The Role of SPECT MPI in the Evaluation of Coronary Artery Disease

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SPECT MPI

**SPECT**
- single-photon emission computed tomography

**MPI**
- myocardial perfusion imaging
Goals

• Basic principles of SPECT MPI
• Interpretation of SPECT MPI
  • Correlate with anatomy and pathophysiology
• Clinical utility of SPECT MPI in patients with or without known CAD
Patient PB

• History
  • 75 yo woman with hypertension and hyperlipidemia presents with chest pain and dyspnea on exertion
  • Strong family history of CAD
  • No history of obesity, smoking, diabetes

• Goals for workup of CAD
  • Diagnosis
  • Risk stratification
  • Management
What studies are available to evaluate PB, a patient with an intermediate to high pre-test probability of CAD?
Modalities for Evaluation of CAD

**Functional Studies**
- Non-invasive
  - Exercise tolerance testing
  - Stress echocardiography
  - Stress SPECT MPI
  - Stress PET
  - MRI

**Anatomical Studies**
- Invasive
  - Coronary angiography
  - IVUS
- Non-invasive
  - EBCT
  - MSCT
  - MRA
SPECT MPI was chosen as the initial study in PB’s workup for CAD. Why?
Functional Studies

- Assessment of hemodynamic consequences of CAD
  - Perfusion defects
  - Left ventricular dysfunction
- Non-invasive
- Well validated
  - ETT
  - Stress echocardiography
  - SPECT MPI
- Widely available
- Useful for diagnosis, risk stratification, and guiding management
Anatomical Studies

• Visualization of coronary vasculature and stenoses
• Inform decisions regarding method of intervention
• Only well validated and widely available modality (coronary angiography) is invasive
  • Associated morbidity and mortality
• Gold-standard for diagnosis of CAD
  • Coronary angiography
SPECT MPI versus other Functional Studies

- Good test characteristics in diagnosis of CAD
  - Better than ETT
  - Roughly equivalent to stress echocardiography
- Can be used in patients with baseline ECG abnormalities
- Not operator dependent
- Validated role in risk stratification for patients with CAD
- Cost-effective
- Widely available
- Detection of early events in ischemic cascade
The Ischemic Cascade

Modified from *Heart*. 2005; 91: 1110-1117
How does SPECT MPI detect ischemia due to CAD?
SPECT: Basic Principles

- Nuclear imaging study
- Gamma particles detected by a rotating camera
- Radionuclides
  - Thallium\(^{201}\)
    - Long half life (73 hours) → low doses
    - Low energy emitter → increased attenuation
    - Low doses and high attenuation → low resolution
  - Technetium\(^{99m}\)
    - Short half life (6 hours) → high doses
    - High energy emitter → decreased attenuation
    - High doses and low attenuation → high resolution
MPI: Basic Principles

• Radionuclides taken up by perfused myocytes
  • Tl\textsuperscript{201}: active transport across membrane by Na\textsuperscript{+}/K\textsuperscript{+} ATPase
  • Tc\textsuperscript{99m} sestamibi and Tc\textsuperscript{99m} tetrofosmin: passive diffusion across cell and mitochondrial membranes

• Identify areas of infarction or inducible ischemia by comparing perfusion in rest and stress states

• Exercise or pharmacologically induced coronary artery vasodilation → proportionately less perfusion distal to stenoses → relatively low radionuclide uptake in myocardium distal to stenoses → relatively low signal from areas of low perfusion
Impaired Coronary Flow Reserve Causes Decreased Perfusion Distal to Stenoses

http://merck.micromedex.com/index
SPECT MPI Protocols

- Exercise vs. pharmacological
  - Exercise: Bruce protocol
    - Patients who can achieve ≥85% of maximal predicted heart rate
    - Exercise preferable since exercise capacity, symptoms, and ST segment changes provide additional prognostic information
  - Pharmacological
    - Vasodilators: adenosine, dipyridamole
    - Iono-/chronotrope: dobutamine

- ECG gated vs. nongated
  - Gated protocol allows determination of LV function

- Single isotope vs. double isotope
  - Rest and stress portions performed back-to-back in double isotope

- Visual, semi-quantitative, or quantitative interpretation
Cardiac Anatomy in SPECT MPI

http://info.med.yale.edu/intmed/cardio/imaging/techniques/spect_anatomy/index.html
Coronary Artery Territories

from Hurst's The Heart

http://brighamrad.harvard.edu/education/online/Cardiac/
Patterns of Ischemia in Various Coronary Artery Territories in SPECT MPI

Single-vessel disease

Multi-vessel disease

A: anterior wall
L: lateral wall
I: inferior wall
S: septum

from Hurst's The Heart
High Risk Features on SPECT MPI

- Perfusion defects in multiple vascular territories
- Extensive hypoperfusion in one vascular territory
- LVEF < 40%
- Increased end-systolic and end-diastolic volumes
- Transient LV cavity dilation during stress
- Increased Tl^{201} lung uptake

Image courtesy of Dr. Kevin Donohoe
How is SPECT MPI used clinically for evaluation of CAD?
SPECT MPI for Diagnosis of CAD

• Patient selection
  • Patients with intermediate pre-test probability of CAD based on historical and clinical factors
  • Patients with intermediate to high likelihood of CAD based on ETT or indeterminate ETT
  • Patients with baseline ECG abnormalities
SPECT MPI for Risk Stratification in CAD

• Identify patients with >1% likelihood of cardiac events
  • Cardiac death
  • Nonfatal MI
  • Progression of CAD

• Use risk stratification to guide management

• Patient selection
  • Intermediate or high risk by Framingham/ATPIII score
  • Patients with known CAD from prior cath or SPECT MPI who have been asymptomatic for >2 years or are symptomatic
  • Patients with prior revascularization who have been asymptomatic for >5 years or are symptomatic
PB’s SPECT MPI Study

- Dual isotope exercise SPECT MPI study
  - Performance
    - Exercised 4 minutes
    - Achieved 87% of maximal predicted heart rate
    - Study stopped due to dyspnea
  - No ECG changes
  - Strongly positive study at low level of exercise
  - LVEF 50%
PB’s Stress SPECT MPI Study:
Apical Ischemia Consistent with LAD Stenosis

images courtesy of Dr. Donohoe
What are the implications of PB’s SPECT MPI study?
Diagnostic Implications

• Test characteristics as compared to angiography
  • Sensitivity
    • Exercise: 87%
    • Vasodilator: 89%
  • Specificity
    • Exercise: 73%
    • Vasodilator: 75%
• Normalcy rate: 91%
  • Corrects for decreased specificity due to referral bias.
    • People with positive studies are referred for coronary angiography while people with negative studies generally are not, thus increasing the apparent proportion of false positive SPECT MPI studies.
Prognostic Implications

- Excellent negative predictive value
  - 0.5% annual cardiac event rate in patients with normal studies
- Specific patient populations have worse prognosis for same degree of perfusion defect
  - Advanced age
  - Known CAD
  - Diabetics
  - Pharmacological stress tests
Severity of Perfusion Defect is Correlated with Likelihood of Future Cardiac Events

Poststress Ejection Fraction is Correlated with Survival

Ejection fraction ≥45%  

Ejection fraction <45%

Implications for Management

- Patients with no or mild ischemia benefit from medical management over revascularization.
- Patients with moderate to severe ischemia (>10% of myocardium) benefit from revascularization over medical management.
- Only patients with inducible ischemia benefit from revascularization.
- Selective referral of patients to catheterization is cost-effective.
Implications of PB’s SPECT MPI Study

- **Diagnosis**
  - High post-test probability of CAD

- **Risk Stratification**
  - >1% annual probability of a major cardiac event

- **Management**
  - Likely to benefit from revascularization
Companion Patient’s Coronary Angiogram

Complete occlusion of proximal LAD

Stented LAD

http://www.path.utah.edu/  http://www.path.utah.edu/
PB’s Post-Stent Stress SPECT MPI Study: Resolution of Inducible Apical Ischemia

Before revascularization

After revascularization

Images courtesy of Dr. Kevin Donohoe
Conclusion

• SPECT MPI identifies regions of myocardial ischemia with decreased perfusion and LV dysfunction

• SPECT MPI has a well validated role in diagnosis and risk stratification in patients with CAD

• Risk stratification with SPECT MPI can be used to cost-effectively guide management of patients with CAD
References

- Loong CY and Anagnostopulous C. Diagnosis of coronary artery disease by radionuclide myocardial perfusion imaging. Heart. 2004; 90: 2-9
- Sabharwal NK and Lahiri A. Role of myocardial perfusion imaging for risk stratification in suspected or known coronary artery disease. Heart. 2003; 89:1291-1297
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