Evidence for Medical Management vs. Revascularization: Guidance from Cardiac MR and CT

Subha Ghosh, MBBS, MD

Management of Coronary Artery Disease: Guidance from Cardiac MRI and CT

Subha Ghosh, MD*

Eric D. McLoney, MD*

Laxmi S. Mehta, MD*

Subha V. Raman, MD***

Coronary Artery Disease (CAD)

- Leading cause of morbidity and mortality in developed countries
- Treatment has rapidly evolved in recent years
- Patient selection for medical treatment versus revascularization remains of utmost importance

Medical Management Versus Revascularization

Symptoms and signs

Clinical Judgment

Long term risk profile

Likelihood of procedural success

Diagnostic tests

Evaluation of suspected CAD

- Anatomic data
  - Location and degree of coronary stenoses
  - Does not imply hemodynamically significant disease that requires revascularization

- Functional data
  - Physiologic consequences of ischemia
  - Myocardial perfusion abnormalities and contractile dysfunction

Cardiac MR and CTA

- Cardiac magnetic resonance imaging (MR) and computed tomography angiography (CTA)
  - Diagnostic tools
  - Both provide functional and anatomic data
- This lecture will review the strengths and weaknesses of both modalities for the evaluation of coronary artery disease

CTA

- Offers detailed anatomical information
- Imparts large radiation dose

MRI

- Ability for improved functional data and myocardial tissue characterization
- Long scan times, limitations of certain implants

Both

- Provide functional and anatomic data
- Limited by irregular rhythms, respirations, and artifacts from calcium and metal
Coronary Artery Assessment: CTA

- Coronary visualization has improved greatly over the past decade with multidetector CT technology
- High sensitivity (94%) and specificity (82%) in detecting CAD
- Has been used to “rule out” low-risk patients
- Appropriateness of CTA as an initial screening test, however, remains controversial
- PROMISE trial is investigating initial assessment with CTA compared with stress testing for intermediate risk patients

Coronary Artery Assessment: MR

- MR coronary angiography is limited in its ability to evaluate for coronary artery stenoses
- MR coronary angiography has shown some success for the evaluation of anomalous coronary artery origins, coronary aneurysms, and graft patency
- CTA remains the preferred imaging modality

Graft patency: CTA

- 97% sensitivity and 100% specificity for detecting graft occlusion after CABG
- CTA on left demonstrates a patent LIMA to LAD graft

Anomalous Coronary Artery: CTA

- CTA remains preferred test for evaluating anomalous coronary artery anatomy
- CTA on right demonstrates an anomalous left coronary artery arising from the right coronary cusp with interarterial course
Cardiac Catheterization
American College of Cardiology National Cardiovascular Data Registry

- 400,000 patients underwent elective cardiac catheterization from 2004-2008
- 84% underwent noninvasive testing first
  - 69% had a positive test
  - 37.6% had obstructive CAD

Cardiac Catheterization

- Clear benefit of PCI over optimal medical management only in moderate to severe ischemia (COURAGE, 2008)
- In patients with functionally insignificant stenosis (fractional flow reserve of ≥ 0.75), no difference in symptoms or 5 year death rate between medical and PCI groups (DEFER, 2007)

Noninvasive Test Stratification

- Adenosine stress MR before referral to cardiac catheterization could reduce the rate of diagnostic coronary angiograms from 34% to 6% by excluding myocardial ischemia
- Patients with multivessel CAD who underwent PCI with the addition of fractional flow reserve-guided therapy had significantly lower adverse cardiac event rates at 1 year (FAME, 2009)

Cardiac Catheterization

- DEFER study: patients with single vessel coronary stenoses
  - Functionally non-significant stenoses were randomized to medical therapy vs. revascularization
  - <1% per year risk of death or acute MI
  - At 5 year follow-up: no significant difference in survival or symptoms
  - Functionally significant stenoses were treated with revascularization
  - 5 times higher death rate for patients with significant stenosis despite revascularization
- Percutaneous coronary intervention should not be recommended in the absence of a functionally significant stenosis

First Pass Myocardial Perfusion MR

- Uses a T1 weighted sequence to demonstrate transit of IV gadolinium through perfused myocardium, reflected by high signal intensity
- Stress perfusion imaging is performed with maximal coronary vasodilation using adenosine, dipyridamole, or regadenoson
  - Perfusion in myocardial territories supplied by vessels with hemodynamically significant CAD will not increase as much with vasodilation as territories without significant CAD
  - Can be evaluated visually or quantitatively
- Excellent sensitivity and specificity

Stress Testing

- Functional test to identify ischemic cardiac segments
- MR first-pass myocardial perfusion studies and nuclear medicine (sestamibi or thalium) SPECT studies identify underperfused segments during stress compared with at rest
- MR cine or echocardiography studies identify wall-motion abnormalities to indicate ischemia
Stress Testing: MR

- First-pass myocardial perfusion MR
  - T1-weighted images demonstrate transit of gadolinium through myocardium
  - Vasodilator such as adenosine administered for maximum coronary vasodilation
  - Signal in territories with hemodynamically significant CAD will not increase as much as territories without significant CAD and will appear dark
- Excellent sensitivity (91%) and specificity (94%) for detecting significant CAD²

Stress Testing: MR

- Dobutamine stress MR
  - Escalating inotrope doses are administered to achieve a target heart rate
  - Cine images acquired at each stage
  - Wall motion abnormalities indicate ischemia
- Accuracy is superior to stress echo
  - Superior image quality
  - Consistent visualization of all segments
- 99% 3-year event-free survival for patients with negative Stress MR (dobutamine or adenosine)³

Stress Testing: CTA

- CTA
  - Provides excellent anatomical assessment of CAD
  - Requires exposure to ionizing radiation
  - Low specificity: lacks functional data to evaluate the hemodynamic significance of CAD
- Hybrid CTA and SPECT
  - Increased sensitivity and specificity compared to CTA alone⁴
  - Newer CT platforms promise lower radiation doses

Acute Coronary Syndromes

- 1.17 million hospital visits annually in the U.S. for acute coronary syndrome
- Standard treatment for STEMI is emergent heart catheterization followed by revascularization with PCI or CABG
- Treatment in Non-STEMI and unstable angina is not as straightforward
- Cardiac MR may provide valuable information, which may aid treatment decisions

Myocardial ischemia

- Myocardial ischemia
  - Myocardial dysfunction and edema occurs early following coronary artery occlusion before irreversible injury occurs
  - Myocardial cell death occurs after prolonged occlusion with a wavefront phenomenon from the subendocardium, to the mid-myocardium, and finally to the subepicardium
- Revascularization interrupts the process of ischemic cell death and salvages “at risk” myocardium
Progression of Ischemic Injury

Myocardial ischemia

Changes in cell membrane permeability

Intramyocardial sodium accumulation

Myocardial dysfunction and edema

Cell death and myocardial necrosis

Myocardial Edema

- Ischemia results in myocardial dysfunction and edema as sodium accumulates in the tissue
- Cell death occurs in a "wavefront" pattern from subendocardium to mid-myocardium and then subepicardium
- Myocardial edema is significantly associated with CAD requiring intervention, independent of baseline characteristics and TIMI risk scores

Role of T2-weighted MR

- Can identify myocardial edema prior to the onset of myocardial necrosis
- Can distinguish acute from chronic MI
- Can differentiate myocardial edema present in acute coronary syndromes from that occurring in myocarditis and tako-tsubo cardiomyopathy

Myocardial ischemia: MR

- Myocardial edema is an early indicator of acute myocardial ischemia
  - Abnormal increased T2 signal indicates edema
  - Present in all at risk myocardium including areas of reversible and irreversible injury
- T2 weighted MR images may identify myocardial edema before the onset of myocardial cell death in patients with chest pain and no EKG or laboratory evidence of MI
- In Non-STEMI, myocardial edema was associated with CAD requiring intervention compared with patients without myocardial edema

Myocardial infarction: MR

- Delayed enhancement on MR represents myocardial infarction
  - Correlates well with myocyte necrosis in animal studies
  - Correlates well with myocardial infarction on SPECT and PET studies
  - More reliable in detecting small subendocardial infarct and right ventricular infarct due to higher spatial resolution
- Combination T2-weighted and DE MR may differentiate acute from chronic MI
  - Abnormal T2 signal indicates an acute event
  - Abnormal DE indicates chronic MI

LV Dysfunction: DE-MR

- Patterns of myocardial enhancement on delayed enhancement (DE) MR images may help differentiate ischemic from nonischemic ventricular dysfunction.
- Myocardial infarction will demonstrate subendocardial or transmural delayed enhancement in a vascular distribution
- Dilated cardiomyopathy may show no enhancement, midwall enhancement, or a pattern similar to CAD.
DE-MR as a Diagnostic Tool

- Infarcted tissue appears bright while reversible ischemia does not.
- Data correlates well with PET and SPECT, but MR offers higher spatial resolution and is able to identify more scarring and smaller infarcts.
- Useful in a patient with symptoms of acute MI but unremarkable EKG who has evidence of multiple stenoses on angiography.

Left Ventricular Dysfunction

- Distinguishing LV dysfunction caused by CAD or nonischemic etiologies is critical to optimize treatment.
- Misdiagnosis results in a worse prognosis for patients who may have benefitted from revascularization.
- Coronary angiography may lead to misdiagnosis if a coronary artery spontaneously recanalizes after a myocardial infarction.

Myocardial Infarction on DE-MR

- Transmural enhancement (arrows) in the mid to distal anterior wall and apex with apical thrombus (*).

LV Dysfunction: DE-MR

- Extent of transmural DE is inversely associated with functional recovery.
  - Myocardial segments with ≥50% transmural DE are unlikely to recover function despite revascularization.
  - Infarct size inversely related to follow-up cardiac function.
- In patients with suspected CAD and no history of MI, even a small amount of delayed myocardial enhancement is associated with a high risk of major cardiac events and cardiac mortality.

Microvascular obstruction: MR

- DE-MR appearance: decreased signal intensity within an area of hyperenhancement.
- DE-MR on left demonstrates a large anterioapical infarct with central area of decreased signal (arrows) indicating microvascular obstruction.

Microvascular obstruction
- Microvascular obstruction results in areas of “no reflow” despite patent epicardial coronary arteries
- Results in segmental myocardial deformation and abnormal function of adjacent tissues
- Associated with ventricular arrhythmias, poor remodeling, CHF, and lower event-free survival

DE-MR as a Prognostic Tool
Infarct Size
- Transmural extent of DE predicts recovery of segmental wall motion in post-MI patients and is inversely related to follow-up ejection fraction and LV diastolic volumes
- Infarct size >18.5% of total myocardium predicts worse event-free survival

Microvascular Obstruction
- Can be depicted by DE as areas of decreased signal intensity within hypoenhanced areas, known as “no-reflow”
- Associated with arrhythmias, congestive heart failure and poor LV remodeling
- Independent of infarct size in predicting lower event-free cardiac survival

Myocardial Infarction: CTA
- CTA demonstrates lower attenuation values in infarcted myocardium
- Myocardial thinning or myocardial calcification may be seen in the setting of chronic MI
- May play a role in the assessment of vulnerable versus stable plaques

Unstable Angina: CTA
- “Triple rule out” CTA may be performed in the emergency department to evaluate chest pain
  - Evaluation for CAD, PE, and aortic dissection
  - Data remains limited
  - Higher volume of intravenous contrast
  - Higher radiation doses
- Many patients require follow-up tests including stress-tests and/or angiography, which further increase exposure to radiation and contrast

Conclusions
- MR is useful in the evaluation of CAD
  - May assess for myocardial ischemia, myocardial function, and myocardial viability
  - Provides important functional and prognostic information
  - Guide choice of revascularization or medical therapy
- CTA provides superior anatomic information about the coronary arteries
  - May help plan for revascularization
  - Lacks specificity about the significance of a coronary stenosis
  - More data required for CTA as a screening tool

References
References

8. Reimer KA, Jennings RB. The "wavefront phenomenon" of myocardial ischemic cell death. In: Transmural progression of necrosis within the framework of ischemic bed size (myocardium at risk) and collateral flow. Lab Invest 40:633-644, 1979.


