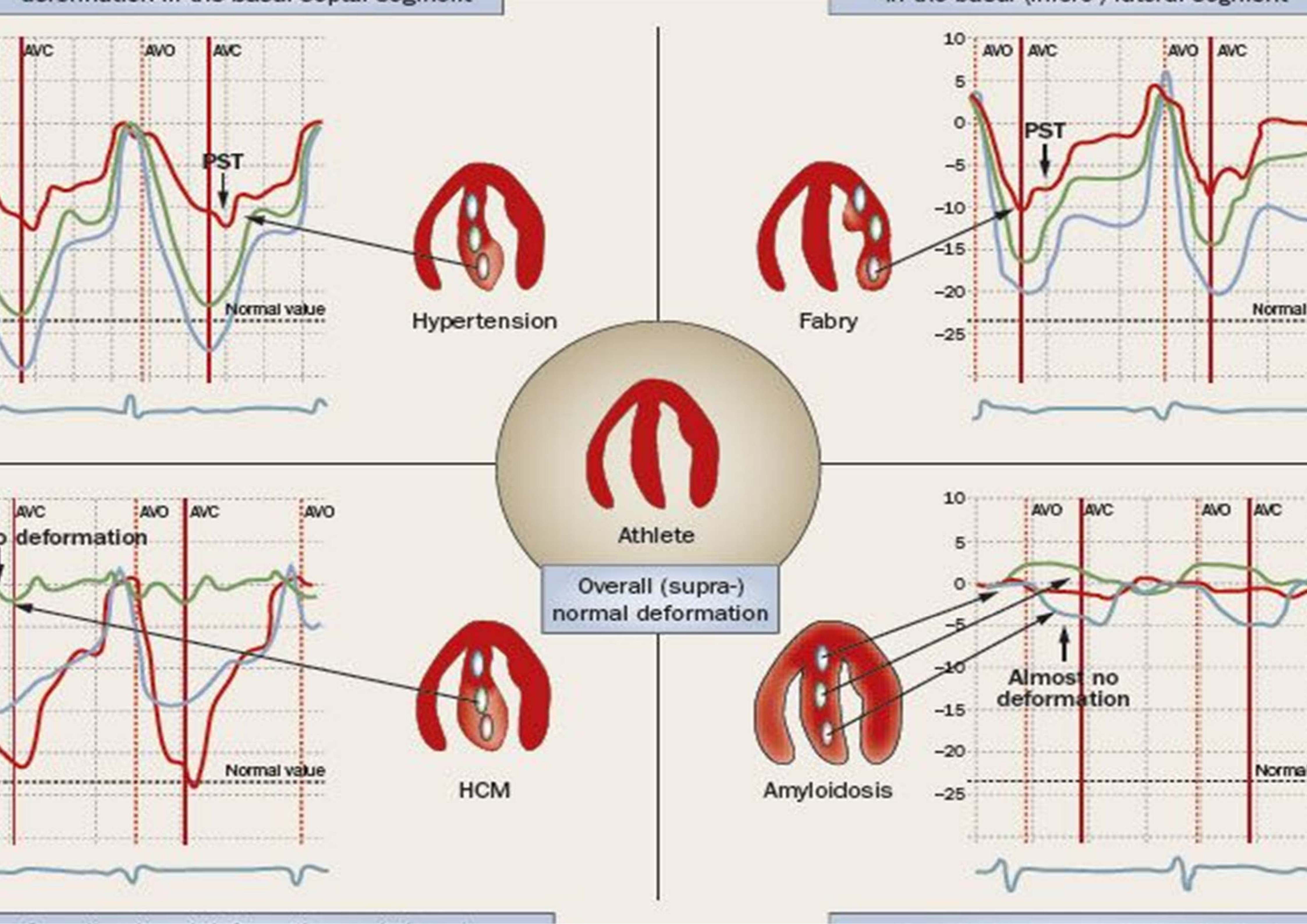
$\sigma = P \times R / 2WT$

Since R curvature is larger in longitudinal direction, the stress on longitudinal fibres is higher, they sho

decreased deformation first

Longitudinal S and SR by RWT





AVC
AVO
PST
Normal value
Hypertension
Fabry
Athlete
Overall (supra-) normal deformation
o deformation
HCM
Amyloidosis
Almost no deformation
10
5
0
−5
−10
−15
−20
−25

train is good parameters of systolic function

Systolic function measured by

train parameters with tissue velocity

Diastolic function by mitral flow

parameters with RBC velocity

fact there is a close link between diastolic and systolic function when

Systolic function !

Contractility (the basic property of myocardiu that reflects its active state, rather than loadir conditions) is reflected by the stress/strain relation

imaging in the field of echocardiography

The high sensitivity of both TDI-derived and 2D speckle tracking derived strain
*nd SR data for the **early detection of myocardial dysfunction** recommend*
his new non-invasive diagnostic method for routine clinical use.

ditional value

masking subtle pathology

antifying myocardial function

sualizing timing issues

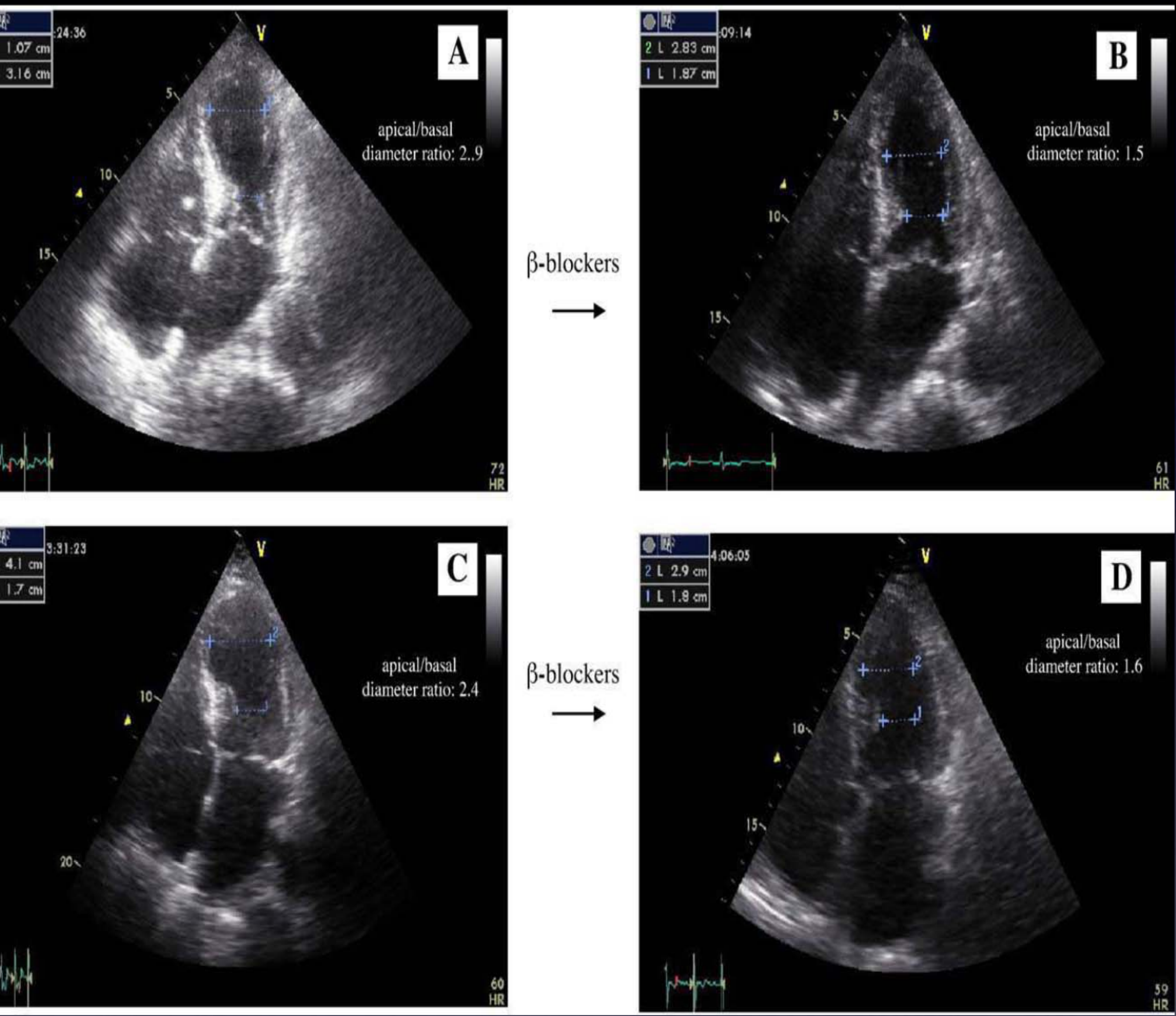
tecting subtle changes over time

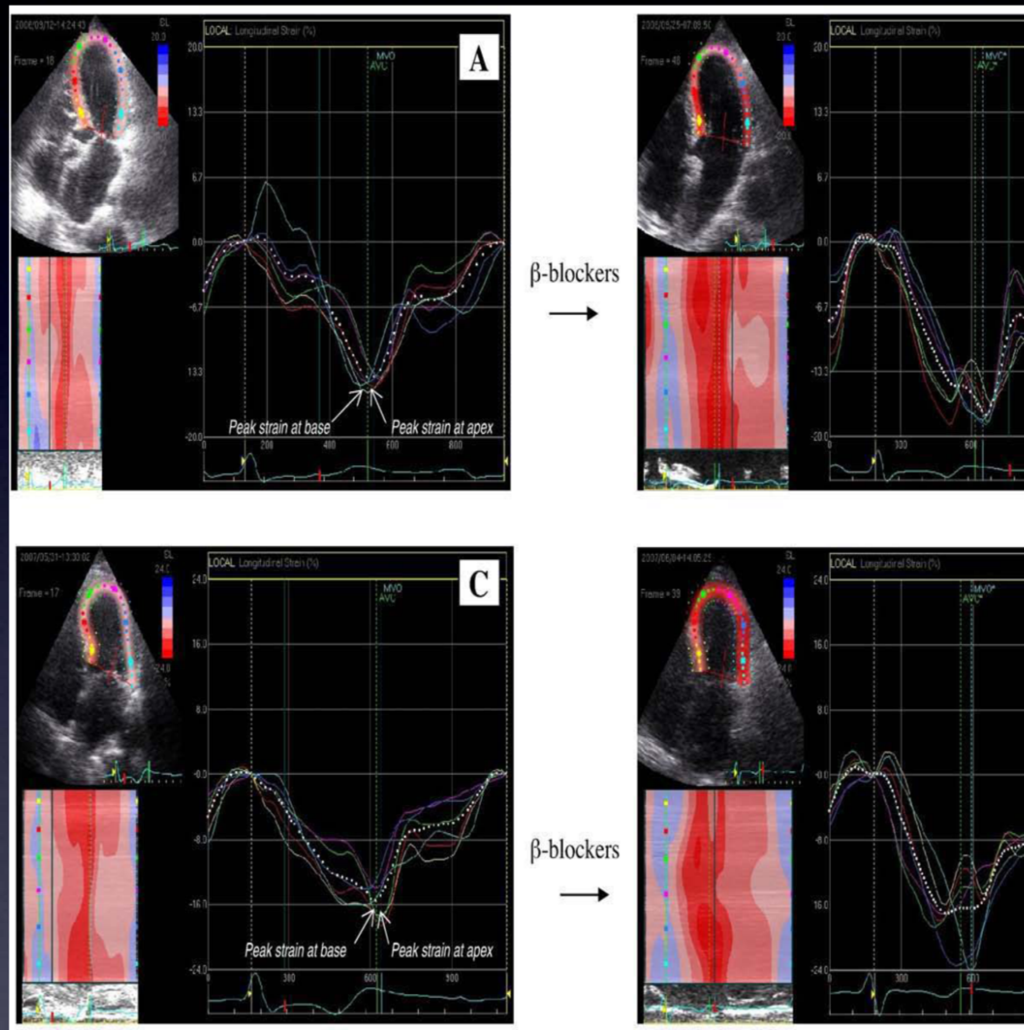
proving inter/intra observer variability

Potential utilities

- Early diagnosis coronary artery disease and cardiomyopathy
- Objective assessment of regional function
- Quantification of timing within a heart cycle
- Therapy evaluation in patient follow-up
- Increasing accuracy of stress echocardiogra

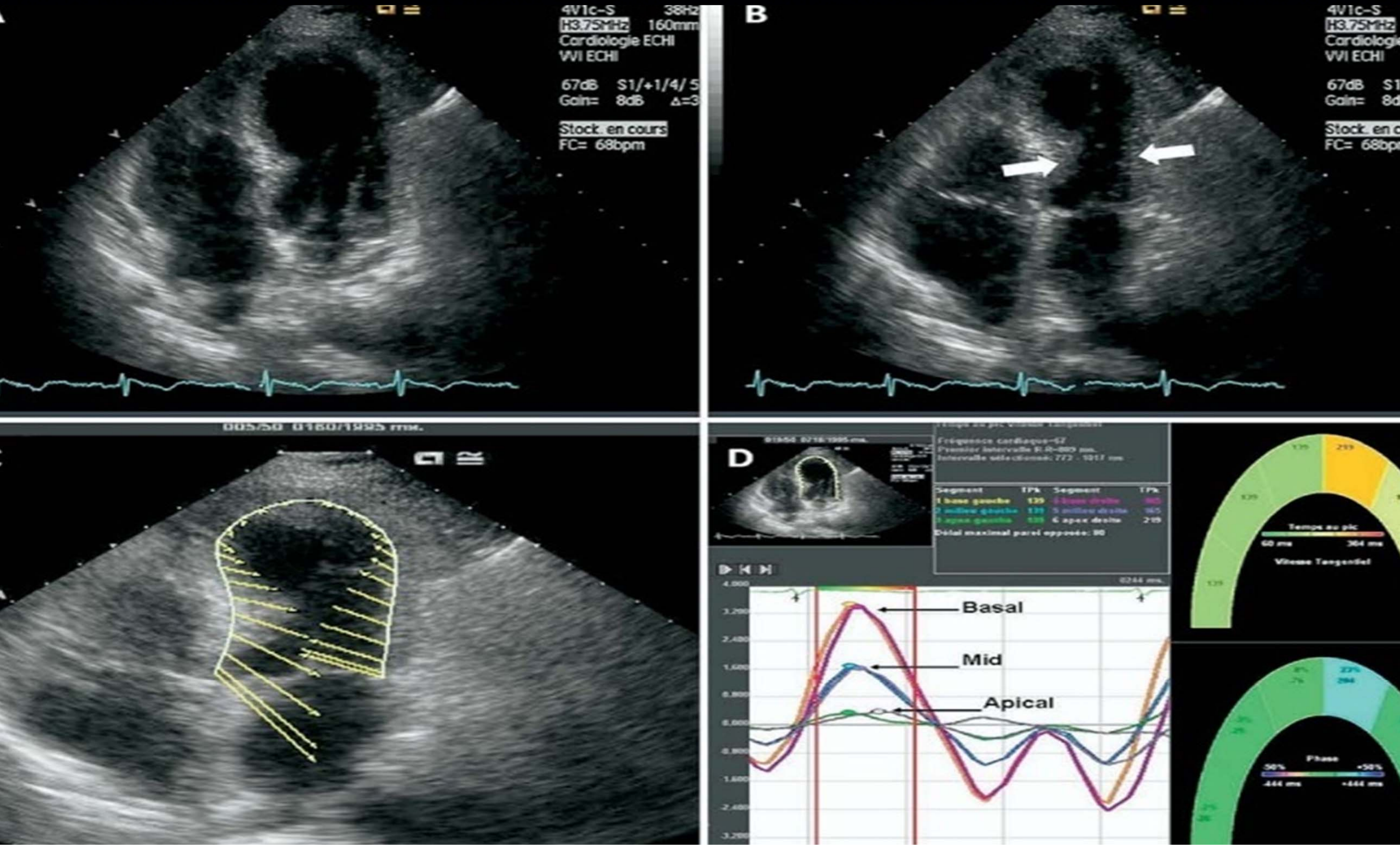
LV wall motion abnormality and myocardial dysfunction in stress cardiomyop



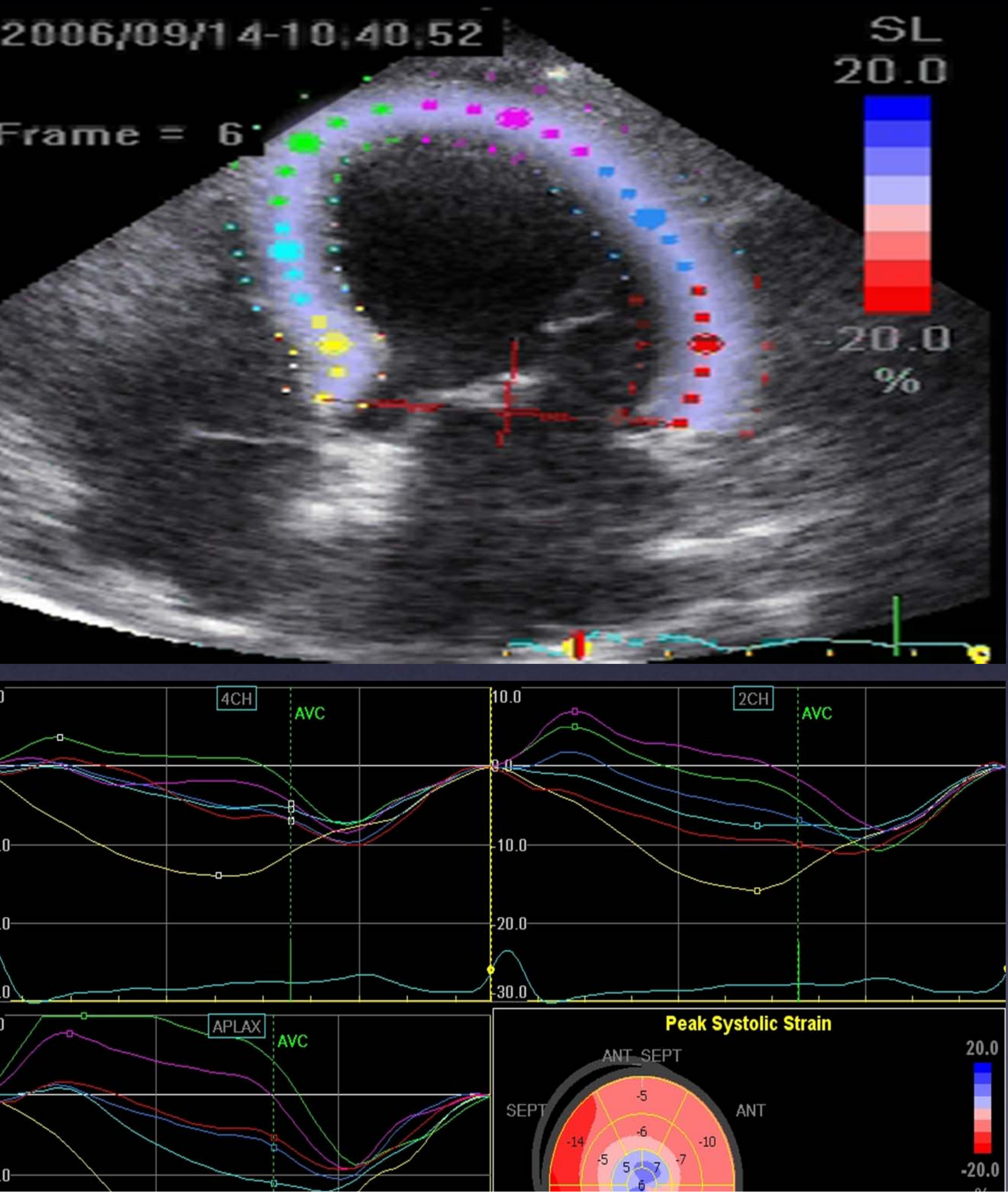


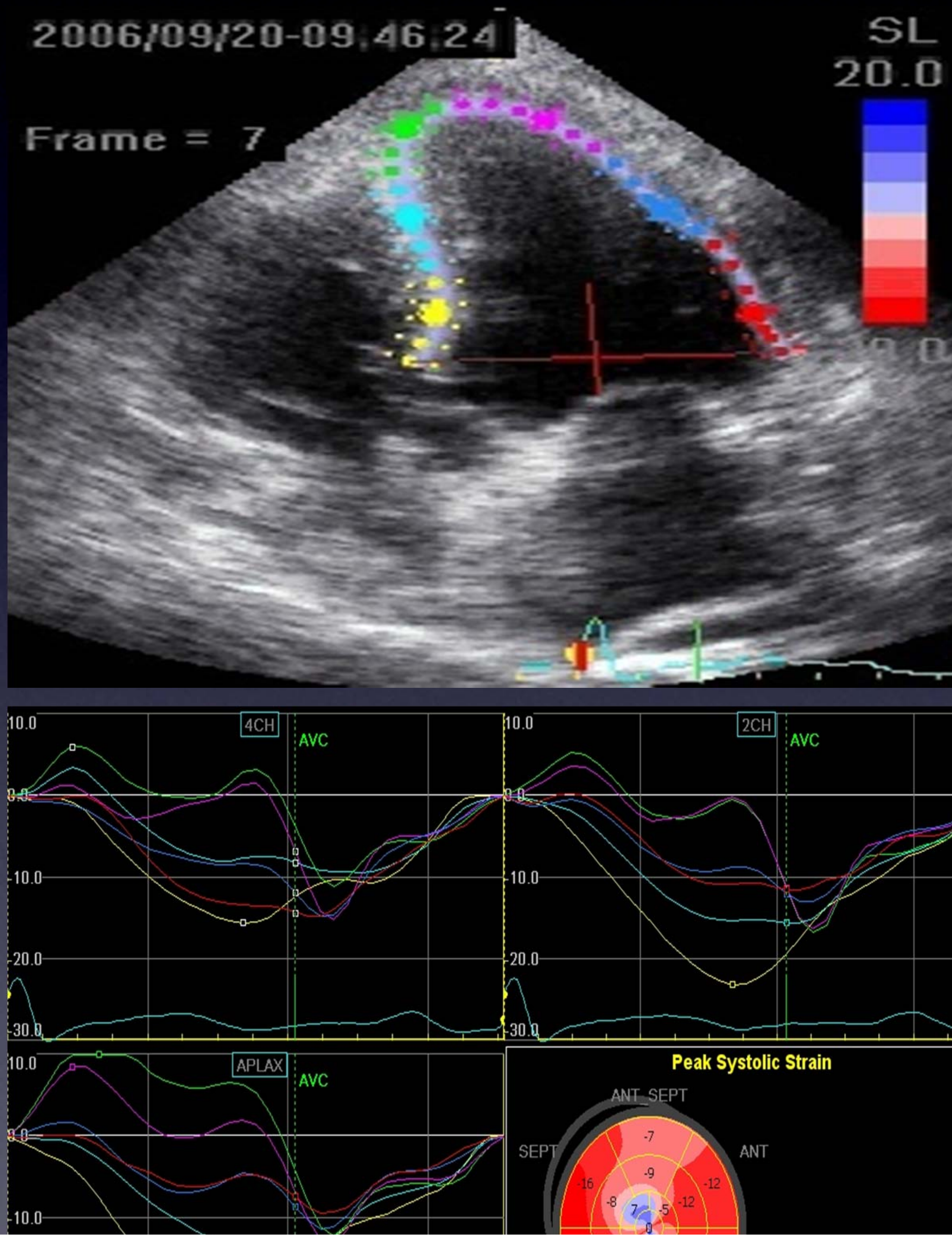
***igh systolic circumferential wall stress reduce* circumferential fiber shorte**
nd thus apical akinesia and ballooning could be mainly the consequences o
eometry-induced regional differences in wall stress, rather than a result of

Assessment of Tako-Tsubo Cardiomyo



recovery of LV function in stress cardiomyopathy

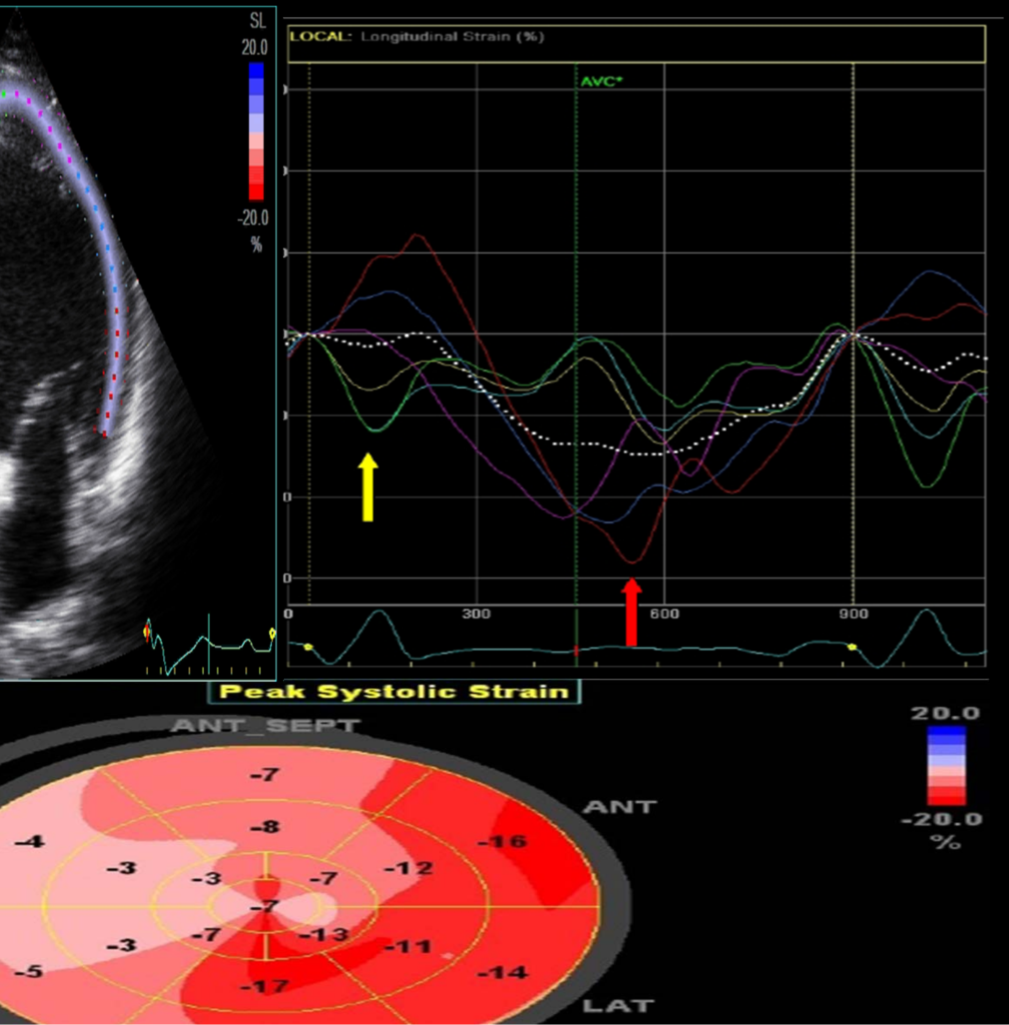




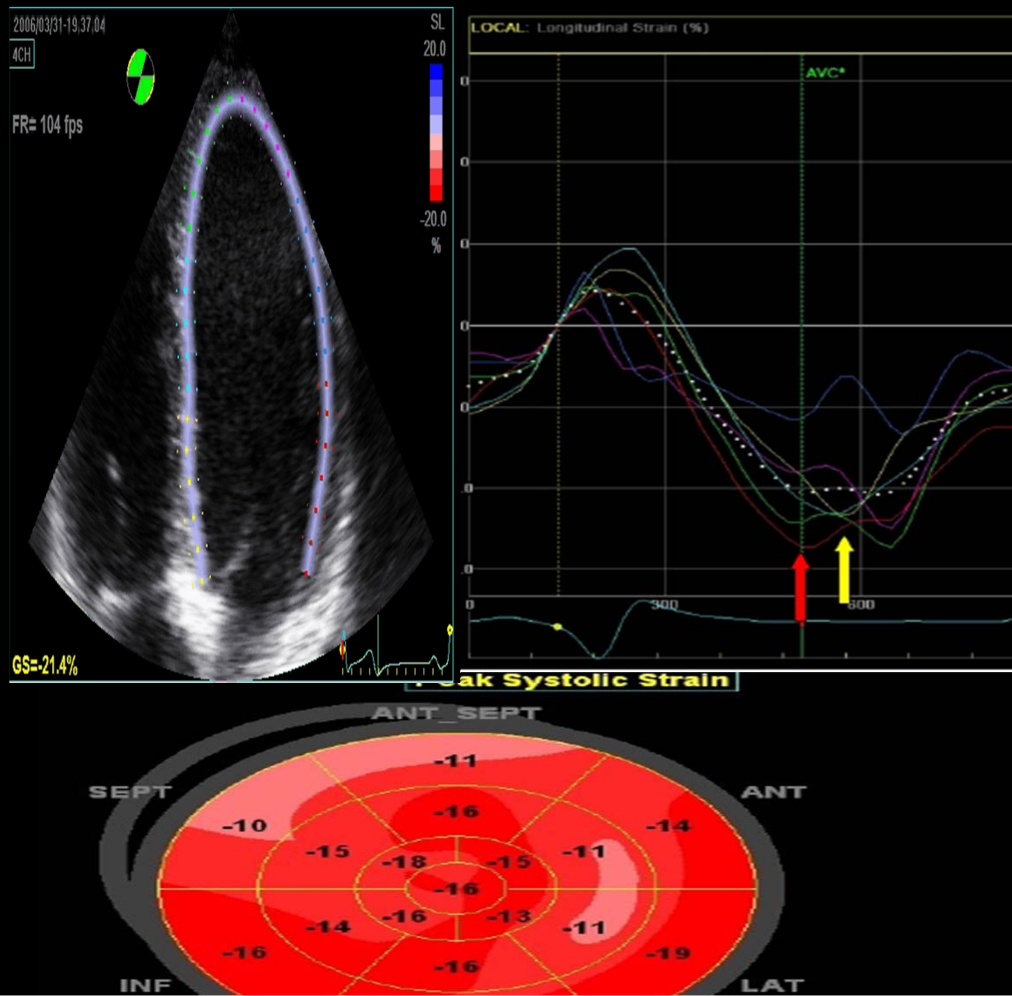
CRT-patient selectio

BB with a QRS-width >120 ms, NYHA-class III-IV d an EF of 22%) who was implanted with a CRT-device

eptal-to-lateral delay to peak strain value of 425 msec using 2DSE

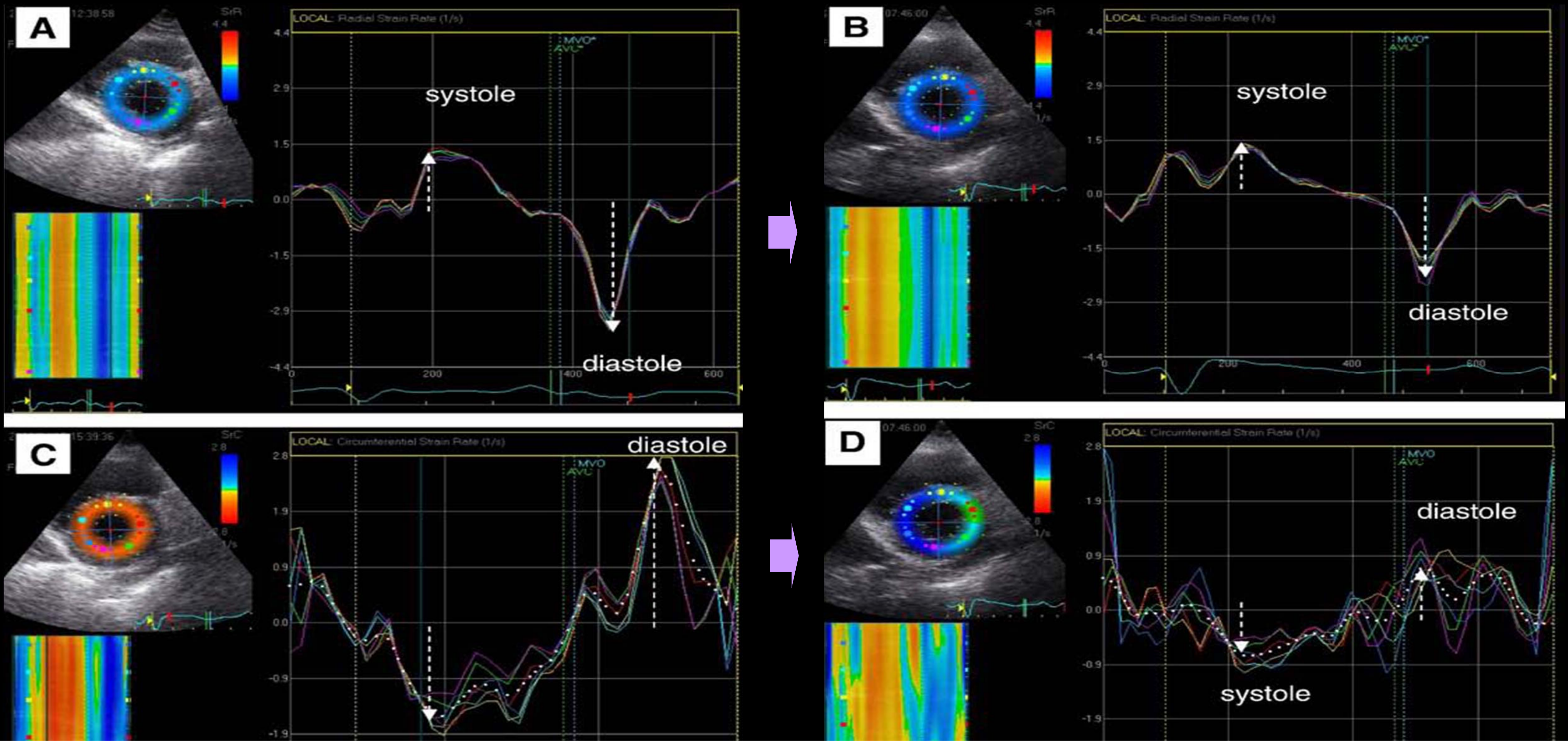


- After 8 months, improvement of EF (to 42% longitudinal deformation during systole, redu LV volume
- 2DSE revealed a nearly synchronous longitu shortening with a septal-to-lateral delay of -6



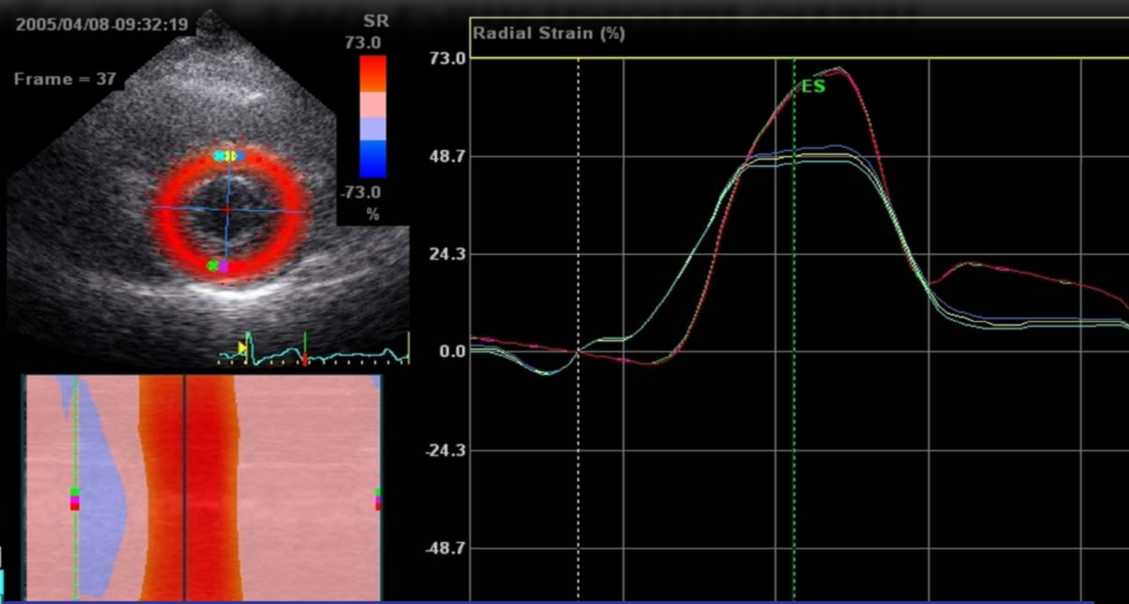
sensitive indicators for surgical LV rest

Systolic and diastolic global strain rate reduction appeared to be mor sensitive for the early detection of acute rejection than the reduction systolic and early diastolic global strain values.

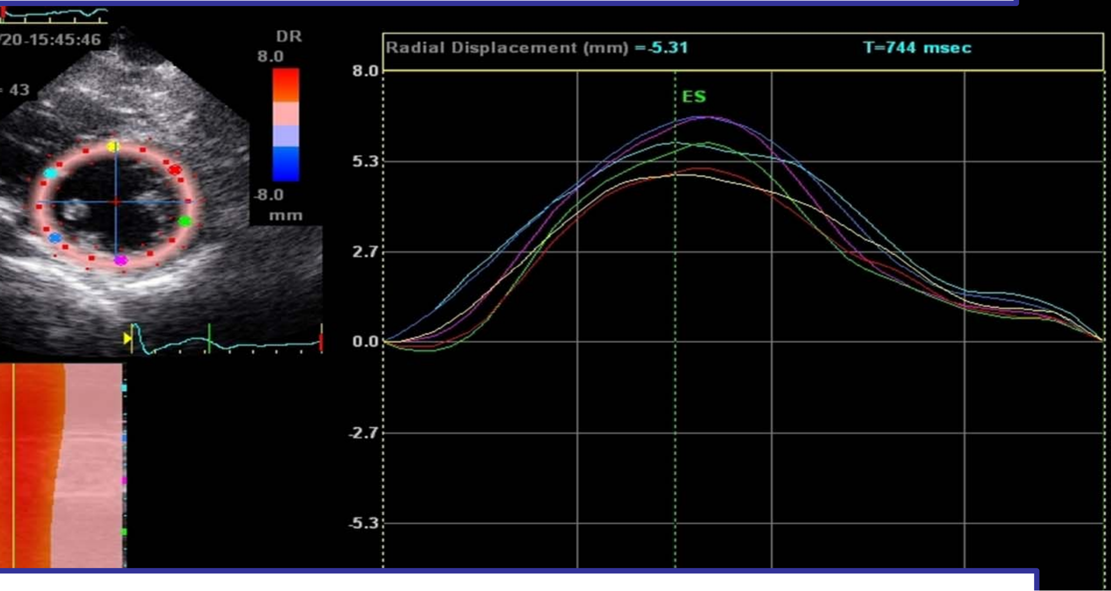


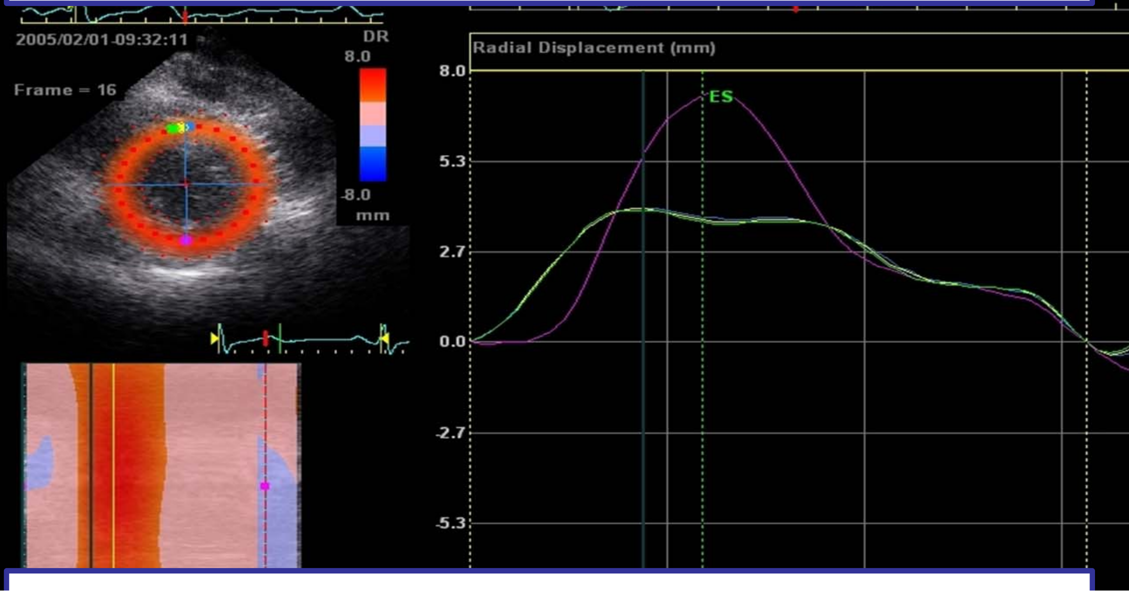
Assessment of Left Ventricular Function in Symptomatic Patie[nts] with Myocardial Bridge using Two-Dimensional Strain

A. Radial strain in control



B. Radial strain in MB





With Stress echocardi

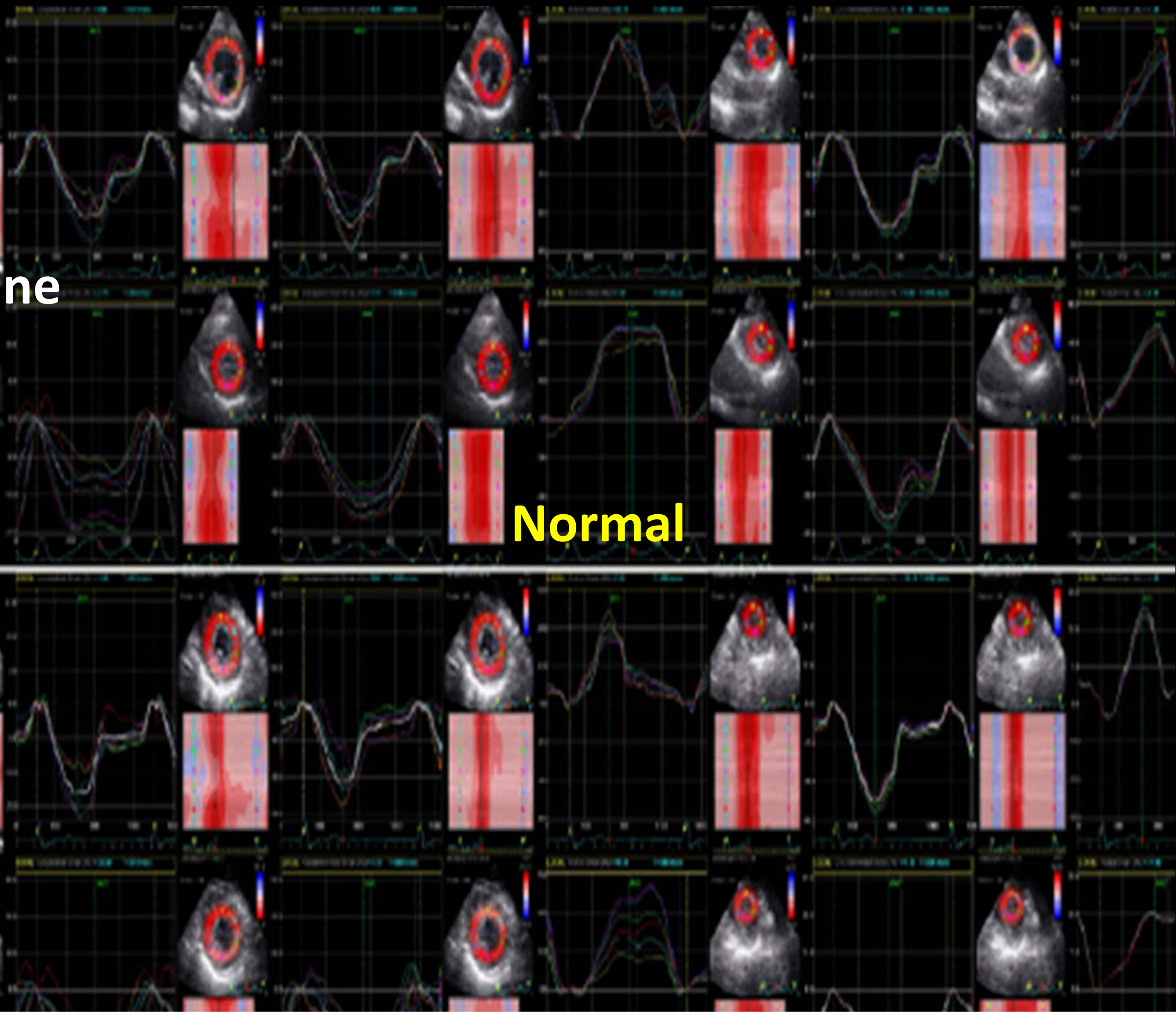
ngitudinal
ain

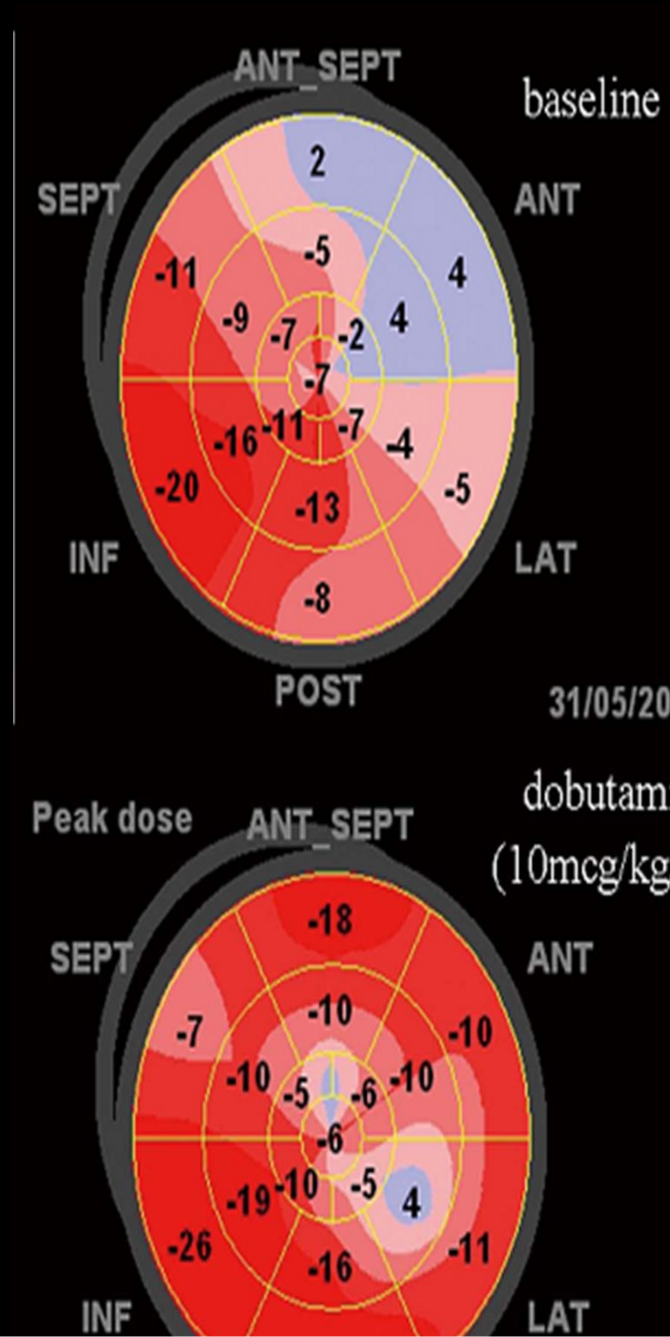
Midventricular circumferntial strain

Midventricular radial strain

Apical circumferntial strain

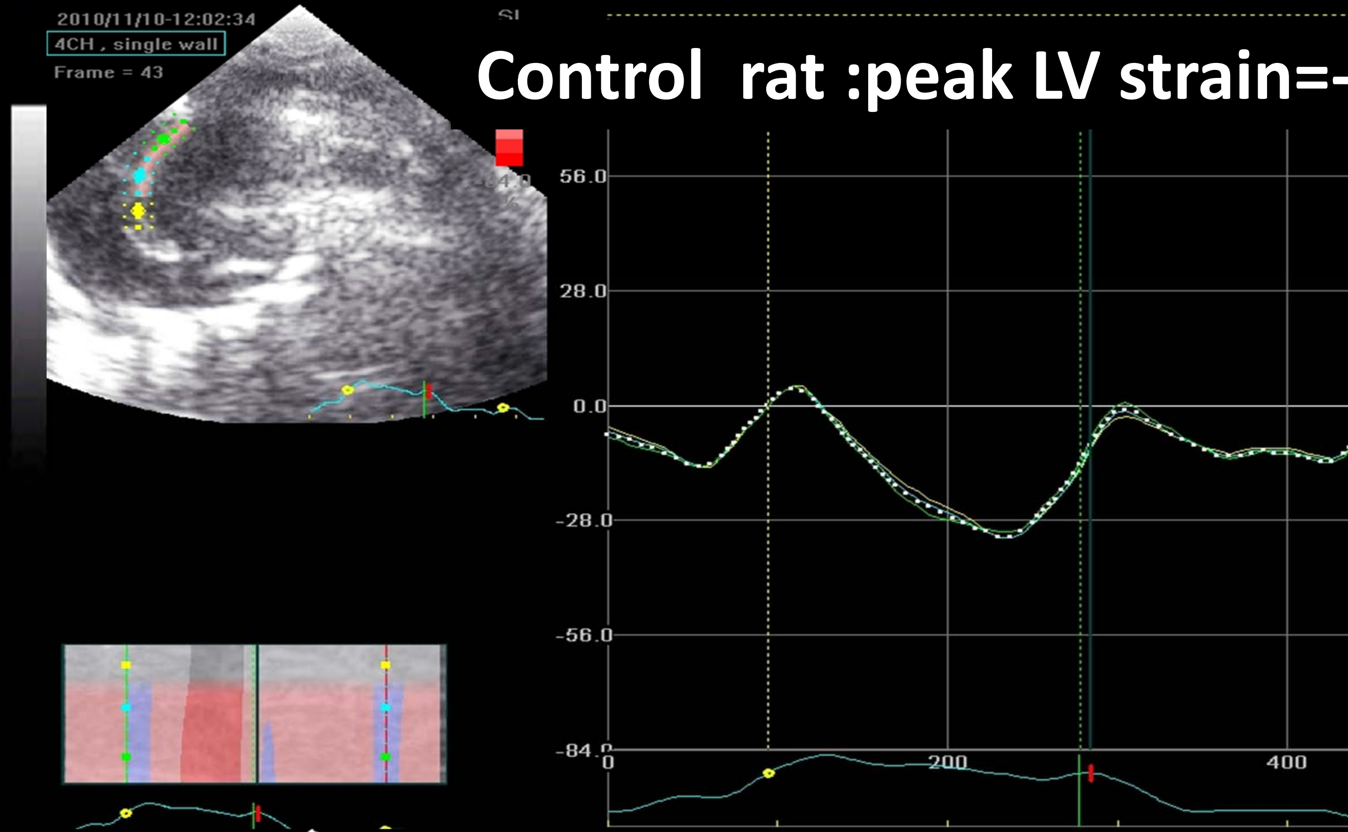
Apical radial strain



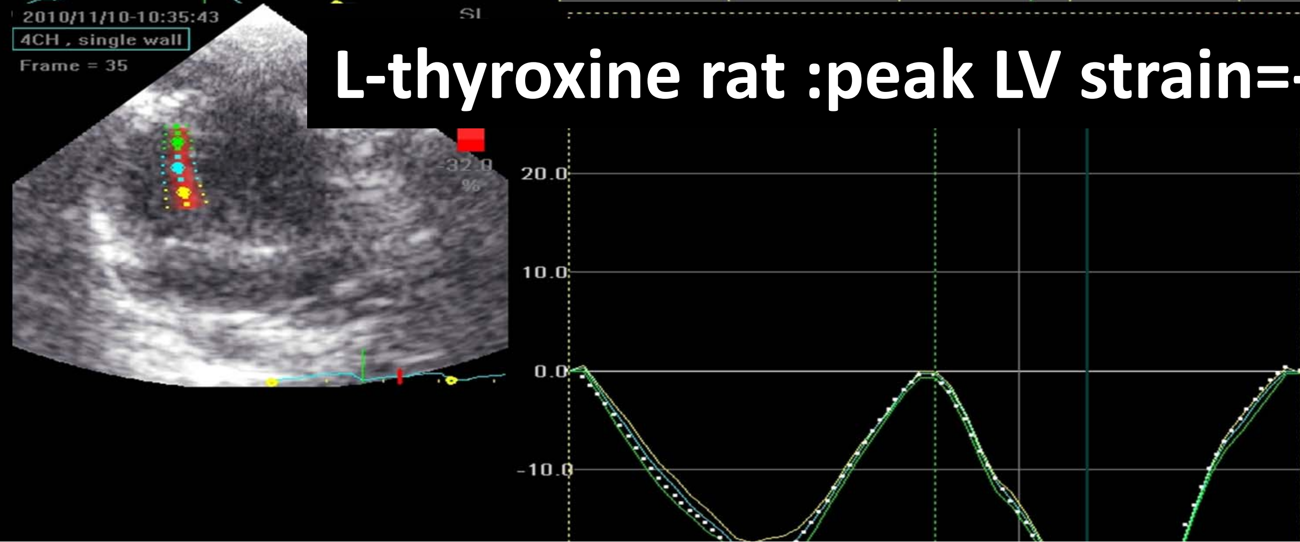


Hyperthyroid cardion

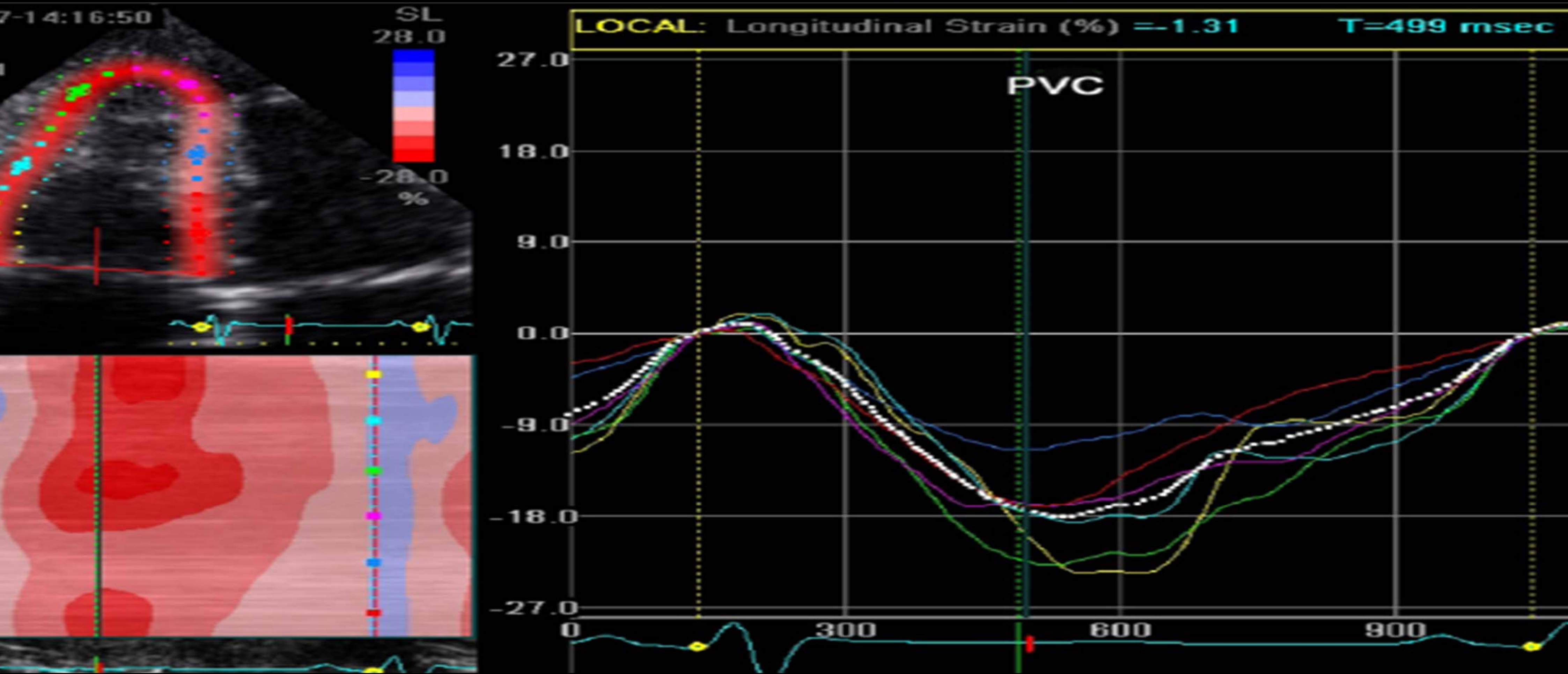
Control rat :peak LV strain=-



L-thyroxine rat :peak LV strain=-



sensitive indicators for and R



train and SR imaging is also useful for the evaluation of **RV functio**
pulmonary hypertension and RV diseases of different etiologies (
infarction, arrhythmogenic RV dysplasia/cardiomyopathy

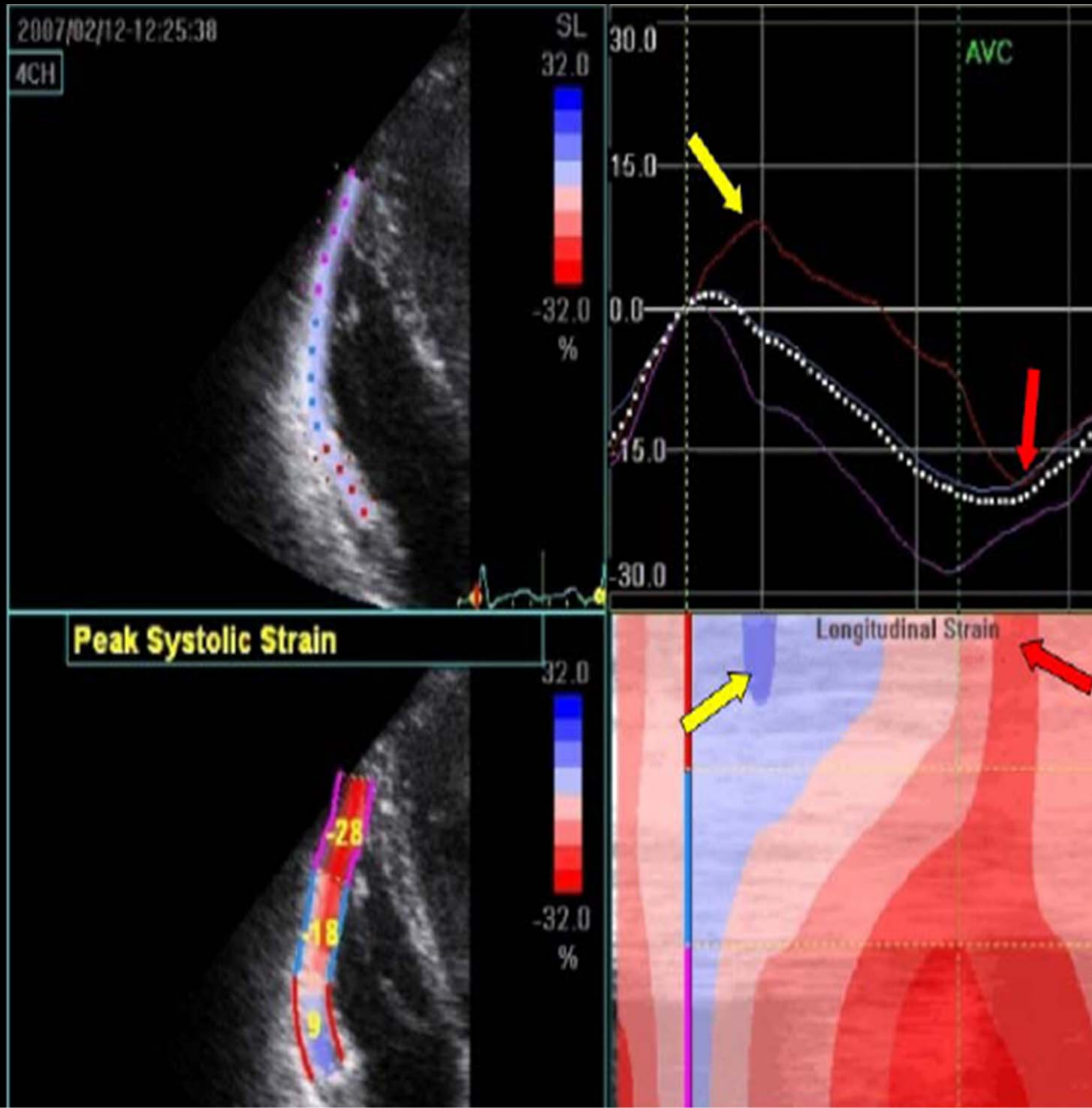
Gondi S, Dokainish H. Echocardiogaphy 2007;24(5):322–32

36 year old woman with arrhythmogenic right ventricular dysplasia (A

he RV was not dilated, no RWMA
or any other typical ARVD findings
n conventional echocardiographic
amination

ssue Doppler strain analysis as
ell as 2DSE revealed an abnormal
eformation pattern in the basal
gment.

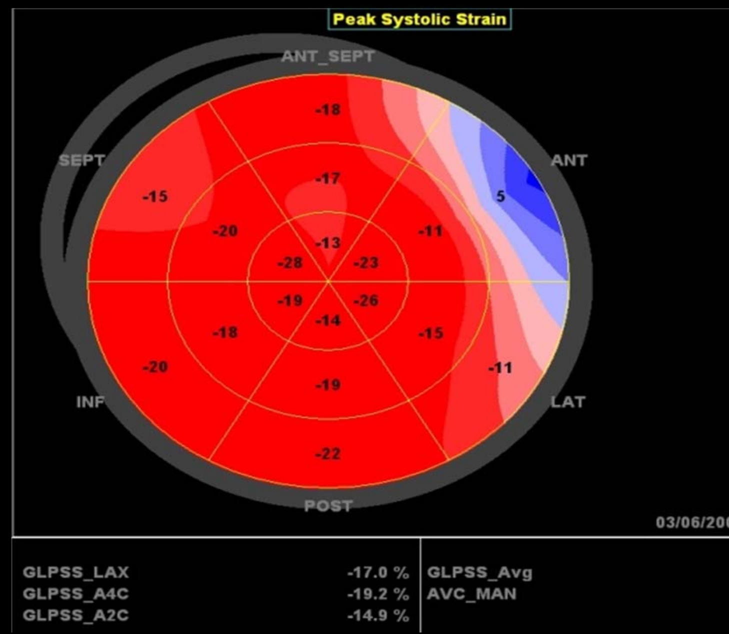
ased on this finding, this patient
ored a minor criterion (regional
/ hypokinesia) fulfilling the
agnostic criteria for ARVD (one
ajor and two minor criteria).



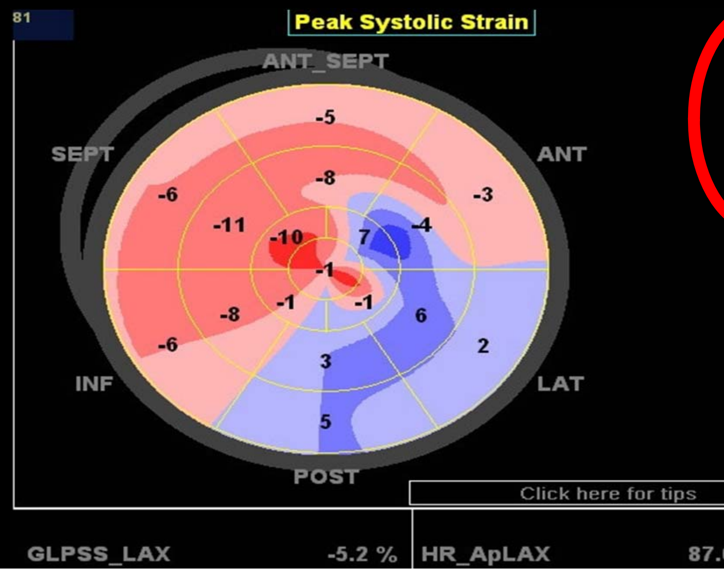
Time-factor to overcome…..

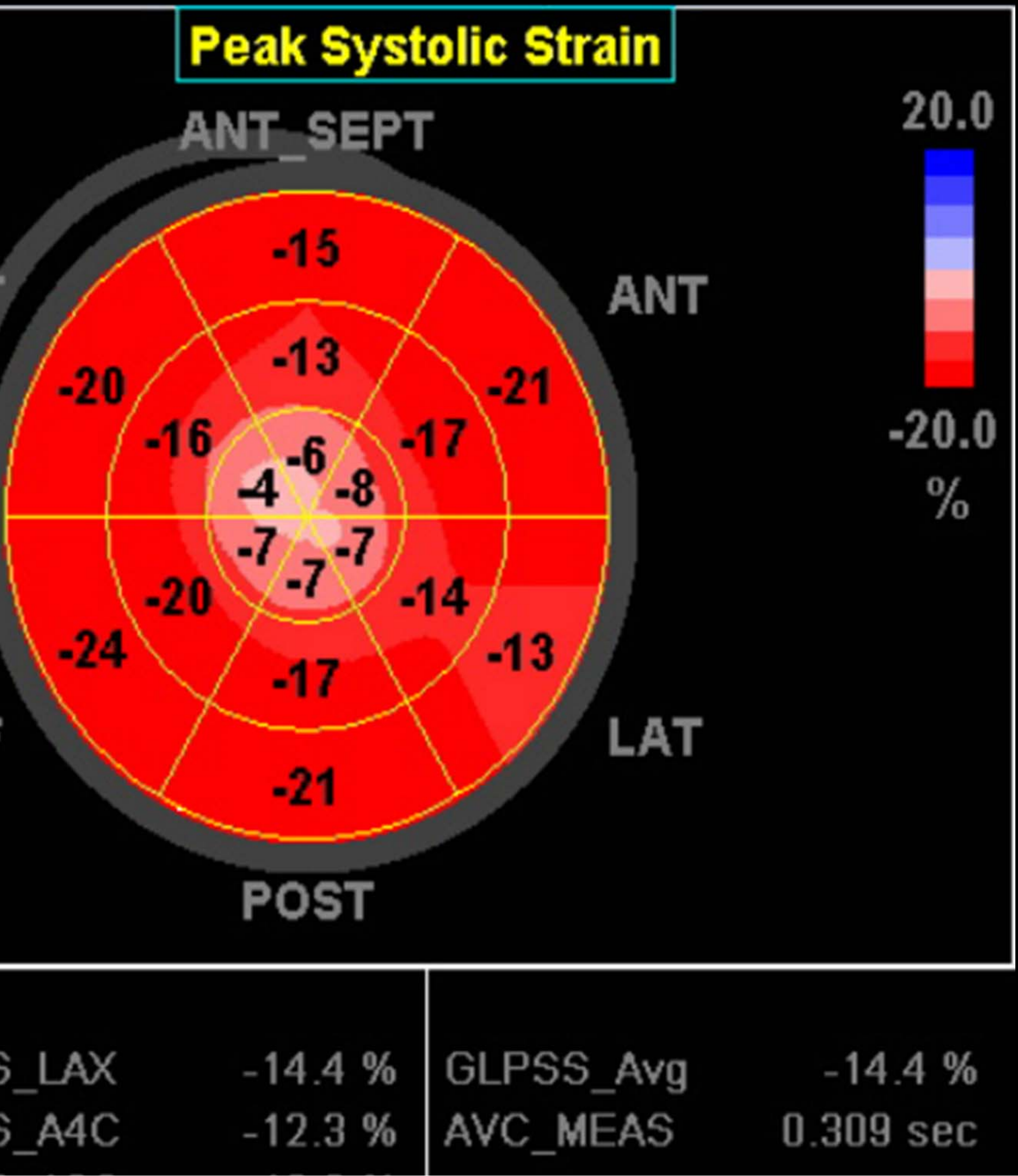
The practical approach to quantify LV function

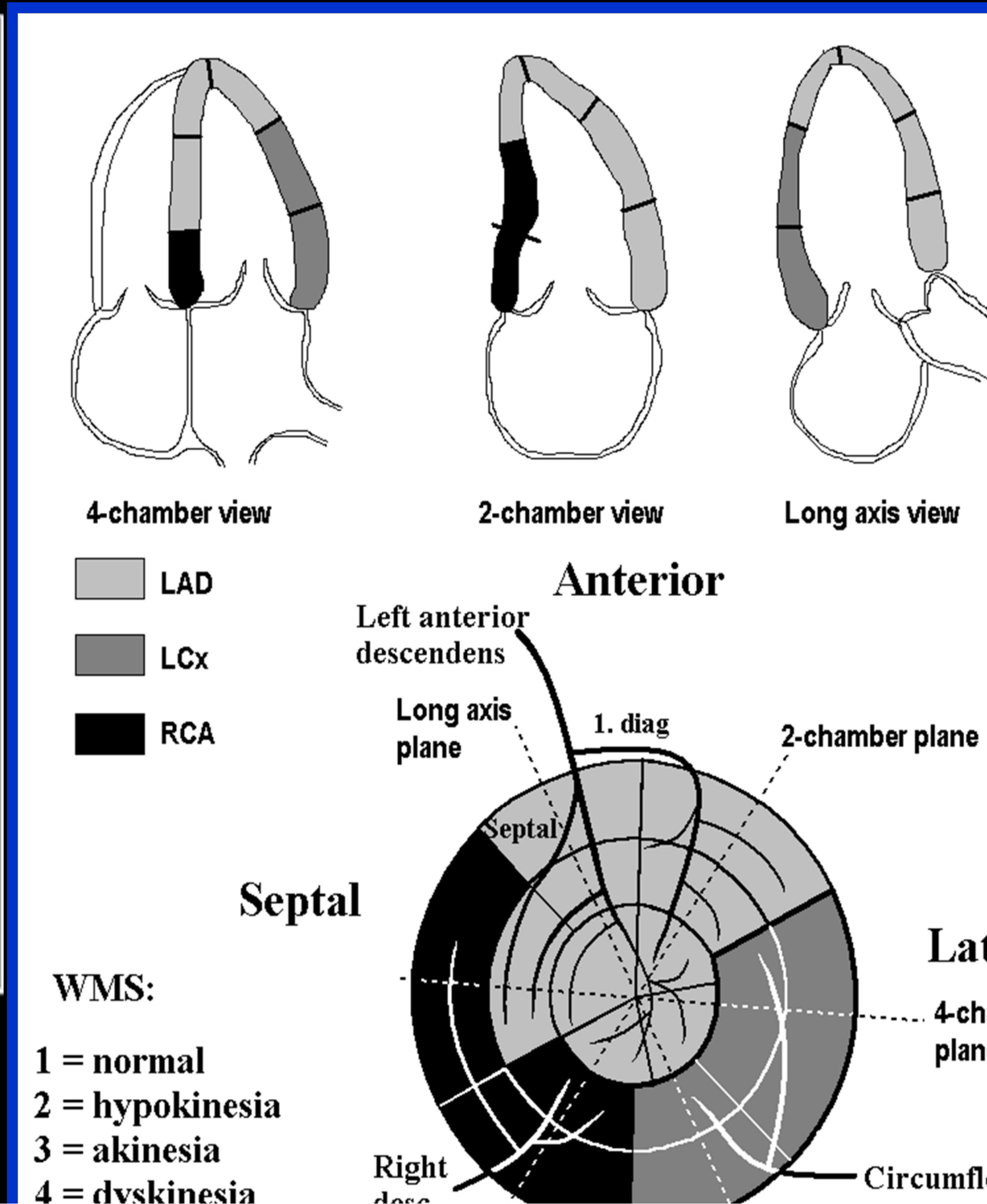
AMI



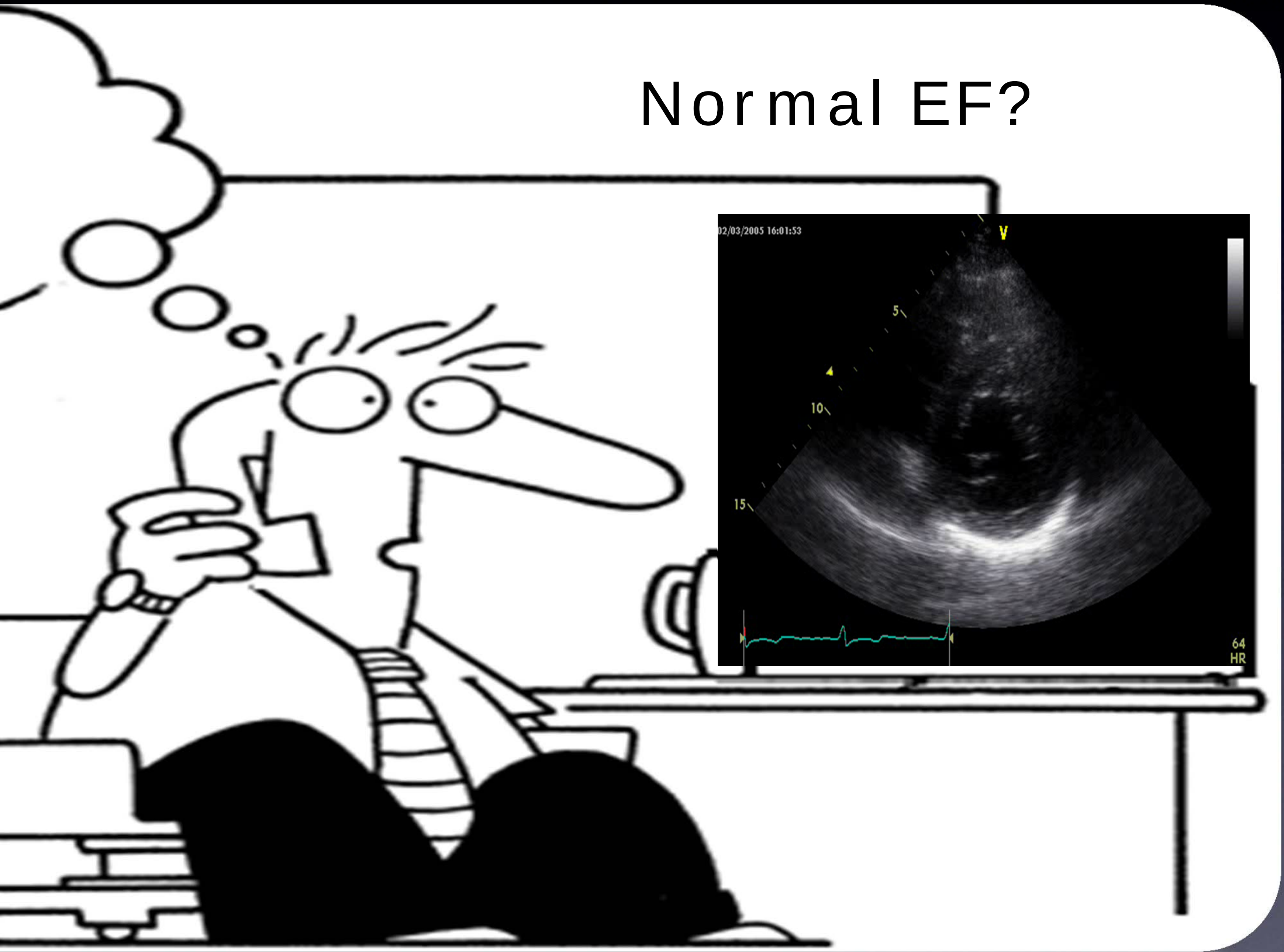
HF



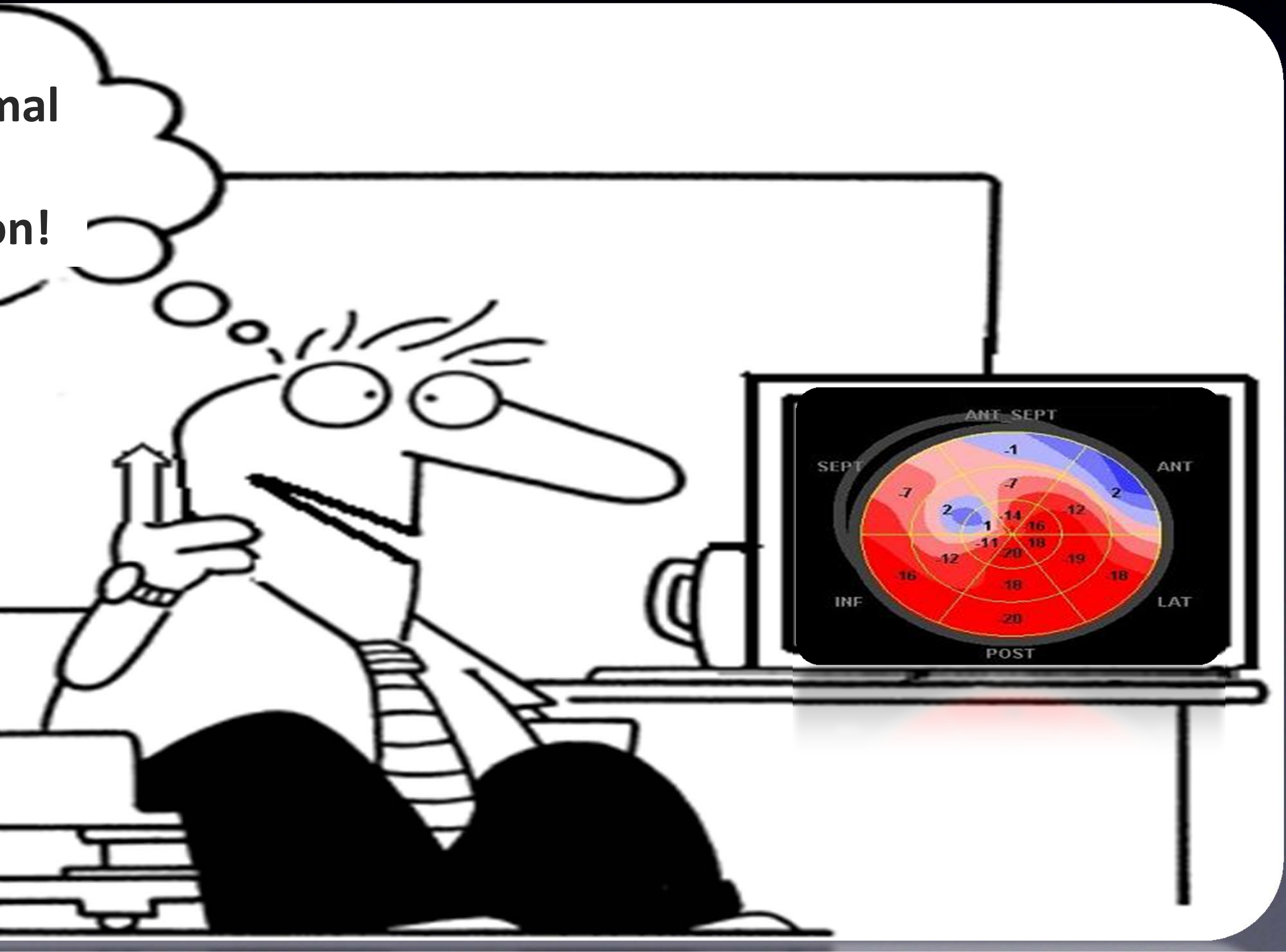

Peak Systolic Strain
ANT_SEPT
ANT
LAT
POST
20.0
-20.0
%
-15
-13
-20
-21
-16
-17
-6
-4
-8
-7
-7
-7
-20
-14
-24
-13
-17
-21
S_LAX -14.4 %
S_A4C -12.3 %
GLPSS_Avg -14.4 %
AVC_MEAS 0.309 sec


4-chamber view
2-chamber view
Long axis view
LAD
LCx
RCA
Anterior
Left anterior descendens
Long axis plane
1. diag
2-chamber plane
Septal
Septal
WMS:
1 = normal
2 = hypokinesia
3 = akinesia
4 = dyskinesia
Right

From Subjective Expert Evaluation



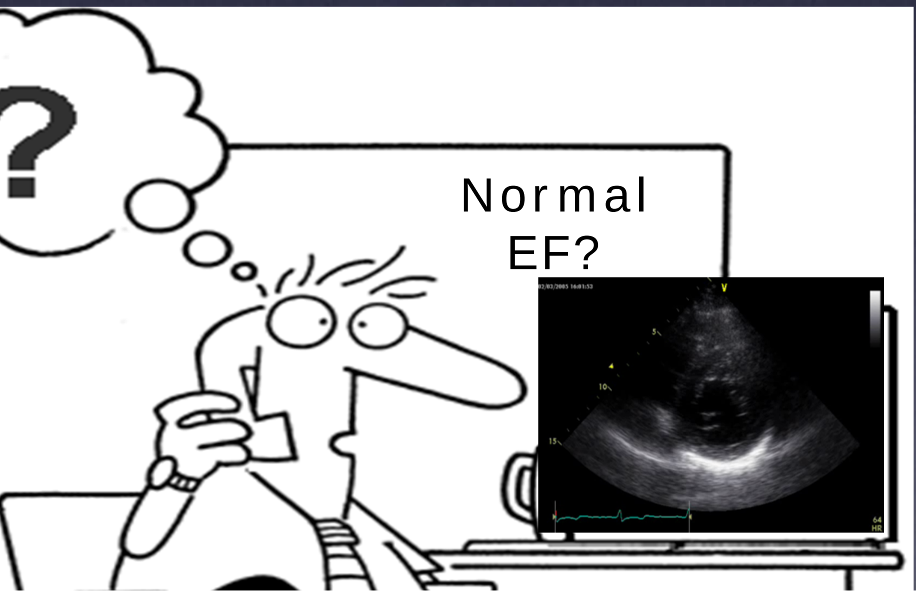
To Quick Quantitative Information

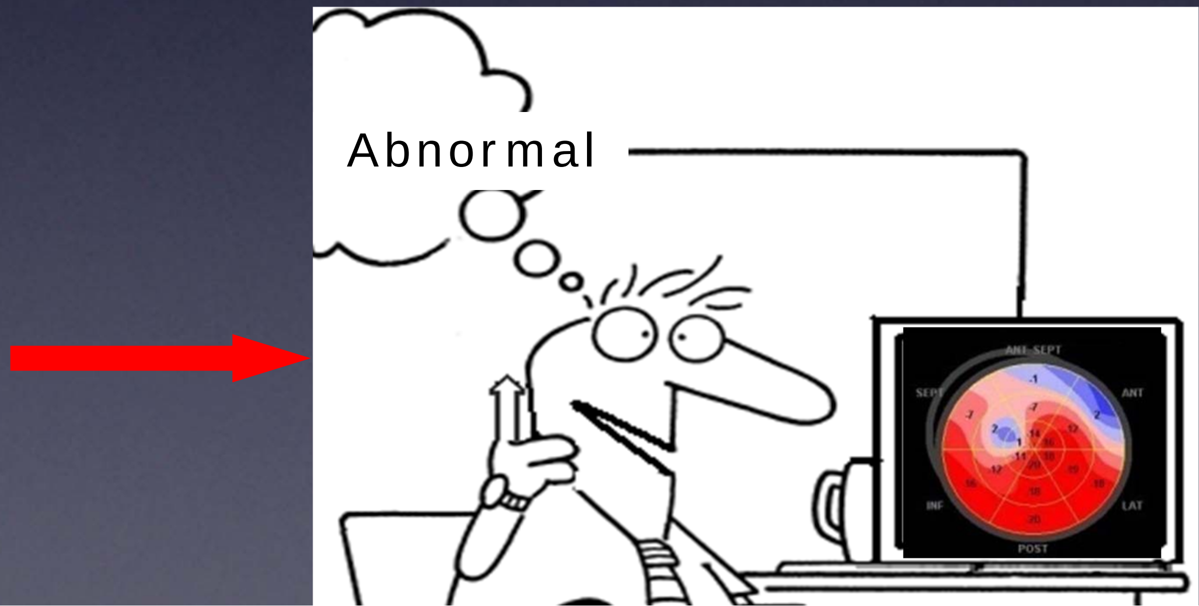


AFI (3-5 m

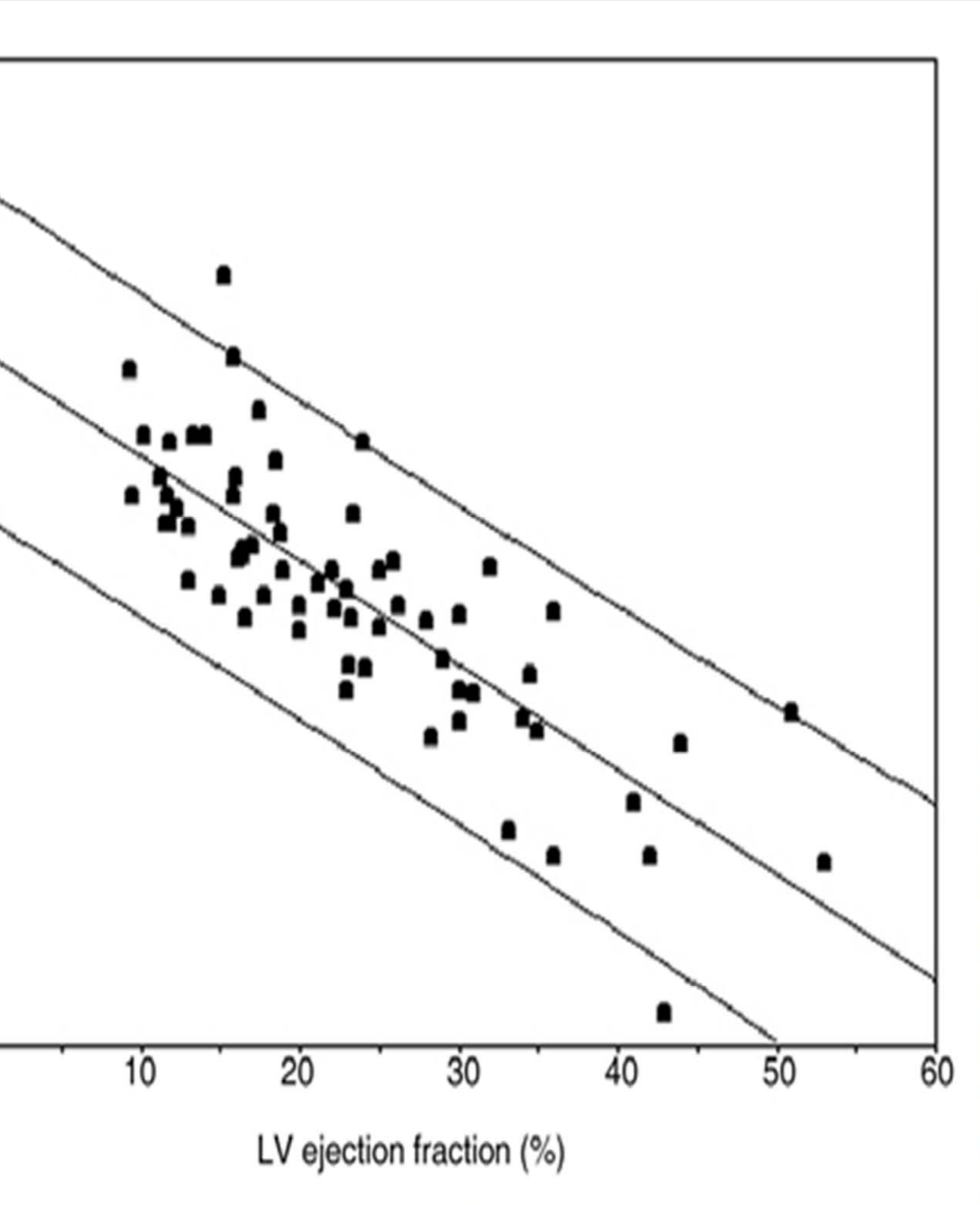
For discussion:

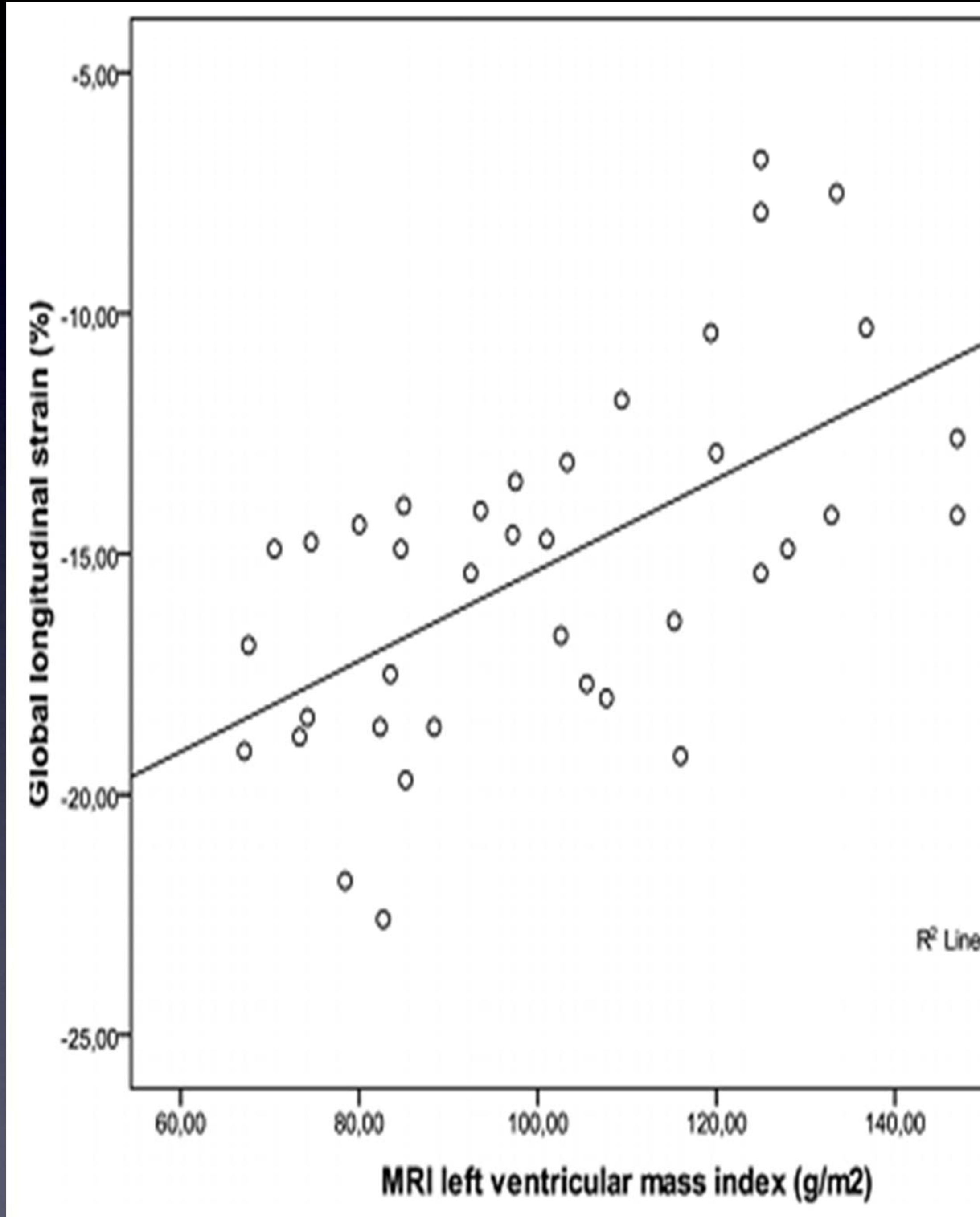
- **How do you see 2D quantification like AFI can be used in your clinic?**
  - *Can Global Strain parameter (from AFI) replace EF?*



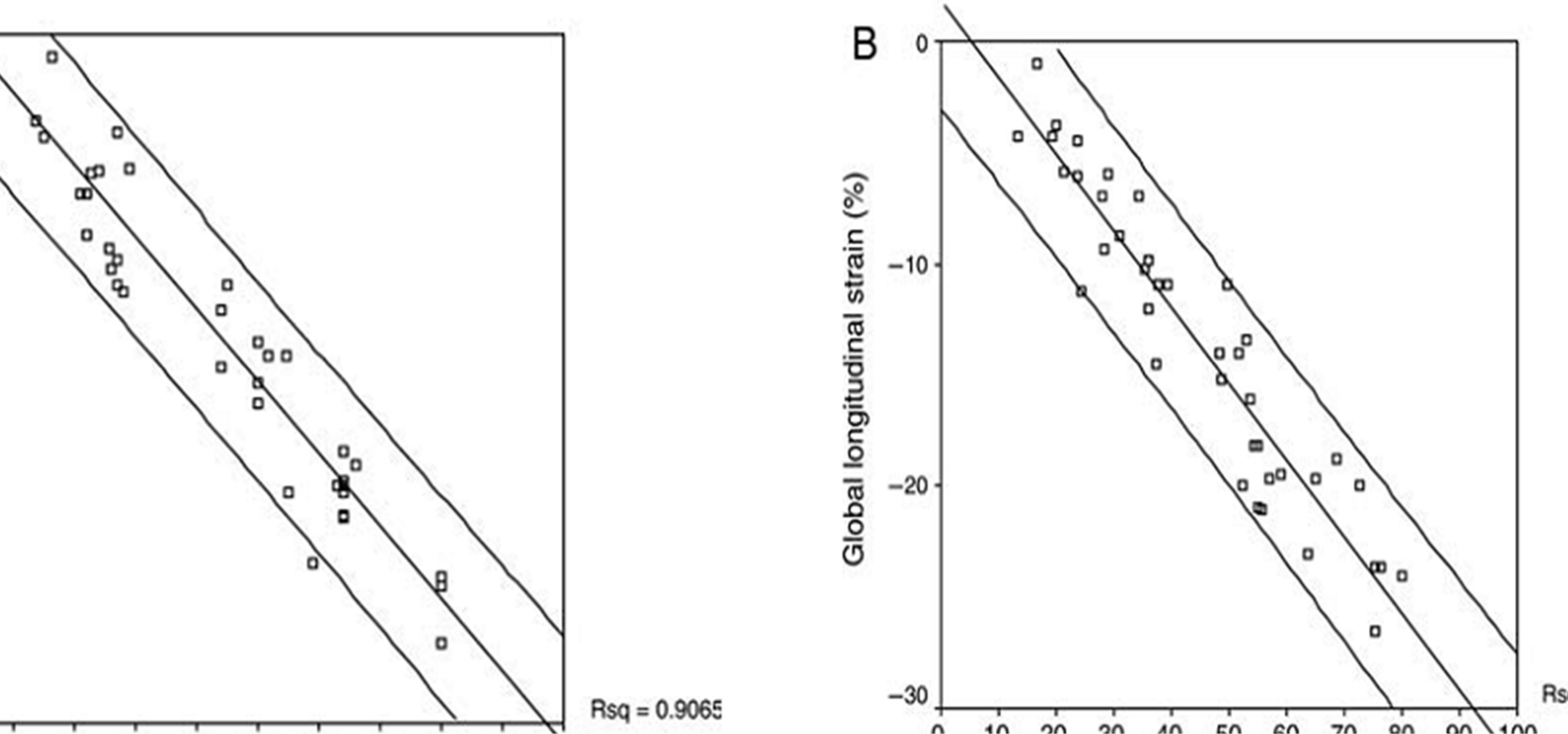


left ventricular systolic function?





vel wall motion score-based method for
mating global left ventricular ejection
ction: validation by real-time 3D
ocardiography and global longitudinal st



Im Cho, MD[1], Ji Hyun Lee, MD[2], Hyeon Gook Lee, MD[1], Seong Man Kim, MD[1] and Tae Ik Kim, MD[1]
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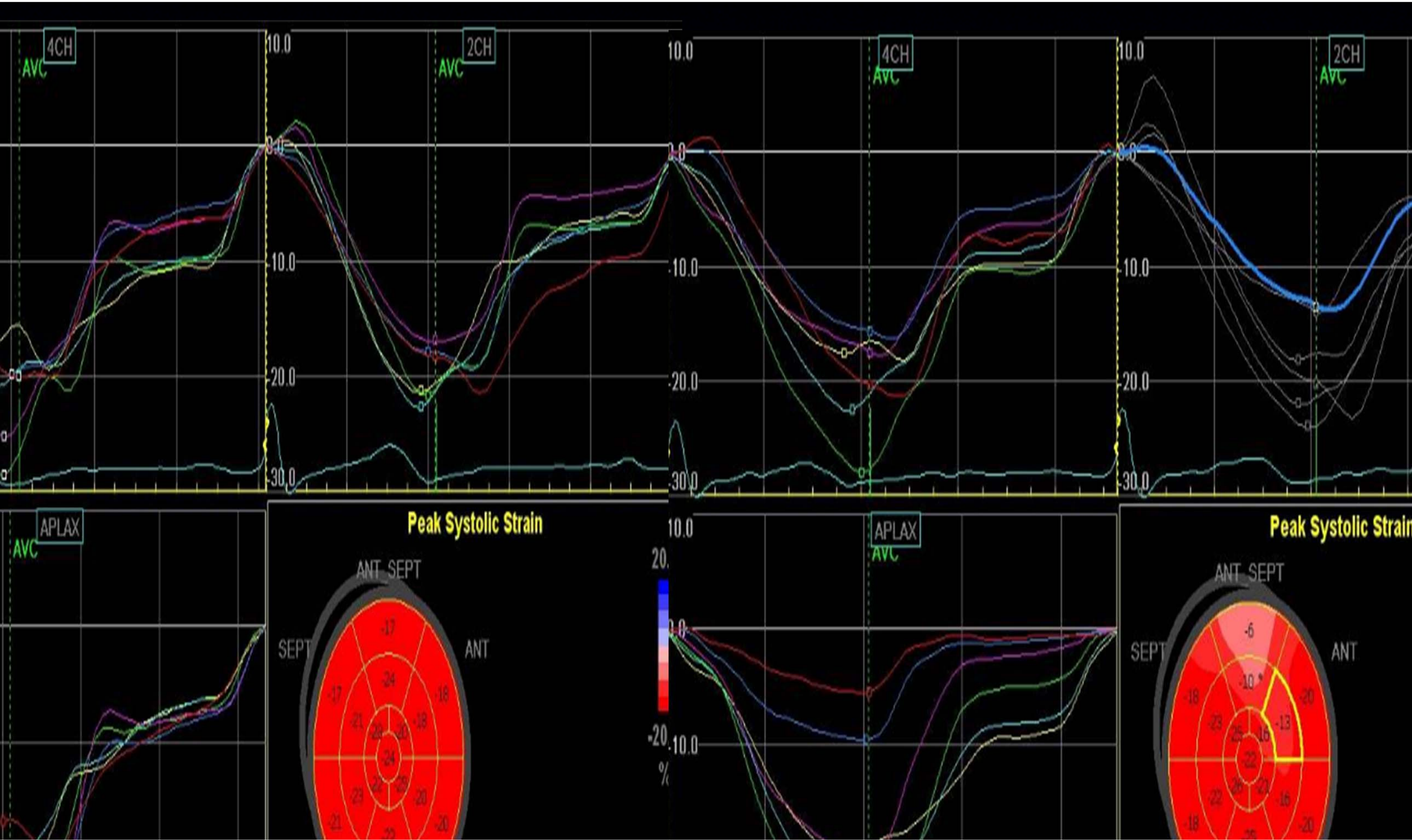

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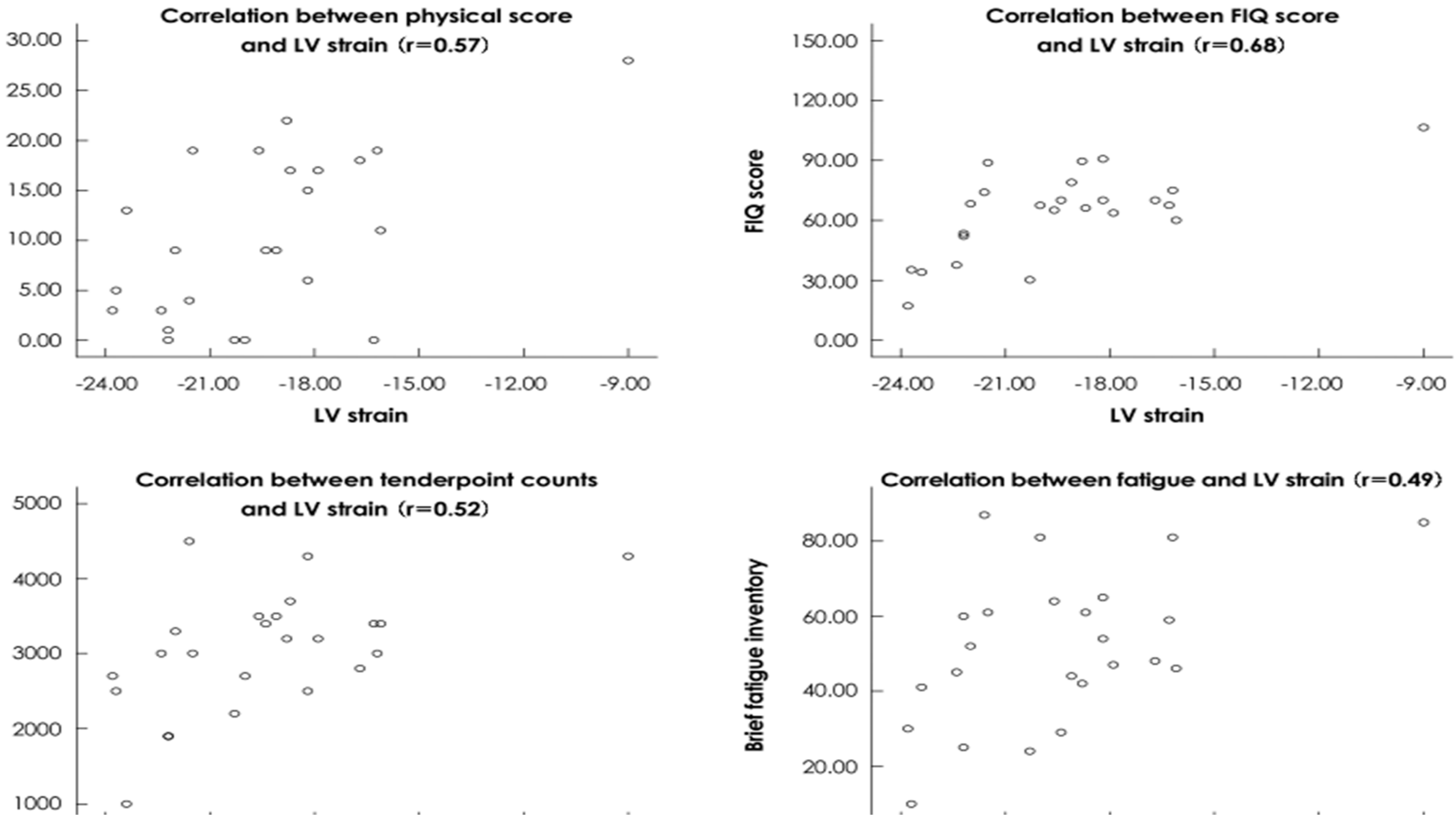

mpact of Gestational Hypertension on Left Ventricular Function and Geometric Pattern

Kyoung-Im Cho, MD; Seong-Man Kim, MD; Mi-Seung Shin, MD; Eui-Joo Kim, MD;
Eun-Joo Cho, MD; Hae-Sun Seo, MD; Sung-Hee Shin, MD;
Se-Jung Yoon, MD; Jung-Hyun Choi, MD

V Function in GHW and NPW

neters	GHW (n=106)	NPW (n=93)	P value
	62.3±9.0	60.7±7.8	0.08
	33.8±6.4	32.6±5.7	0.18
	171.9±44.2	173.5±35.2	0.81
	79.5±19.7	79.0±18.7	0.88
	11.7±2.83	10.0±2.4	0.001
	75.4±21.7	64.2±14.3	<0.001
	1.00±0.29	1.27±0.33	0.002
)	117.7±18.2	82.3±12.6	0.003
	0.51±0.09	0.48±0.23	0.003

Table 4. Follow-up Echocardiography and Clinical Featu

Parameters	GHW before delivery (n=37)	GHW after delivery (n=37)	P v
Systolic BP (mmHg)	155.5±18.3	128.5±15.6	<0
Diastolic BP (mmHg)	96.8±13.0	74.8±14.3	<0
Weight (kg)	75.5±12.5	64.8±14.5	<0
LVEDD (mm)	50.2±4.7	49.5±3.9	0
LVESD (mm)	34.9±4.2	32.7±4.5	0
IVSTd (mm)	9.4±1.2	8.6±1.4	0
PWTd (mm)	9.0±1.3	8.7±1.5	0
RWT	0.40±0.08	0.36±0.09	0
LVMI (g/m²)	95.8±18.5	88.8±20.1	0
LAD (mm)	39.1±4.5	37.0±5.7	0
ARD (mm)	29.4±2.7	28.3±2.4	0
EF (%)	58.3±9.7	63.8±8.3	0
FS (%)	33.6±6.2	33.9±7.5	0
DT (ms)	178.8±50.8	171.5±40.7	0
E (cm/s)	81.7±20.9	82.7±20.5	0
E/Ea	12.7±4.5	11.7±3.8	0
A (cm/s)	76.3±20.2	69.5±20.3	0
E/A	1.08±0.31	1.23±0.42	0
IVRT (ms)	118.8±19.3	96.5±19.7	

Impact of Gestational Hypertension on Left Ventricular Function and Geometric Pattern

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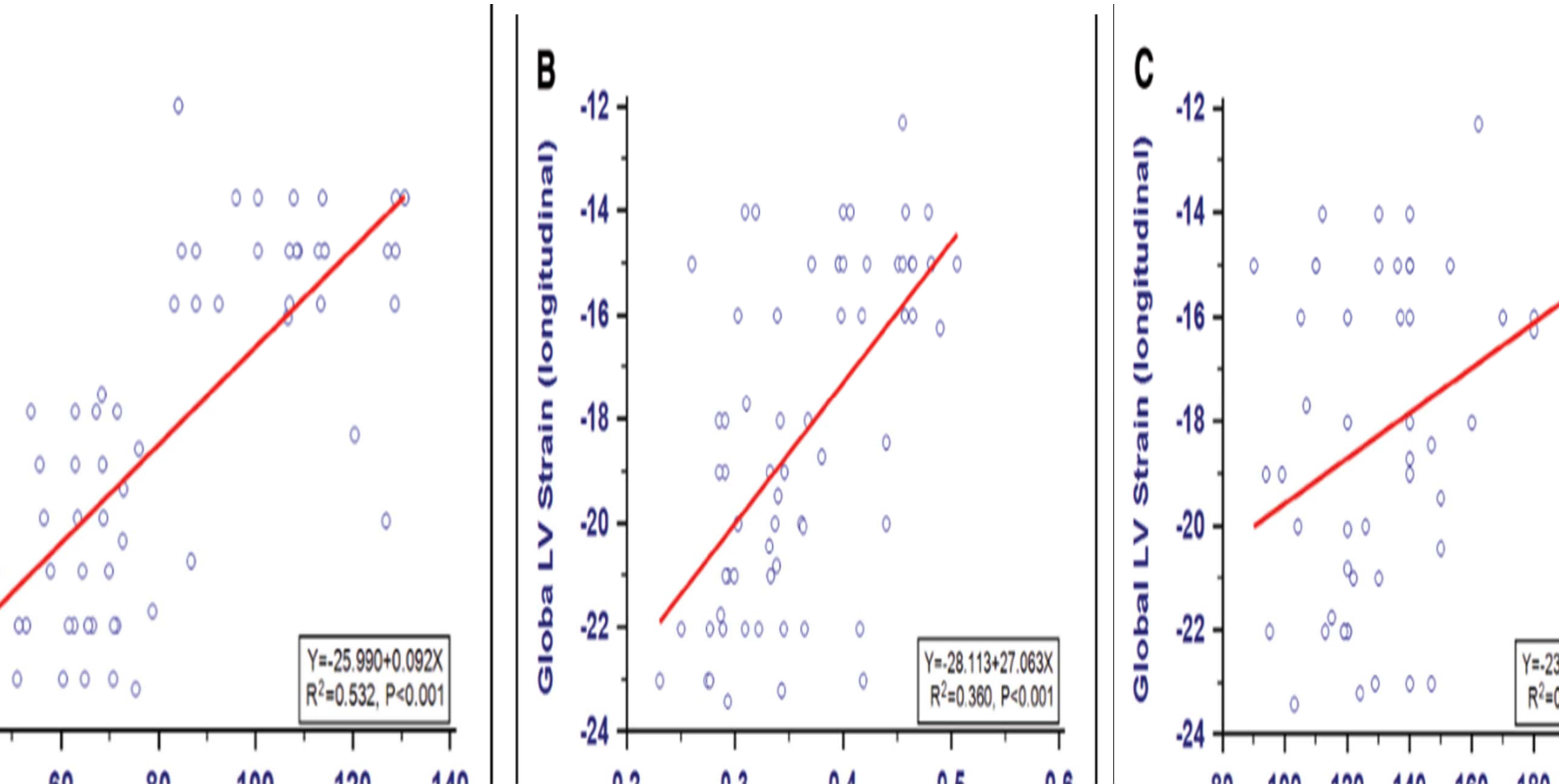
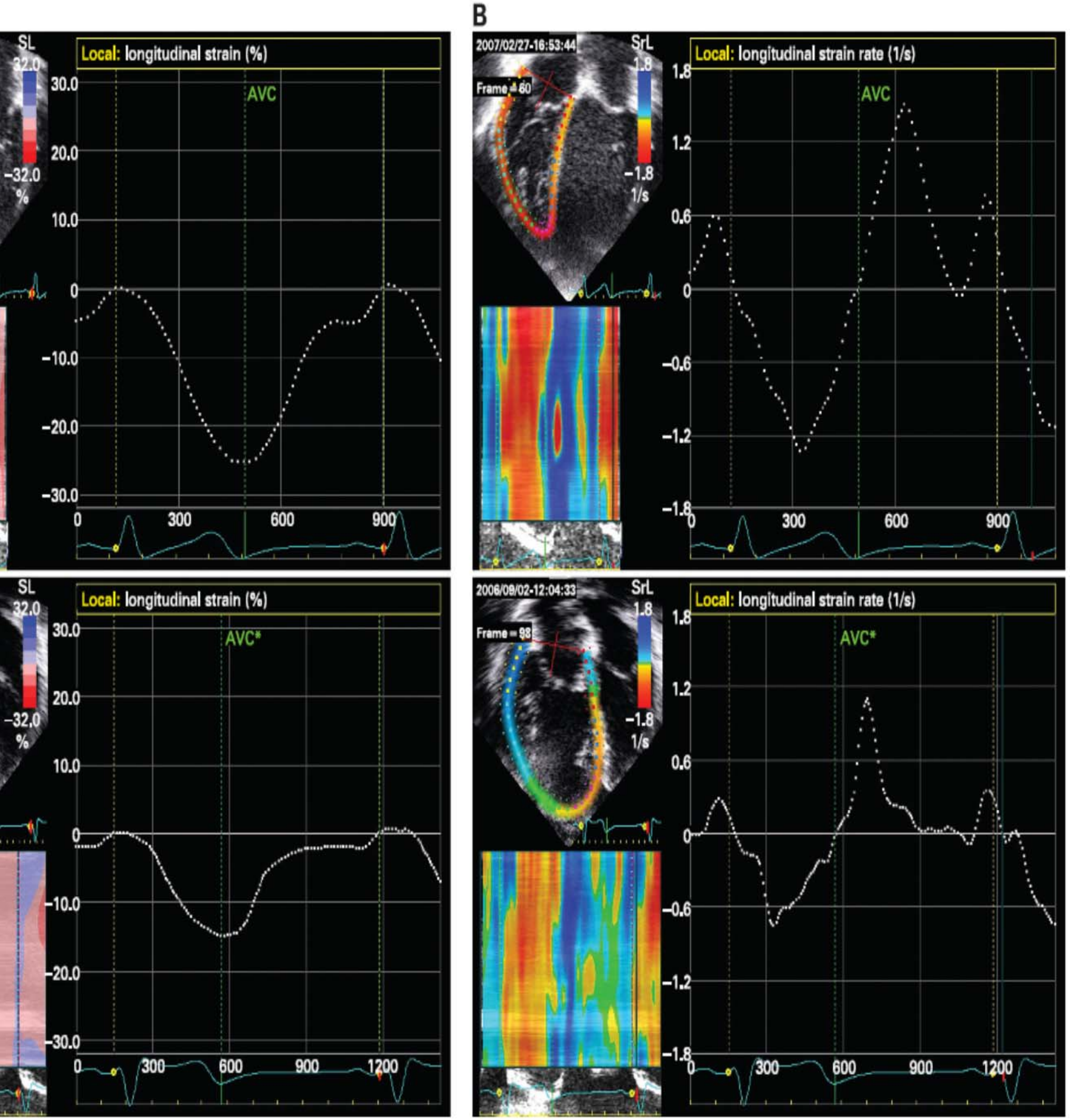


aging for assessment of systemic right ventricular functio



imensional strain imaging showing right ventricular (A) global longitudinal strain and (B) strain rate analysis in patients (upper panels)
er panels).

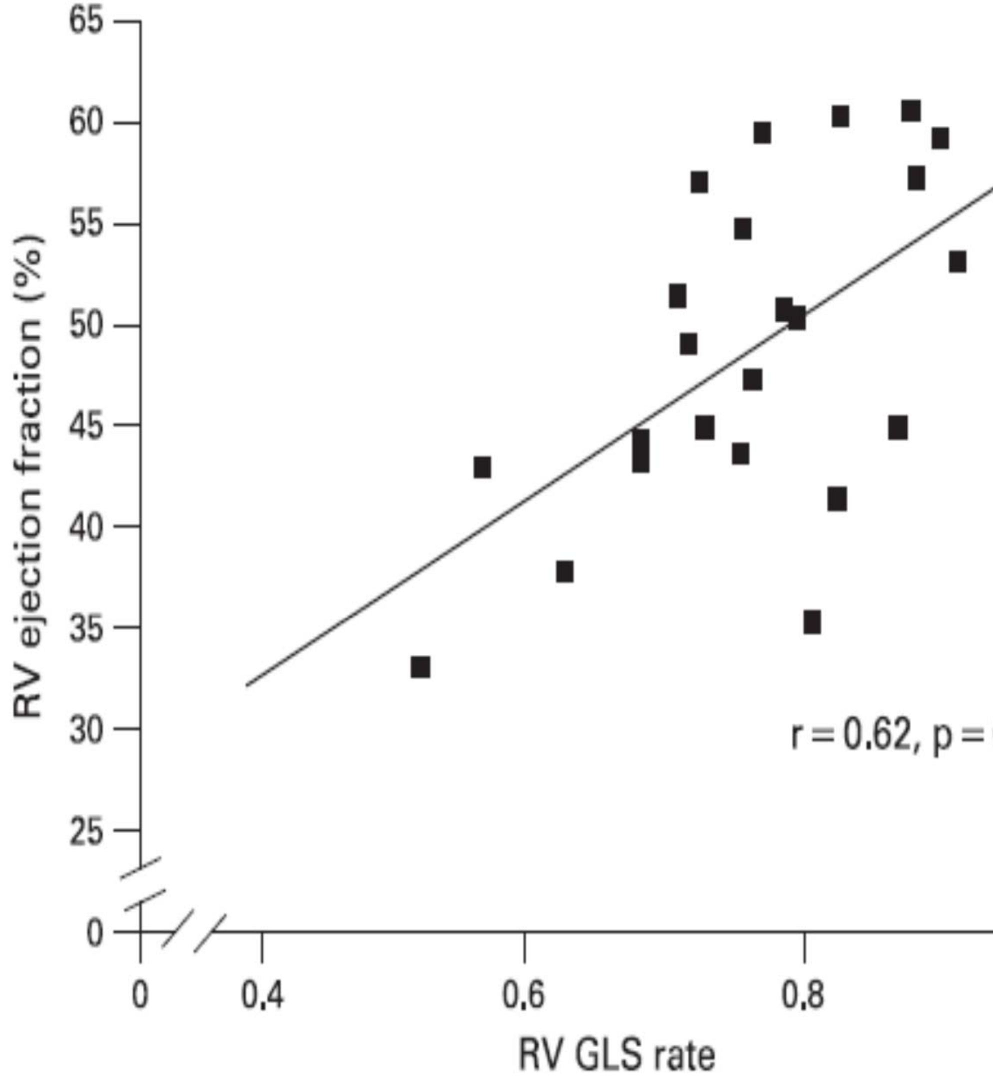
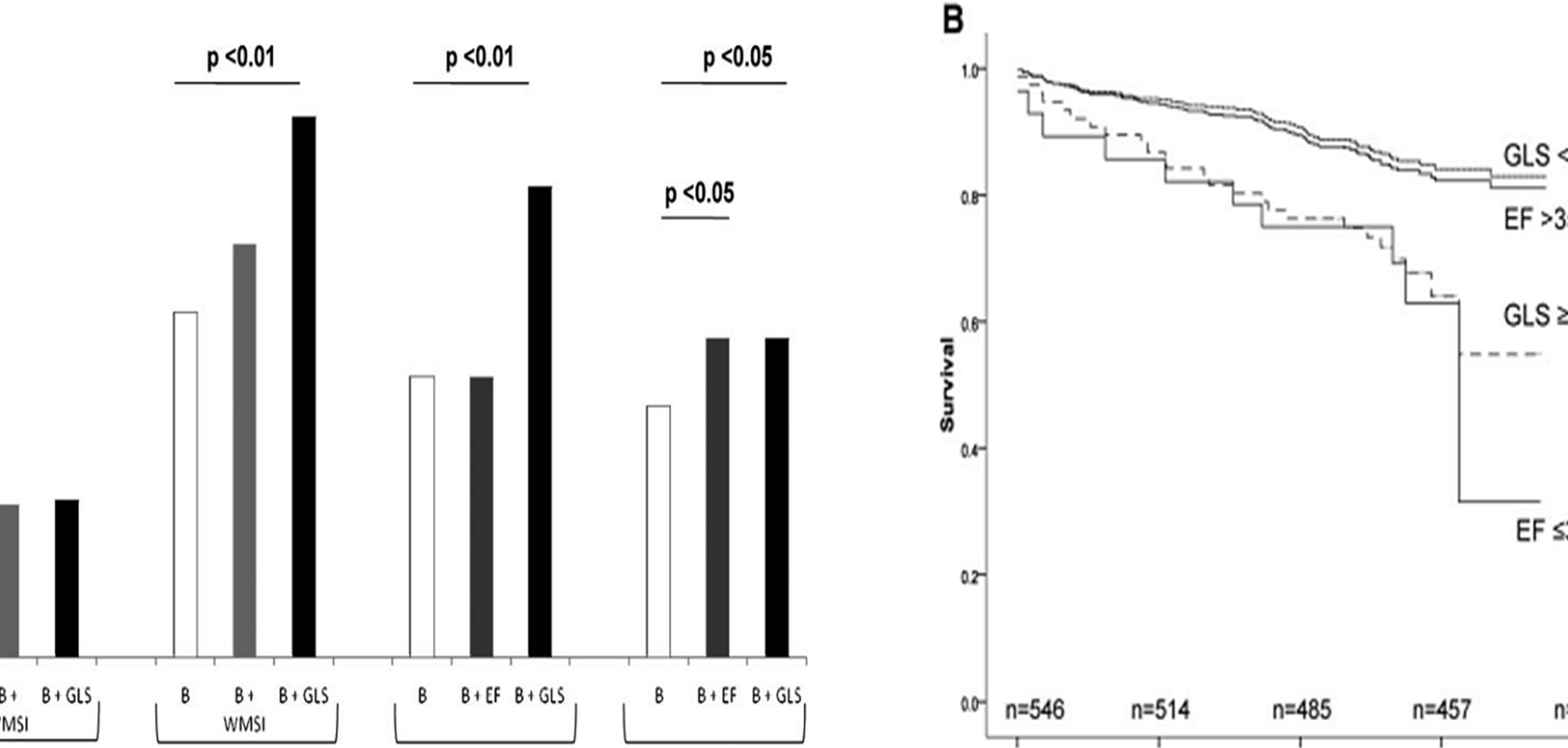


Figure 3 Scatter plot showing a positive correlation between
ventricular (RV) global systolic strain (GLS) rate and RV ejection f

ardiovascular Imaging
L OF THE AMERICAN HEART ASSOCIATION

diction of All-Cause Mortality From Global Longitudin Speckle Strain

Comparison With Ejection Fraction and Wall Motion Scoring



(from AFI) replace EF!

he development of GLS has advanced the measurement of ngitudinal function, because of

. Automation

. Measure the longitudinal function of the entire ventricle rathe han basal segments alone

. Longitudinal contraction is a particular marker of subendocard unction, which may be disproportionately involved in subclinical isease, including myocardial ischemia

Can Global Strain parameter (from AFI) replace EF!

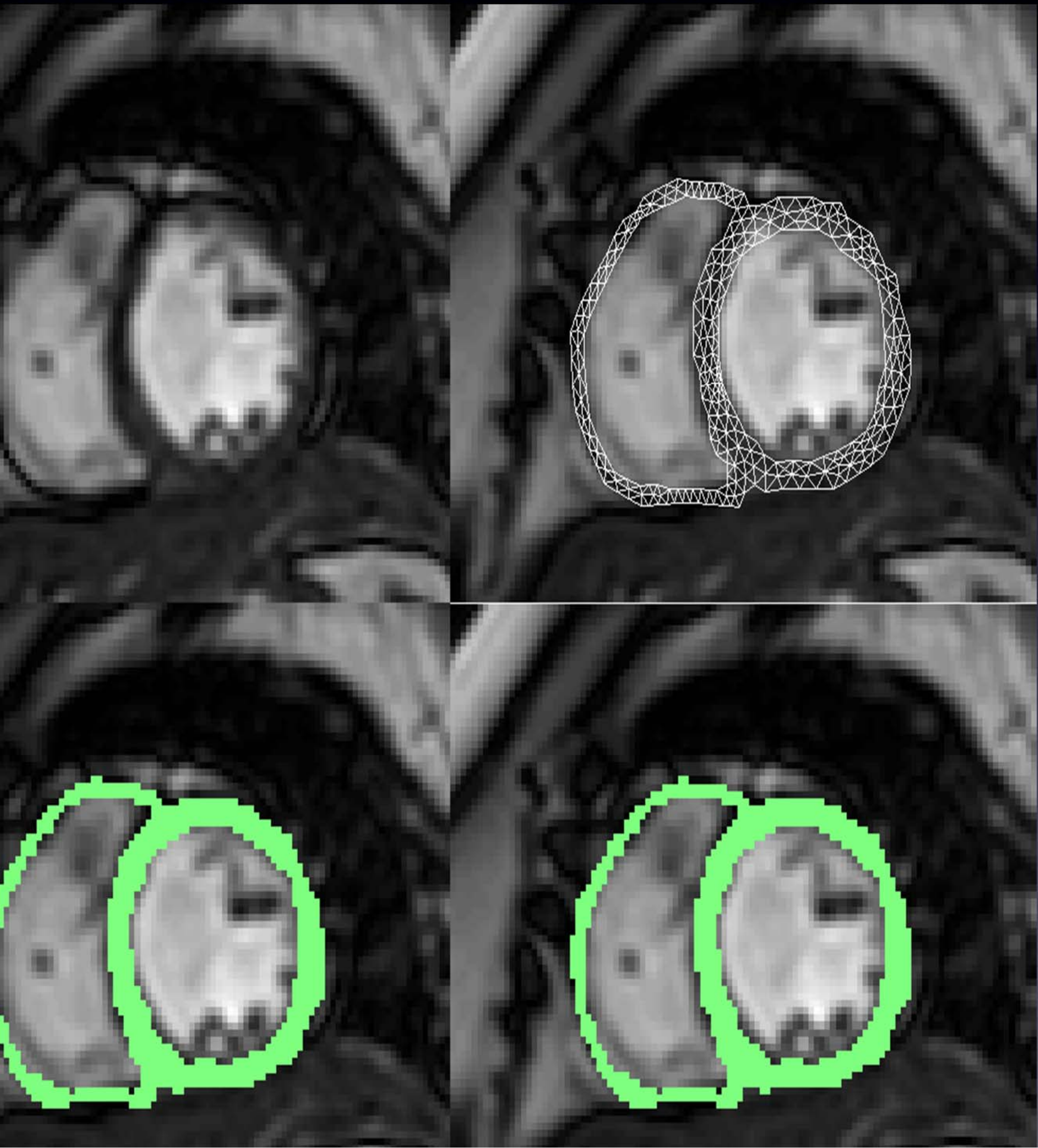
GLS not only measures contraction but is also able to refl
nterstitial myocardial changes such as fibrosis, which are
often subclinical.

This may explain the superior predictive power of GLS over
n those without wall motion abnormalities.

- Compromise between spatial resolution and background noise
- Reverberation artifacts and drop-out
- Definition of end-systole to differentiate systolic shortening from post-systolic shortening
- Diagnostic or prognostic incremental value over standard assessment
- Myocardial deformation is a 3- dimensional process

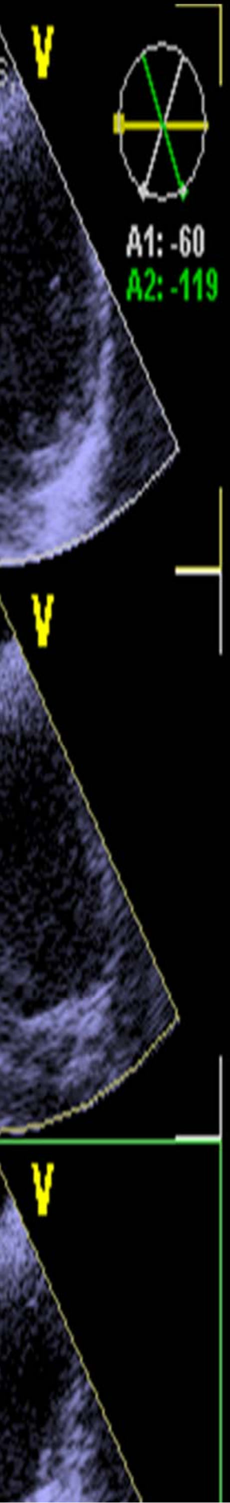
Comparison with cardiac MR

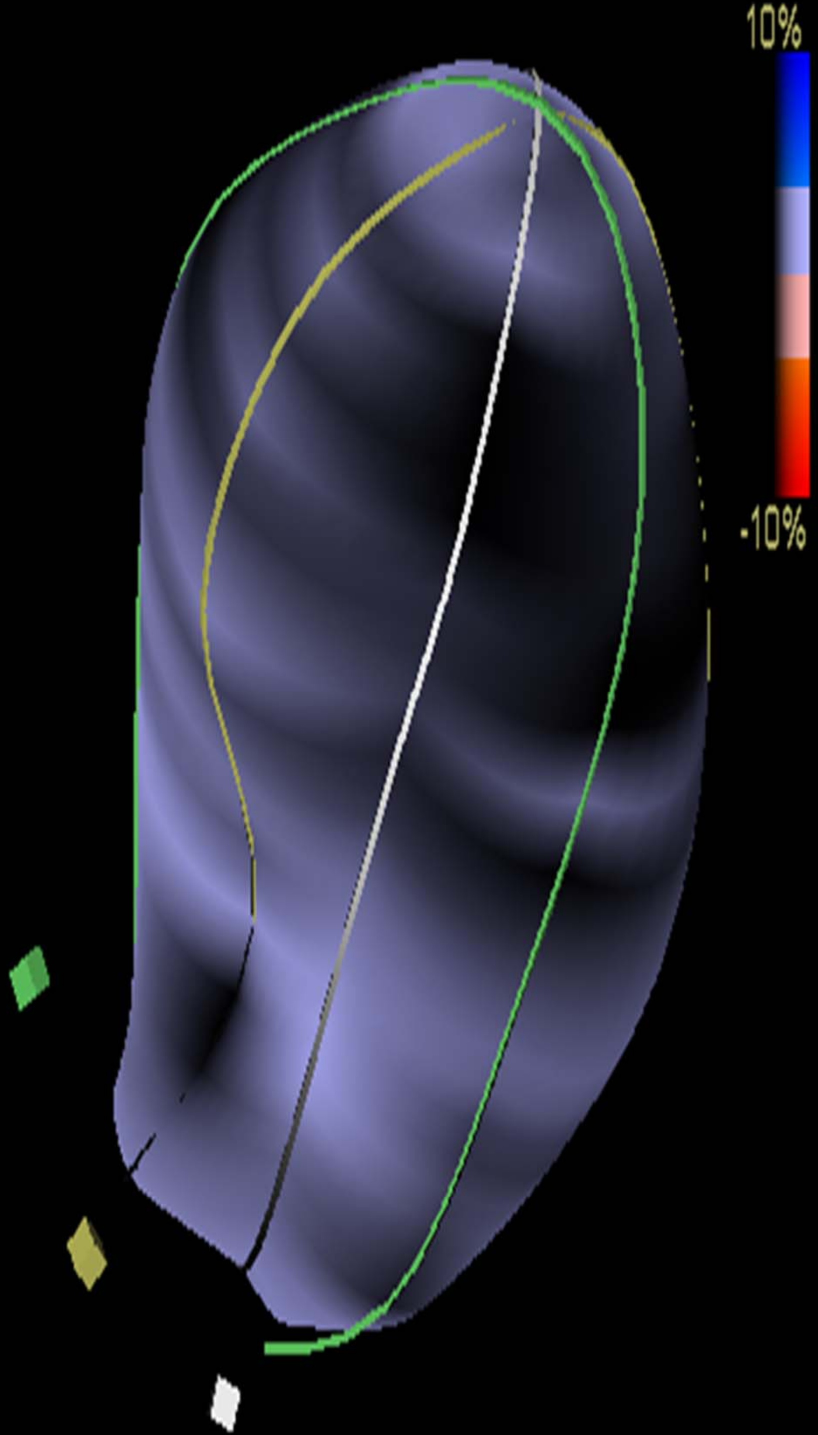
Speckle tracking echocardiograp



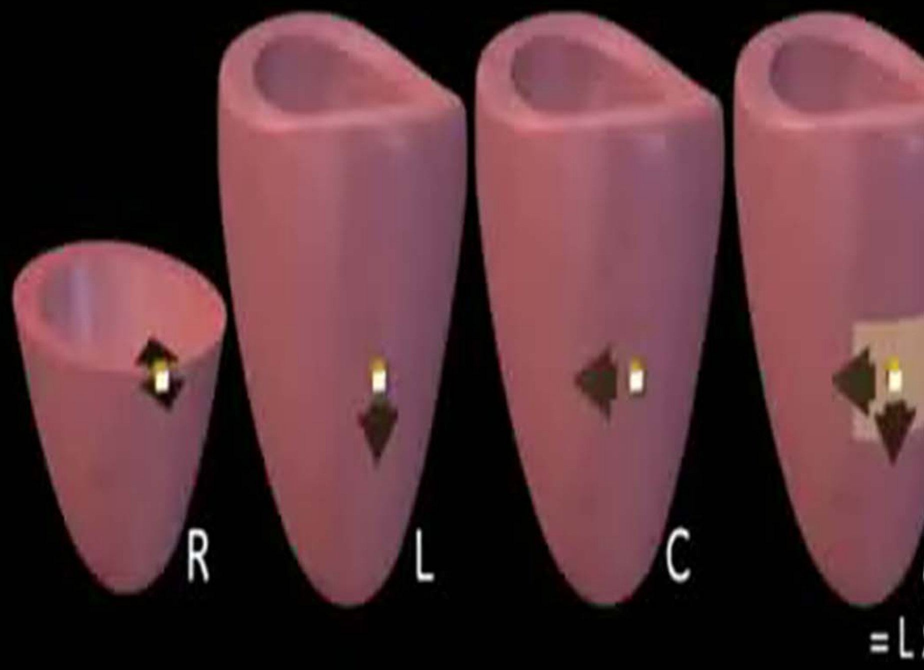
- Speckle tracking applied to 2-dimensional images is limited because regions of the myocardiu represented by speckle patterns reality move through 3-dimensio space, rather than being limited the 2- dimensional sector, resulti reliance on geometric remodelli

- Nishikage et al. demonstrated *significant correlation between 3 dimensional speckle tracking echocardiography and cardiac M for measuring LV volumes.*





Radial strain, Longitudinal strain, Circumferential strain and Area strain.



: a new prognostic parameter?

- **Assessment of ventricular function in valvular disease.**
- **Myocardial Viability**

✓ **Transmurality of myocardial infarction**

✓ **Detection of viable myocardium with dobutamine echo.**

- **Detection of myocardial ischemia with stress echo.**
- **LV Synchrony**
- **RV function**
- **LA function**

YES! Because...
new insights into ventricular function, adaptation and mal-adaptation in response to pathology.

Take Home Message

Angle dependency and the impact of artifacts in TDI derived parameters and the low temporal resolution in STE are important limiting factors in the technology

A combination of the two techniques (high quality, angle independent gra scale data and Doppler data with high temporal resolution) could enhance the robustness of the technique and reduce the post-processing time.

LS is superior to EF because GLS not only measures contraction also able to reflect subclinical myocardial changes and may ecome the optimal method for assessment of global LV systolic nction->

Future guidelines of LV function may need to be


Thank you for your attention