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 Hypertension
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
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

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

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.

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

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

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

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

Time (sequential frames)

Courtesy of Z Friedman, P Lysyansky (GE Israel)
**Strain** is calculated as the change in length (ΔL) divided by the original length (L₀) and expressed as a percentage.
Three-layer longitudinal and circumferential strain: normal subject

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

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
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

<table>
<thead>
<tr>
<th>Cut-off</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>AUC</th>
<th>NPV</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF</td>
<td>57%</td>
<td>60%</td>
<td>0.64 (0.52–0.75)</td>
<td>0.81</td>
<td>0.34</td>
</tr>
<tr>
<td>WMSI</td>
<td>1.08</td>
<td>70%</td>
<td>0.73 (0.63–0.83)*</td>
<td>0.89</td>
<td>0.39</td>
</tr>
<tr>
<td>Global strain</td>
<td>−16.3%</td>
<td>67%</td>
<td>0.76 (0.67–0.85)*</td>
<td>0.87</td>
<td>0.38</td>
</tr>
<tr>
<td>Functional risk area by WMS</td>
<td>≥2 segments</td>
<td>70%</td>
<td>0.73 (0.62–0.82)*</td>
<td>0.88</td>
<td>0.38</td>
</tr>
<tr>
<td>Functional risk area by strain</td>
<td>≥4 segments</td>
<td>85%</td>
<td>0.81 (0.74–0.86)*</td>
<td>0.94</td>
<td>0.44</td>
</tr>
</tbody>
</table>

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.
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**

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.

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

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)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Univariate Logistic Regression</th>
<th>Multivariate Logistic Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Endocardial TLS, %</td>
<td>1.88</td>
<td>1.42–2.49</td>
</tr>
<tr>
<td>Age, yrs</td>
<td>1.02</td>
<td>0.97–1.08</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>1.10</td>
<td>0.96–1.26</td>
</tr>
</tbody>
</table>

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

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

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

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

**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.

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

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

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

Shimoni et al. JASE 2011;24:748
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.

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

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.
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).

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.
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.
Comparison of global and segmental peak systolic longitudinal strains


Fig 2

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

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

\[
w = \frac{k_{ff} \cdot (E_v)_{ff}^2}{(c_{ff} - (E_v)_{ff})^2} + \frac{k_{ss} \cdot (E_v)_{ss}^2}{(c_{ss} - (E_v)_{ss})^2} + \frac{k_{nn} \cdot (E_v)_{nn}^2}{(c_{nn} - (E_v)_{nn})^2} \\
+ \frac{k_{fs} \cdot (E_v)_{fs}^2}{(c_{fs} - (E_v)_{fs})^2} + \frac{k_{sn} \cdot (E_v)_{sn}^2}{(c_{sn} - (E_v)_{sn})^2} + \frac{k_{fn} \cdot (E_v)_{fn}^2}{(c_{fn} - (E_v)_{fn})^2},
\]

(24)

\[
w = C_1(e^Q - 1), \quad Q = C_2 E_{ff}^2 + C_3 \left( E_{ss}^2 + E_{nn}^2 + 2E_{sn}^2 \right) \\
+ 2C_4 \left( E_{fs}E_{sf} + E_{fn}E_{nf} \right)
\]

(25)

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