Η Πυρηνική Καρδιολογία στην Κλινική πράξη

Σπινθηρογράφημα αιμάτωσης μυοκαρδίου SPECT. Μια παλαιά μέθοδος που παραμένει πάντα επίκαιρη

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Disclosure: No conflict of interest to declare
Nuclear Cardiology
Sustained innovation


- Scintillation
- Plannar γ-camera
- Supine RNA
- Mobile Camera
- Vest Nuclear Holter
- Tomography g-SPECT
- Multi-headed
- PET
- D-SPECT
- CZT Technology
- Hybrid SPECT-PET/CT
- Hybrid 3T MRI/PET
- \(^{13}\text{N-NH}_3\)
- \(^{18}\text{F-FDG}\)
- \(^{18}\text{F-FDG}\)
- \(^{18}\text{F-FDG}\)
SPECT Myocardial Perfusion Imaging

Current strengths

• Extensively validated, useful for the cost-effective risk stratification & patient management

• Widely available-out-patient settings: Technology “inexpensive”

• Standardized protocols

• Excellent procedural and clinical utilization guidelines by professional medical societies

• ACCF/ASNC Appropriateness Criteria identify 80 “appropriate” clinical indications

J Am Coll Cardiol 2013
Cardiac Radionuclide Imaging

Appropriate Use Criteria

- Detection of CAD: Symptomatic
- Detection of CAD/Risk Assessment Without Ischemic Equivalent
- Assessment of Viability/Ischemia
- Evaluation of Ventricular Function

Appropriate Use Criteria for Cardiac Radionuclide Imaging
### Characteristics of tests commonly used to diagnose the presence of CAD

<table>
<thead>
<tr>
<th>Test</th>
<th>Diagnosis of CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>Exercise ECG&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45-50</td>
</tr>
<tr>
<td>Exercise stress echocardiography</td>
<td>80-85</td>
</tr>
<tr>
<td>Exercise stress SPECT</td>
<td>73-92</td>
</tr>
<tr>
<td>Dobutamine stress echocardiography</td>
<td>79-83</td>
</tr>
<tr>
<td>Dobutamine stress MRI&lt;sup&gt;b&lt;/sup&gt;</td>
<td>79-88</td>
</tr>
<tr>
<td>Vasodilator stress echocardiography</td>
<td>72-79</td>
</tr>
<tr>
<td>Vasodilator stress SPECT</td>
<td>90-91</td>
</tr>
<tr>
<td>Vasodilator stress MRI&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67-94</td>
</tr>
<tr>
<td>Coronary CTA&lt;sup&gt;c&lt;/sup&gt;</td>
<td>95-99</td>
</tr>
<tr>
<td>Vasodilator stress PET</td>
<td>81-97</td>
</tr>
</tbody>
</table>

CAD: coronary artery disease; CTA: coronary computed tomography angiography; ECG: electrocardiography; MRI: magnetic resonance imaging; PET: positron emission tomography.
Whether an individual does or does not have CAD it too simplistic and not enough....

Need to know what are the risks
Risk Stratification

Low Risk Patients
- Avoid further testing
- Eliminate test risk
- Reduce expense

High Risk Patients
- Alter management
- Revascularization
- Reduce expense
Case report

- A 73 years old male, BMI of 28, no chest pain, complaining of dyspnea on low workload exercise.
- He has high blood pressure and is a former smoker with chronic obstructive pulmonary disease (COPD).
- He uses oral steroids due to significant component of bronchospasm.
- He was referred for cardiac evaluation by his GP.
- Clinical findings nl
- Resting EKG (figure 1).
- Echo: Suboptimal study “poor window” pLVEF
Rest EKG

FC 103 bpm

Basa Rede 32 Hz

Unidades: mm/mV 25 mm/s
What is the next diagnostic step if any?

- A) Watchful waiting
- B) Physical stress protocol
- C) Imaging stress test
  - Dypiridamole/adenosine
  - Regadenoson
  - Dobutamine
- D) Direct diagnostic catheterization
### 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>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
</tr>
<tr>
<td>30-39</td>
<td>59</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>40-49</td>
<td>69</td>
<td>37</td>
<td>38</td>
</tr>
<tr>
<td>50-59</td>
<td>77</td>
<td>47</td>
<td>49</td>
</tr>
<tr>
<td>60-69</td>
<td>84</td>
<td>58</td>
<td>59</td>
</tr>
<tr>
<td>70-79</td>
<td>89</td>
<td>68</td>
<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.*

Figure 1. Initial diagnostic management of patients with suspected SCAD

ALL PATIENTS
- Assess symptoms
  Perform clinical examination
- Symptoms consistent with unstable angina
- Follow specific NSTE-ACS guidelines

<table>
<thead>
<tr>
<th>ECG</th>
<th>Bio-Chemistry</th>
<th>Resting echocardiography</th>
<th>CXR in selected patients</th>
</tr>
</thead>
</table>

Consider comorbidities and QoL

Cause of chest pain other than CAD?

- No
  - LVEF <50?
    - Yes
      - Typical angina?
        - Yes
          - Offer ICA if revascularization suitable
        - No
          - See Fig. 2 for selection of test
    - No
      - Assess PTP for the presence of coronary stenoses
      - Low PTP (<15%)
        - Investigate other causes
          - Consider functional coronary disease
      - Intermediate PTP, e.g., 15-85%
        - Non-invasive testing for diagnostic purposes
          - See Fig. 2 for decisions based on non-invasive testing and choice between stress testing and coronary CTA
          - See Fig. 3 for further management pathway
      - High PTP (>85%)
        - Diagnosis of SCAD established
          - Proceed to risk stratification (see Fig. 3)
            - In patients with severe symptoms or clinical constellation suggesting high risk coronary anatomy initiate guideline-directed medical therapy and offer ICA

- Yes
  - Treat as appropriate
  - Comorbidities and QoL make revascularization unlikely
    - Medical therapy
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 if not done before
    - 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

- Coronal CTA in patients at low intermediate PTP (15% - 50%)
  - If suitable candidate
  - If adequate technology and local expertise available

- Determine patient characteristics and preferences
  - Unclear
  - Ischaemia
  - No ischaemia
    - No stenosis
    - Stenosis
    - Unclear

- Consider functional CAD: Investigate other causes
  - Diagnosis SCAD established further risk stratification (see Fig. 3)
    - Ischaemia testing using stress imaging if not done before
In patients with left bundle branch block (LBBB) and active COPD the best imaging stress protocol would be Regadenoson.

Since regadenoson is not available in our country and he has limited exercise capacity due to dyspnea and orthopedical problems, and although less than ideal,

A dobutamine stress protocol was performed. (Figure 2 and 3)
<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>An imaging stress test is recommended as the initial test for diagnosing SCAD if the PTP is between 66–85% or if LVEF is &lt;50% in patients without typical angina.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>An imaging stress test is recommended in patients with resting ECG abnormalities which prevent accurate interpretation of ECG changes during stress.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Exercise stress testing is recommended rather than pharmacologic testing whenever possible.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>An imaging stress test should be considered in symptomatic patients with prior revascularization (PCI or CABG).</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>An imaging stress test should be considered to assess the functional severity of intermediate lesions on coronary arteriography.</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>
Case report

Take a look at the images and select the best option for your report.

• A) LAD ischemia, myocardial stunning and transient ventricular dilation
• B) The specificity of this finding is limited due to LBBB and the use of dobutamine as a stressor
• C) three vessel disease pattern
• D) A and B are valid possibilities
Case report

Take a look at the images and select the best option for your report.

• A) LAD ischemia, myocardial stunning and transient ventricular dilation
• B) The specificity of this finding is limited due to LBBB and the use of dobutamine as a stressor
• C) three vessel disease pattern
• D) A and B are valid possibilities

• WHATS NEXT?
What would be your next step?
A) Send the patient to invasive coronary angiography
B) Echo stress
C) Close clinical follow-up
D) I am pretty confident that this patient does not have obstructive coronary artery disease. I would do nothing else.
Case report - Σχολιασμός

Το περιστατικό δεν μπορεί να θεωρηθεί ευθύς εξ αρχής εύκολο αλλά παριστά ένα σύνηθες στην κλινική πράξη περιστατικό με ρεαλιστικούς περιορισμούς στη διαγνωστική προσπέλαση.

• Γιατί επιλέξαμε το SPECT με Δοβουταμίδη (DSE) Κακό παράθυρο λογω εμφυσήματος, Διπυριδαμόλη , Αδενοσινή ως διεγέρτες των Α2Β και Α3 υποδοχών προκαλούν βρογχοσπασμό και έχουν χαμηλή ευαισθησία με DSE . Τα ινότροπα δημιουργούν συχνά ψευδή παθολογικά ευρήματα διαφράγματος. Ιδανική η χρήση του νέου ειδικού αγωνιστή των Α2Α υποδοχών της REGADENOSON

• Γιατί οδηγηθήκαμε σε διαγνωστική ιστονομογραφία ?
1. Λογω της μέτριας έκτασης ισχαιμίας στα πρόσθιο-διαφραγματικό, διαφραγματικό, κατώτερο-διαφραγματικό και κορυφαίο τοιχώματα της αρ. Κοιλίας με πτώση του EF το Gated SPECT (50%-45%) και αύξησης χ του EDV (45-57ml)

2. Λόγω LBBB και Dobutamine δεν μπορούσε απόλυτα να αποκλεισθεί το ψευδής θετικό έλλειμμα σε πρόσθιο-διαφραγματικό και διαφραγματικό τοιχώμα
## Risk stratification by invasive or non-invasive coronary arteriography in patients with SCAD

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICA (with FFR when necessary) is recommended for risk stratification in patients with severe stable angina (CCS 3) or with a clinical profile suggesting a high event risk, particularly if the symptoms are inadequately responding to medical treatment.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>ICA (with FFR when necessary) is recommended for patients with mild or no symptoms with medical treatment in whom non-invasive risk stratification indicates a high event risk and revascularization is considered for improvement of prognosis.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>ICA (with FFR when necessary) should be considered for event risk stratification in patients with an inconclusive diagnosis on non-invasive testing, or conflicting results from different non-invasive modalities.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>If coronary CTA is available for event risk stratification, possible overestimation of stenosis severity should be considered in segments with severe calcification, especially in patients at high intermediate PTP. Additional stress imaging may be necessary before referring a patient with few/no symptoms to ICA.</td>
<td>IIa</td>
<td>C</td>
</tr>
</tbody>
</table>
Case report  Πόσο μας βοήθησε το σπινθηρογράφημα καρδιάς

Information from MPI

- Myocardial perfusion
  - Physiologic information regarding blood flow
- Myocardial viability
- Functional data (gated SPECT)
  - Global and regional assessment of LV function

Parameters associated with adverse prognosis

- Exercise time, stress modality
- Defect extent, severity and reversibility
- Transient cavity dilation
- Decrease in LV ejection fraction
- Increased pulmonary radiotracer uptake
- Increased RV tracer uptake
MPI moderate, partially reversible defect, involving the anteroseptal, septal, inferoseptal, apical regions of the heart. Quantitative analysis. SDS 5, LV involvement <10%, TID=1,
“Large ischemia” superimposing infarction involving more than 15-20% of the LV volume
Cardiac Death or Infarction
Based on Sestamibi SPECT and Likelihood of CAD

- Normal (SSS<4)
- Abnormal (SSS≥4)

Event Rate (%)

- Low: 0.2
- Intermediate: 4 (P<0.05)
- High: 10.4 (P<0.05)

Prognosis by MPI Result

- **Cardiac Death**
  - Normal (SSS<4): 0.3
  - Mildly Abnormal (SSS 4-8): 0.8
  - Moderately Abnormal (SSS 9-13): 2.3
  - Severely Abnormal (SSS>13): 2.9

- **Myocardial Infarction**
  - Normal (SSS<4): 0.5
  - Mildly Abnormal (SSS 4-8): 2.7
  - Moderately Abnormal (SSS 9-13): 2.9
  - Severely Abnormal (SSS>13): 4.2

* *p<0.05 as result of MPI*

**MPI Prognosis over Time**

![Graph showing cumulative event free survival over time for different MPI categories: Normal, Mildly Abnormal, Moderately Abnormal, Severely Abnormal.](image)

"Warranty" of Normal MPI

Adverse Markers
- Pharmacologic Stress
- Age
- LV Ejection Fraction
- Transient Cavity Dilation (TCD)
- Diabetes
- Renal Failure

Event Rate (%)

First Year  Second Year  Third Year
0.1  0.2  0.1  0.5  3.1
Regadenoson

- Selective A2a receptor agonist
- Single 10s bolus injection
- Onset of action within 30s
- Vasodilator effect ~ 2min

![Graph showing myocardial perfusion ml/g/min](image)
Global and regional assessment of LV fx with gated SPECT

Prognostic Value of TCD in normal MPI

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Total Events</th>
<th>Hard Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Quartile</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Second Quartile</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Third Quartile</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Fourth Quartile</td>
<td></td>
<td>2.4</td>
</tr>
</tbody>
</table>

TCD = 1.21-1.79

P < 0.001

So, we know the risk...

But can we do something about it?
Ποιο θα ήταν το επόμενο βήμα;

- Φαρμακευτική αγωγή
- Διάνοιξη βλαβών με αγγειοπλαστική
- Εξέταση με IVUS, Μετρηση FFR?
- Αορτοστεφανιαία παράκαμψη
Λαμβάνοντας υπ’οψιν ότι δεν υπήρχε νόσος στελέχους η εγγυς LAD αποφασίσαμε την συντηρητική αντιμετώπιση με επιθετική δευτεροπαθή πρόληψη και βελτιστοποίηση της φαρμακευτικής αγωγής. Πιστεύουμε ότι θα βοηθούσε την λήψη κλινικών αποφάσεων το IVUS και το FFR για να αποκλείσει εντελώς το ενδεχόμενο σοβαρής αποφρακτικής αλλοίωσης που υποεκτιμήθηκε από την στεφανιογραφία.
Gated SPECT and clinical outcomes of pts of the COURAGE Trial

RESOLUTION OF ISCHEMIA
? Role for SPECT to Monitor Therapy

BASELINE
• M50 SAP III
• 80% mid LAD
• Aggressive BP and lipid therapy
• Dipyridamole dual isotope studies

STRESS

STRESS

O'Rourke et al Circulation 2001;103:2315
# Revascularization of SCAD patients on OMT

(Adapted from the ESC/EACTS 2010 Guidelines)

<table>
<thead>
<tr>
<th>Indication</th>
<th>To improve prognosis</th>
<th>To improve symptoms persistent on OMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Heart Team approach to revascularization is recommended in patients with unprotected left main, 2–3 vessel disease, diabetes or comorbidities.</td>
<td>Class I Level C</td>
<td>Class I Level C</td>
</tr>
<tr>
<td>Left main &gt;50% diameter stenosis.</td>
<td>Class I Level A</td>
<td>Class I Level A</td>
</tr>
<tr>
<td>Any proximal LAD &gt;50% diameter stenosis.</td>
<td>Class I Level A</td>
<td>Class I Level A</td>
</tr>
<tr>
<td>2–3 vessel disease with impaired LV function/CHF.</td>
<td>Class I Level B</td>
<td>Class IIa Level B</td>
</tr>
<tr>
<td>Single remaining vessel (&gt;50% diameter stenosis).</td>
<td>Class I Level C</td>
<td>Class I Level A</td>
</tr>
<tr>
<td>Proven large area of ischaemia (&gt;10% LV).</td>
<td>Class I Level B</td>
<td>Class I Level B</td>
</tr>
<tr>
<td>Any significant stenosis with limiting symptoms or symptoms non responsive/intolerant to OMT.</td>
<td>NA</td>
<td>Class I Level A</td>
</tr>
<tr>
<td>Dyspnoea/cardiac heart failure with &gt;10% ischaemia/viability supplied by stenosis &gt;50%.</td>
<td>Class IIb Level B</td>
<td>Class IIa Level B</td>
</tr>
<tr>
<td>No limiting symptoms with OMT in vessel other than left main or proximal LAD or single remaining vessel or vessel subtending area of ischaemia &lt;10% of myocardium or with FFR ≥0.80.</td>
<td>Class III Level A</td>
<td>Class III Level C</td>
</tr>
</tbody>
</table>
Low Diagnostic Yield of Elective Coronary Angiography


ABSTRACT

BACKGROUND
Guidelines for triaging patients for cardiac catheterization recommend a risk assessment and noninvasive testing. We determined patterns of noninvasive testing and the diagnostic yield of catheterization among patients with suspected coronary artery disease in a contemporary national sample.

METHODS
From January 2004 through April 2008, at 665 hospitals in the American College of Cardiology National Cardiovascular Data Registry, we identified patients without known coronary artery disease who were undergoing elective catheterization. The patients' demographic characteristics, risk factors, and symptoms and the results of noninvasive testing were correlated with the presence of obstructive coronary
Cardiac Events Based on Amount of Ischemia and Type of Treatment

Adjusted Risk of Cardiac Death

### Use of fractional flow reserve, intravascular ultrasound, & optical coherence tomography in SCA

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFR is recommended to identify hemodynamically relevant coronary lesion(s) when evidence of ischaemia is not available.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Revascularization of stenoses with FFR &lt;0.80 is recommended in patients with angina symptoms or a positive stress test.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>IVUS or OCT may be considered to characterize lesions.</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>IVUS or OCT may be considered to improve stent deployment.</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>Revascularization of an angiographically intermediate stenosis without related ischaemia or without FFR &lt;0.80 is not recommended.</td>
<td>III</td>
<td>B</td>
</tr>
</tbody>
</table>
Stenting of lesions with an FFR 0.80 in the current era may actually be detrimental
Hypothesis: An initial invasive strategy of cath and optimal revascularization (PCI or CABG) + OMT is superior to a conservative strategy of OMT alone with cath reserved for OMT failure
Summary

- Myocardial perfusion imaging with SPECT is useful for diagnosis and risk stratification
- Decisions regarding further evaluation and treatment can be made confidently based on the data from myocardial perfusion imaging
- Used appropriately, myocardial perfusion imaging is cost effective
Radiation Exposure From Cardiac Diagnostic Imaging
## Dosimetry & Radiation Exposure

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Imaging</th>
<th>Activity (MBq)</th>
<th>Effective dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thallium-201</td>
<td>Stress-redistribution</td>
<td>80</td>
<td>11</td>
</tr>
<tr>
<td>Technetium-99m</td>
<td>Stress (one day)</td>
<td>250</td>
<td>2 – 2.5</td>
</tr>
<tr>
<td></td>
<td>Rest (one day)</td>
<td>750</td>
<td>5.6 – 7.5</td>
</tr>
<tr>
<td></td>
<td>Two day</td>
<td>400</td>
<td>3 - 4</td>
</tr>
</tbody>
</table>
Low Dose, Stress-only Imaging with Solid state CZT y-camera

- High count sensitivity
- High spatial resolution
- High contrast resolution
- Permits use of much lower doses
- Much lower radiation exposure

- 2 - 4 mCi Tc-99m
- ~ 10 min acquisition
- Dosimetry ~ 1 mSv
Table 3. Medical Imaging Procedures with Largest Contribution to Cumulative Effective Dose.*

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Average Effective Dose</th>
<th>Annual Effective Dose per Person</th>
<th>Proportion of the Total Effective Dose from All Study Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial perfusion imaging</td>
<td>15.6</td>
<td>0.540</td>
<td>22.1</td>
</tr>
<tr>
<td>CT of the abdomen</td>
<td>8</td>
<td>0.446</td>
<td>18.3</td>
</tr>
<tr>
<td>CT of the pelvis</td>
<td>6</td>
<td>0.207</td>
<td>12.2</td>
</tr>
<tr>
<td>CT of the chest</td>
<td>7</td>
<td>0.184</td>
<td>7.5</td>
</tr>
<tr>
<td>Diagnostic cardiac catheterization</td>
<td>7</td>
<td>0.113</td>
<td>4.6</td>
</tr>
<tr>
<td>Radiography of the lumbar spine</td>
<td>1.5</td>
<td>0.080</td>
<td>3.3</td>
</tr>
<tr>
<td>Mammaryography</td>
<td>0.4</td>
<td>0.076</td>
<td>3.1</td>
</tr>
<tr>
<td>CT angiography of the chest (noncoronary)</td>
<td>15</td>
<td>0.075</td>
<td>3.1</td>
</tr>
<tr>
<td>Upper gastrointestinal series</td>
<td>6</td>
<td>0.058</td>
<td>2.4</td>
</tr>
<tr>
<td>CT of the head or brain</td>
<td>2</td>
<td>0.049</td>
<td>2.0</td>
</tr>
<tr>
<td>Percutaneous coronary intervention</td>
<td>15</td>
<td>0.043</td>
<td>1.8</td>
</tr>
<tr>
<td>Nuclear bone imaging</td>
<td>0.3</td>
<td>0.035</td>
<td>1.4</td>
</tr>
<tr>
<td>Radiograph of the abdomen</td>
<td>0.7</td>
<td>0.028</td>
<td>1.1</td>
</tr>
<tr>
<td>CT of the cervical spine</td>
<td>6</td>
<td>0.020</td>
<td>0.8</td>
</tr>
<tr>
<td>CT of the lumbar spine</td>
<td>6</td>
<td>0.018</td>
<td>0.7</td>
</tr>
<tr>
<td>Chest radiograph</td>
<td>0.02</td>
<td>0.016</td>
<td>0.7</td>
</tr>
<tr>
<td>Thyroid uptake</td>
<td>1.9</td>
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</tr>
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<td>Intravenous urography</td>
<td>3</td>
<td>0.014</td>
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<td>CT of the neck</td>
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</tr>
<tr>
<td>Cardiac resting ventriculography</td>
<td>7.8</td>
<td>0.014</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Figure 1. Overall Distribution of Annual Effective Doses of Radiation in the Study Population, Stratified According to Sex. Percentages may not total 100 because of rounding.
Radiation Safety

- **SPECT-CT**
  analyzed claims data from 952,420 nonelderly adults in 4 states, and reported moderately elevated radiation doses in 19.4% of enrollees and high doses in 2.1%. SPECT MPI accounted for 22.1% of the total effective dose.

  Fazel R NEJM 2009

- **Recommendations for reducing radiation exposure**
  Based on these recommendations, we expect that for the population of patients referred for SPECT or PET MPI, on average a total radiation exposure of <9 mSv can be achieved in 50% of studies by 2014.

  Cerqueira M. JNC2010

- **Fusion SPECT/CT and PET/CT**
  Hybrid SPECT/CT AND PET–CT imaging has tremendous potential. Investigators report their initial experience with low-dose, prospectively gated coronary CTA, which reduced radiation exposure by 70% without compromising image quality or integration with spect or PET.

  Javadi MJ. J Nucl Cardiol 2008
Table 2  Low-dose cadmium zinc telluride single-photon emission computed tomography results in obese and non-obese patients

<table>
<thead>
<tr>
<th>Study</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Radiation dose (mSv)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duval et al.⁹</td>
<td>89</td>
<td>66</td>
<td>5.8</td>
<td>25</td>
</tr>
<tr>
<td>Gimelli et al.¹⁰</td>
<td>92</td>
<td>67</td>
<td>5.1 (male)</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.12 (female)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1  Effect of Cardiac CT Radiation Reduction Techniques on Image Quality

<table>
<thead>
<tr>
<th>First Author (Ref. #)</th>
<th>Scan Techniques Investigated</th>
<th>n</th>
<th>Main Outcome Variable</th>
<th>Major Findings</th>
<th>Mean Effective Dose</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hausleiter (5)</td>
<td>Prospective ECG triggering (axial) vs. retrospective ECG gating (helical)</td>
<td>400</td>
<td>Image quality (ordinal, 1-4)</td>
<td>Image quality noninferior in axial vs. helical scanning (3.36 ± 0.59 vs. 3.37 ± 0.56)</td>
<td>3.5 ± 2.1 vs. 11.2 ± 5.9 mSv</td>
<td>Beta-blocker use 77% vs. 79% HR 54 ± 6.1 vs. 56 ± 5.5</td>
</tr>
<tr>
<td>Neefjes (6)</td>
<td>High-pitch scanning vs. prospective ECG triggering (narrow window) (HR &lt;65 beats/1 min; n = 160)</td>
<td>272</td>
<td>Image quality (ordinal, 1-3)</td>
<td>Image quality scores: 2.67 ± 0.38 vs. 2.86 ± 0.21 (p &lt; 0.001) 2.81 ± 0.28 vs. 2.80 ± 0.38 (p = 0.54)</td>
<td>0.81 ± 0.03 vs. 2.74 ± 1.14 mSv (120 kVp)</td>
<td>Metoprolol 100 mg PO 1 h before scan unless contraindicated</td>
</tr>
<tr>
<td></td>
<td>Prospective ECG Triggering (wide window) vs. retrospective ECG gating with ETCM (HR ≥65 beats/1 min; n = 112)</td>
<td></td>
<td></td>
<td></td>
<td>1.65 ± 0.69 vs. 4.21 ± 1.2 mSv (100 kVp)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.07 ± 1.07 vs. 5.54 ± 1.76 mSv (120 kVp)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.50 ± 1.79 vs. 9.83 ± 3.49 mSv (100 kVp)</td>
<td></td>
</tr>
</tbody>
</table>

K. Ghafourian, J Am Coll Cardiol Img, 5 (2012),
Recommendations for Reducing Radiation Exposure in Myocardial Perfusion Imaging

Cerqueira E, et al. ASNC Info Statement J. Nucl Cardiol 2010
Από τον βομβαρδισμό της Χιροσίμα και του Ναγκασάκι έως το δυστύχημα του Τσερνόμπιλ, οι καταστροφές από την πυρηνική ενέργεια έχουν προκαλέσει φόβο και δυσπιστία για τη χρήση της, καθώς και παγκόσμια πίεση να κρατηθεί η ακτινοβολία στα χαμηλότερα δυνατά επίπεδα, αναφέρει ο Άλισον στο βιβλίο του «Ακτινοβολία και λογική». Τονίζει ότι όλα τα στοιχεία για την υγεία των επιζώντων από τη Χιροσίμα και το Ναγκασάκι αποδεικνύουν πόσο καλά μπορεί να προστατευθεί το ανθρώπινο σώμα από μόνο του απέναντι σε επιθέσεις με ακτινοβολία και χημικά. «Τα τελευταία 50 χρόνια ανακαλύψαμε ότι η ικανότητα επιδιόρθωσης ζημιών και αντικατάστασης κυττάρων δείχνει πως η ακτινοβολία προκαλεί βλάβες μόνο υπό ακραίες συνθήκες», λέει. «Την ακτινοβολία που δέχεται ένας ασθενής ο οποίος υποβάλλεται σε θεραπεία για τον καρκίνο μέσα σε μία ημέρα θα την δεχόταν κάποιος εάν εξετίθετο ένα εκατομμύριο ώρες μέσα σε διάδρομο του πυρηνικού εργοστασίου στο Σέλαφιλντ. Και οι ακτινοθεραπείες γίνονται επί εβδομάδες». 
Innovations in technology

• Cardiac imaging has rapidly evolved in recent years with the release of technologies that improve the capabilities of PET and SPECT in heart disease diagnosis.

• **PET/CT** are some of the tools that allow clinicians to more easily collect better-quality images. New systems such as Siemens Healthcare's Biograph mCT Flow PET/CT system, Philips Healthcare's Vereos PET/CT and GE Healthcare's Q.Clear

• **SPECT/CT** system generates fully integrated high-resolution images and quantitative data, Siemens' Symbia Intevo, GE Healthcare's Alcyon CZT/VCT Discovery NM/TC

• **AdreView** tracer provides a new window into cardiac nerve activity, an important tool for understanding heart failure.
Issues with Current Nuclear Cardiology Procedures

• Radiation exposure, Einstein et al Circulation 2007;116:1290
  • Tc-99m –rest/stress 10-15 mSv standard
  • Dual isotope - 29 mSv
  • TI-201 Stress redistribution - 22 mSv

• Long Protocol:
  • Rest/stress TI-201/Tc-99m: 2-4 hours
  • Rest/stress Tc 99m: 2 ½-4 hours

• Long Camera time
  • 30 minutes for dual head camera, rest/stress, longer for additional prone imaging

• Lack of Confidence by referring physicians (Training –experience)
• High false positive rate, un-necessary catheterizations (Fx significance)
Biological effects of low-dose radiation: of harm and hormesis

Tommaso Gori and Thomas Münzel*

[Graphical representation of models: (dots) stochastic model, Linear model, Exponential model, Hormesis model, Damage, Baseline risk (risk in the absence of the stressor), Protection, Stres sor]
SPECT Myocardial Perfusion Imaging Currents clinical applications

Applications

1. Διάγνωση, διαστρωμάτωση επικινδυνότητας, πρόγνωση
2. Λειτουργικός έλεγχος μέσης βαρύτητας βλαβών μετά την στεφανιογραφία)
3. Εκτίμηση θεραπευτικών παρεμβάσεων (Φαρμ-PCI-CABG)
4. Ταυτόχρονη μελέτη αιμάτωσης-λειτουργικότητας (gated SPECT)
5. Μελέτη συμπαθητικής εννεύρωσης (Καρδιακή ανεπάρκεια-Μυοκαρδιοπάθειες)
6. Εκτίμηση μεταβολισμού της καρδιάς (Βιωσιμότητα)
7. Έλεγχος μικροκυκλοφορίας (MVO)- Εκτίμηση ACS
8. Εντόπιση αθηρωματικής πλάκας με ενδείξεις φλεγμονής PET
9. Συνδυασμένη απεικόνιση (Fusion imaging)
Appropriate Use Criteria

- Detection of CAD: Symptomatic
- Detection of CAD/Risk Assessment Without Ischemic Equivalent
- Assessment of Viability/Ischemia
- Evaluation of Ventricular Function
- Risk Assessment With Prior Test Results and/or Known Chronic Stable CAD
- Risk Assessment: Preoperative Evaluation for Noncardiac Surgery Without Active Cardiac Conditions
- Risk Assessment: Within 3 Months of an Acute Coronary Syndrome
- Risk Assessment: Postrevascularization (Percutaneous Coronary Intervention or Coronary Artery Bypass Graft)
Adenosine

- Naturally occurring purine nucleotide
- Direct coronary arteriolar dilator
- Non-selective action, A1, A2a, A2b, A3
- Half life <10 sec
- IV infusion
Παρουσίαση περιστατικού

• Άνδρας 65 ετών
• Άτυπο άλγος στη ράχη μη σχετιζόμενο με κόπωση
• Παραγ κινδύνου:
  – υπέρταση
  – υπερλιπιδαιμία
ΗΚΓ ήρεμίας
Δοκιμασία κόπωσης

- Διάρκεια 10,5 min
- Μεγίστη ΚΣ 147/min 95% της προβλεπόμενης
- ΑΠ 160/80→210/105 mmHg
- Κατά την κόπωση εμφάνισε άλγος χαμηλά στη ράχη που δεν περιόρισε την συνέχιση της εξέτασης
ΗΚΓμα στη μεγίστη κόπωση
1. Ποιο θα ήταν το επόμενο βήμα σας;

1. Κλινική παρακολούθηση
2. Λειτουργική δοκιμασία (απεικονιστική) με μεγαλύτερη ευαισθησία από την απλή δοκιμασία κόπωσης
3. Στεφανιογραφία
Σπινθηρογράφημα αιμάτωσης με 99mTc-Tetrofosmin
2. Ποιο θα ήταν το επόμενο βήμα σας;

1. Παρακολούθηση
2. Επανάληψη ΣΑΜ σε 6-12 μήνες
3. Στεφανιογραφία
Στεφανιογραφία

- Κατά την στεφανιογραφία εμφάνισε VF η οποία ανατάχθηκε αμέσως ηλεκτρικά χωρίς άλλες επιπλοκές
Use of exercise or pharmacologic stress testing in combination with imaging

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>An imaging stress test is recommended as the initial test for diagnosing SCAD if the PTP is between 66–85% or if LVEF is &lt;50% in patients without typical angina.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>An imaging stress test is recommended in patients with resting ECG abnormalities which prevent accurate interpretation of ECG changes during stress.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Exercise stress testing is recommended rather than pharmacologic testing whenever possible.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>An imaging stress test should be considered in symptomatic patients with prior revascularization (PCI or CABG).</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>An imaging stress test should be considered to assess the functional severity of intermediate lesions on coronary arteriography.</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>
Myocardial Perfusion Imaging
Diagnostic Test (binary outcome)

To rule out presence of sign. CAD in patients with intermediate likelihood of CAD

high diagn. performance
sens.: 85 – 90% spec.: 75 – 85%

neg. MPI: excellent prognosis
death / MI 0.6 (0.5 – 0.9) year

Gate-keeper of Invasive Coronary Angiography

Shaw J Nucl. Cardiol. 2004;11:171

Dx: 79 studies 8.964 pts
Pg: 31 papers 69.655 pts
ASNC Position Statement 1997

“…Normal Stress Myocardial Perfusion Imaging predicts very low (<1%) Likelihood of Cardiac Death or MI in the next 12 Months.”

J Nucl. Cardiol 1997; 4:172

1. In in-hospital and early post-discharge period
   Kontos MC. JACC 1997

2. In intermediate and long term follow-up period.
   Vassiliadis I. JNC 2003
• Χ 77 με ιστορικό παλαιού κατωτερού Ε και αραια επεισοδια προκαρδίου αλγους (στηθαγχη CCS I) προσπαθειας
• ΑΥ-ηπιος ΣΔ και δυσλιπιδαιμία
• Αγωγη bb- AMEA-Αντ CA,ASA, STATIN
Table 3. Medical Imaging Procedures with Largest Contribution to Cumulative Effective Dose.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Average Effective Dose</th>
<th>Annual Effective Dose per Person</th>
<th>Proportion of the Total Effective Dose from All Study Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial perfusion imaging</td>
<td>15.69</td>
<td>0.540</td>
<td>22.1</td>
</tr>
<tr>
<td>CT of the abdomen</td>
<td>8</td>
<td>0.446</td>
<td>18.3</td>
</tr>
<tr>
<td>CT of the pelvis</td>
<td>6</td>
<td>0.297</td>
<td>12.2</td>
</tr>
<tr>
<td>CT of the chest</td>
<td>7</td>
<td>0.184</td>
<td>7.5</td>
</tr>
<tr>
<td>Diagnostic cardiac catheterization</td>
<td>7</td>
<td>0.113</td>
<td>4.6</td>
</tr>
<tr>
<td>Radiography of the lumbar spine</td>
<td>1.5</td>
<td>0.080</td>
<td>3.3</td>
</tr>
<tr>
<td>Mammaryography</td>
<td>0.4</td>
<td>0.076</td>
<td>3.1</td>
</tr>
<tr>
<td>CT angiography of the chest (noncoronary)</td>
<td>15</td>
<td>0.075</td>
<td>3.1</td>
</tr>
<tr>
<td>Upper gastrointestinal series</td>
<td>6</td>
<td>0.058</td>
<td>2.4</td>
</tr>
<tr>
<td>CT of the head or brain</td>
<td>2</td>
<td>0.049</td>
<td>2.0</td>
</tr>
<tr>
<td>Percutaneous coronary intervention</td>
<td>15</td>
<td>0.043</td>
<td>1.8</td>
</tr>
<tr>
<td>Nuclear bone imaging</td>
<td>6.3</td>
<td>0.035</td>
<td>1.4</td>
</tr>
<tr>
<td>Radiograph of the abdomen</td>
<td>0.7</td>
<td>0.028</td>
<td>0.1</td>
</tr>
<tr>
<td>CT of the cervical spine</td>
<td>6</td>
<td>0.020</td>
<td>0.8</td>
</tr>
<tr>
<td>CT of the lumbar spine</td>
<td>6</td>
<td>0.018</td>
<td>0.7</td>
</tr>
<tr>
<td>Chest radiograph</td>
<td>0.025</td>
<td>0.016</td>
<td>0.7</td>
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<td>Thyroid uptake</td>
<td>1.9</td>
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<td>CT of the neck</td>
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<td>0.6</td>
</tr>
<tr>
<td>Cardiac resting ventriculography 7.8</td>
<td>0.014</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Overall Distribution of Annual Effective Doses of Radiation in the Study Population, Stratified According to Sex. Percentages may not total 100 because of rounding.
Biological effects of low-dose radiation: of harm and hormesis

Tommaso Gori and Thomas Münzel*
The END Study
Events based on clinical risk and diagnostic strategy

- **Graph 1:**
  - **Y-axis:** Death or MI (%)
  - **X-axis:** Low, Intermediate, High
  - **Bars:** Direct Cath, MPI + Cath

- **Graph 2:**
  - **Y-axis:** Revascularization (%)
  - **X-axis:** Low, Intermediate, High
  - **Bars:** Direct Cath, MPI + Cath

The END Study
Diagnostic and Follow-Up Costs Based on Treatment Strategy and Clinical Risk

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICA (with FFR when necessary) is recommended for risk stratification in patients with severe stable angina (CCS 3) or with a clinical profile suggesting a high event risk, particularly if the symptoms are inadequately responding to medical treatment.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>ICA (with FFR when necessary) is recommended for patients with mild or no symptoms with medical treatment in whom non-invasive risk stratification indicates a high event risk and revascularization is considered for improvement of prognosis.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>ICA (with FFR when necessary) should be considered for event risk stratification in patients with an inconclusive diagnosis on non-invasive testing, or conflicting results from different non-invasive modalities.</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>If coronary CTA is available for event risk stratification, possible overestimation of stenosis severity should be considered in segments with severe calcification, especially in patients at high intermediate PTP. Additional stress imaging may be necessary before referring a patient with few/no symptoms to ICA.</td>
<td>IIa</td>
<td>C</td>
</tr>
</tbody>
</table>