Radiologic Assessment of Myocardial Viability

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Patient EF

- 66yo female with a 3-year history of intermittent chest pain previously relieved by sublingual nitroglycerin, now presenting with angina and symptoms of CHF
- Standard studies (exercise MIBI, echocardiogram) showed a fixed apical wall defect and severe global LV hypokinesis
  - Minimal reversibility in anterior portion of apical wall defect (MI)
  - Left ventricular ejection fraction: 23%
- Findings consistent with ischemic cardiomyopathy: extensive coronary artery disease and severely decreased global left ventricular function
  - Scarring secondary to myocardial necrosis and/or
  - Hibernating myocardium
Hibernating Myocardium

• Definition: tissue that exhibits chronic contractile dysfunction secondary to persistently reduced perfusion
  – By definition, contractility will improve if perfusion increases
  – Improvement can take from weeks to months

• Residual blood flow is sufficient to sustain viability of myocytes but not systolic contraction

• Distinct from “stunned” myocardium and transient dysfunction secondary to ischemia
Why Distinguish Hibernating Myocardium from Irreversible Injury?

• Identify patients with ischemic cardiomyopathy who would benefit most from revascularization (CABG, PTCA)
  – Higher rates of peri-operative and late survival
  – Greater improvements in regional and global LV function
  – Better exercise tolerance after revascularization

• Patients with hibernation as the primary cause of LV dysfunction have a better prognosis after revascularization than after medical therapy

• Consideration of CABG as alternative to transplant
Imaging Modalities Available for Detection of Hibernating Myocardium

- Dobutamine echocardiography
- Nuclear studies
  - SPECT imaging with thallium-201, Te 99m sestamibi, or Te 99m tetrofosmin
  - SPECT imaging with 18-fluorodeoxyglucose (\(^{18}\text{FDG}\)) as a metabolic tracer
  - PET imaging with 18-fluorodeoxyglucose as a metabolic tracer
- MRI
Dobutamine Echocardiography

- Used to examine “inotropic reserve” of dysfunctional but viable myocardium
- Dobutamine-induced systolic thickening in asynergic myocardial segments is indicative of viability
- Results predict both likelihood of functional recovery and long-term outcome after CABG
  - Predictive value greatest with biphasic response: improvement at low dose and worsening at high dose
Parasternal long axis
Parasternal short axis

RV

LV

Anterior wall

Posterior papillary muscle

Anterior papillary muscle

Yale Center for Advanced Instructional Media
http://info.med.yale.edu/intmed/cardio/imaging/
Echocardiographic findings of cardiomyopathy...may represent viable myocardium at rest

Parasternal long axis

Parasternal short axis

Low-dose Normal dobutamine

Cardiomyopathy

LV, AO, LA

American College of Cardiology
http://www.acc.org/education/online/echo_month/0101/Jan01_01.htm
Dobutamine Echocardiography

- **Advantages**
  - Inexpensive
  - High specificity (80-85%) compared to other methods
  - Demonstrated prognostic value
  - No ionizing radiation

- **Disadvantages**
  - Response requires > 50% viable myocytes in a given segment
  - Incomplete visualization of all segments in 15-20% of patients
  - Reliance on visual assessment of wall thickening
  - Decreased sensitivity for severely ischemic but viable segments
Nuclear Studies: SPECT with Thallium-201 Rest-redistribution

- Thallium-201: potassium analog that traces Na\(^+\)/K\(^+\)-ATPase activity
- Regions with normal perfusion show enhanced uptake
- Hibernating myocardium with functional Na\(^+\)/K\(^+\)-ATPase show thallium uptake after redistribution
Thallium-201 rest-redistribution showing viability of inferior wall

Rest

4 hours post-injection

Rest

4 hours post-injection

Atlas of Myocardial Perfusion SPECT
http://brighamrad.harvard.edu/education/online/Cardiac/
Thallium-201 Rest-redistribution

• Advantages
  – Widely available and inexpensive
  – Extensive experience (in use since 1977)
  – Sensitivity and specificity comparable to more expensive methods
  – Demonstrated prognostic value

• Disadvantages
  – Limited spatial resolution
  – Poor image quality in some obese patients
  – Attenuation artifacts that may be misinterpreted as perfusion defects
  – Inability to differentiate endocardial from epicardial viability
  – Time consuming
Nuclear Studies: SPECT Imaging with 18-Fluorodeoxyglucose

• Tc 99m sestamibi: traces perfusion
• 18-Fluorodeoxyglucose ($^{18}$FDG): traces glucose metabolism
• Hibernating myocardium demonstrates flow/metabolism mismatch
Patient SP

*63yo male with history of diet-controlled DM, now presenting with a three week history of angina and symptoms of CHF
• Admitted to the hospital and ruled-in for AMI
• Echocardiogram: severe left ventricular dysfunction (LVEF 25%) with ?LV thrombus
• Cardiac catheterization: pulmonary hypertension, LVEF 18%, advanced 3-vessel disease
• Findings consistent with ischemic cardiomyopathy; is the patient a good candidate for revascularization?
Patient SP:
SPECT study with $^{18}$FDG showing areas of viable and non-viable myocardium

Perfusion (MIBI)

Viability ($^{18}$FDG)

Perfusion (MIBI)

Viability ($^{18}$FDG)

Perfusion (MIBI)

Viability ($^{18}$FDG)

Courtesy J. Anthony Parker, M.D., Ph.D.—BIDMC
Patient SP: Follow-up

- Underwent 4-vessel CABG two months after viability study
- Did well postoperatively (developed atrial fibrillation on post-op day 3)
- Discharged on post-op day 8 in sinus rhythm
- Echocardiogram 3 months post-op: left ventricular function “slightly improved” compared to previous echocardiogram
18FDG-SPECT Scanning

- Advantages
  - Higher sensitivity compared to dobutamine echocardiography (85-90% compared to 75-80%)
  - Generally good agreement with PET studies at a much lower cost
  - Demonstrated prognostic value (data limited)

- Disadvantages
  - Requires addition of 511-keV collimators to existing SPECT cameras (though not difficult…)
  - Limited spatial resolution
  - Poor image quality in some obese patients
  - Attenuation artifacts that may be misinterpreted as perfusion defects
  - Inability to differentiate endocardial from epicardial viability
MRI

- Cine images obtained to determine left ventricular function at rest with high spatial resolution
- Gadolinium-based contrast agent injected
  - Biologically inert
  - Diffuses into interstitial space
  - Exit from interstitial space delayed in zones of irreversible myocardial injury (mechanism not fully understood)
  - “Hyperenhancement:” increased concentration of contrast in irreversibly injured areas compared with viable areas
MRI showing hyperenhancement of infarcted, non-viable myocardium

Normal heart with completely viable myocardium

Lateral wall MI resulting in scarred, non-viable myocardium

Courtesy Susan B. Yeon, M.D., J.D.—BIDMC
MRI determination of viability

Normal wall-motion

Hyperenhancement in the antero-lateral wall: scarred, non-viable myocardium

Left, top right: Society for Cardiovascular Magnetic Resonance
http://www.scmr.org/

Bottom right: courtesy Susan B. Yeon, M.D., J.D.—BIDMC
Patient EF: pre-contrast cine MRI showing global hypokinesis

Patient EF: Short-axis cine MRI, moving progressively from apex to base

Patient XX: Short-axis cine MRI, showing normal wall motion

Courtesy Susan B. Yeon, M.D., J.D.—BIDMC

Society for Cardiovascular Magnetic Resonance
http://www.scmr.org/
Patient EF: cine MRI showing thinning of distal septum and apex
Patient EF: post-contrast MRI showing large areas of viable myocardium

Short axis

Hyperenhancement of inferior septum

Long axis

Thinning of apex

4-chamber

Hyperenhancement of distal septum and apex

Courtesy Susan B. Yeon, M.D., J.D.—BIDMC
Patient EF: Follow-up

- Cardiac catheterization:
  - LAD: total occlusion in mid-portion after the takeoff of the second diagonal branch
  - RCA: subtotal proximal occlusion with total mid-occlusion
  - Global LV hypokinesis, areas of apical dyskinesis, LVEF 22%

- Managed medically given lack of sufficient targets for CABG and extremely poor LV function
• **Advantages**
  - Predictive accuracy very high in severely dysfunctional segments (PPV 88%, NPV 89%)
  - Large body habitus does not preclude excellent image quality
  - High spatial resolution allows transmural extent of injury to be determined

• **Disadvantages**
  - Excludes patients with permanent pacemakers or implantable cardioverter-defibrillators
  - Prognostic value not yet known
  - High cost
  - Mechanism of hyperenhancement not fully understood
Summary

• Extent of myocardial viability predicts response to revascularization

• Accuracy of various modalities are similar, so use clinical judgement in determining when and how to assess viability
  – Factors to consider: availability and cost of the various techniques, patient characteristics, and preference of the medicine/cardiology team
  – Algorithms for approaching assessment of hibernating myocardium have been proposed, but generally do not yet include MRI and can be center specific

• Remember that viability is not the only issue
  – Are there targets for CABG?
  – What is the patient’s risk of peri-operative and post-operative complications?
References

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Acknowledgements

• Susan B. Yeon, M.D., J.D.
• J. Anthony Parker, M.D., Ph.D.
• Toseef Khan, M.D.
• Pamela Lepkowski
• Larry Barbaras and Cara Lyn D’amour