Echocardiography in acute chest pain

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Lots of options:

Talk to the patient

Examine the patient

ECG

Chest X ray

Biomarkers

Stress tests

CTA

Lots of constraints:

Time to diagnosis

Costs

Radiation

Availability

So why echo:

Availability

Inexpensive

Bedside

No irradiation

Will answer many questions

What is the question:

Is their a cardiac reasons for the patients complaint:

chest pain

Cardiovascular:

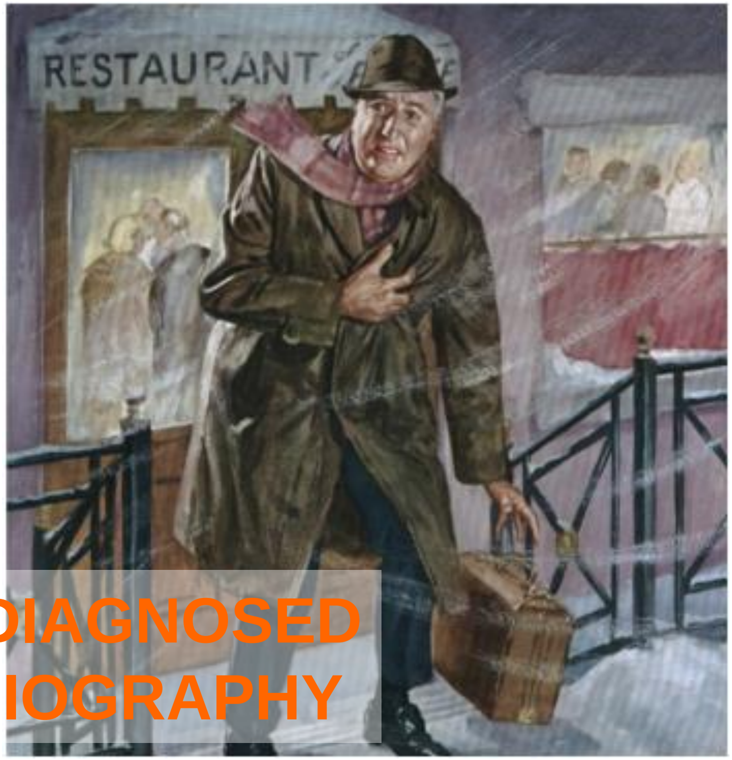
Ischemic Heart Disease – Acute Coronary Syndromes
Valvular Heart Disease
Aortic Dissection
Pericarditis, **Pericardial Effusion, Tamponade**
Myocarditis
Stress Induced Cardiomyopathy

Pulmonary:

Pulmonary Embolism
Lung Disease
Pulmonary Hypertenstion
Pneumothorax

Others:

Gastrointestinal
Mediastinal
Psychiatric



MOST CAN BE DIAGNOSED BY ECHOCARDIOGRAPHY

So I am sure you are all convinced now to use echo!

But the real question is:
how can echo help in the diagnosis of acute coronary syndrome

Go to: ICCU + Cath Lab vs. HOME

Can echo contribute? HOW?

Transthoracic echocardiography:
Left Ventricular function: Global and Segmental

We need more!
Is it possible to detect subtle changes implicating coronary artery disease?

Stress Echocardiography

- **Change in segmental LV contraction during stress;** Implicating limited blood flow caused by coronary artery stenosis.
- Stress echo can **distinguish** between **high risk patients** who will probably need hospitalization and further evaluation and those with low risk and good prognosis.

- Sensitivity and specificity of stress echo for obstructive CAD: 86 and 81%, respectively.
- DSE: excellent negative predictive value for obstructive CAD in CPU patients, 6-month follow-up, between 91 - 96%.

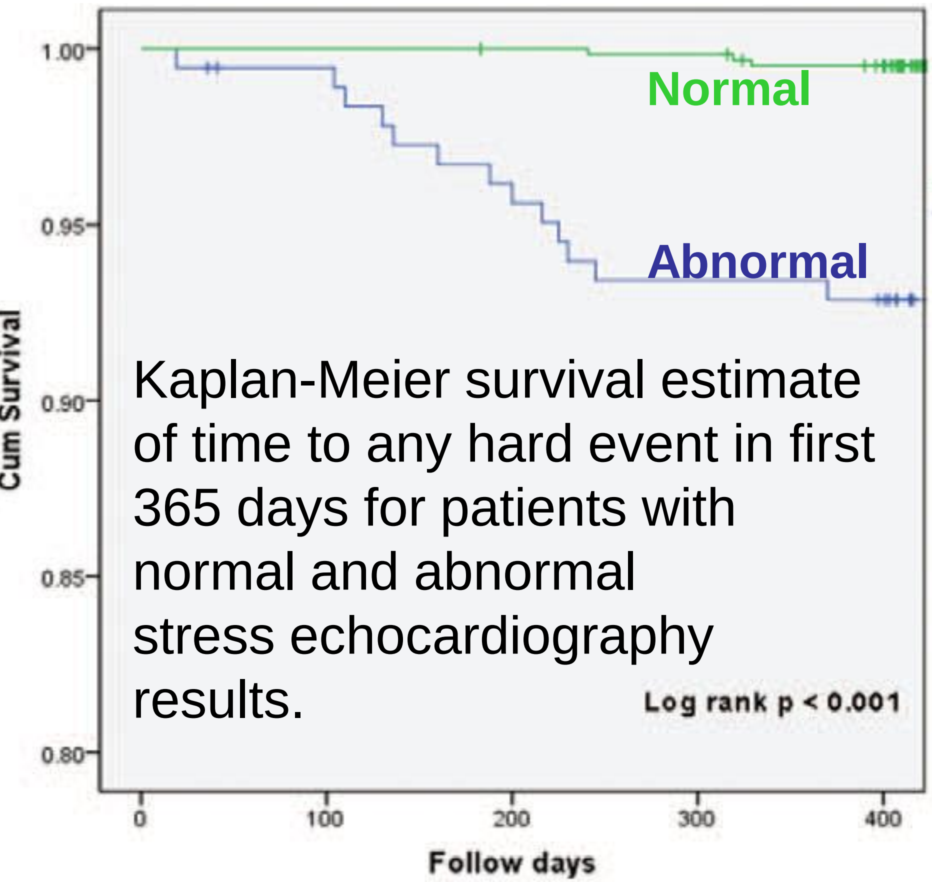
Sechtem U, …Zamorano JL **Non-invasive imaging in acute chest pain syndromes EJE 2011**
Sicari R, et al. Stress Echocardiography Expert Consensus Statement EAE, Eur Heart J 2009;278
Amsterdam EA,et al Immediate exercise testing to evaluate low-risk patients presenting to the emergency department with chest pain. JACC 2002;251

Incremental Diagnostic and Prognostic Value of Contemporary **Stress Echocardiography in a Chest Pain Unit**

Mortality and Morbidity Outcomes From a **Real-World Setting**

Shah, … Senior, *Circ Cardiovasc Imaging*. **2013**;6:202-209

839 patients assessed for feasibility, safety, impact on triaging, discharge, 30-day readmission, **followed for all-cause mortality and acute MI**.



Kaplan-Meier survival estimate of time to any hard event in first 365 days for patients with normal and abnormal stress echocardiography results.

Among all prognostic variables, only **abnormal stress echo** and advanced age **predicted hard events** in multivariable regression analysis.

Conclusions:

Stress echo incorporated into chest pain unit has excellent feasibility, provides **rapid assessment and discharge** with **accurate risk** stratification of patients with suspected acute coronary syndrome, non diagnostic ECG and negative 12-hour troponin.

Contrast Echocardiography:
enhance borders + myocardial perfusion

Comparison of **Myocardial Contrast Echocardiography** vs **Rest Sestamibi Myocardial Perfusion Imaging** in Early Diagnosis of Acute Coronary Syndrome

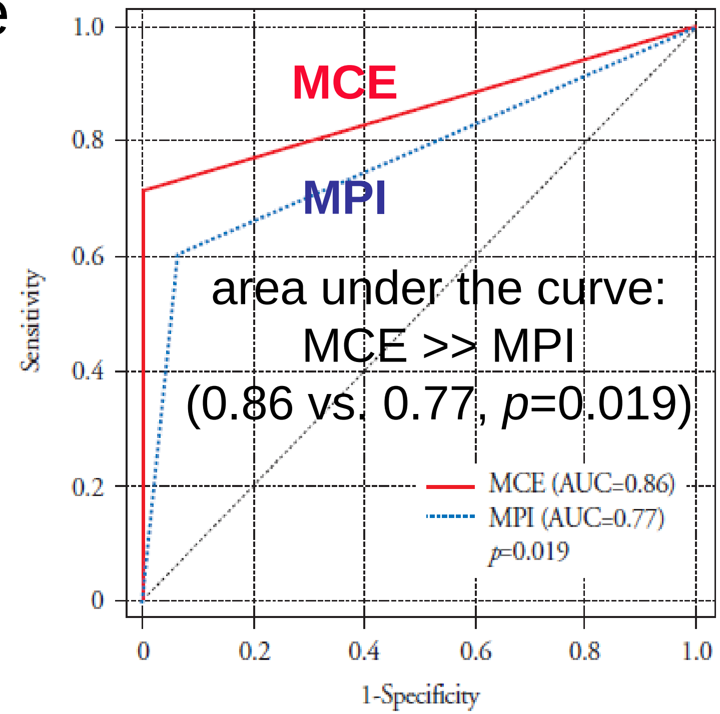
Kang …. Park, J Cardiovasc Ultrasound 2010;18:45

98 pts: chest pain suggestive of acute ischemia.
Early MCE and Sestamibi MPI obtained.
32 patients - acute MI, 35 - unstable angina.

Sensitivity for diagnosis of ACS:
MCE 72% MPI 61%.

Significantly higher than ST segment change and troponin I.

Similar specificities 90% - 100%.



Conclusion: MCE and MPI overcome the low sensitivity of routine triage tests for detecting ACS.

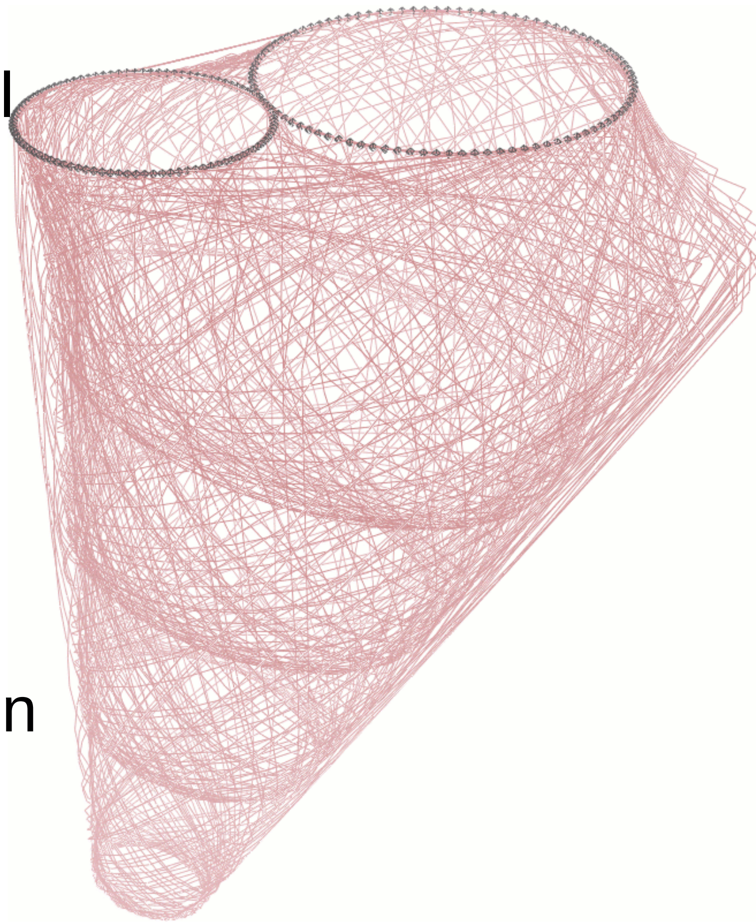
MCE is more accurate than MPI for diagnosis of ACS in ER

Left Ventricular Muscle Structure

CONTRACTION – DEFORMATION

Deformation in Ischemia

Left Ventricular Muscle Structure + Contraction



- During morphogenesis, the myocardial wall matures from a **single-layered** epithelium to a complex, **multi-layered** structure.
- LV wall is not homogenous,
is composed of **3 layers** of fibers.
- **Subendocardial** and **subepicardial** layers have **opposite** fiber orientation.
- This is important for equal redistribution of **stress and strain** in the heart.

E. **Griffith**. Simulating the blood-muscle-valve mechanics of the heart by an adaptive and parallel version of the immersed boundary method. PhD Thesis, Courant Institute of Mathematical Sciences, New York University, 2005

LV myofiber orientation changes from a **left-handed helix in subepicardium** to a **right-handed helix** in the **subendocardium**

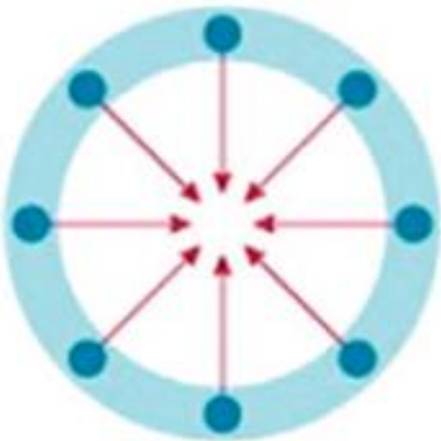
Thick-walled cylindrical myofibers

Subepicardial fiber wrapped in a **left**-handed **helix**
Subendocardial fiber wrapped in a **right**-handed **helix**
Arrows represent circumferential force components that results from force development in each fiber direction

LV base and apex rotate in opposite directions in systole**:**
Apex rotates **counterclockwise**,
Base rotates **clockwise**

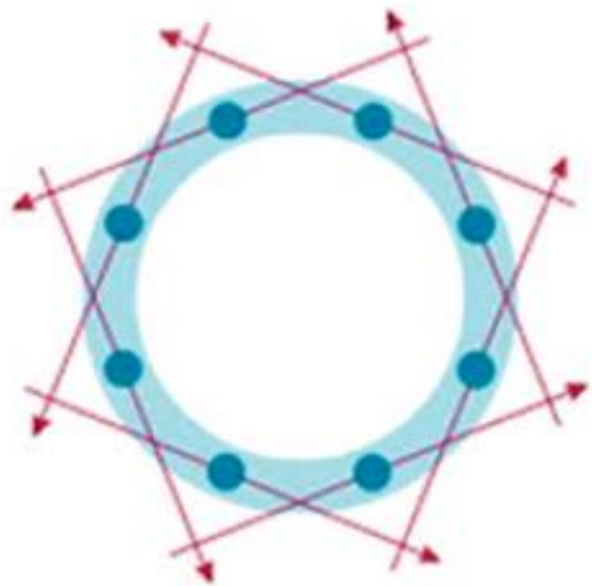
Twist Mechanics of the LV: Principles and Application Sengupta PP, Tajik AJ, Chandrasekaran K, Khandheria BK **JACC**: CVI 1, 2008 366 - 376

Radial



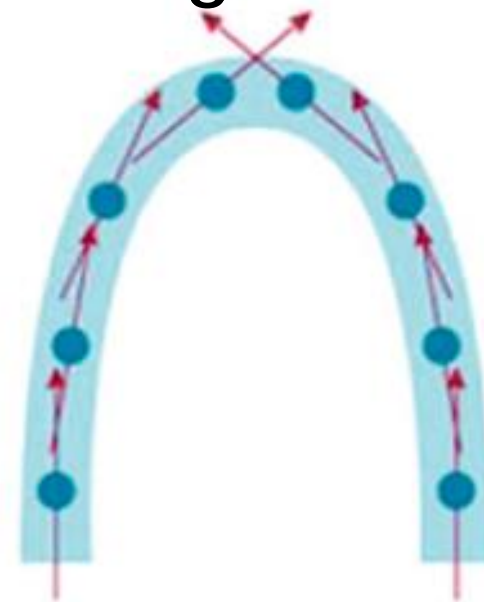
perpendicular to epicardium away from cavity

Circumferential



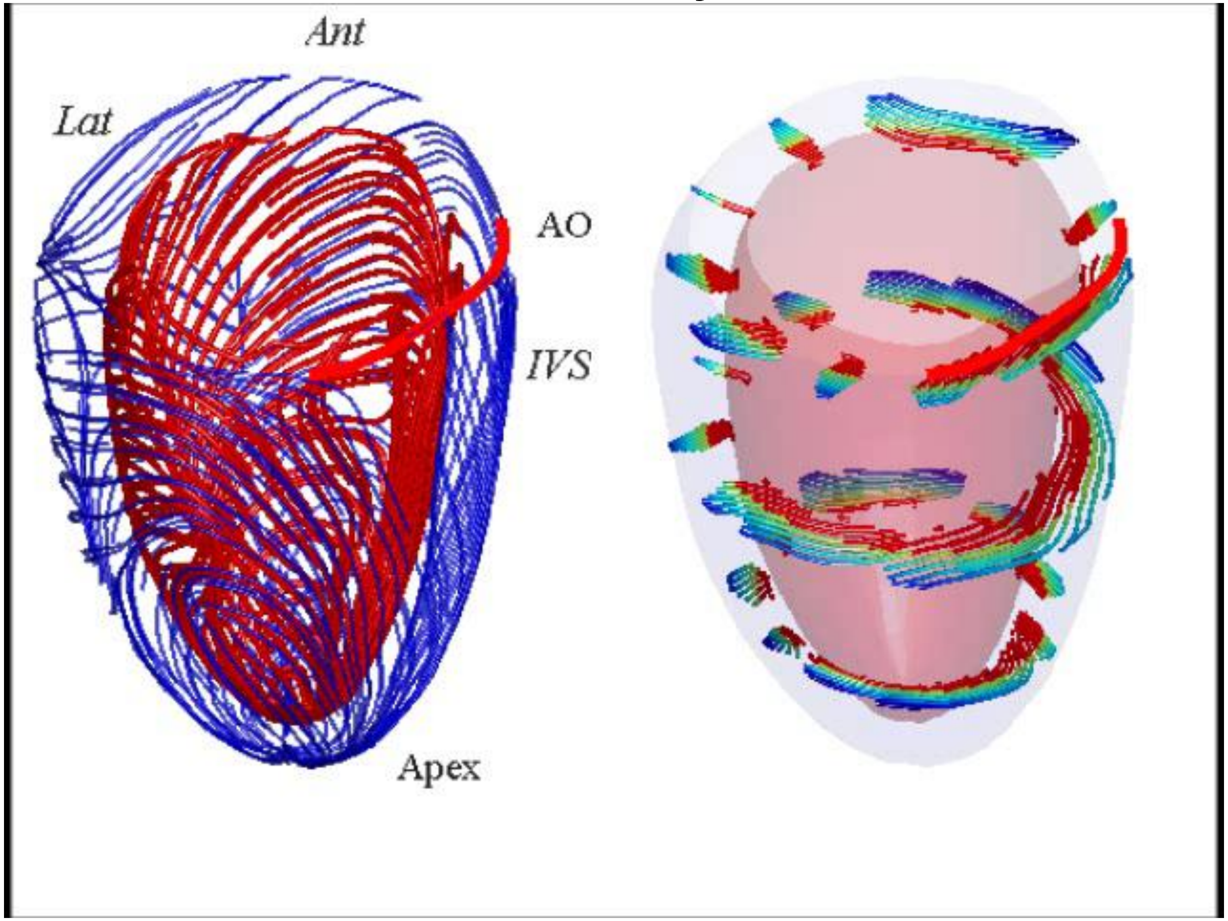
counterclockwise around short-axis

Longitudinal



directed from apex to base

Dynamic 3-D strain-line patterns over the myocardium during the cardiac cycle



epicardial layer - **blue**
endocardial layer - **red** stream lines

short axial view of 3 planes (basal, mid and apical), with **stream lines color pattern changing** from blue at sub-epicardium to red at the sub-endocardium.

Mangual J O et al. Circ CVI 2012;5:808

CONTRACTION – DEFORMATION

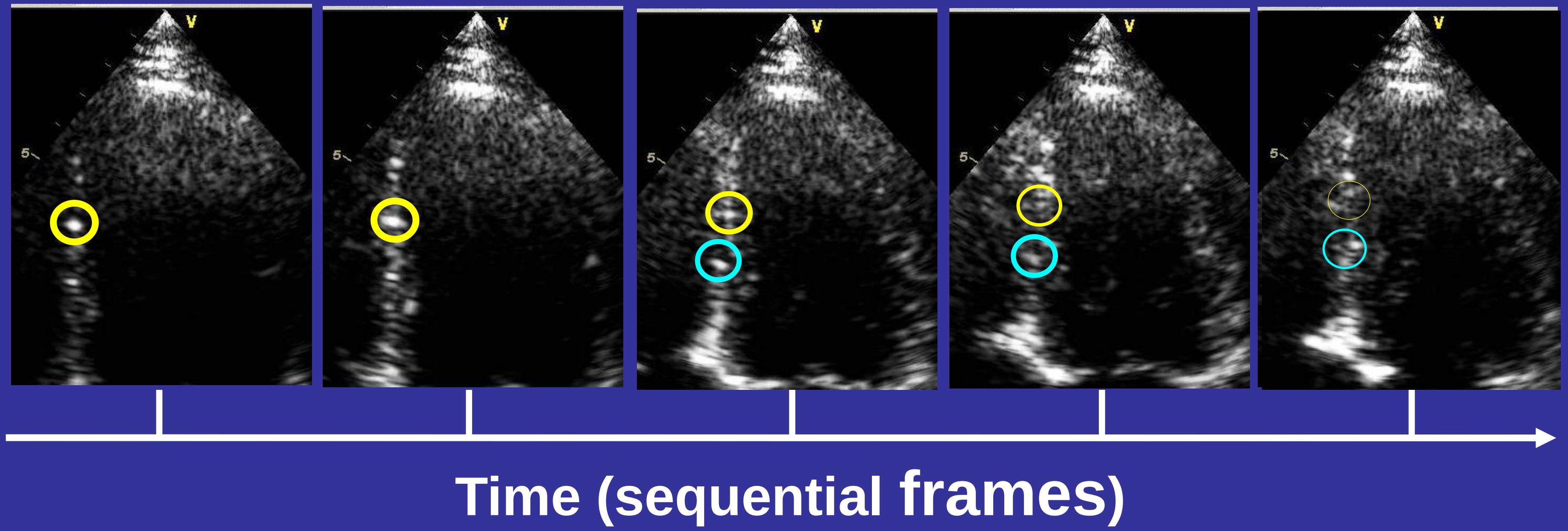
Can be evaluated by echocardiography

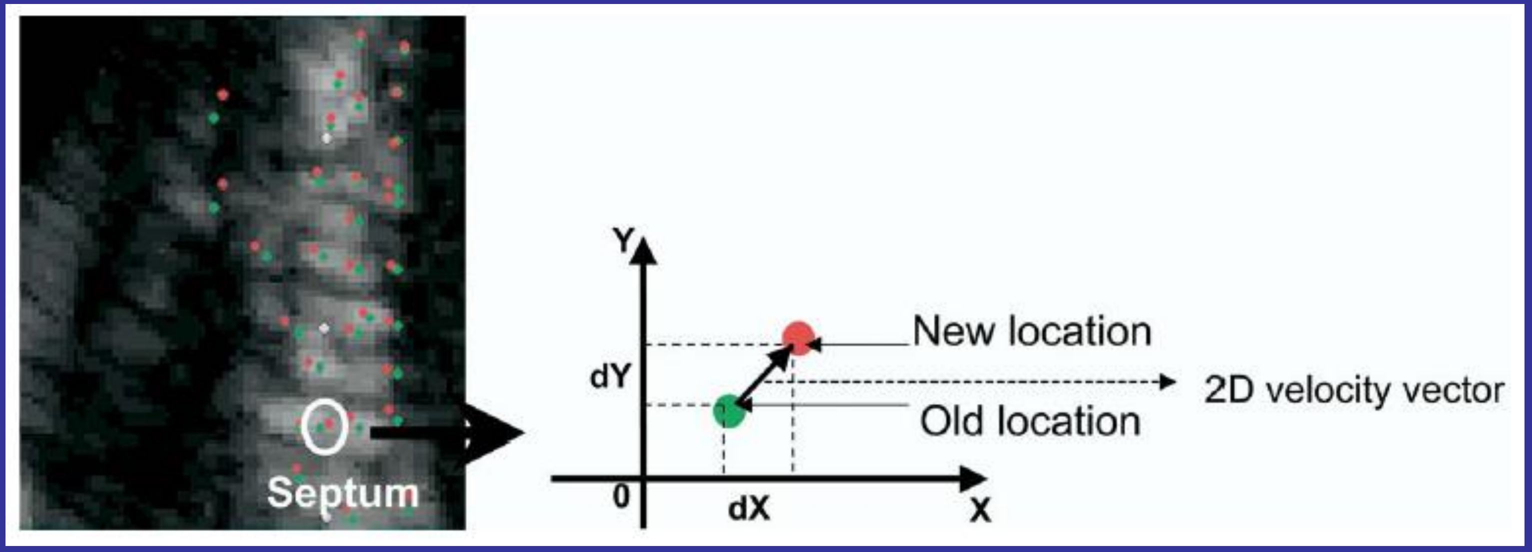
2 Dimensional Strain = 2DS

Speckle Tracking Echocardiography

Automated Function Imaging = AFI

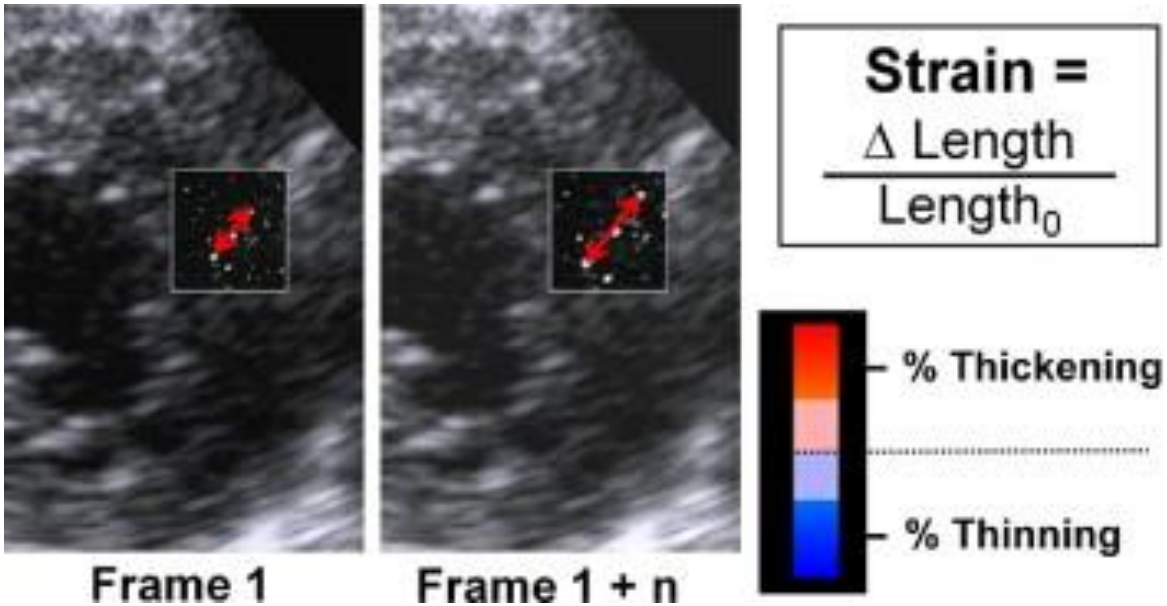
Speckle Tracking Echocardiography





Courtesy of Z Friedman, P Lysyansky (GE Israel)

Speckle Tracking Strain by Echocardiography



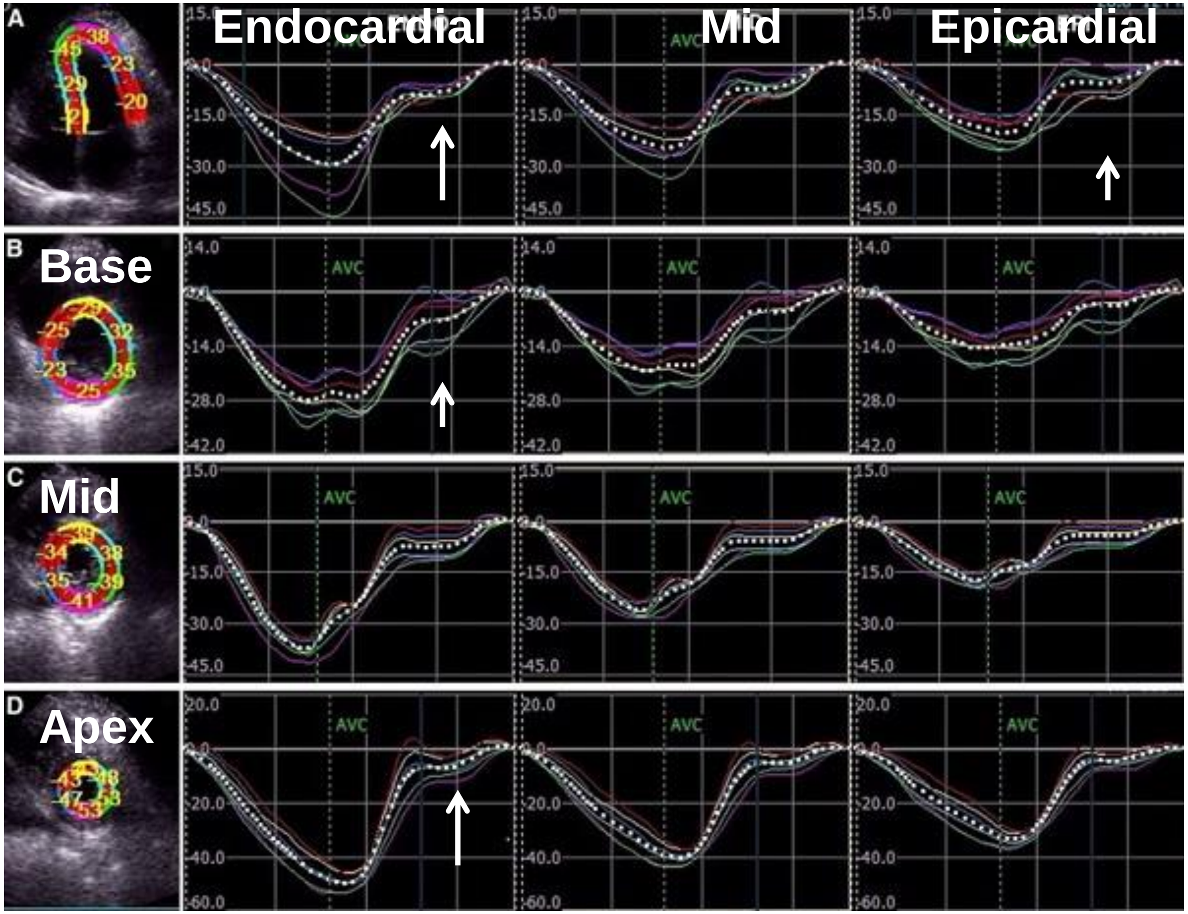
Strain is calculated as the change in length (ΔL) divided by the original length (L_0) and expressed as a **percentage**.

Echocardiographic Assessment of Myocardial Strain, John Gorcsan III , Hidekazu Tanaka Journal of the American College of Cardiology Volume 58, 2011 1401 - 1413

Three-layer longitudinal and circumferential **strain:** normal subject

Apical 4-chamber view

Short-axis views



Apical to basal gradient: high at apex, lower at base
Endocardial strain is highest, epicardial lowest

Circumferential and Longitudinal Strain in 3 Myocardial Layers in Normal Subjects and in Patients with Regional Left Ventricular Dysfunction, **Leitman** M, Lysiansky M, Lysyansky P, Friedman Z, Tyomkin V, FuchsT, Adam Dan, Krakover R and **Vered** Zvi. JASE Vol 23, **2010**

A New Tool for Automatic Assessment of Segmental Wall Motion Based on Longitudinal 2D Strain

A Multicenter Study by the Israeli Echocardiography Research Group

Noah Liel-Cohen, MD; Yossi Tsadok, BSc; Ronen Beeri, MD; Peter Lysyansky, PhD;
Yoram Agmon, MD; Micha S. Feinberg, MD; Wolfgang Fehske, MD; Dan Gilon, MD; Ilan Hay, MD;
Rafael Kuperstein, MD; Marina Leitman, MD; Lisa Deutsch, PhD; David Rosenmann, MD;
Alik Sagie, MD; Sarah Shimoni, MD; Mordehay Vaturi, MD;
Zvi Friedman, PhD; David S. Blondheim, MD

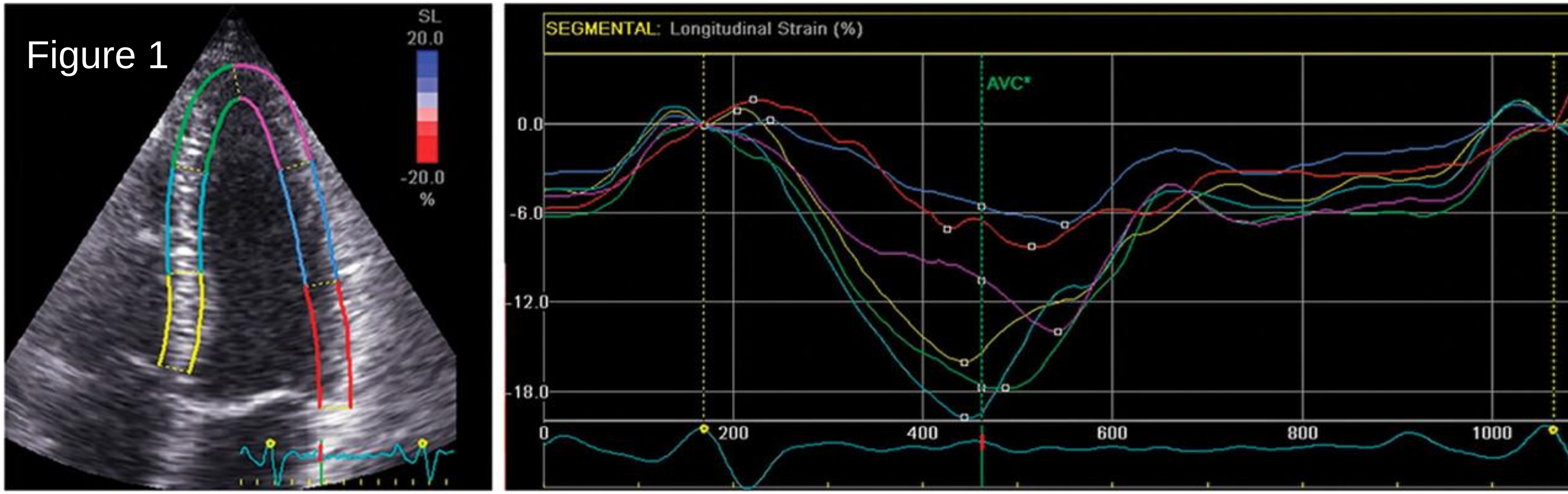
Longitudinal 2D strain echo using AFI
(Automated Function Imaging)
is highly accurate and reproducible for detection of Left Ventricular Wall Motion Abnormalities

Liel-Cohen et al, Circ Cardiovasc Imaging 2010

Deformation in Ischemia

Use of 2D strain

Strain echocardiography predicts acute coronary occlusion

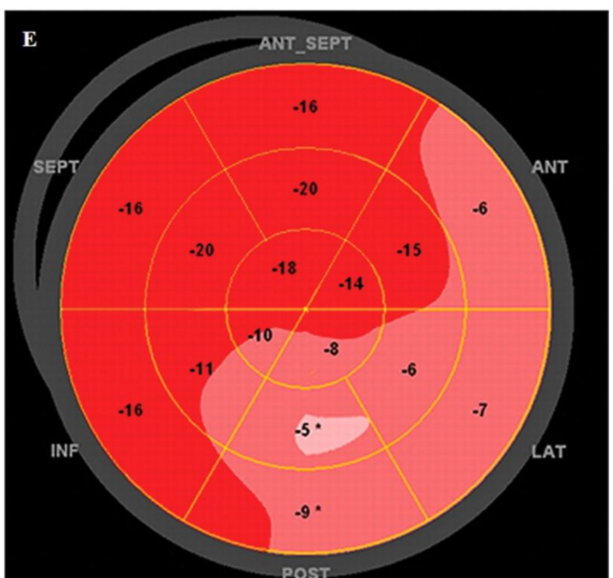


Region of interest drawn in apical 4-Ch view and corresponding strain curves

Peak systolic strain (PSS) values:

Reduced in the lateral wall (red, blue, and purple traces) **−5** to **−10%**,

Normal in the septum (yellow, cyan, and green traces) **−16** to **−20%**.



Bull's eye plot of strain values:
functional risk area of nine adjacent segments
with strain greater than or equal to −14% .

Eek C et al. EJE 2010;11:501

150 patients enrolled from 2007-2008, clinical diagnosis of **NSTE-ACS**, and planned coronary angiography within 3 days of index admission.

Table 5 Receiver operator characteristic analysis of echocardiographic parameters for identification of acute coronary occlusion

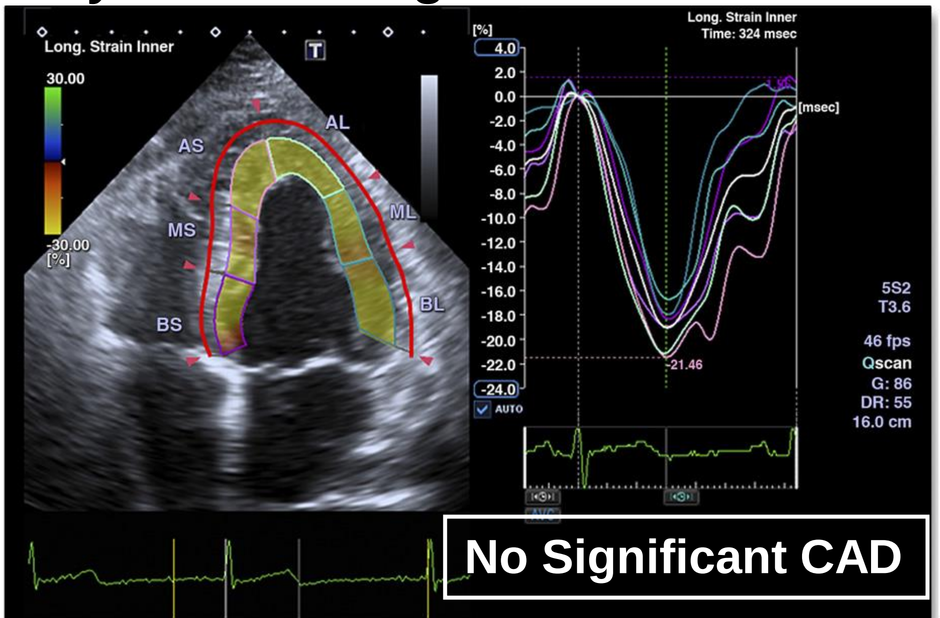
	Cut-off	Sensitivity	Specificity	AUC	NPV	PPV
LVEF	57%	58%	60%	0.64 (0.52–0.75)	0.81	0.34
WMSI	1.08	70%	70%	0.73 (0.63–0.83)*	0.89	0.39
Global strain	−16.3%	67%	71%	0.76 (0.67–0.85)*	0.87	0.38
Functional risk area by WMS	≥2 segments	70%	68%	0.73 (0.62–0.82)*	0.88	0.38
Functional risk area by strain	≥4 segments	85%	70%	0.81 (0.74–0.88)*	0.94	0.44

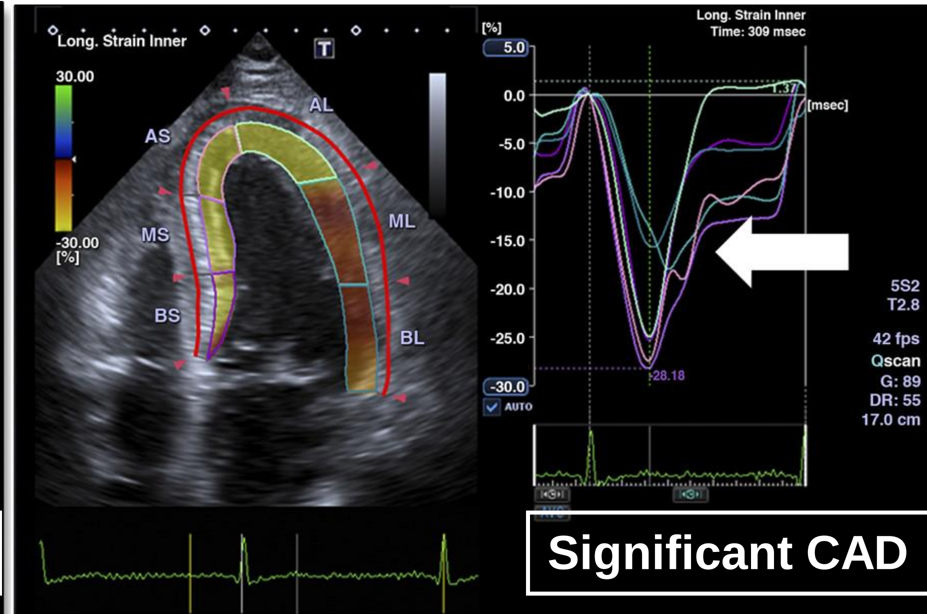
The AUC is reported with 95% confidence interval. Estimates of risk area are based on number of adjacent segments with WMS ≥2 or strain greater than or equal to −14%, respectively. AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value. *P < 0.05 vs. LVEF.

- By **multivariate logistic regression**, only **functional risk area by strain analysis remained an independent predictor of acute coronary occlusion**.
- **ROC analysis** demonstrated that **functional risk area by strain** analyses had the **best ability to identify patients** with **acute coronary occlusion**.
- **Functional risk area by strain of minimum 4 segments** yields: **sensitivity** of **85%** and a **specificity** of **70%** for predicting occlusion.

Strain echocardiography predicts acute coronary occlusion **Eek** C et al. EJE 2010;11:501

Layer-Specific Quantification of Myocardial Deformation by Strain May Reveal Significant CAD in Pts With Non ST Elevation ACS





Normal strain **(–19%)** in **healthy** person

Color-coded automatic endocardial longitudinal strain in apical 4-ch view. **Yellow** indicates preserved strain. **Brown** indicates reduced strain. The red line and arrowheads depict epicardial border. **Strain curves** for 6 **endocardial** segments are displayed.

Reduced endocardial strain in segments supplied by the **CX** artery –15% to –17% (white arrow) in a patient with non ST-elevation ACS with occluded circumflex artery.

Endocardial global longitudinal strain was reduced to **–15%.**

Territorial longitudinal strain = TLS

Sarvari SI, Haugaa KH, Zahid W, Bendz B, MD, Aakhus S, Aaberge L, Edvardsen T, JACC CVI, **In Press 2013**

72 pts referred to coronary angiography for suspected NSTE ACS:
28 with coronary occlusion, 21 significant stenosis, 28 no stenosis.
Echo performed 1 - 2 h before angiography.

Table 5. **Endocardial TLS and Parameters Influencing Myocardial Function in Patients With Suspected NSTE ACS (N = 77)**

	Univariate Logistic Regression			Multivariate Logistic Regression		
	OR	**95% CI**	**p Value**	**OR**	**95% CI**	**p Value**
Endocardial TLS, %	1.88	1.42–2.49	<0.001	2.10	1.47–3.09	<0.001
Age, yrs	1.02	0.97–1.08	0.39	1.05	0.97–1.14	0.21
BMI, kg/m^2	1.10	0.96–1.26	0.16	1.00	0.89–1.12	0.98

ACS = acute coronary syndromes; BMI = body mass index; CI = confidence interval; NSTE = non–ST-segment elevation; OR = odds ratio; TLS = territorial longitudinal strain.

Multivariate regression analysis showed that (including parameters influencing myocardial function): **the only predictor of the presence of significant CAD was reduced myocardial function by <u>endocardial</u> TLS** (per 1% change), independently of the variables included in the model in addition to endocardial TLS.

Conclusions:

Assessment of endocardial and mid-myocardial TLS by layer-specific strain echo provided higher accuracy than epicardial strain, **WMSI, EF in identification of pts with NSTE-ACS** and **significant CAD**.

Endocardial function was more affected than epicardial function in patients with significant CAD.

Sarvari SI, , **Edvardsen** T, JACC CV Imaging, **In Press 2013**

European Journal of Echocardiography (2009) 10, 695–701
doi:10.1093/ejechocard/jep041

EUROPEAN SOCIETY OF CARDIOLOGY®

Longitudinal 2D strain at rest predicts the presence of left main and three vessel coronary artery disease in patients without regional wall motion abnormality

Jin-Oh Choi, Sung Won Cho, Young Bin Song, Soo Jin Cho, Bong Gun Song, Sang-Chol Lee, and Seung Woo Park*

Division of Cardiology, Cardiac and Vascular Centre, Department of Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, no. 50, Irwon-dong, Gangnam-gu, Seoul 135-710, Korea

108p referred to coronary angio & echo
(96p adequate speckle tracking)

Stable & unstable AP

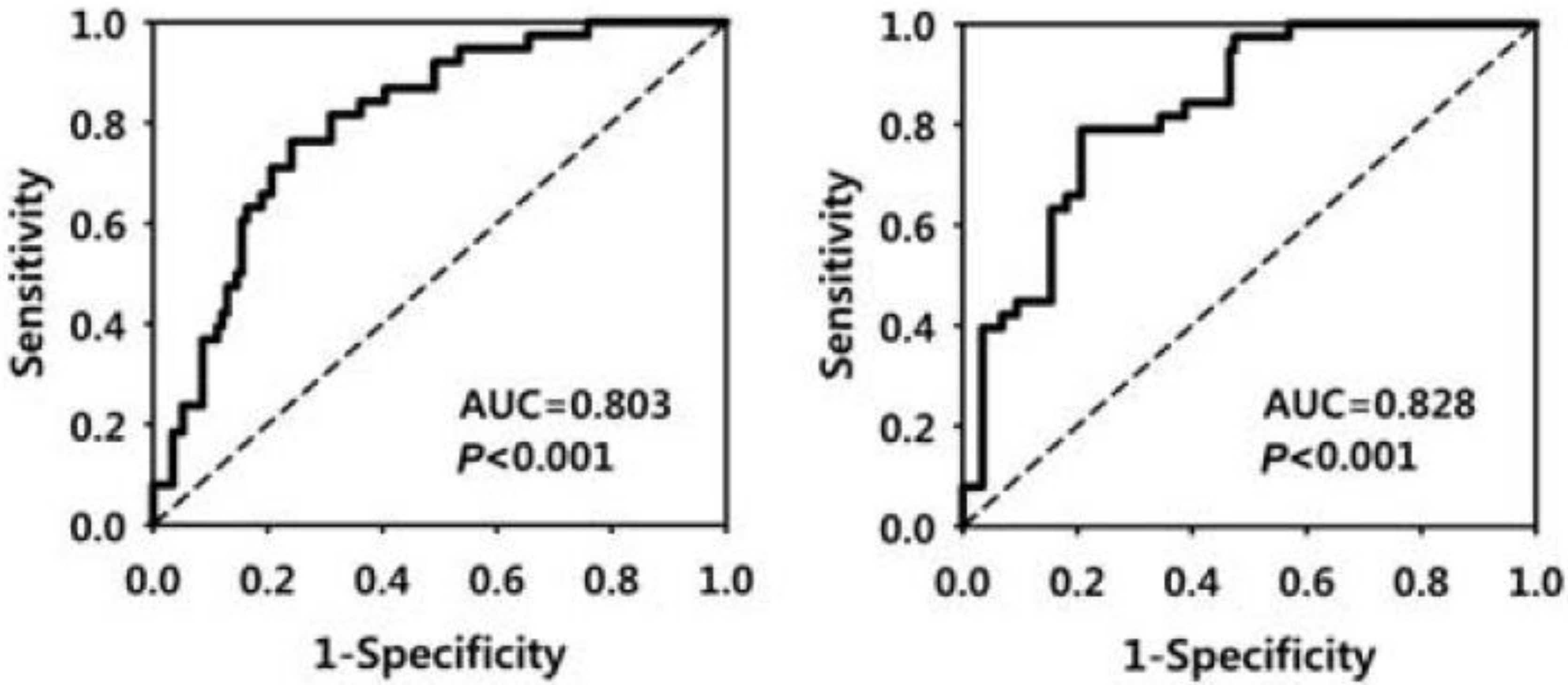
Normal LV on 2D echo

59±9y, 71% males

High risk 38p, low risk=28p normal=30p

Global PSLS -19.4%
Sens=76.3%, Spec=74.1%

Mid-basal PSLS -17.9%
Sens=78.9%, Spec=79.3%



Resting PSLS is significantly reduced in patients with severe CAD including LM or 3 vessel CAD, even when resting wall motion and LV ejection fraction are normal.
Therefore, **PSLS measured by 2D strain may be a more sensitive marker than wall motion abnormality** for severe ischaemic disease.

Choi J et al. Eur J Echocardiogr 2009;10:695-701

Fig 3

Differential Effects of Coronary Artery Stenosis on Myocardial Function: The Value of Myocardial Strain Analysis for the Detection of Coronary Artery Disease

Shimoni S, Gendelman G, Ayzenberg O, Smirin N, Lysyansky P, Edri O, Deutsch L, Caspi A and **Friedman** Z, Israel

J Am Soc Echocardiogr 2011;24:748-57

Aim: assess predictive value of **2D longitudinal strain** in **detection of LV dysfunction** and **identification of coronary artery disease** in patients **hospitalized with angina with normal LV function on 2D echo**

- 97 patients hospitalized with **stable and unstable angina**
- **Normal LVEF and regional function**
- Echo performed within 5 days of hospitalization and before cath

Shimoni et al. JASE 2011;24:748

An example of 2D longitudinal strain deformation analysis: knots and segments

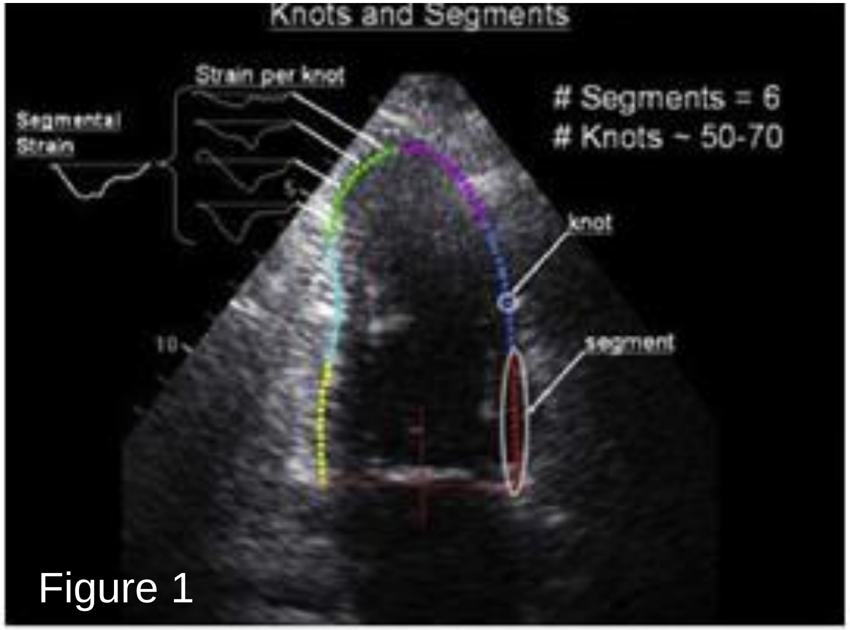
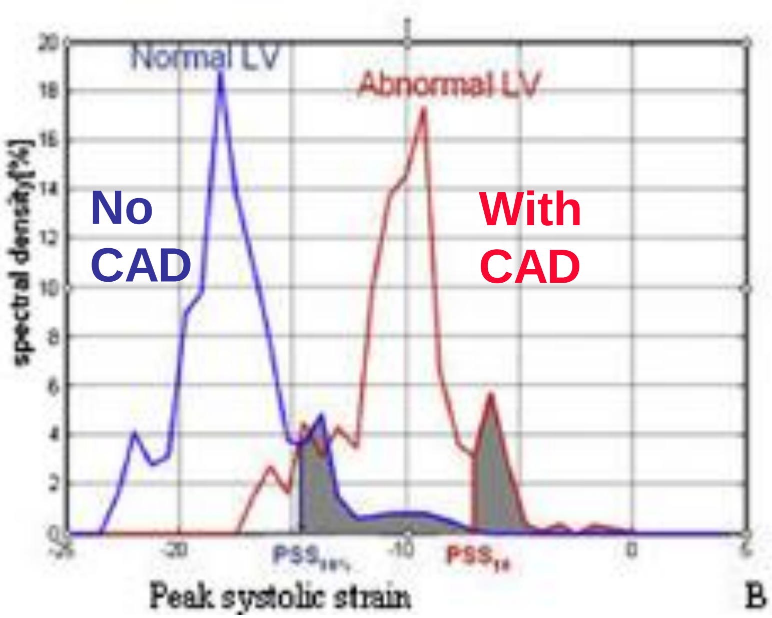


Figure 1

Segmental analysis: longitudinal strain traces in each segment are averaged to a **single segmental strain trace**.

Knots are elements of 1-2 mm in length. 2D strain software generates strain traces of all **150 - 200** knots in 3 apical views and **generates a histogram**.



Shimoni et al. JASE 2011;24:748

Example: **histograms** and parameters for **$PSS_{10\%}$**, in patients with and without CAD.

Blue histogram: **longitudinal PSS** distribution from **entire LV** of a patient with no CAD. $PSS_{10\%}$ in this patient was **15%**.

Red histogram shows the longitudinal PSS traces of a patient with CAD. $PSS_{10\%}$ in this patient was **7%**.

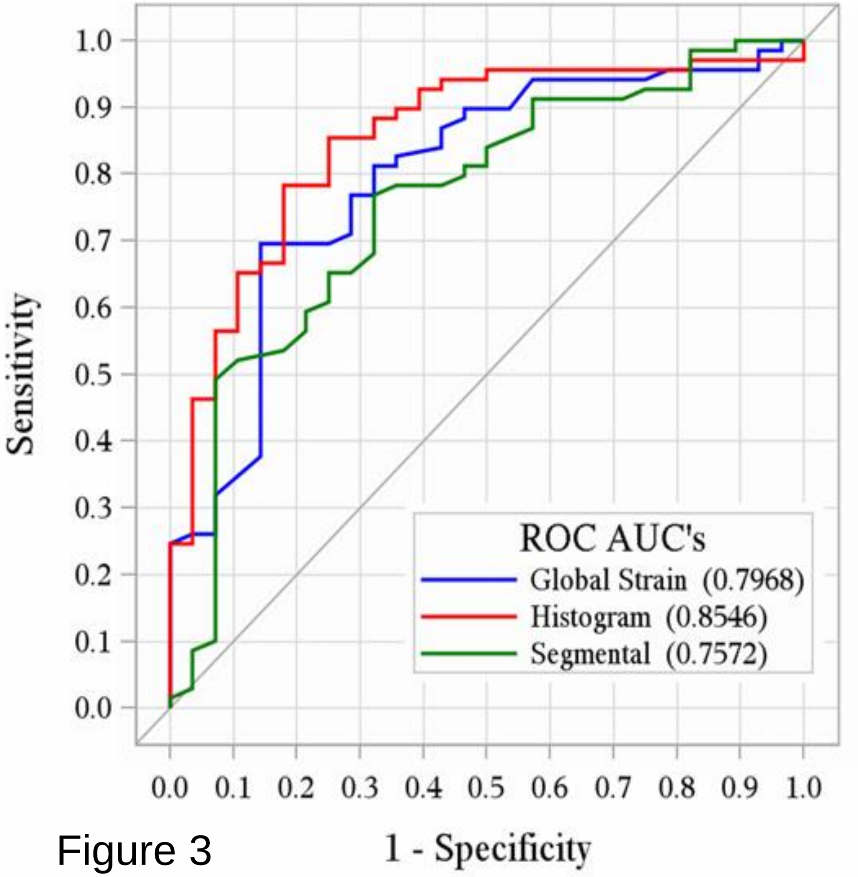


Figure 3

The AUC for **PSS$_{10\%}$** significantly higher than AUC for **SegPSS** (0.86, 0.76, resp;P=.004).

Conclusions:

Global and regional longitudinal systolic function is impaired in patients hospitalized with stable and unstable angina who have significant CAD.

Histogram analysis improved the accuracy of longitudinal strain analysis in detecting global and regional impaired function.

The test is noninvasive and can be performed at the bedside, and the analysis can be fast and quantitative.

Further studies needed to prospectively evaluate the use of longitudinal LV systolic function in patients admitted to chest pain units or hospitalized for the evaluation of chest pain.

Shimoni et al. JASE 2011;24:748

2D Strain Echocardiography for Diagnosing Chest Pain in the Emergency Room (2DSPER):

A multicenter prospective observational study
by the **Israeli Echocardiography Research Group**

Participating 11 Israeli Medical Centers
Avinoam Shiran MD, Lady Davis Carmel Medical Center

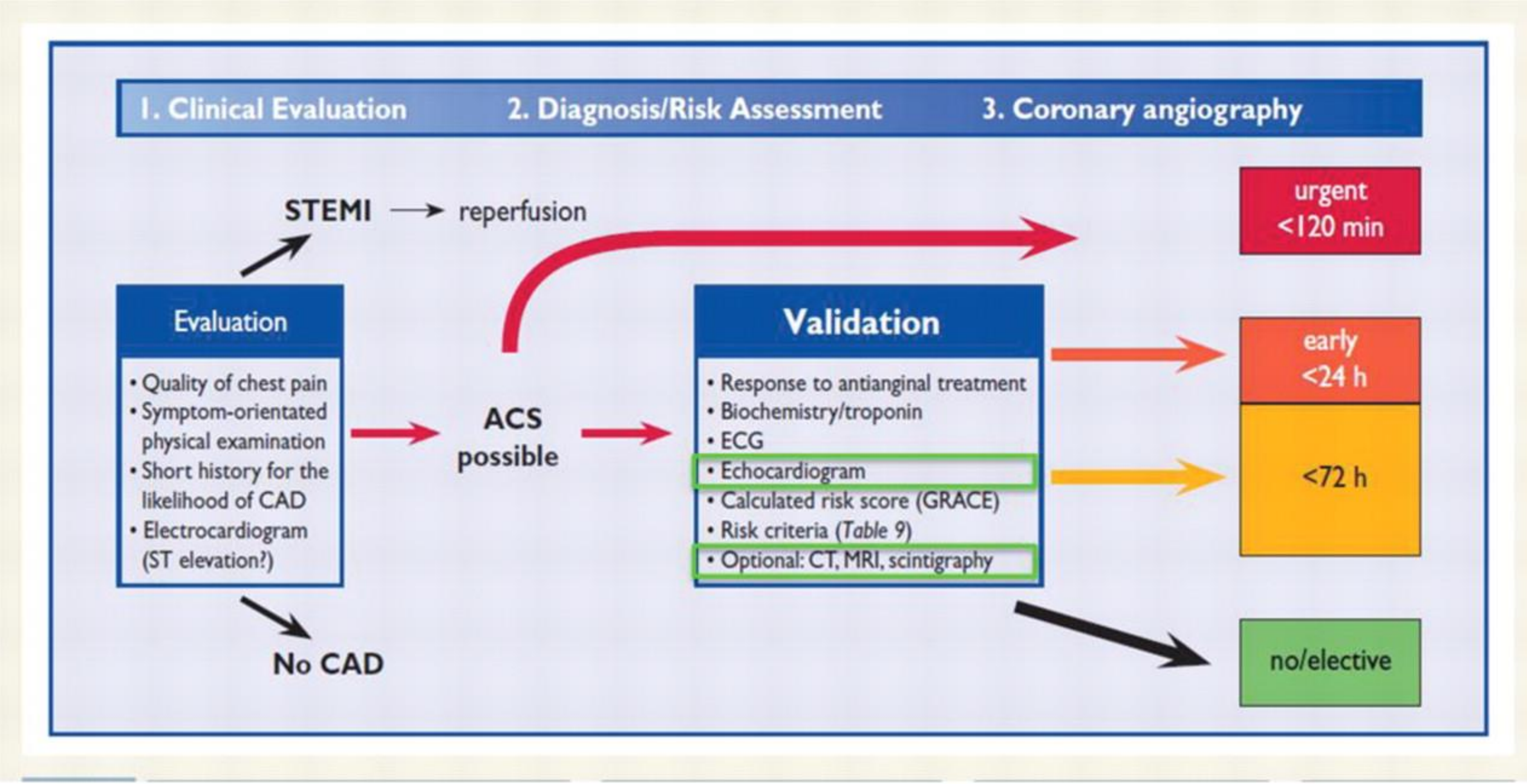
Hypothesis:
Normal longitudinal strain from a bedside echo, performed in patients with chest pain and medium risk for ACS,
will safely and effectively **rule out ACS**.

>700 patients, 10% positive for CAD

Longitudinal 2D strain for suspected ACS

- **Noninvasive, bedside**
- **Immediate and quantitative results**
- **Automated and objective (inexperienced operator)**
- **Reproducible**
- **Sensitive for ischemia (more than visual assessment)**
- **“Memory” effect**
- **Depends on 2D echo quality and frame rate**

Decision-making algorithm in ACS.
Echocardiography is mandatory in each patient, whereas other forms of imaging are optional
(framed green in the validation box).



Sechtem U et al. Eur J Echocardiogr 2012

Hamm C W et al. Eur Heart J 2011;32:2999-3054

Clearly echocardiography has a
multitude of options
which contribute to *the*
risk stratification,
diagnosis and
better patient care
for patients with acute chest pain.

Thank you

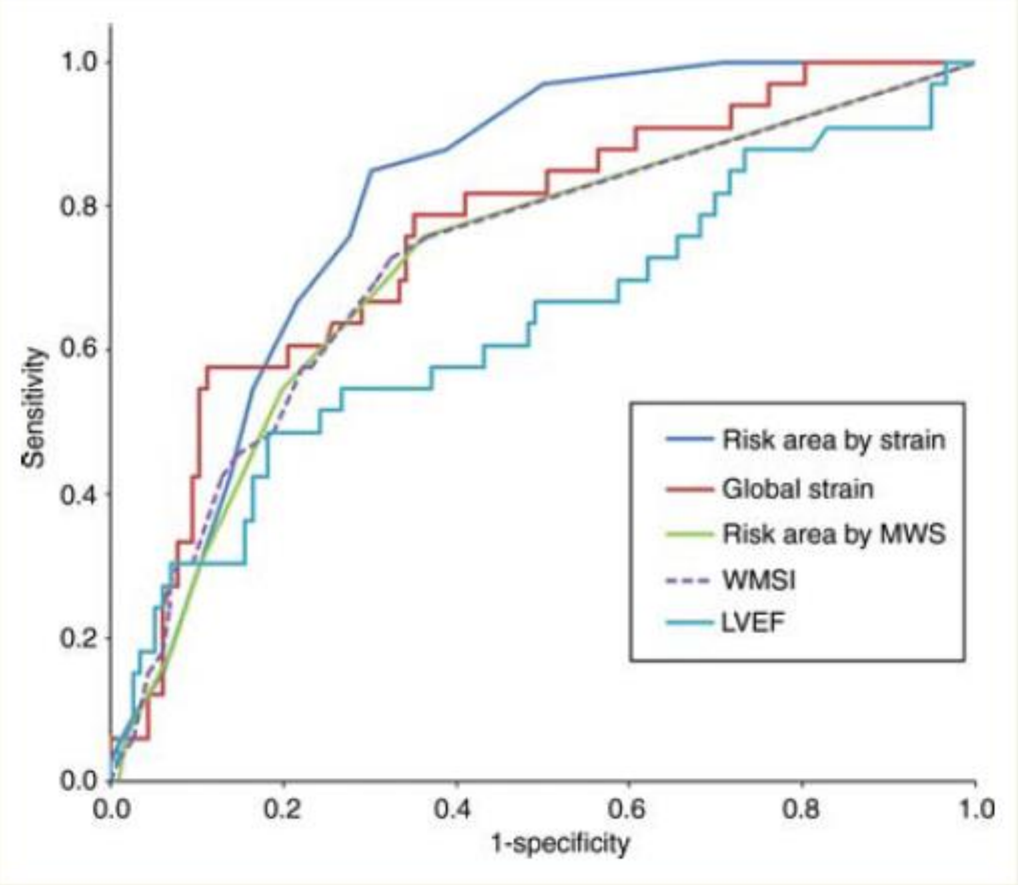
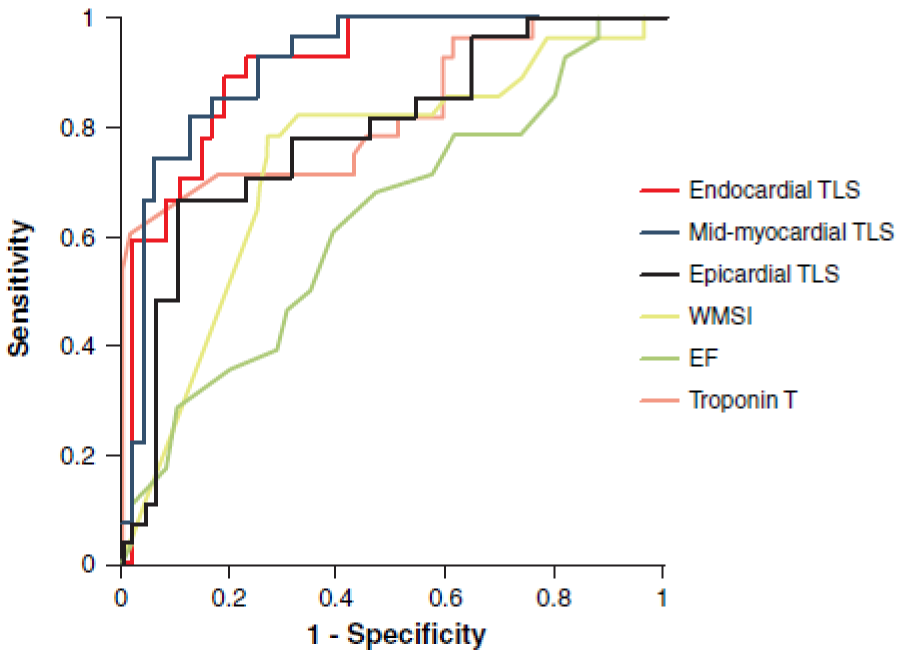


Figure 3 Receiver operator characteristic analyses of echocardiographic parameters for identification of patients with acute coronary occlusion.

Strain echocardiography predicts acute coronary occlusion Eek C et al. EJE 2010;11:501



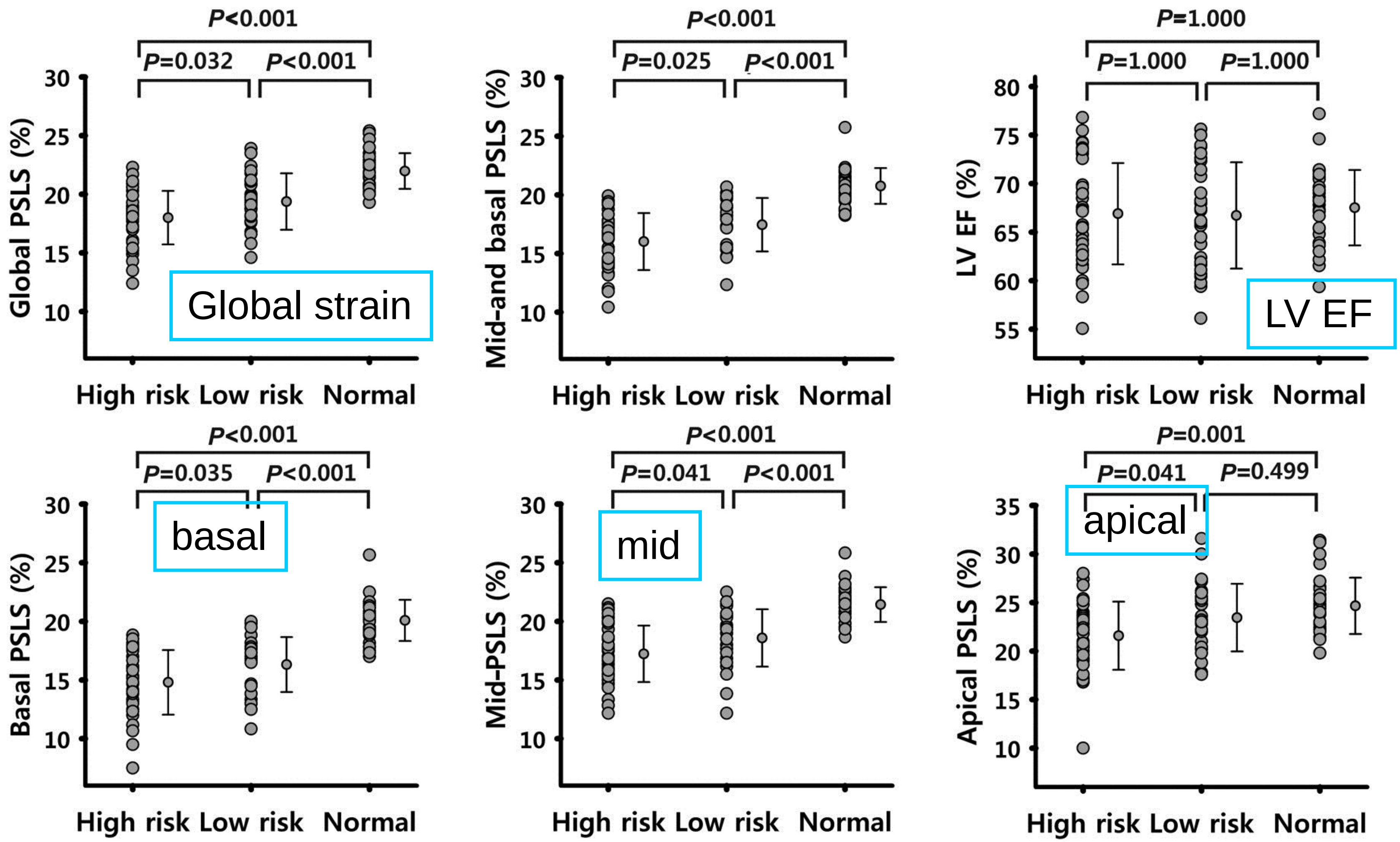
	AUC	95% CI	Optimal cutoff	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Troponin T (ng/l)	0.83	0.72-0.93	8	64	94	86	82
EF (%)	0.63	0.50-0.76	62	61	61	73	47
WMSI	0.74	0.62-0.85	1.07	79	73	63	86
Endocardial TLS (%)	0.91	0.84-0.97	-16.4	89	81	73	93
Mid-myocardial TLS (%)	0.91	0.85-0.98	-14.7	82	88	79	89
Epicardial TLS (%)	0.79	0.68-0.90	-12.6	78	69	58	85

Figure 3. ROC Analyses of TLS

Receiver-operating characteristic (ROC) curve analyses for the ability of Troponin T, ejection fraction (EF), Wall Motion Score Index (WMSI), and territorial longitudinal strain (TLS) parameters to identify patients with significant coronary artery disease. The analyses include all study participants (N = 77). AUC = area under the curve; PPV = positive predictive value; NPV = negative predictive value.

Sarvari SI, …, **Edvardsen** T, JACC CV Imaging, **In Press 2013**

Comparison of global and segmental peak systolic longitudinal strains



High risk 38p, low risk=28p normal=30p

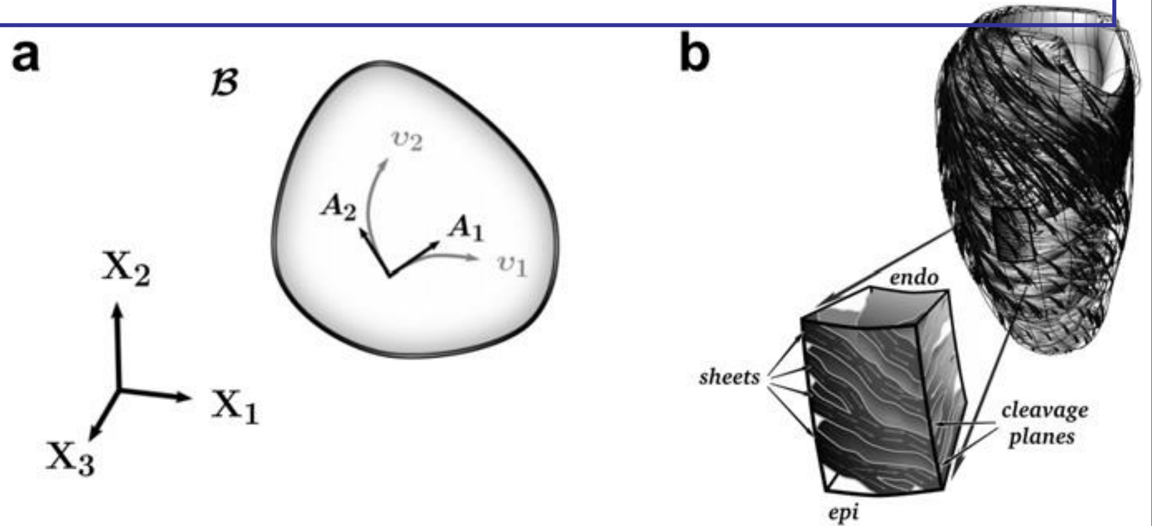
Global + segmental PSLSs were greater in normal than in high-risk

Choi J et al. Eur J Echocardiogr 2009;10:695-701

Fig 2

Coordinated contraction and relaxation of LV myocardium produces several fundamental movements of the left ventricle: **nonhomogenous deformation** of the basal, mid, and apical ventricular segments.

Pioneering estimates of ventricular wall stress were based on **“Law of Laplace”** for thin-walled spheres a simplification of equations (10) and (11).



$$\mathbf{w} = \frac{k_{\mathrm{ff}} \cdot (E_v)_{\mathrm{ff}}^2}{\left(c_{\mathrm{ff}} - (E_v)_{\mathrm{ff}}\right)^2} + \frac{k_{\mathrm{ss}} \cdot (E_v)_{\mathrm{ss}}^2}{\left(c_{\mathrm{ss}} - (E_v)_{\mathrm{ss}}\right)^2} + \frac{k_{\mathrm{nn}} \cdot (E_v)_{\mathrm{nn}}^2}{\left(c_{\mathrm{nn}} - (E_v)_{\mathrm{nn}}\right)^2}$$

$$+ \frac{k_{\mathrm{fs}} \cdot (E_v)_{\mathrm{fs}}^2}{\left(c_{\mathrm{fs}} - (E_v)_{\mathrm{fs}}\right)^2} + \frac{k_{\mathrm{sn}} \cdot (E_v)_{\mathrm{sn}}^2}{\left(c_{\mathrm{sn}} - (E_v)_{\mathrm{sn}}\right)^2} + \frac{k_{\mathrm{fn}} \cdot (E_v)_{\mathrm{fn}}^2}{\left(c_{\mathrm{nf}} - (E_v)_{\mathrm{fn}}\right)^2}, \qquad (24)$$

$$\mathbf{w} = C_1 (e^Q - 1), \quad Q = C_2 E_{ff}^2 + C_3 \left(E_{\mathrm{ss}}^2 + E_{\mathrm{nn}}^2 + 2E_{\mathrm{sn}}^2\right)$$

$$+ 2C_4 \left(E_{\mathrm{fs}} E_{\mathrm{sf}} + E_{\mathrm{fn}} E_{\mathrm{nf}}\right) \qquad (25)$$

Coupling multi-physics models to cardiac mechanics D.A. Nordsletten et al,
Progress in Biophysics and Molecular Biology 2011