Role of imaging in coronary artery disease

How to evaluate ischemic burden in chronic coronary artery disease

Ευάγγελος Οικονόμου

Καρδιολόγος, Α’ Πανεπιστημιακή Καρδιολογική Κλινική
The Cardiovascular Continuum

- Ischemia
- Coronary artery disease
- Atherosclerosis
- Endothelial dysfunction
- Risk factors
- Myocardial infarction
- Heart insufficiency
- Terminal heart disease

modified from Dzau and Braunwald
Ischemic Cascade

Functional testing ECG/Imaging

- Treadmill exercise ECG
- Stress Echocardiography
- Myocardial perfusion scintigraphy (SPECT) or PET
- CMRI stress imaging
Initial diagnostic management of patients with suspected SCAD (1)

ALL PATIENTS

Assess symptoms
Perform clinical examination

Symptoms consistent with unstable angina

Follow specific NSTE-ACS guidelines

ECG
Bio-Chemistry
Resting echocardiography\(^a\)
CXR in selected patients

Consider comorbidities and QoL

Comorbidities or QoL make revascularization unlikely

Medical therapy\(^b\)

Cause of chest pain other than CAD?

Yes

Treat as appropriate

No

LVEF <50%?

Yes

Typical angina?

Yes

Offer ICA if revascularization suitable

No

See Fig. 2 for selection of test

Assess pre-test-probability (PTP) (see Table 13) for the presence of coronary stenoses

\(^a\) May be omitted in very young and healthy patients with a high suspicion of an extracardiac cause of chest pain and in multimorbid patients in whom the echo result has no consequence for further patient management.

\(^b\) If diagnosis of SCAD is doubtful, establishing a diagnosis using pharmacological stress imaging prior to treatment may be reasonable.
Initial diagnostic management of patients with suspected SCAD (2)

Assess pre-test-probability (PTP) for the presence of coronary stenoses

High PTP (>85%)

Diagnosis of SCAD established

Proceed to risk stratification
In patients with severe symptoms or clinical constellation suggesting high risk coronary anatomy initiate guideline-directed medical therapy and offer ICA

Low PTP (<15%)

Investigate other causes
Consider functional coronary disease

Intermediate PTP, eg 15-85%

Non-invasive testing for diagnostic purposes

This slide corresponds to Figure 1 in the full text
ICA = invasive coronary angiography.
## Clinical Classification of Chest Pain

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical angina (definite)</td>
<td>Meets <strong>three</strong> of the following characteristics</td>
</tr>
<tr>
<td></td>
<td>- Substernal chest discomfort of characteristic quality and duration</td>
</tr>
<tr>
<td></td>
<td>- Provoked by exertion or emotional stress</td>
</tr>
<tr>
<td></td>
<td>- Relieved by rest and/or GTN within minutes</td>
</tr>
<tr>
<td>Atypical angina (probable)</td>
<td>Meets <strong>two</strong> of these characteristics</td>
</tr>
<tr>
<td>Non-anginal chest pain</td>
<td>Meets <strong>one or none</strong> of the characteristics</td>
</tr>
</tbody>
</table>
Clinical pre-test probabilities in patients with stable chest pain symptoms

<table>
<thead>
<tr>
<th>Age</th>
<th>Typical angina</th>
<th>Atypical angina</th>
<th>Non-anginal pain</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
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<td>70-79</td>
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<td>69</td>
</tr>
<tr>
<td>&gt;80</td>
<td>93</td>
<td>76</td>
<td>78</td>
</tr>
</tbody>
</table>

*Probabilities of obstructive coronary disease shown reflect the estimates for patients aged 35, 45, 55, 65, 75, and 85 years. This slide corresponds to Table 13 in the full text.*

Non-invasive testing in suspected SCAD with intermediate PTP

- Patients with suspected SCAD and intermediate PTP of 15% - 85%
  - Consider:
    - Patient criteria/suitability for given test
    - Availability
    - Local expertise

- Stress testing for ischaemia
  - PTP 15-65% and LVEF ≥50%
    - Exercise ECG if feasible - stress imaging testing preferred (echo, CMR, SPECT, PET)
      - if local expertise and availability permit

- PTP 66-85% or LVEF <50% without typical angina
  - Stress imaging (echo, CMR, SPECT, PET); ECG exercise stress testing possible if resources for stress imaging not available

- PTP 66-85% and LVEF ≥50%
  - Exercise ECG if feasible - stress imaging testing preferred (echo, CMR, SPECT, PET)
    - if local expertise and availability permit

- Coronal CTA in patients with intermediate PTP
  - If suitable candidate
    - If adequate technology and availability
  - If history of CAD

- Coronary CTA in suitable patient
  - If not done before

- ICA (with FFR when necessary)

- Determine patient characteristics and preferences

- Consider functional CAD
  - Investigate other causes

- SCAD established
  - Further risk stratification (see Fig. 3)

- Stress imaging if not available

---

a. Consider age of patient versus radiation exposure.
b. In patients unable to exercise use echo or SPECT/PET with pharmacologic stress instead.
c. CMR is only performed using pharmacologic stress.
d. Patient characteristics should make a fully diagnostic coronary CTA scan highly probable (see section 6.2.5.1.2) consider result to be unclear in patients with severe diffuse or focal calcification.
e. Proceed as in lower left coronary CTA box.
f. Proceed as in stress testing for ischaemia box.
Ischemic burden Evaluation
Echocardiography
Stable CAD/Rest echo
First Case

• 71 year male patient
• Presented with atypical chest pain
• DM on insulin treatment for 10 years
• Smoker

• hsTnI (-)
The impairment of systolic function correlates with the severity of flow reduction:

- A 20% reduction in sub-endocardial flow produces a 15–20% decrease in left ventricular wall thickening;
- A 50% reduction in sub-endocardial flow decreases regional wall thickening by about 40%;
- And when sub-endocardial flow is reduced by 80%, akinesia occurs.
- When the flow deficit is extended to the sub-epicardial layer, dyskinesia appears.

- Lower LV volumes for any given pressure increase (Sabbah, Marzilli. Am J Physiol 1981)
- Possible anti-arrythmic and anti-remodeling effect of subepicardium (Kaul S. Circulation 1995)
Functional Imaging Testing

- **Stress Echocardiography**

- **Myocardial perfusion scintigraphy (SPECT) or PET**

- **CMRI stress imaging**
Stress Echo

- Echocardiography is well recognized for its noninvasive application
- It does not require isotopes—there is no risk of radiation
- It does not require magnetic resonance
- It’s portable
- It provides both anatomy and function
- It’s the tool to follow up...
The three most commonly used stressors are exercise, dobutamine, and dipyridamole.

Exercise is the prototype of demand-driven ischemic stress

However, out of five patients, one cannot exercise, one exercises submaximally, and one has an uninterpretable ECG.

Pharmacologic stressors minimize factors such as hyperventilation, tachycardia, hypercontraction of normal walls, and excessive chest wall movement, which render the ultrasonic examination difficult during exercise.

<table>
<thead>
<tr>
<th>TEST</th>
<th>EQUIPMENT</th>
<th>PROTOCOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>Semi-supine bycicle</td>
<td>25 W × 2’ with incremental loading</td>
</tr>
<tr>
<td></td>
<td>ergometer</td>
<td></td>
</tr>
<tr>
<td>Dobutamine</td>
<td>Infusion Pump</td>
<td>5 μg/kg/min 10–20–30–40 + atropine (0.25 × 4) up to 1 mg</td>
</tr>
<tr>
<td>Dipyridamole</td>
<td>Syringe</td>
<td>0.84 mg/kg in 6 min or 0.84 mg/kg in 10 min + atropine (0.25 × 4) up to 1 mg</td>
</tr>
<tr>
<td>Adenosine</td>
<td>Syringe</td>
<td>140 μg/kg/min in 6’</td>
</tr>
<tr>
<td>Pacing</td>
<td>External Pacing</td>
<td>From 100 bpm with increments of 10 beats/min up to target heart rate</td>
</tr>
</tbody>
</table>
All stress echocardiographic diagnoses can be easily summarized into equations centered on regional wall function describing the fundamental response patterns as normal, ischemic, viable, and necrotic myocardium.

<table>
<thead>
<tr>
<th>REST</th>
<th>+</th>
<th>STRESS</th>
<th>=</th>
<th>DIAGNOSIS</th>
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<tr>
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<td>Hypo, A, Dyskinesis</td>
<td>=</td>
<td>Ischemia</td>
</tr>
<tr>
<td>Akineses</td>
<td>+</td>
<td>Hypo, Normokinesis</td>
<td>=</td>
<td>Viable</td>
</tr>
<tr>
<td>A-, Dyskinesis</td>
<td>+</td>
<td>A-, Dyskinesis</td>
<td>=</td>
<td>Necrosis</td>
</tr>
</tbody>
</table>

doi:10.1093/ejehocard/jen175
Dobutamine Stress Echocardiography Protocol

Figure 1 State-of-the art protocol of dobutamine stress echocardiography.

17 segments

Long axis

Two chamber

Anterior

Anteroseptal

Anterolateral

Inferoseptal

Inferolateral

Four chamber

Apical cap
Apical lateral
Apical septum
Mid inferoseptal
Basal inferoseptal
Basal anterolateral

Apical Cap
Apical anterior
Mid anterior
Mid inferior
Basal inferior
Basal anterolateral

Apical Cap
Apical lateral
Apical anterolateral
Mid inferolateral
Basal inferolateral
Basal anteroseptal

Four chamber

Long axis
A Randomized Cross-Over Study for Evaluation of the Effect of Image Optimization With Contrast on the Diagnostic Accuracy of Dobutamine Echocardiography in Coronary Artery Disease

The OPTIMIZE Trial

Juan Carlos Plana, MD, FACC, Issam A. Mikati, MD, FACC, Hisham Dokainish, MD, FACC, Nasser Lakis, MD, FACC, John Abouhasil, RT(R), Robert Davis, RDMS, Brian C. Hertzell, MS, William A. Zoghbi, MD, FACC

Houston, Texas

**Contrast Echo**

**Figure 1. Impact of Contrast Agent Use on Visualization of Segments and Confidence of Interpretation**

With the use of a contrast agent, an increase in percentage of segments with excellent or adequate endocardial visualization (score 1) is seen. Furthermore, the distribution of the degree of confidence of interpretation was different, with a much larger percentage of studies interpreted with high confidence when the contrast agent was added.

**Figure 6. Effect of Contrast Agent Use on the Sensitivity and Specificity of DSE**

The effect of contrast agent use on the sensitivity and specificity of dobutamine stress echocardiography (DSE) for coronary artery disease is shown, grouped by confidence of interpretation in unenhanced studies. Only interpretable studies are included in the analysis. A trend was seen mostly for improvement in specificity in low- to medium-confidence studies and a lesser improvement in sensitivity, and a trend for worsening in specificity was observed in unenhanced studies interpreted with high confidence.
The Prognostic Value of Normal Exercise Myocardial Perfusion Imaging and Exercise Echocardiography

A Meta-Analysis

Louise D. Metz, MD, * Mary Beattie, MD, † Robert Hom, MD, ‡ Rita F. Redberg, MD, MSc, § Deborah Grady, MD, MPH, ¶ Kirsten E. Fleischmann, MD, MPH

New York, New York; and San Francisco, California

Estimates of Events After a Negative Test:

a Meta-Analysis

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Annualized Event Rate %</th>
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</thead>
<tbody>
<tr>
<td>Cardiac Death/MI</td>
<td>0.45</td>
</tr>
<tr>
<td>Exercise Echocardiography</td>
<td>0.54</td>
</tr>
<tr>
<td>Revascularization/UA</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>0.95</td>
</tr>
</tbody>
</table>
Risk stratification for a negative test

<table>
<thead>
<tr>
<th>1-year Risk (hard events)</th>
<th>Very Low (&lt;0.5% year)</th>
<th>Low (1–3% year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress</td>
<td>Maximal</td>
<td>Submaximal</td>
</tr>
<tr>
<td>Resting EF</td>
<td>&gt;50%</td>
<td>&lt;40%</td>
</tr>
<tr>
<td>Anti-ischaemic therapy</td>
<td>Off</td>
<td>On</td>
</tr>
<tr>
<td>CFR</td>
<td>&gt;2.0</td>
<td>&lt;2.0</td>
</tr>
</tbody>
</table>
Prognostic value

Stress Echo and Cardiac death

Cardiac mortality (%)

Follow-up (months)

P = 0.0000

92%
DET -

71.2%
DET +

Sicari et al. JACC 2003
Prognostic value/WMSI

Stress Echo and Extent of Ischemia

Delta WMSI < 0.37
90.1%

Delta WMSI > 0.37
76.7%

P < 0.0143

Sicari et al. JACC 2003
CFR: 68/32 = 2.13

“Whenever possible, it is recommended to perform dual imaging vasodilator stress echo” (EAE Guidelines 2008)
Incremental value of CFR over wall motion to predict mortality

\[ n = 4,313 \]
\[ p < 0.0001 \]

<table>
<thead>
<tr>
<th>Subjects at risk</th>
<th>Follow-up (years)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
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<td>516</td>
<td>120</td>
<td>53</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>SE + / CFR &gt; 2</td>
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<td>249</td>
<td>108</td>
<td>69</td>
<td>42</td>
<td>23</td>
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<tr>
<td>SE - / CFR &lt; 2</td>
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<td>903</td>
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<td>316</td>
<td>209</td>
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<tr>
<td>SE - / CFR &gt; 2</td>
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<td>2645</td>
<td>2018</td>
<td>1292</td>
<td>799</td>
<td>405</td>
</tr>
</tbody>
</table>

Cortigiani. JACC Cardiovasc Imaging 2012;5:1079
**MECHANICAL INDEX**

M.I. enables the power of the US beam to be quantified:

\[
M.I. = \frac{\langle P \rangle}{\langle \sqrt{V} \rangle}
\]

\(\langle P \rangle\) = the peak of maximum negative pressure at the point of focalization

\(\langle \sqrt{V} \rangle\) = mean frequency of the US beam

M.I. expresses the acoustic pressure of the US beam produced on insonated structures.
Myocardial ischaemia and viability: the pivotal role of echocardiography

Petros Nihoyannopoulos¹,²* and Jean Louis Vanoverschelde³,⁴

Figure 3  Apical four-chamber view using myocardial contrast echocardiography at rest and during stress (dobutamine). While the resting images show an homogeneous myocardial opacification, during stress there is a clear absence of opacification at the apex.
• LV longitudinal strain is attenuated in the presence of subendocardial ischemia.
Rest global longitudinal 2D strain to detect coronary artery disease in patients undergoing stress echocardiography: a comparison with wall-motion and coronary flow reserve responses
Nuclear Cardiology
Myocardial perfusion scan

Reduction of tracer uptake on stress imaging (arrows), at the apex and in the anterior wall
Prognostic Value

Positron emission tomography

PET is more commonly used to assess myocardial perfusion and it is generally considered the non-invasive gold standard for this

Radiotracers, such as $^{13}$N-ammonia, $^{15}$O-water, Rubidium-82

Relative perfusion appears abnormal within the RCA territory (70% of the maximum) but normal elsewhere (90% of maximum). Absolute perfusion is however abnormal in all three coronary territories (LAD 0.9, LCx 1.0 RCA 0.7 ml/g/min; normal value >2.5 ml/g/min). Coronary angiography showed severe proximal three vessel disease.

Although 2/3 (64%) of the pts undergo NIT prior to elective cardiac catheterization, most have nonobstructive CAD.

Conclusions

- Diagnosis of SCAD starts with careful clinical evaluation

- Pat. with very low and very high pretest probability should not undergo non-invasive testing for CAD

- A variety of non-invasive tests are available to evaluate the presence of CAD in those patients intermediate probability for CAD

- Combining anatomical with functional noninvasive testing may improve the diagnostic yield in future
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<td>+</td>
<td>A-, Dyskinesis</td>
<td>=</td>
<td>Necrosis</td>
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</tbody>
</table>
Atropine (0.3 mg, maximum 1.2 mg) is given, if there is no adequate increase in heart rate.
<table>
<thead>
<tr>
<th>Age</th>
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<th>Atypical angina</th>
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<tr>
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</tr>
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</table>
How to evaluate ischemic burden: from 2D to parametric and contrast analysis

C. Aggeli
Hippokrateion Hospital of Athens
Greece
NO CONFLICT OF INTEREST
The Cardiovascular Continuum

- Ischemia
- Coronary artery disease
- Atherosclerosis
- Endothelial dysfunction
- Risk factors
- Myocardial infarction
- Heart insufficiency
- Terminal heart disease

modified from Dzau and Braunwald
Ischemic cascade

Blood flow mismatch
Diastolic dysfunction
Systolic dysfunction
Perfusion defects on nuclear imaging, MCE

Wall motion abnormalities on echocardiography/MRI
ST↓ on ECG
EKG abnormalities
Symptoms
Angina

Coronary Blood Flow Reserve

During Hyperemia
At Rest

Gould, AJC, 1979

Stenosis + Adenosine

Van Camp et al., EASE 2003:16 253
A range of different imaging modalities across the spectrum of CAD
Echocardiography is well recognized for its noninvasive application.

- It does not require isotopes—there is no risk of radiation
- It does not require magnetic resonance
- It’s patient-friendly
- It’s portable
- It provides both anatomy and function
- It’s the sine qua non to detect and elucidate or to exclude structural cardiac disease.
- It’s the tool to follow up…
Stress Echocardiography from 1979 to Present

William F. Armstrong, MD, and Thomas Ryan, MD, FASE, Ann Arbor, Michigan; and Columbus, Ohio

<table>
<thead>
<tr>
<th>Table 1 Stress echocardiography methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
</tr>
<tr>
<td>Posttreadmill exercise</td>
</tr>
<tr>
<td>Supine or upright bicycle</td>
</tr>
<tr>
<td>Handgrip</td>
</tr>
<tr>
<td>Pharmacologic</td>
</tr>
<tr>
<td>Dobutamine (+ atropine)</td>
</tr>
<tr>
<td>Dipyridamole (+ atropine)</td>
</tr>
<tr>
<td>Adenosine (+ atropine)</td>
</tr>
<tr>
<td>Combined dobutamine + dipyridamole</td>
</tr>
<tr>
<td>Pharmacologic ± handgrip</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Transesophageal atrial pacing</td>
</tr>
<tr>
<td>Transvenous pacing (temporary or permanent)</td>
</tr>
<tr>
<td>Ergonovine&quot;</td>
</tr>
<tr>
<td>Hyperventilation&quot;</td>
</tr>
<tr>
<td>Cold pressor</td>
</tr>
<tr>
<td>Mental stress</td>
</tr>
<tr>
<td>Temporary pacing</td>
</tr>
</tbody>
</table>
Multimodality echo approach of myocardial ischemia/viability

Myocardial perfusion

Contractile reserve

Myocardial thickness

Myocardial mechanics

Scar Tissue?
Recent advances in echocardiography

- The miniaturization of echocardiography and the hand-held machine
- Contrast echocardiography
- TDI-2D strain, strain rate/cardiac mechanics
- 3D Echocardiography
Standardized Myocardial Segmentation and Nomenclature for Tomographic Imaging of the Heart: A Statement for Healthcare Professionals From the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association

American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging: Manuel D. Langone, MD; Neil J. Weissman, MD; Vasken Der Lizikian, MD; Alice K. Jacobs, MD; Sanjiv Kaul, MD; Warren K. Lasley, MD; Dudley J. Pernoll, MD; John A. Rumberger, MD; Thomas Ryan, MD; Mario S. Verani, MD

Table 1 Interpretation of exercise and pharmacologic stress echocardiography

<table>
<thead>
<tr>
<th>Nature of tissue</th>
<th>Resting function</th>
<th>Low dose</th>
<th>Peak/post-stress function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Hypokinetic</td>
</tr>
<tr>
<td>Ischaemic</td>
<td>Normal</td>
<td>Normal (may worsen with severe CAD)</td>
<td>Worse than rest</td>
</tr>
<tr>
<td>Viable, ischaemic</td>
<td>Rest WMA</td>
<td>Improvement at low dose</td>
<td>Worse than adjacent segments</td>
</tr>
<tr>
<td>Viable, non-ischaemic</td>
<td>Rest WMA</td>
<td>Improvement at low dose</td>
<td>Reduction (compared with low dose)</td>
</tr>
<tr>
<td>Infarct</td>
<td>Rest WMA</td>
<td>No change</td>
<td>Sustained improvement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No change</td>
</tr>
</tbody>
</table>

CAD, coronary artery disease; WMA, wall motion abnormalities (severe hypokinesis, akinesia, dyskinesia).
Myocardial ischemia based on conventional echocardiographic assessment

3.6. Myocardial Ischemia
Conventional echocardiographic assessment of regional myocardial function is based on the measurement of wall thickening and does not provide information regarding the transmural distribution of contractile performance. The analysis of fiber thickening across the different layers of the myocardial wall is important to differentiate the various patterns of contractile abnormalities that may occur during acute or chronic (hibernation) myocardial ischemia. Ischemic myocardium is characterized by a reduced or missing regional systolic
A Randomized Cross-Over Study for Evaluation of the Effect of Image Optimization With Contrast on the Diagnostic Accuracy of Dobutamine Echocardiography in Coronary Artery Disease

The OPTIMIZE Trial

Juan Carlos Piana, MD, FACC, Issam A. Mikati, MD, FACC, Hisham Dokainish, MD, FACC, Nasser Lakkis, MD, FACC, John AbuKhalil, RT(R), Robert Davis, RDCS, Brian C. Hettzel, MS, William A. Zoghbi, MD, FACC

Houston, Texas

**Figure 1. Impact of Contrast Agent Use on Visualization of Segments and Confidence of Interpretation**

With the use of a contrast agent, an increase in percentage of segments with excellent or adequate endocardial visualization (score 1) is seen. Furthermore, the distribution of the degree of confidence of interpretation was different, with a much larger percentage of studies interpreted with high confidence when the contrast agent was added.

**Figure 6. Effect of Contrast Agent Use on the Sensitivity and Specificity of DSE**

The effect of contrast agent use on the sensitivity and specificity of dobutamine stress echocardiography (DSE) for coronary artery disease is shown, grouped by confidence of interpretation in unenhanced studies. Only interpretable studies are included in the analysis. A trend was seen mostly for improvement in specificity in low- to medium-confidence studies and a lesser improvement in sensitivity, and a trend for worsening in specificity was observed in unenhanced studies interpreted with high confidence.
There are no studies published on ultrasound contrast agents, which did not show a benefit in patients with suboptimal windows!!!!
By looking at what is behind wall motion...
Link between transmural variation of myocardial fiber direction
Tissue Doppler velocities
Function parameters derived from one region of interest within the same color Doppler data set:
A: velocity
B: displacement
C: SR
D: strain
Figure 15 Example of ischemic (apical segment) and nonischemic (basal segment) stress response in strain and SR curves. Note the reduced systolic shortening and the marked postystolic shortening (ps) during stress-induced ischemia. AVC, Aortic valve closure; AVO, aortic valve opening; MVC, mitral valve closure; MVO, mitral valve opening. Adapted with permission from Voigt et al. 
Myocardial Contrast Echocardiography: A Wondrous Journey!
MECHANICAL INDEX

M.I. enables the power of the US beam to be quantified:

\[ \text{M.I.} = \frac{\langle P \rangle}{\langle \sqrt{V} \rangle} \]

- \(\langle P \rangle\) is the peak of maximum negative pressure at the point of focalization
- \(\langle \sqrt{V} \rangle\) is the mean frequency of the US beam

M.I. expresses the acoustic pressure of the US beam produced on insonated structures.
Microvascular damage

- Lower intensity
- Delayed peak
- Long refilling period

A = plateau MCI
β = rate of rise
Aβ = myocardial blood flow
The assessment of two of the main features of myocardial viability, i.e. maintained resting perfusion and residual inotropic reserve.

*Figure 2* Two-dimensional speckle tracking echocardiography from an apical three-chamber projection showing reduced contraction in the anterior wall expressed by the most faint coloration as opposed to the normal contraction of the posterior wall expressed by the most vivid red coloration. The bar code
The clinical role of new echocardiographic techniques in CAD diagnosis and assessment

• Acute coronary syndromes
  – Diagnosis
  – Viability in recent or acute MI (detection of stunned myocardium)

• Chronic CAD
  – Diagnosis
  – Evaluation of viability (detection of hibernating myocardium)
Myocardial No-Reflow in Humans

Figure 5: Therapies of No-Reflow Targeted to Main Pathogenetic Mechanisms

Giampaolo Niccoli  JACC  2009
# Myocardial contrast echocardiography in ST elevation myocardial infarction: ready for prime time?

Sajad A. Hayat and Roxy Senior

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## Table 1: Summary of studies indicating effect of MCE determined reflow vs. no-reflow on LVEF

<table>
<thead>
<tr>
<th>Authors</th>
<th>Patients (n)</th>
<th>Route</th>
<th>Reflow group</th>
<th>No-reflow group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LVEF at baseline</td>
<td>LVEF FU</td>
</tr>
<tr>
<td>Ito et al.5</td>
<td>39</td>
<td>Intracoronary</td>
<td>42 ± 11</td>
<td>56 ± 13</td>
</tr>
<tr>
<td>Sakuma et al.30</td>
<td>50</td>
<td>Intracoronary</td>
<td>44 ± 9</td>
<td>56 ± 12*</td>
</tr>
<tr>
<td>Bolognese et al.28</td>
<td>124</td>
<td>Intracoronary</td>
<td>40 ± 7</td>
<td>51 ± 11</td>
</tr>
<tr>
<td>Porter et al.29</td>
<td>45</td>
<td>Intravenous</td>
<td>59 ± 10</td>
<td>63 ± 9*</td>
</tr>
<tr>
<td>Ito et al.6</td>
<td>116</td>
<td>Intracoronary</td>
<td>46 ± 11</td>
<td>57 ± 13</td>
</tr>
<tr>
<td>Ito et al.27</td>
<td>86</td>
<td>Intracoronary</td>
<td>46 ± 13</td>
<td>57 ± 12</td>
</tr>
<tr>
<td>Authors</td>
<td>Type of imaging</td>
<td>No. of patients (n = 548)</td>
<td>MCE perfusion</td>
<td>Wall motion with DSE</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------</td>
<td>---------------------------</td>
<td>---------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sensitivity (%)</td>
<td>Specificity (%)</td>
</tr>
<tr>
<td>Sbano et al.</td>
<td>High MI</td>
<td>50</td>
<td>95</td>
<td>52</td>
</tr>
<tr>
<td>Senior et al.</td>
<td>High MI</td>
<td>96</td>
<td>62</td>
<td>83</td>
</tr>
<tr>
<td>Aggeli et al.</td>
<td>High MI</td>
<td>34</td>
<td>88</td>
<td>61</td>
</tr>
<tr>
<td>Hillis et al.</td>
<td>Low MI</td>
<td>33</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td>Main et al.</td>
<td>Low MI</td>
<td>46</td>
<td>69</td>
<td>85</td>
</tr>
<tr>
<td>Swinburn et al.</td>
<td>Low MI</td>
<td>19</td>
<td>68</td>
<td>88</td>
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<tr>
<td>Hillis et al.</td>
<td>High MI</td>
<td>35</td>
<td>80</td>
<td>67</td>
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<tr>
<td>Lepper et al.</td>
<td>High MI</td>
<td>35</td>
<td>94</td>
<td>87</td>
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<tr>
<td>Janardhanan et al.</td>
<td>Low MI</td>
<td>42</td>
<td>82</td>
<td>83</td>
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<tr>
<td>Hickman et al.</td>
<td>Low MI</td>
<td>56</td>
<td>83</td>
<td>78</td>
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<tr>
<td>Greaves et al.</td>
<td>Low MI</td>
<td>15</td>
<td>88</td>
<td>74</td>
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<tr>
<td>Janardhanan et al.</td>
<td>Low MI</td>
<td>50</td>
<td>92</td>
<td>75</td>
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<tr>
<td>Main et al.</td>
<td>Low MI</td>
<td>34</td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>82</td>
<td>74</td>
</tr>
</tbody>
</table>
Identification of Viable Myocardium in Acute Anterior Infarction Using Duration of Systolic Lengthening by Tissue Doppler Strain: A Preliminary Study

Trond Vartdal, MD, Eirik Pettersen, MD, Thomas Helle-Valle, MD, Erik Lyseggen, MD, PhD, Kai Andersen, MD, PhD, Hans-Jørgen Smith, MD, PhD, Lars Aaberge, MD, PhD, Otto A. Smiseth, MD, PhD, and Thor Edvardsen, MD, PhD, Oslo, Norway

<table>
<thead>
<tr>
<th>Strain parameter</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Area under the curve</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak systolic strain &lt; −8%</td>
<td>96%</td>
<td>70%</td>
<td>0.934</td>
<td>0.902–0.961</td>
</tr>
<tr>
<td>Postsystolic shortening &lt; 3%</td>
<td>68%</td>
<td>73%</td>
<td>0.811</td>
<td>0.643–0.804</td>
</tr>
<tr>
<td>L-S ratio &lt; 0.5</td>
<td>60%</td>
<td>94%</td>
<td>0.934</td>
<td>0.885–0.958</td>
</tr>
<tr>
<td>Duration of systolic lengthening &lt; 67%</td>
<td>90%</td>
<td>94%</td>
<td>0.968</td>
<td>0.950–0.986</td>
</tr>
</tbody>
</table>
Bedside Assessment of Myocardial Viability Using Transmural Strain Profile in Patients With ST Elevation Myocardial Infarction: Comparison With Cardiac Magnetic Resonance Imaging

Takashi Tanimoto, MD, Toshio Imanishi, MD, PhD, Atsushi Tanaka, MD, PhD, Takashi Yamano, MD, Hironori Kitabata, MD, Shigeo Takarada, MD, PhD, Takashi Kubo, MD, PhD, Kazushi Takemoto, MT, Nobuo Nakamura, MD, Kumiko Hirata, MD, PhD, Masato Mizukoshi, MD, PhD, and Takashi Akasaka, MD, PhD, Wakayama, Japan

A: TEI 0-25%
B: TEI 26-50%
C: TEI 51-75%
D: TEI 76-100%

Journal of the American Society of Echocardiography September 2009

Myocardial strain

Endocardium

Epicardium

A: Peak strain value
(maximum of radial strain)

B: Location of peak strain
(%distance of the wall thickness from the endocardium)
Left Ventricular Function and Functional Recovery Early and Late after Myocardial Infarction: A Prospective Pilot Study Comparing Two-Dimensional Strain, Conventional Echocardiography, and Radionuclide Myocardial Perfusion Imaging

Shemy Carasso, MD, Yoram Agmon, MD, Ariel Roguin, MD, PhD, Zohar Keidar, MD, Ora Israel, MD, Haim Hammerman, MD, and Jonathan Lessick, MD, DSc, Haifa, Israel
Principal strain maintains its superiority identifying abnormal segments over its components along the timeline.
Relationship between Left Ventricular Longitudinal Deformation and Clinical Heart Failure during Admission for Acute Myocardial Infarction: A Two-Dimensional Speckle-Tracking Study

Mads Ersbøll, MD, Nana Valeur, MD, PhD, Ulrik Madshig Mogensen, MD, Mads J. Andersen, MD, Jacob Eifør Møller, MD, PhD, DMSi, Christian Hansen, MD, DMSi, Peter Søgaard, MD, DMSi, and Lars Kober, MD, DMSi, Copenhagen and Gentofte, Denmark

![Graph showing -2 log likelihood and Akaike Information Criterion for different covariates.]

**Figure 1** Incremental improvement in model performance as assessed by the $-2$ log likelihood and Akaike information criterion. Addition of LVEF and LAVI significantly improved a model including clinical information (age, history of heart failure, multivessel disease, left anterior descending coronary artery involvement, episodes of AF, troponin T, estimated glomerular filtration rate, and log NT-proBNP). Doppler indices (E/A ratio and MV deceleration time) did not improve the model, whereas the addition of GLS yielded significantly better model performance.
Figure 4: Receiver-operating characteristic curves depicting the improved model performance attained by adding GLS to a baseline model (age, episodes of AF, troponin T, LVEF, LAVI, and log NT-proBNP).
3D strain –strain rate in a patient with lateral wall ischemia
Role of mce after myocardial perfusion

Myocardial Contrast Echocardiography After Myocardial Infarction

Hiroshi Ito

Microvascular Function in Takotsubo Cardiomyopathy With Contrast Echocardiography: Prospective Evaluation and Review of Literature

Sahar S. Abdelmoneim, MD, MSc, Sunil V. Mankad, MD, FASE, Mathieu Bernier, MD, Abhijet Dhoble, MD, Mary E. Hagen, RN, Sue Ann C. Ness, RN, Krishnaswamy Chandrasekaran, MD, FASE, Patricia A. Pellikka, MD, FASE, Jac K. Oh, MD, and Sharon L. Mulvagh, MD, FASE, Rochester, Minnesota

A

Pre Flash | Immediate Post Flash | 5 Beats Post Flash

B

End-diastolic frame | End-systolic frame
Strain/strain rate in CAD

- LV longitudinal strain is attenuated in the presence of subendocardial ischemia.
- LV circumferential strain deformation-twist remained unaltered.
Assessment of the physiologic significance of coronary disease with dipyridamole real-time myocardial contrast echocardiography. Comparison with technetium-99m sestamibi single-photon emission computed tomography and quantitative coronary angiography.

M. Pellier et al JACC 2004;43:257-264
Myocardial Contrast Echocardiography for the Detection of Coronary Artery Stenosis (J Am Coll Cardiol 2006;47:141–5)
• When CAD was defined as 50% coronary stenosis, the specificity of MCE increased to 83% without any change in sensitivity.

• MCE was found to be superior to SPECT during dipyridamole stress for the diagnosis of CAD in patients with a medium pretest probability of CAD.
The Diagnostic Value of Adenosine Stress-Contrast Echocardiography for Diagnosis of Coronary Artery Disease in Hypertensive Patients - Comparison to TI-201 Single-Photon Emission Computed Tomography
# Transient ST-Segment Depression During Paroxysms of Atrial Fibrillation in Otherwise Normal Individuals

Relation With Underlying Coronary Artery Disease


<table>
<thead>
<tr>
<th>Patients with CAD (+/− for Ischemia) (n = 27)</th>
<th>Treadmill Stress Test*</th>
<th>Thallium-201 Myocardial Scintigraphy</th>
<th>Myocardial Contrast Stress Echocardiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/6</td>
<td>23/4</td>
<td>24/3</td>
<td>7/49</td>
</tr>
<tr>
<td>21/27</td>
<td>23/33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity, % (95% CI)</td>
<td>75.0 (53.3-90.2)</td>
<td>85.2 (66.3-95.8)</td>
<td>88.9 (70.8-97.6)</td>
</tr>
<tr>
<td>Specificity, % (95% CI)</td>
<td>56.3 (41.2-70.5)</td>
<td>58.9 (45.0-71.9)</td>
<td>87.5 (73.9-94.8)</td>
</tr>
<tr>
<td>PPV, % (95% CI)</td>
<td>46.2 (30.1-62.8)</td>
<td>50.0 (34.9-66.1)</td>
<td>77.4 (54.9-90.4)</td>
</tr>
<tr>
<td>NPV, % (95% CI)</td>
<td>81.8 (65.4-93.0)</td>
<td>89.2 (74.6-97.0)</td>
<td>94.2 (54.1-96.8)</td>
</tr>
</tbody>
</table>
Myocardial Contrast Echocardiography for Distinguishing Ischemic From Nonischemic First-Onset Acute Heart Failure. Insights Into the Mechanism of Acute Heart Failure
Roxy Senior, MD, Circulation 2005

<table>
<thead>
<tr>
<th>MCE defects (rest and stress)</th>
<th>CAD present</th>
<th>CAD absent</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCE defects present</td>
<td>18</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>MCE defects absent</td>
<td>4</td>
<td>29</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>30</td>
<td>52</td>
</tr>
</tbody>
</table>

Sensitivity – 92%
Specificity – 97%
Positive predictive value – 95%
Negative predictive value – 88%

Figure 2. Relationship between MI defects and CAD.

AUC: 0.93
Cut-off value: 1.00
Sensitivity: 91%
Specificity: 89%
Two-Dimensional Longitudinal Strain Assessment in the Presence of Myocardial Contrast Agents Is Only Feasible with Speckle-Tracking after Microbubble Destruction

João L. Cavalcante, MD, Patrick Colier, MD, PhD, Joan C. Pana, MD, Deborah Agier, RDMS,
James D. Thomas, MD, and Thomas H. Myers, MD, PhD, MPH
Pittsburgh, Pennsylvania; Cleveland, Ohio; Tasmania, Australia
Comparison of Sulfur Hexafluoride Microbubble (SonoVue)-Enhanced Myocardial Echocardiography to gated Single Photon Emission Computerized Tomography for the Detection of Significant Coronary Artery Disease: A Large European Multicentre Study

Roxy Senior, MD Antonella Moreo, MD Nicola Gaibazzi, MD Luciano Agati, MD Klaus Tiemann, MD Bharati Shivalkar, MD Stephan von Bardeleben, MD Leonardo Galiuto, MD Hervé Lardoux, MD Giuseppe Trocino, MD Ignasi Carrió, MD Dominique Le Guludec, MD Gianmario Sambuceti, MD Harald Becher, MD Paolo Colonna, MD Folkert ten Cate, MD Ezio Bramucci, MD Ariel Cohen, MD, PhD Gianpaolo Bezante, MD Costantina Aggeli, MD Jaroslaw D. Kasprzak, MD

MCE

Qualitative evaluation of images was performed using both real-time and end-systolic triggered digital clips. Myocardial perfusion was considered normal at rest or stress if the myocardium replenished with 5 cardiac cycles at rest or within 2 cardiac cycles at stress following the flash. Resting perfusion abnormality was considered possible if there was a delay of >5 cardiac cycles or if there was patchy or no filling at rest. Myocardial ischemia was diagnosed if, during stress, there was a delay of ≥3 cardiac cycles or if there was newly visible patchy or subendocardial defect or absent contrast. Any deterioration of wall motion was also considered ischemic.
Diagnostic accuracy of MCE and SPECT

**Sensitivity**
- MCE: 121/161
- SPECT: 79/161
- p < 0.0001

**Specificity**
- MCE: 186/355
- SPECT: 286/355
- p < 0.0001

**LAD**
- MCE: 45/54
- SPECT: 28/54
- p = 0.0007

**LCx**
- MCE: 48/61
- SPECT: 36/61
- p = 0.003

**RCA**
- MCE: 58/80
- SPECT: 42/80
- p = 0.001

**Additional Data**
- Single Vessel Disease
  - MCE: 95/131
  - SPECT: 56/131
  - p < 0.0001

- Multi-vessel Disease
  - MCE: 26/30
  - SPECT: 23/30
  - p = 0.18

- Proximal Stenosis
  - MCE: 40/50
  - SPECT: 29/50
  - p = 0.005
SPECT-no abnormalities
RCA DISEASE
Prognostic implication of Doppler echocardiographic derived coronary flow reserve in patients with left bundle branch block

Lauro Cortigiani¹, Fausto Rigo¹, Sonia Gherardi², Francesco Bovenzi¹, Sabrina Molinaro⁴, Eugenio Picano⁴, and Rosa Sicari⁴*
Spectrum of myocardial dysfunction in ischemic cardiomyopathy

**Figure 1** Spectrum of myocardial dysfunction in ischemic cardiomyopathy. (A) Stunned myocardium more likely to recover function if revascularized (green arrow). (B) Hibernating myocardium demonstrates more advanced cellular degeneration and thus less likely to recover function after revascularization (orange arrow). Boxes on the left side illustrate the pathophysiological responses seen at each stage. CFR, coronary flow reserve; CR, contractile reserve; MET, metabolism; PERF, perfusion; SCAR, scar or fibrosis; √, present; ↔, equivocal response; X, absent.
ECHO MODALITIES to study myocardial viability

<table>
<thead>
<tr>
<th>Technique</th>
<th>Imaging finding</th>
<th>Criteria for viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echocardiography</td>
<td>Left ventricular wall thickness</td>
<td>&gt;6 mm [9]</td>
</tr>
<tr>
<td></td>
<td>Inotropic contractile reserve</td>
<td>Biphasic response better predictive accuracy versus monophasic response [14]</td>
</tr>
<tr>
<td></td>
<td>Contrast echocardiography perfusion imaging</td>
<td>No perfusion defect [16]</td>
</tr>
<tr>
<td></td>
<td>Strain and strain rate imaging</td>
<td>Global left ventricular strain of −13.7% on automated function imaging [13]</td>
</tr>
</tbody>
</table>
### Comparison of the various imaging techniques for detecting hibernating myocardium

<table>
<thead>
<tr>
<th>Technique</th>
<th>No. of studies</th>
<th>No. of patients</th>
<th>Mean EF (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dobutamine echocardiography—total</td>
<td>41</td>
<td>1421</td>
<td>25–48</td>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>Low-dose DbE</td>
<td>33</td>
<td>1121</td>
<td>25–48</td>
<td>79</td>
<td>78</td>
</tr>
<tr>
<td>High-dose DbE</td>
<td>8</td>
<td>290</td>
<td>29–38</td>
<td>83</td>
<td>79</td>
</tr>
<tr>
<td>Myocardial contrast echocardiography—total</td>
<td>10</td>
<td>268</td>
<td>29–38</td>
<td>87</td>
<td>79</td>
</tr>
<tr>
<td>Thallium scintigraphy—total</td>
<td>40</td>
<td>1119</td>
<td>23–45</td>
<td>87</td>
<td>54</td>
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<tr>
<td>TI-201 rest-redistribution</td>
<td>28</td>
<td>776</td>
<td>23–45</td>
<td>87</td>
<td>56</td>
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<tr>
<td>TI-201 re-injection</td>
<td>12</td>
<td>343</td>
<td>31–49</td>
<td>87</td>
<td>50</td>
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<tr>
<td>Technetium scintigraphy—Total</td>
<td>25</td>
<td>721</td>
<td>23–54</td>
<td>83</td>
<td>65</td>
</tr>
<tr>
<td>Without nitrates protocol</td>
<td>17</td>
<td>516</td>
<td>23–52</td>
<td>83</td>
<td>57</td>
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<tr>
<td>With nitrates protocol</td>
<td>8</td>
<td>205</td>
<td>35–54</td>
<td>81</td>
<td>69</td>
</tr>
<tr>
<td>Positron emission tomography—total</td>
<td>24</td>
<td>756</td>
<td>23–53</td>
<td>92</td>
<td>63</td>
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<tr>
<td>Cardiovascular magnetic resonance—total</td>
<td>14</td>
<td>450</td>
<td>24–53</td>
<td>80</td>
<td>70</td>
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<tr>
<td>Low-dose dobutamine protocol</td>
<td>9</td>
<td>272</td>
<td>24–53</td>
<td>74</td>
<td>82</td>
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<tr>
<td>Late gadolinium-enhancement protocol</td>
<td>5</td>
<td>178</td>
<td>32–52</td>
<td>84</td>
<td>63</td>
</tr>
</tbody>
</table>
Detection and Quantification of Myocardial Scars by Contrast-Enhanced 3D Echocardiography

Patrick Montant, MD; Fabien Chenot, MD; Céline Goffinet, MD; Alain Poncelet, MD; David Vancraeynest, MD; Agnès Pasquet, MD, PhD; Bernhard L. Gerber, MD, PhD; Jean-Louis J. Vanoverschelde, MD, PhD

Clinical studies have shown that the transmurality of myocardial scars is critical in determining the recovery of function after revascularization: the more transmural the extent of scar tissue, the lower the likelihood of recovery in function.18–20
Representative CE-3D-Echo and DE-cMR
CE-3D-Echo illustrating a well-defined septal scar
Microvascular structural correlates of myocardial contrast echocardiography in patients with coronary artery disease and left ventricular dysfunction

Implications for the assessment of myocardial hibernation
Relation of....

- Microvascular Density vs. Normalized Peak MCI
  - $r = 0.29$, $p = 0.011$, SEE = 1.10

- Capillary Area vs. Normalized Peak MCI
  - $r = 0.44$, $p < 0.001$, SEE = 1.04

- Microvascular Density Ratio vs. Normalized Peak MCI Ratio
  - $r = 0.44$, $p < 0.001$, SEE = 0.25

- Capillary Area Ratio vs. Normalized Peak MCI Ratio
  - $r = 0.37$, $p = 0.001$, SEE = 0.12

- Normal Function vs. Dysfunctional + Recovery vs. Dysfunctional No Recovery

- Normalized Peak MCI vs. Beta
  - $r = 0.45$, $p < 0.01$, SEE = 0.1

- Peak MCI* Beta vs. % Collagen
  - $r = 0.20$
Identification of hibernating myocardium with quantitative intravenous myocardial contrast echocardiography. Comparison with dobutamin echocardiography and thallium-201 Scintigraphy

Myocardial Contrast Echocardiography Versus Single Photon Emission Computed Tomography for Assessment of Hibernating Myocardium in Ischemic Cardiomyopathy: Preliminary Qualitative and Quantitative Results

Rajesh K. Chelliah, MBChB, MRCP, Michael Hickman, MBBS, MRCP, Christopher Kinsey, HND, Leah Burden, BSc, and Roxy Senior, MBBS, MD, DM, FRCP, FESC, FACC, London, United Kingdom

Figure 1 Quantitative MCE in segments with and without HM.
Echocardiographic Myocardial Scar Burden Predicts Response to Cardiac Resynchronization Therapy in Ischemic Heart Failure

Donato Mele, MD, Eustachio Agricola, MD, Maurizio Galderisi, MD, Fausto Rigo, MD, Rodolfo Citro, MD, Alessandro Del Monte, MD, Patrizia Della Valentina, MD, Alice Calabrese, MD, and Roberto Ferranti, MD on behalf of the Study Group of Echocardiography of the Italian Society of Cardiology, Forlì, Brescia, Milano, Napoli, Matera-Venezia, and Valle della Lucania, Italy

Comparison of real-time tri-plane and conventional 2D dobutamine stress echocardiography for the assessment of coronary artery disease

Elif Eroglu, Jan D’hooge, Lieven Herbots, Daisy Thijs, Christophe Dubois, Peter Sinnaeve, Joseph Dens, Johan Vanhaecke, and Frank Rademakers*


Sensitivity, Specificity and Accuracy of RT3D and 2D on a segment level

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT3P</td>
<td>68 (CI 62–74%)</td>
<td>89 (CI 86–92%)</td>
<td>81 (CI 78–84%)</td>
</tr>
<tr>
<td>2D</td>
<td>67 (CI 61–73%)</td>
<td>90 (CI 87–93%)</td>
<td>81 (CI 78–84%)</td>
</tr>
</tbody>
</table>

Sensitivity, Specificity and Accuracy of RT3D and 2D for the apical segments

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT3P patient level</td>
<td>96 (CI 89–100%)</td>
<td>78 (CI 51–100%)</td>
<td>92 (CI 83–100%)</td>
</tr>
<tr>
<td>2D patient level</td>
<td>93 (CI 83–100%)</td>
<td>78 (CI 51–100%)</td>
<td>89 (CI 79–99%)</td>
</tr>
<tr>
<td>RT3P segmental level</td>
<td>70 (CI 61–79%)</td>
<td>89 (CI 83–95%)</td>
<td>80 (CI 75–85%)</td>
</tr>
<tr>
<td>2D segmental level</td>
<td>66 (CI 57–75%)</td>
<td>87 (CI 81–93%)</td>
<td>77 (CI 71–83%)</td>
</tr>
</tbody>
</table>
Real-time three-dimensional dobutamine stress echocardiography is feasible and identifies wall-motion abnormalities at least as well as 2D stress echo (with angiography as reference), but in a fraction of the time (all image data required to perform wall-motion analysis can be acquired in less than 30 sec).

Future perspective: It is possible that when certain technical limitations are resolved (lower frame-rate and spatial resolution), 3D may become more accurate in identifying wall-motion abnormalities.
Contrast-enhanced three-dimensional dobutamine stress echocardiography: between Scylla and Charybdis?


Department of Cardiology, Erasmus MC, Thoraxcenter, Room Ba 316, Dr Molewaterplein 40, 3015 GD Rotterdam, The Netherlands

Myocardial image quality at rest and peak stress with and without contrast enhancement

<table>
<thead>
<tr>
<th></th>
<th>Rest</th>
<th>Peak stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contrast −</td>
<td>Contrast +</td>
</tr>
<tr>
<td>Number of invisible segments</td>
<td>63 (11%)</td>
<td>55 (%)</td>
</tr>
<tr>
<td>Overall visibility index</td>
<td>2.5 ± 1.2</td>
<td>3.2 ± 1.0</td>
</tr>
<tr>
<td>Apical segments</td>
<td>2.7 ± 1.2</td>
<td>3.2 ± 0.9</td>
</tr>
<tr>
<td>Mid-ventricular segments</td>
<td>2.5 ± 1.2</td>
<td>3.2 ± 1.0</td>
</tr>
<tr>
<td>Basal segments</td>
<td>2.3 ± 1.2</td>
<td>3.1 ± 1.0</td>
</tr>
</tbody>
</table>
Real-time three-dimensional dobutamine stress echocardiography in detection of myocardial ischemia - validation with coronary angiography
Real-time three-dimensional myocardial contrast echocardiography: is it clinically feasible?

A. Bhan¹, S. Kapetanakis¹, B.S. Rana¹, E. Ho¹, K. Wilson¹, P. Pearson¹, S. Mushemi¹, J. Deguzman¹, J. Reiken¹, M.D. Harden¹, N. Walker¹, P.G. Rafter², and M.J. Monaghan¹

Disadvantages of RT3D stress echocardiography

- Inferior spatial resolution and
- lower frame rates, as compared with 2D echocardiography,
- the lack of flash echocardiography application
Keep up with competition
Improved assessment of the LV wall motion/feasibility of myocardial perfusion
Getting ready for the future
The chance to drive this technology forward
Echocardiography is the most versatile imaging modality for assessing myocardial ischemia/viability.

- 1. wall motion abnormalities
- 2. residual wall thickness-tissue reflectivity
- 3. MBF at rest and during hyperemia
- 4. assessment of recruitable inotropic reserve
- 5. Cardiac mechanics

It’s the most frequently used technique to assess functional recovery after revascularization.