Cardiac Imaging for Coronary Artery Disease

Rajeev Malhotra, Harvard Medical School Year IV
Gillian Lieberman, MD
Coronary Artery Disease

- Major cause of morbidity and mortality in the U.S.
- 1.2 million MI’s every year
- 600,000 deaths yearly related to CAD
- Cardiac cath and echocardiography both top the list of the amount spent in U.S. health care of all imaging modalities
Modalities

- Angiography
- Nuclear Medicine
- Echocardiography
- MRI
- Conventional CT/Electron beam CT
Cardiac Catheterization -- Indications

- Angina unresponsive to medical management
- Unstable angina
- Angina following MI or CABG
- Asymptomatic patients with high suspicion of CAD (e.g., abnormal EKGs or positive stress tests or numerous cardiac risk factors)
- Patients undergoing surgery for valvular dz
- LV dysfunction of unclear etiology
Cardiac Catheterization -- Contraindications

- Bleeding diatheses
- Advanced age with poor physiology
- Uncontrolled hypertension
- Significant electrolyte abnormalities
- Fever/Infection
- Severe anemia
- Active GI bleeding
- Recent h/o CVA
- Prior contrast reaction
- Significant renal failure or anuria
Right Anterior Oblique

http://info.med.yale.edu/intmed/cardio/imaging/
Left Anterior Oblique

http://info.med.yale.edu/intmed/cardio/imaging/
LAO

http://info.med.yale.edu/intmed/cardio/imaging/
Ventriculogram

http://info.med.yale.edu/intmed/cardio/imaging/
Patient #1: History

• A 49 year old man with 4 hours of chest pain.
• EKG: ST elevation in II, III, aVF, V5 and V6. ST depression in V1 and V2.
• Treatment: aspirin, beta-blockers and thrombolysis.
• Peak CK: 3905, TNI >50
Patient #1
Sent to cardiac cath lab

BIDMC patient, courtesy Dr. Danias
Patient #1 (cont’d)

BIDMC patient, courtesy Dr. Danias
Patient #2: RCA stenosis

http://info.med.yale.edu/intmed/cardio/imaging/
Patient #2: Post-Angioplasty

http://info.med.yale.edu/intmed/cardio/imaging/
Patient #2: post-angioplasty

http://info.med.yale.edu/intmed/cardio/imaging/
Echocardiography

- Regional wall motion abnormalities can be seen within seconds of a coronary artery occlusion (prior to onset of symptoms)
- Localized decrease in amplitude and rate of myocardial excursion
- Excellent negative predictive value for chest pain
Echocardiography

180 patients presenting to emergency room with chest pain

- 169 (94%) had adequate 2DE
  - 60 (36%) No regional or global dysfunction
    - 2 (4%) AMI
  - 22 (13%) Global dysfunction without any RWMA
    - 0 (0%) AMI
  - 87 (51%) RWMA with or without global dysfunction
    - 27 (31%) AMI

Echocardiography to evaluate chest pain in emergency room Flow chart

Circulation 1991 Sep;84(3 Suppl):I85-92
Left Parasternal Long Axis View

http://info.med.yale.edu/intmed/cardio/imaging/
Echo -- Long Axis View

-- Reliable view of the septum and posterior LV wall.

-- Diastolic opening of mitral valve.

-- Systolic opening of the aortic valve

Left parasternal long axis view
(http://info.med.yale.edu/intmed/cardio/echo_atlas/views/index.html)
Short Axis View of the LV

http://info.med.yale.edu/intmed/cardio/imaging/
Short Axis View of the LV

View of the ventricular contractile motion, which should be symmetric.

Good view to focus in on septal or inferior wall defects.

http://info.med.yale.edu/intmed/cardio/imaging/
Short Axis View of the Aortic Valve

http://info.med.yale.edu/intmed/cardio/imaging/
Short Axis View of the Aortic Valve

-- “en face” view of the aortic valve leaflets
-- LA behind aortic root
-- Pulmonary valve opening

http://info.med.yale.edu/intmed/cardio/imaging/
Transesophageal Echo

- High-frequency (5 MHz) ultrasound transducer mounted on the tip of a directable gastroscope-like tube about 12mm in diameter
- Close direct fluid contact with the posterior heart
- Superb images; no interference from lungs
Transesophageal Echo

http://info.med.yale.edu/intmed/cardio/imaging/techniques/echo_tee/index.html
Patient #1 with Inferior MI
Short axis view useful for detecting akinesia in coronary distributions

BIDMC patient
Echo and Valvular Disease

http://info.med.yale.edu/intmed/cardio/imaging/
Echo and Valvular Disease: Aortic Regurgitation

http://info.med.yale.edu/intmed/cardio/imaging/
Cardiac MRI

- Uses high intensity magnetic fields and radiofrequency to generate 3D/tomographic images with high resolution and excellent contrast
Cardiac MR -- Indications

- Carotid artery disease, risk assessment of emboli
- Coronary anomalies
- Aortic aneurysm
- Aortic dissection, intramural hematoma
- Aortitis
- Congenital anomalies
Cardiac MR – Other Applications

• EF assessment
• Valvular disease
• Wall motion abnormalities
• Coronary MRA
Cardiac MR -- Techniques

• **Spin-echo for anatomic imaging** → obtain single static pictures in slices;
  - depicts the tissue structures of the heart as bright and the blood pool as dark
  - For assessing myocardial mass and zones of infarction

• **Gradient echo for functional imaging** → obtain cine loops, multiple images at different phases of the cardiac cycle
  - the blood pool appears as bright and cardiac tissue structure appears dark
  - Used to evaluate ventricular function, valvular lesions, shunts
Cardiac MR – Coronal Slice

http://info.med.yale.edu/intmed/cardio/imaging/
Return to Patient #1 with Inferior MI

Akinesia of antero and infero-lateral LV wall

BIDMC patient, courtesy Dr. Danias
Patient #1: Hyperenhancement seen after Gd-DTPA administration

Diagnosis: Transmural myocardial infarction with a large no reflow zone in the circumflex territory. Confirmed by cath.6
MRI and CAD

- Provides an accurate, 3-D perspective of the heart, with measurements of EF, volume, and mass
- Ischemic territories can be identified by using IV gadolinium for a first-pass perfusion study
- Dobutamine infusion visualize segments that become ischemic (ie, demonstrate reduced motion) during stress
- Direct assessment of coronary plaques
Patient #3: 26-year-old asymptomatic female with normal EKG, echo, and CXR. Patient’s mother died suddenly at age 48 with v-fib.

- Borderline sized LV with good systolic function (LVEF 68%).
- Mildly dilated RV, but with normal function
- On spin echo images, regional enhancement of MR signal intensity in a circumscribed area of the free right ventricular wall (not just coronary fat).

Images courtesy Dr. Danias
Patient #3: Arrhythmogenic RV Dysplasia

- Prevalence: 1 in 5000
- Is a cause of sudden death in the young
- Strong genetic correlation (e.g., prevalent in southern Italy)
- Characterized by ventricular arrhythmias
- Fibrofatty replacement of the RV myocardium
- Approx. 50% have normal EKG upon discovery
- MRI is the tool of choice for diagnosis
Cardiac MR -- Contraindications

- Pacemaker
- Implanted defibrillator
- Aneurysm clips
- Cochlear implants
- Swan-Ganz catheter
- History of recent coronary artery stenting (<6wks)
- Prosthetic valves are safe except for the Starr-Edwards ball valves
Conventional CT and Coronary Artery Calcification (CAC)

- In asymptomatic patients, conventional CT discovered coronary calcification in 29% of men and 19% of women over the age of 40
- Sensitivity: CT showed calcium in 62% of vessels with significant lesions on angiography (Rienmuller et al.)
- 90% of those patients with high calcification detected by CT had significant stenosis on angiography (PPV) (Masuda et al.)
Conventional CT and CAC
Limitations of Conventional CT

- Slow scan times, motion artifacts
- Volume averaging
- Breathing misregistration
- Inability to quantify the amount of plaque
Electron Beam CT

www.vitalimaging.com
Electron Beam CT

- Traditional CT – uses x-ray tube that revolves around patient. Scan times are on the order of 1 second.
- EBCT – uses an electron beam that focuses on tungsten targets beneath the patient, producing x-rays.
Electron Beam CT

- Highly sensitive in detecting coronary artery calcifications
- Can be used as a screening tool in asymptomatic patients
ULTRAFAST CT®

Electron Beam Tomography

- Scan times as fast as 50 and 100 milliseconds
- Three scanning modes
- 1.5, 3, 6 and 10mm scans
- Ability to ECG trigger cardiac images
- High throughput capability

www.vitalimaging.com
CAC Exam

• Only Noninvasive test to detect early CAD

• Only Noninvasive test to:
  – Directly Image Coronary Arteries
  – Quantify Disease Present
  – Institute Measures to Stop Progression
  – Monitor Progression
Examples of Coronary Artery Scans

NO CALCIFICATION

MODERATE CALCIFICATION

SIGNIFICANT CALCIFICATION

Images courtesy of HeartScan San Francisco
DIAGNOSTIC SENSITIVITY

NON-INVASIVE MODALITIES
- STRESS ECG
- STRESS ECHO
- STRESS THALLIUM
- PET SCANNING
- ELECTRON BEAM CT
- INTRAVASCULAR ULTRASOUND
- CORONARY ANGIOGRAPHY

INVASIVE MODALITIES

0% 20% 45% 60% 70% 90%

DEGREE OF STENOSIS

"THE DAWN OF A NEW ERA" - NON-INVASIVE CORONARY IMAGING" R. ERBEL HERZ 1996; 21, 75-77
Agatston Scoring

• Evaluates the area of calcification in sequential images
• Using threshold of 130 HU, a score for each lesion is given:
  \[ \text{AREA (in } \text{mm}^2) \times \text{CO-FACTOR} \]
• Co-factor ranges from 1-4 depending on the HU peak value of the lesion
• Separate scores obtained for left main, LAD, LCx, and RCA
Three-vessel-disease

BIDMC PACS, courtesy Dr. Mastromatteo
Isolated LAD Disease

BIDMC PACS, courtesy Dr. Mastromatteo
When to use EBCT for CAC?

- 1. In the asymptomatic but high-risk patient to assess need for further testing.
- 2. In evaluating equivocal cardiac screening tests, such as stress EKG.
- 3. In evaluating the patient with chest pain in the ED, where a cardiac origin is much less likely in the absence of CAC.
- 4. In influencing therapeutic decisions in patients with hypercholesterolemia.
Other Indications for EBCT

- To evaluate bypass graft patency
- Congenital cardiac lesions
- Quantify ventricular muscle mass, chamber volumes, and function (CO and EF)
EBCT

• **Advantages**
  - Non-invasive
  - Quick
  - Best modality at detecting calcium in vessels
  - Could be used as a screening for CAD (calcium deposition comes well before symptoms arise)

• **Disadvantages**
  - It is still unclear how CAC correlates with risk of significant vessel narrowing
  - Does not detect soft plaques.
EBCT

• EBCT measurement of coronary calcium is of no known value in patients who have already had a heart attack or undergone CABG

• The increased predictive value of EBCT for coronary disease relative to traditional risk factor assessment isn't yet completely defined.
Acknowledgements

- Dr. Peter Danias
- Dr. Michael Mastromatteo
- Larry Barbaras our Webmaster
- Gillian Lieberman, MD
- Pamela Lepkowski
- And special thanks to Griffin Weber
References

- BIDMC PACS
- www.medscape.com
- Lecture on Cardiac MR by Dr. Peter Danias, BIDMC, July 2003.
- http://info.med.yale.edu/intmed/cardio/imaging/
- www.uptodateonline.com
- www.scmr.org
- www.vitalimaging.com
- Circulation 1991 Sep;84(3 Suppl):I85-92