Multimodality Imaging and Heart Disease

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Disclosures: None

Objectives

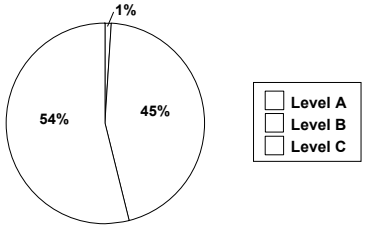
- Introduction
- Different imaging modalities and their strengths/weaknesses
- Incorporation of multi-modality imaging in different clinical indications
- Appropriateness criteria
- Conclusions

Introduction

- CVD: biggest source of morbidity and mortality
- Many new imaging technologies
- Advances in imaging outpacing our ability to digest the changes
- Cost, risks, what to do with the information?
  - In 2009, CCF did more than 61000 echoes, 7500 CTs and 2500 CMR's

Imaging and Real Data: A Major Disconnect

- ACC/AHA guidelines:
  - 750 recommendations related to cardiac imaging



Some sobering information !!!!!!

Recent data shows that only 38 % coronary angiographies were clinically indicated

Patel: NEJM 2010

Different Noninvasive imaging modalities

- **Echocardiography**
  - **Mainstay of noninvasive CV diagnosis**
- **Myocardial perfusion scintigraphy**
  - **SPECT, PET**
- **Cardiac magnetic resonance**
- **Cardiac computed tomography**

Utility and Limitations

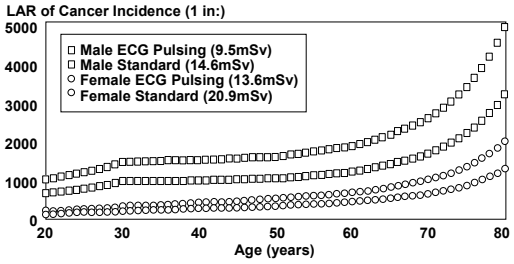
Imaging technique	Potential diagnostic utility	Limitations
Echo	* LV thickness * valves and hemodynamics •global and regional LV function * Ischemia * Viability	* Limited acoustic windows * Inaccurate wall thickness measurements * Suboptimal assessment of subvalvular apparatus
MPI	* Ischemia *Viability * coronary flow reserve (PET)	* Limited availability (PET) * Expensive (PET) * High radiation exposure
CMR	•LV dimensions •Cardiac morphology * Tissue characterization * Regional myocardial mechanics * Aortic pathology	* Limited availability * Multiple device-related contraindications
MDCT	* CAD, •LV function and morphology •Emerging role in viability •Aortic pathology	* Radiation exposure •Nephrotoxicity •Emerging data

Radiation Doses for Medical Procedures

Diagnostic procedure	Typical effective dose (mSv)	Equivalent period of natural background radiation
Natural background radiation	3-4 (range 1.5-7.5)	1 year
Chest X-ray (PA and lateral)	0.04	6 days
Transatlantic flight	0.03	5 days
Lung perfusion study (99m Tc)	1	4-6 months
Calcium scoring	0.8-2	3-6 months
CT head	2	8 months
Cardiac catheterization (diagnostic)	3-4	1 year
64-slice MDCT (with dose modulation)	Male: 4.8-10 Female: 6.8-14	2-3 years
CT angio prospective	2-4	1 year
Rb-82 PET myocardial perfusion	16	4-5 years
Tl-201 stress and reinjection	25.1	6-8 years
Dual isotope (Tl-201 and Tc-99m)	27.3*	7-9 years

* Thompson RC, Cullom SJ. J Nucl Cardiol 2006;12:19-23.

Lifetime Attributable Cancer Risk



Einstein A, JAMA 2007

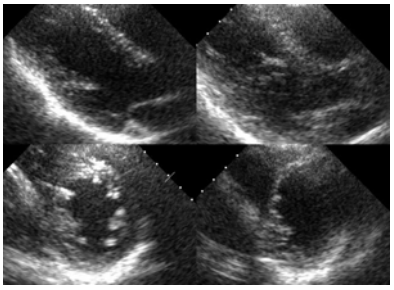
Noninvasive Diagnostic Testing in Ischemic Heart Disease

Anybody wonder why CAD is such an epidemic ?

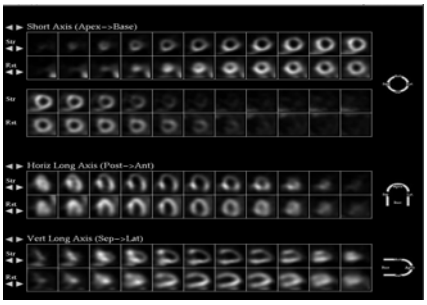
Different Stress Testing Modalities

- **Exercise**
  - **Treadmill (either with echo or nuclear)**
  - **Sitting bicycle**
  - **Supine bicycle**
- **Pharmacological**
  - **Dobutamine-- Contractility and HR increase (either with echo, nuclear or CMR)**
  - **Dipyridamole – vasodilating (mostly nuclear)**
  - **Adenosine – vasodilating (mostly nuclear, CMR, ?? CT is emerging)**

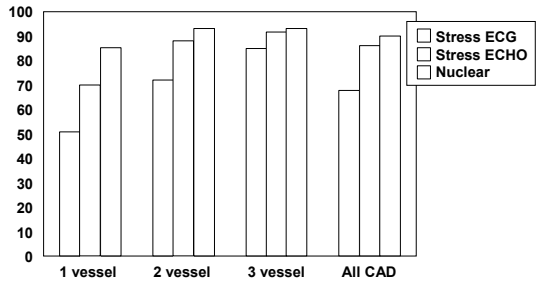
Exercise echocardiography



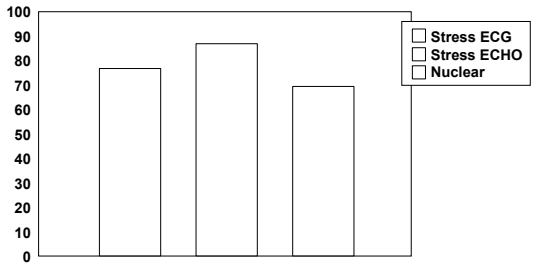
Stress MPI



Sensitivity Comparison of Different Testing Modalities



Specificity of Different Stress Testing Modalities



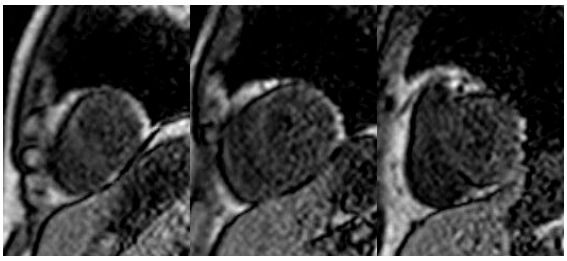
NUCLEAR TECHNIQUES MORE SENSITIVE BUT LEAST SPECIFIC

Comparison between SPECT (^{201}Tl and ^{99m}Tc) and PET-^{82}Rb

	SPECT	PET
« excellent » images	62%	78%
Interpretation certainty (normal,abnormal)	81%	96%
Diagnostic accuracy	71%	87%

Bateman T.M. et al J Nucl Cardiol 2006; 13: 24-33

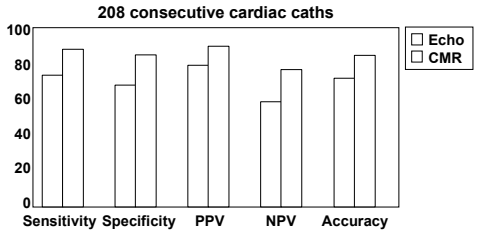
Adenosine MRI



Adenosine stress MRI: Sensitivity 100%
Specificity 93%

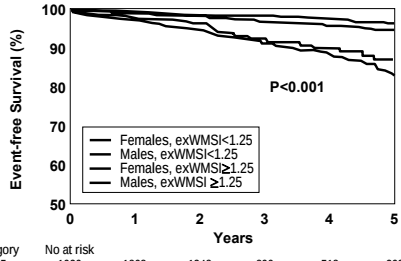
Arai JACC 2006

Dobutamine Echo vs. CMR



Nagel et al. Circ 1999;99:763-70

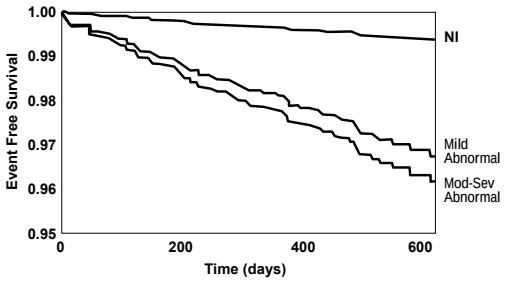
Stress Echo and Prognosis



Category	No at risk					
F<1.25	1929	1808	1348	890	518	299
M<1.25	1945	1783	1376	920	568	321
F≥1.25	538	457	327	210	120	63
M≥1.25	1372	1104	846	551	345	199

Arruda-Olsen et al JACC 2002

Prognostic Value of SPECT
Patients with Normal ECG

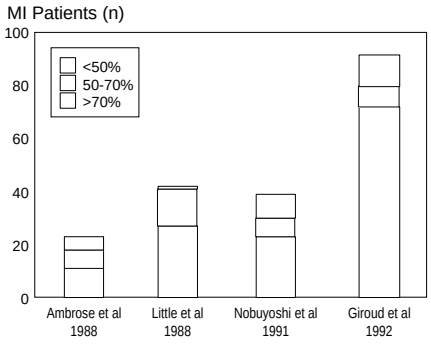


Hachamovitch et al. Circulation 2002;105(7):823-829

But life is not that simple

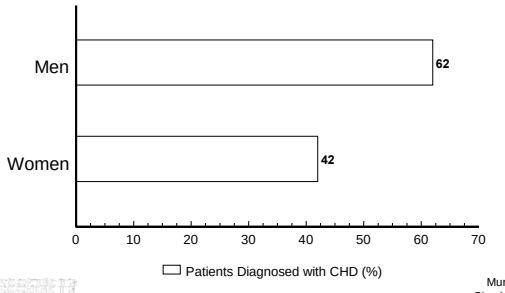
Quest to search for the "predisposed" patient

MI and Severity of Stenosis



Adapted from Falk et al. *Circulation*. 1995;92:657-671.

MI or SCD as Initial Presentation of CHD

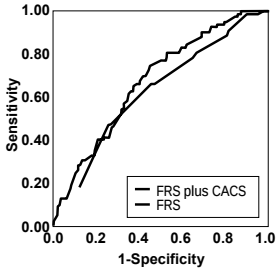


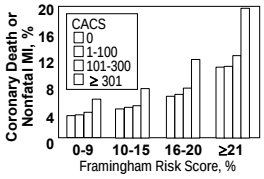
Murabito et al
Circulation 1993

Coronary Calcium Scoring

Possibly indicated in asymptomatic individuals with intermediate Framingham risk score

Coronary Calcium & Framingham Risk Score





- **Prospective study**
- **N=1461**
- **Mean f/u 7.0 years**
- **84 pts AMI or CHD death**

Greenland P, et al. JAMA. 2004 14;291(2):210-5

MDCT Coronary Angiography

- **Diagnostic utility in patients with intermediate likelihood of CAD**
- **High number of unnecessary invasive procedures†:**
  - **40% of women**
  - **20-25% of men**
  - **? potential in patients to exclude CAD**

†Kugelmass AD. J Am Coll Cardiol 2001;37:497A*

Meta-Analysis of MDCT for Coronary Artery Stenosis ≥ 16 Slice

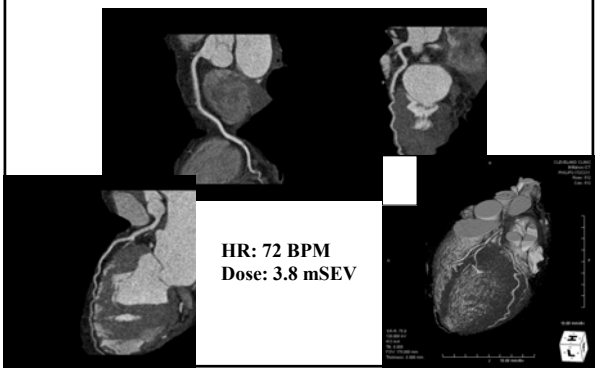
•27 studies with ≥ 16 slice CT between 2002-2006

Analysis	N	Sensitivity (95% CI)	Specificity (95% CI)	LR + (95% CI)	LR - (95% CI)	DOR (95% CI)
Per segment	22,798	0.81 (0.72-0.89)	0.93 (0.90-0.97)	21.54 (13.07-35.48)	0.11 (0.06-0.21)	189.32 (93.47-383.43)
Per vessel	2726	0.82 (0.80-0.85)	0.91 (0.90-0.92)	11.80 (6.75-20.64)	0.08 (0.02-0.32)	146.45 (31.95-671.21)
Per patient	1570	0.96 (0.94-0.98)	0.74 (0.65-0.84)	5.36 (3.45-8.33)	0.05 (0.03-0.09)	133.05 (57.29-308.98)

STRENGTH IS HIGH SENSITIVITY AND NEGATIVE PREDICTIVE VALUE

Hamon M. J Am Coll Cardiol 2006; 48:1896-1910

Case: 48-year old female presenting to ER with recurrent chest pressure. EKG and enzymes negative. Smoker, hypertensive. Underwent 256-slice coronary CT angiography



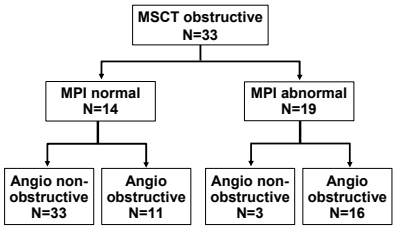
HR: 72 BPM
Dose: 3.8 mSEV

Advanced CAD

Heavily calcified 3-vessel CAD

Noncalcified plaque in proximal LAD

Correlation of Coronary CT and Perfusion

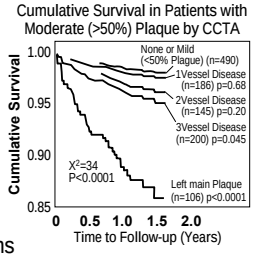


Stenoses in CT not closely correlated to an abnormal MPI

Schuijf et al, JACC 2006

Outcomes after MDCT >50% stenosis

CCTA Result	Risk Adjusted Hazard Ratio (95% CI)	P value
Any severe stenosis	2.14(0.95-4.81)	0.07
Moderate or severe coronary stenosis (per seg)	1.05(1.02-1.09)	<0.01
Any severe proximal stenosis	1.44(0.74-2.81)	NS
Any left main stenosis	2.65(1.37-5.12)	<0.01
Segment involvement score (per seg involved)	1.16(1.05-1.28)	0.004
Three vessel coronary plaque, any severity	2.04(0.99-4.20)	0.05

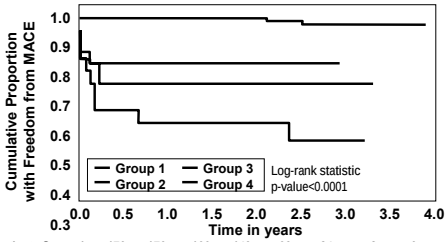


- N = 1127- patients with symptoms
  - 70% with intermediate or high pretest probability
- Endpoint: Death – by Social Security Death Index

Min et al. J Am Coll Cardiol 2007;50:1161-70

Prognostic Utility of MDCTA

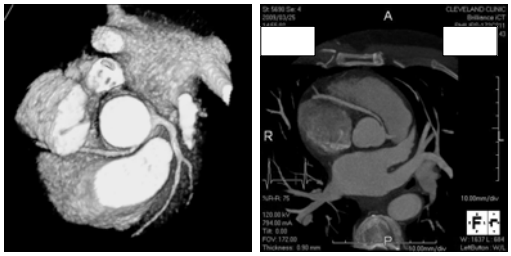
227 patients with no documented CAD had 64-MDCTA with 2.5 years f/u



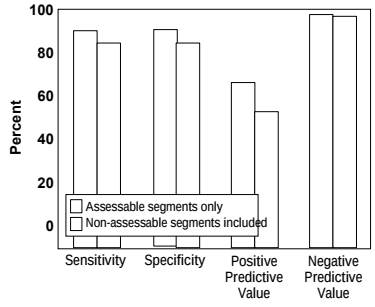
Number of patients at risk of events									
	Group 1	170	170	166	149	69	24	2	0
	Group 2	19	19	19	17	6	0	0	0
	Group 3	9	9	9	9	5	4	0	0
	Group 4	13	12	12	12	6	3	0	0

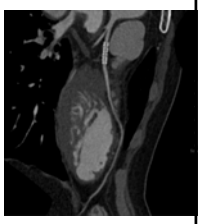
Desai MY. European Heart Journal Jan 2009

Coronary Anomalies



MSCT for Coronary Stent Assessment: A Meta-analysis

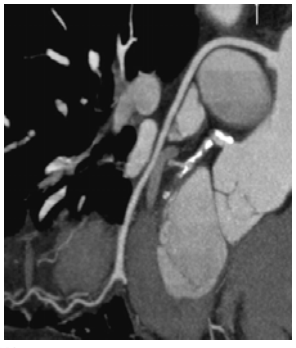


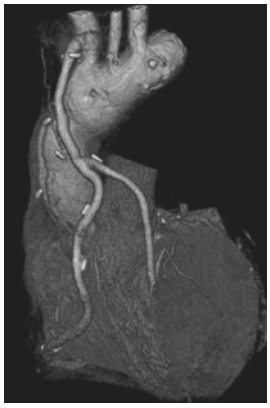


MSCT not good for stents < 2.5 mm in size

Desai MY. AJC 2009

Bypass Grafts





Diagnostic Accuracy of CT for CABG Evaluation: A meta-analysis

Analysis Type and No. of Studies (n=15)	No. of Grafts	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)
Graft obstruction, 15	2023	97.6 (96.0,98.6)	96.7 (95.6,97.5)	92.7 (90.5,94.6)	98.9 (98.2,99.4)
16-section, 9	1047	96.9 (94.2,98.6)	96.4 (94.8,97.6)	91.3 (87.6,94.2)	98.8 (97.7,99.4)
64-section, 6	976	98.1 (96.0,99.2)	96.9 (95.2,98.1)	94.1 (91.0,96.3)	99.1 (98.0,99.7)
Occlusion, 10	1308	99.3 (97.3,99.9)	98.7 (97.9, 99.3)	95.4 (92.2,97.5)	99.8 (99.3,100)
Stenosis, 9	871	94.4 (87.5,98.2)	98.0 (96.7,98.8)	84.2 (75.6,90.7)	99.4 (98.5,99.8)

Hamon M. Radiology 2008; 247 (3): 679-86

Role in Pre-op Planning before Redo OHS

- **In patients undergoing redo OHS CT helps to assess**
  - **Location of prior grafts**
  - **Distance of grafts from sternum**
  - **Patency of grafts**
  - **Proximity of right sided cardiac structures**
  - **Proximity of aorta**
  - **Degree of ascending aortic calcification**
- **Necessary to adopt preventive surgical strategies**

Kamdar A, Desai M. ATS April 2008

Inappropriate Indications for CT

Indication	Appropriateness Criteria (Median Score)
Detection of CAD: Symptomatic-Evaluation of Chest Pain Syndrome (use of CT angiogram)	
• High pre-test probability of CAD	I (2)
Detection of CAD: Symptomatic-Acute Chest Pain (use of CT angiogram)	
• High pre-test probability of CAD	I (1)
• ECG-ST-segment elevation and /or positive cardiac enzymes	
Detection of CAD: Asymptomatic (without chest pain syndrome)-Asymptomatic (use of CT angiogram)	
• Low CHD risk (Framingham risk criteria)	I (1)
• Moderate CHD risk (Framingham)	I (2)
Risk Assessment: General Population-Asymptomatic (Calcium scoring)	
• Low CHD risk (Framingham)	I (1)
Detection of CAD with Prior Test Results-Evaluation of Chest Pain Syndrome (use of CT angiogram)	
• Evidence of moderate to severe ischemia on stress test (exercise, perfusion, or stress echo)	I (2)
Risk Assessment with Prior Test Results-Asymptomatic (Calcium Scoring)	
• Prior calcium score within previous 5 years	I (1)

Hendel RC et al. JACC September 2006

Appropriate Indications for CT

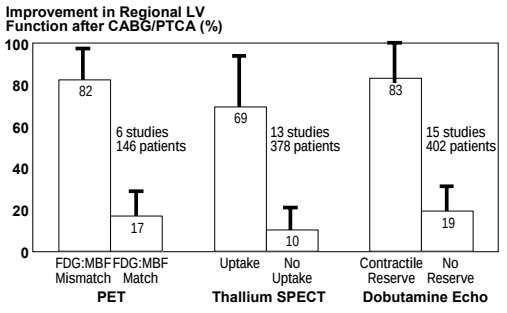
Indication	Appropriateness Criteria (Median Score)
Detection of CAD: Symptomatic - Evaluation of Chest Pain Syndrome (use of CT angiogram)	
• Intermediate pre-test probability of CAD	A (7)
• ECG uninterpretable OR unable to exercise	
Detection of CAD: Symptomatic - Evaluation of Intra-Cardiac Structures (use of CT angiogram)	
• Evaluation of suspected coronary anomalies	A (9)
Detection of CAD: Symptomatic - Acute Chest Pain (use of CT angiogram)	
• Intermediate pre-test probability of CAD	A (7)
• No ECG changes and serial enzymes negative	
Detection of CAD with Prior Test Results - Evaluation of Chest Pain Syndrome (use of CT angiogram)	
• Uninterpretable or equivocal stress test (exercise, perfusion or stress echo)	A (8)
Structure and Function-Morphology (use of CT angiogram)	
• Assessment of complex congenital heart disease including anomalies of coronary circulation, great vessels, and cardiac chambers & valves	A (7)
• Evaluation of coronary arteries in patients with new onset heart failure to assess etiology	A (7)

Imaging Assessment of Myocardial Viability

Definitions

- **Stunned Myocardium**
  - Acute MI
  - Decreased function
  - Normal blood flow
  - Has the potential to recover function
- **Hibernating Myocardium**
  - Reduced contraction at rest
  - Chronically reduced blood flow
  - Function can improve after revascularization
- **Nonviable Myocardium**
  - Cell death of myocytes and replacement of myocytes by fibrosis or scar tissue
  - Lack of recovery of normal function after revascularization

Viability Imaging and Functional Improvement

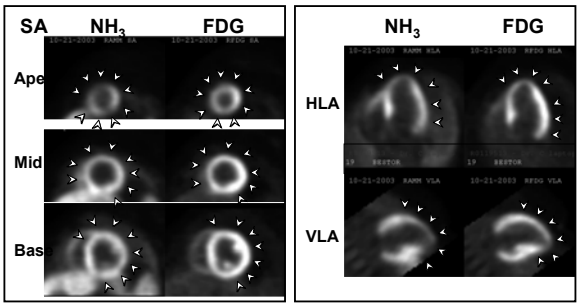


Kloner et al, Circulation 1998; 97:1848

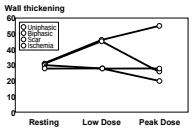
Methods for Assessing Viable Myocardium

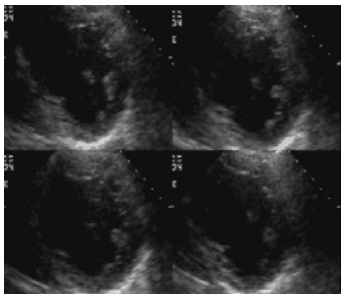
- **Assessment of myocardial metabolism/Cell integrity/perfusion: nuclear techniques**
- **Assessment of extent of necrosis: MRI**
- **Contractile reserve: dobutamine echo**

Viability PET



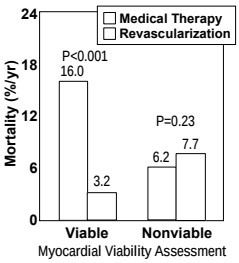
Biphasic Response of viability in dobutamine echo





Late Survival with Revascularization Versus Medical Therapy for Patients with CAD and LV Dysfunction

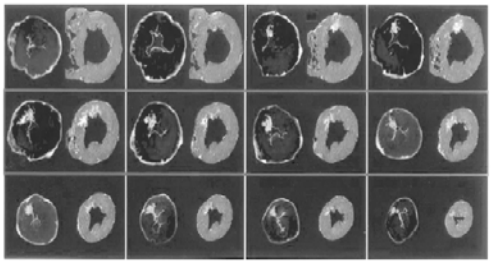
- Meta-analysis
- 24 studies (n=3088)
- Revascularization vs. med Rx associated with a reduction in mortality in patients with viability
- No advantage in patients without myocardial viability



Allman KC et al. J Am Coll Cardiol 2002;39:1151-1158

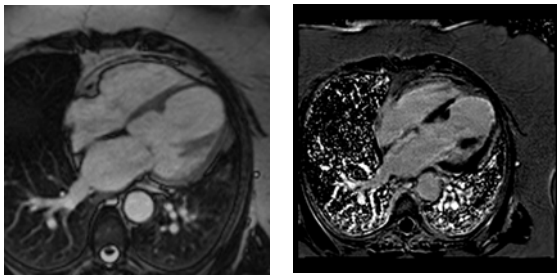
CMR assessment of viability: combination of function, stress and scar assessment

- Scar appears bright against a backdrop of dark normal myocardium on special sequences

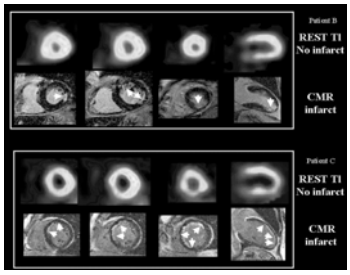


Kim R. Circulation 1999;100:1992–200

CMR and viability



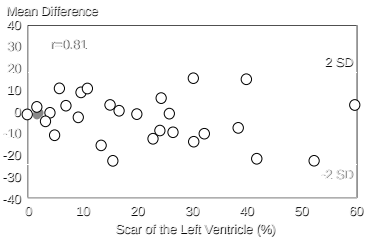
DHE-MRI vs. SPECT



DHE-MRI has ~ 10 fold greater spatial resolution than SPECT

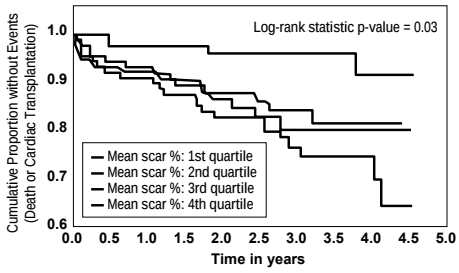
MRI versus PET

- **Good agreement between DHE-MRI and PET for detecting viability**
- **However, 11% segments deemed viable by PET showed a scar by MRI**



Klein C et al. Circulation 2002 Jan 15:105(2):162-7

Extent of Scar on MRI and Prognosis



Kwon D, Desai MY et al. JACC Imaging

Guidelines for Stress and Viability Testing

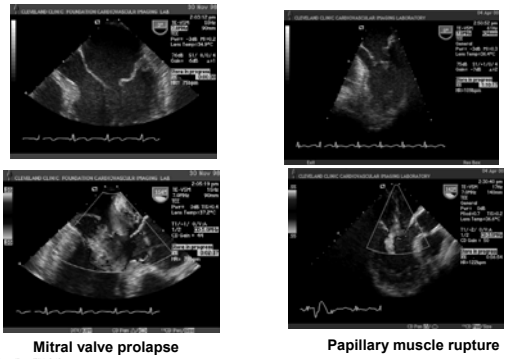
- Class I
  - Diagnosis of myocardial ischemia in symptomatic patients.
  - Hibernating myocardium
  - For targeted intervention
  - Assessment for restenosis after revascularization in patients
  - With atypical recurrent symptoms.
- Class IIA
  - After revascularization in patients with typical recurrent symptoms.
  - In patients unable to exercise or in whom ECG is less reliable
  - After cardiac transplantation.
  - In women with intermediate pretest likelihood of CAD
- Class III
  - Asymptomatic persons with low likelihood of CAD
  - Routine periodic reassessment of stable patients for whom no change in therapy is contemplated
  - Routine reassessment of asymptomatic patients after revascularization

Circulation. 2008 Mar 18;117(11):1478-97

Valvular heart disease

- Echo remains the primary diagnostic modality for valvular heart disease
- CMR for accurate LV volumetric assessment
- Emerging role of MDCT in planning prior to percutaneous valve procedures

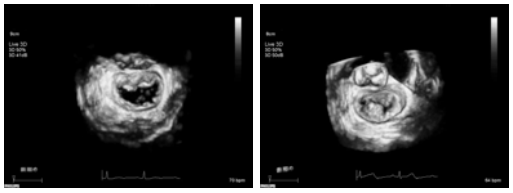
Different Etiologies of MR



Mitral valve prolapse

Papillary muscle rupture

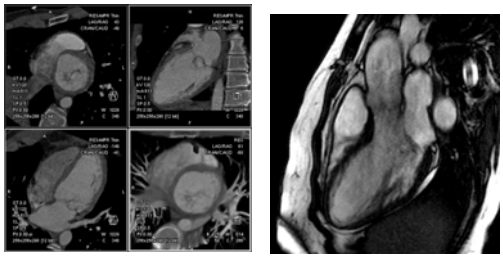
3D echo



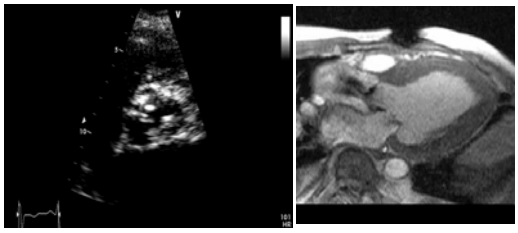
Normal mitral valve from LA

Mitral valve with P2 flail from LA

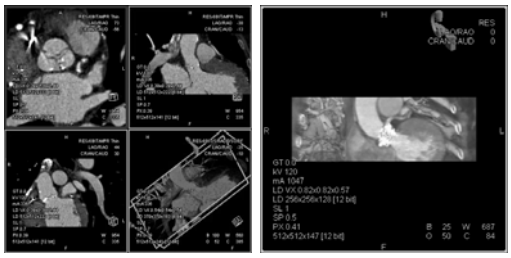
CT and CMR and mitral valve morphology



Aortic valve disease



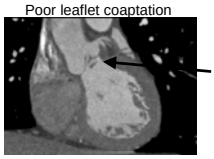
Aortic valve



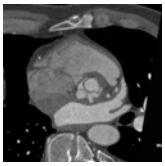
SBE and ring abscess:

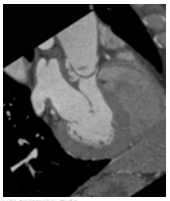
AI with poor leaflet coaptation

Poor leaflet coaptation



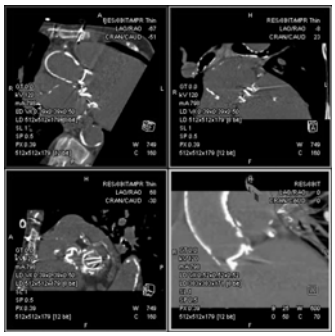
Vegetation





No significant coronary artery disease therefore coronary arteriography deferred

Prosthetic Valves

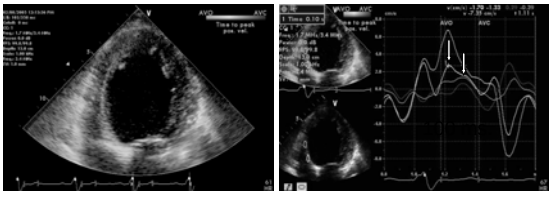


Role of Imaging in Electrophysiology

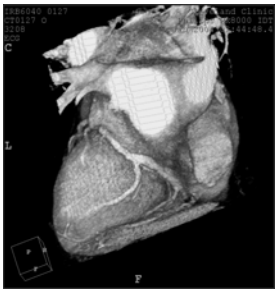
CRT Applications
A Fib applications

Echo techniques and CRT

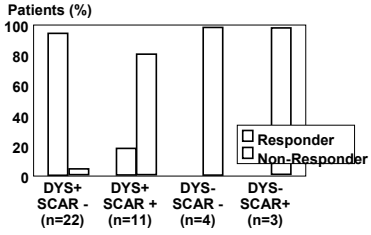
- **Septal to Posterior Wall Mechanical Delay (SPWMD) - M-mode**
- **Tissue Doppler Imaging (TDI)**
  - **PW TDI**
    Time to onset or peak systolic myocardial velocities
  - **Color TDI**
    Time to peak systolic myocardial velocities

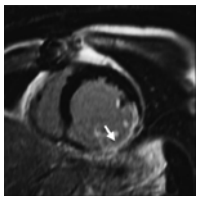


CT and Cardiac Veins



CMR Scar Location and Response to CRT

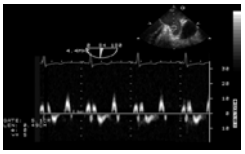


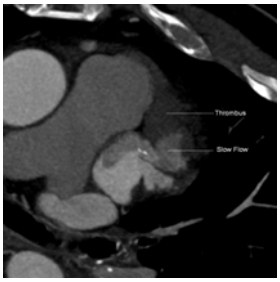


- 14 patients had a transmural scar in the posterolateral region and 26 did not
  - 81 % in the no scar group vs. 14 % in the scar responded to CRT ($p < 0.01$)

Bleeker GB et al. Circulation 2006;113:969-76

Atrial Fibrillation and Imaging





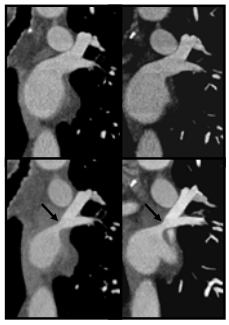
MDCT Sensitivity, specificity and NPV 92, 91 and 98 %

Kim Y and Desai MY et al. AHJ 2007

Pulmonary veins and Imaging

PRE-PVI

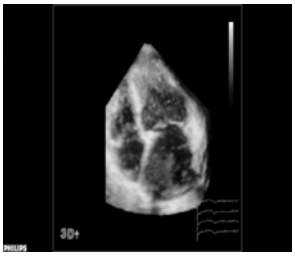
POST-PVI
[93 DAYS]



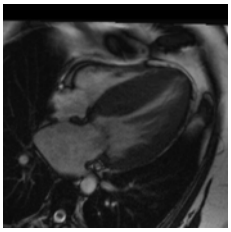
Imaging and Cardiomyopathies

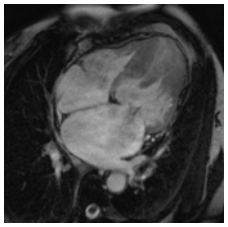
- Echo is first line modality
- CMR is widely gaining prominence
  - Tissue characterization is key
- Emerging role of MDCT

Hypertrophic CMP: Echocardiography



Cardiac Magnetic Resonance

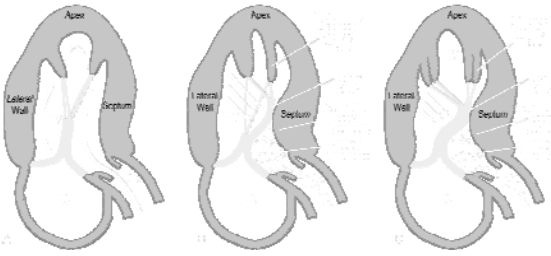




In 6 % patients, CMR accurately diagnosed HCM missed on echocardiography

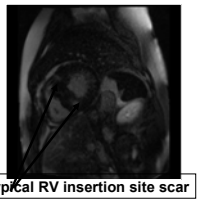
Rickers et al. Circulation 2005;112:855-61
Spirito P et al. N Engl J Med 342: 1778–1785

Abnormal Papillary Muscles and Dynamic LVOT Obstruction

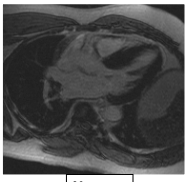


Kwon D, Desai MY et al. Heart August 2007

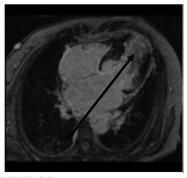
CMR, Fibrosis and HCM: No specific pattern

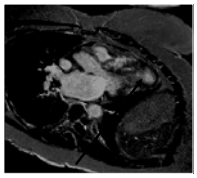


Typical RV insertion site scar

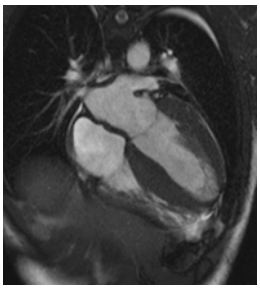


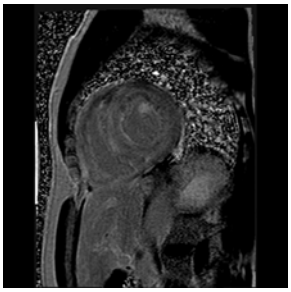
No scar





Amyloidosis



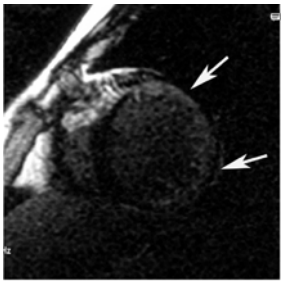


Cox Proportional Hazard Analysis

Variable	χ^2	p value
DHE-CMR Positive	4.91	0.03
Age	3.8	0.05
NYHA Class	3.3	0.07
Low voltage on ECG	0.67	0.41
Interventricular septal thickness	1.7	0.19
E/E' > 15 on Doppler echocardiography	1.12	0.29
Deceleration time on Doppler echocardiography ≤ 150 msec	1.41	0.23
Myocardial performance index	2.10	0.15
Diastology grade	0.35	0.55

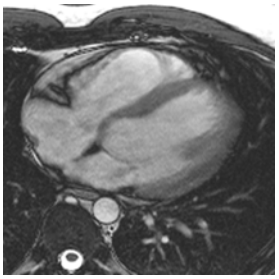
Austin B, Desai MY: JACC 2009

Myocarditis



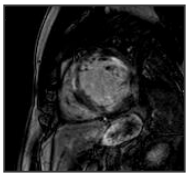
Marholdt et al. 2004. Circulation 109:1250-8

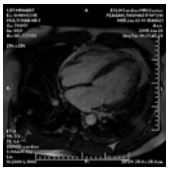
ARVD



Bluemke et al. Cardiology. 2003. 99;153-62

Sarcoidosis





- Normal or impaired LVEF
- Edema around granulomas
- Patchy DHE
  - Usually basal-mid anteroseptal and basal lateral segments
- Sens 100%, spec 78% in 58 patients

Smedema JP. JACC 2005;45:1683-90.

Assessment of the Pericardium

Echocardiography remains the initial modality of choice

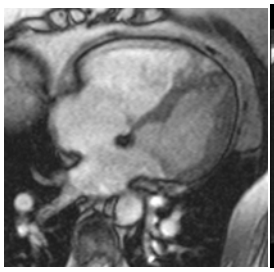
Constrictive pericarditis

Associated with pericardial thickening, calcification, tethering, diastolic septal bounce, conical deformity of the ventricles

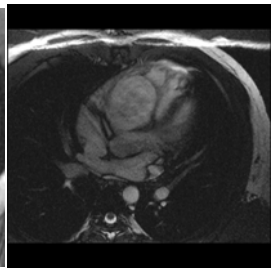
Congenital Heart Disease

Echo is a first start, but tomographic imaging is vital

ASD

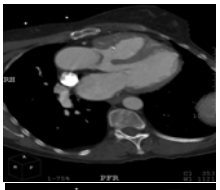


Secundum ASD



Sinus venosus ASD

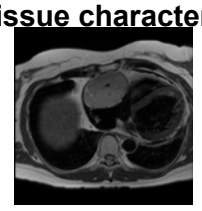
Tetralogy of Fallot



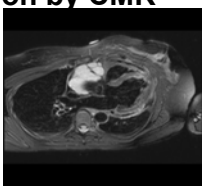
Cardiac masses

- **Echo is mainstay of initial diagnosis**
  - **In classic benign lesions, might not need anything else (eg. myxoma, papillary fibroelastomas etc)**
- **However, multimodality imaging (CMR +/- CT) generally very useful**
  - **Evaluate for satellite lesions**
  - **Tissue characterization**
  - **Extracardiac involvement**

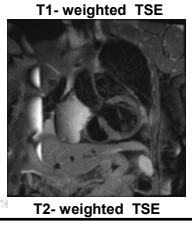
Tissue characterization by CMR



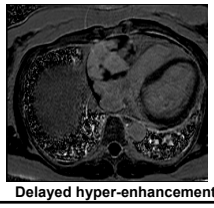
T1- weighted TSE



Fat sat TSE



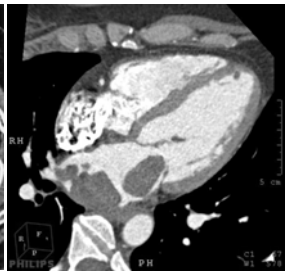
T2- weighted TSE



Delayed hyper-enhancement

MSCT in Cardiac Masses

Intramascular Lipoma



Spindle cell carcinoma

Appropriate Indications for CT and CMR in Structural heart disease

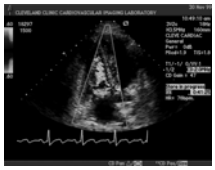
Structure and Function-Evaluation of intra- and extra-cardiac structures

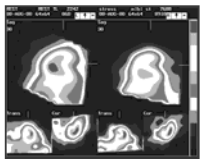
• Evaluation of cardiac mass (suspected tumor or thrombus) • Patients with technically limited images from Echo or TEE	A (8)
• Evaluation of pericardial conditions (pericardial mass, constrictive pericarditis, or complications of cardiac surgery)	A (8)
• Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation	A (8)
• Noninvasive coronary vein mapping prior to placement of biventricular pacemaker	A (8)
• Noninvasive coronary arterial mapping, including internal mammary artery prior to repeat cardiac surgical revascularization	A (8)

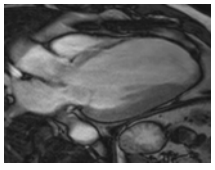
Structure and Function - Evaluation or Aortic and Pulmonary Disease)

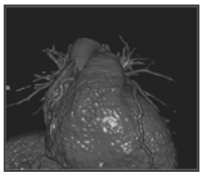
• Evaluation of suspected aortic dissection or thoracic aortic aneurysm	A (9)
• Evaluation of suspected pulmonary embolism	A (9)

How Does all This Work Politically??

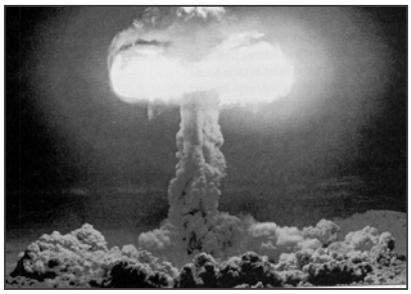








Manhattan Project



Conclusions

- **Multi-modality cardiac imaging has a potential diagnostic role in every facet of cardiovascular medicine**
  - **Extremely vital in ischemic heart disease; reduce number of invasive procedures**
  - **Emerging important role in EPS**
  - **Non-coronary cardiovascular evaluation**
- **JUST HAVE TO KNOW WHEN TO USE, HOW TO US AND MORE IMPORTANTLY WHEN NOT TO USE**
- **Collaboration between cardiology and radiology is key**