

## **Advanced Cardiac Imaging for the General Practitioner**

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## **Outline**

- Intro to cardiac imaging/stress testing. Advanced imaging modalities MRI/CT
- Overview of indications and contraindications to cardiac MRI
  - Patient selection
  - Stress Testing with CMR
  - Video for treadmill CMR
- Overview of indications and contraindications to cardiac CT
  - Difference between Calcium score and CTA
  - Patient selection for CTA/calcium score
  - Clinical case for calcium score

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## **Introduction to Cardiac MRI**

- Allows for assessment of anatomical structures in any plane
- Functional information (quantitative)
  - Ventricular function (left and right)
  - Intracardiac shunt assessment
  - Stenotic lesions
- Infiltrative diseases/fibrosis
  - Viability
  - ARVD
  - Sarcoid, Amyloid
- Vascular imaging (aorta)

## Cardiac MRI Clinical Applications

- Ischemic Evaluation: Adenosine, dobutamine or treadmill stress testing
- Viability assessment: prior to revascularization
- Cardiomyopathy assessment
  - Biventricular function assessment
  - Ischemic/non-ischemic/infiltrative
  - Risk for Sudden Cardiac Death
  - Response to cardiac resynchronization therapy

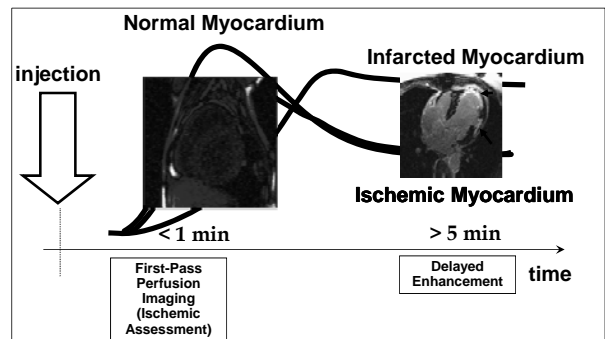
## Additional Clinical Applications

- Congenital Heart Disease
- Aortic Evaluation
- Intracardiac Mass Evaluation
- Pericardial Disease

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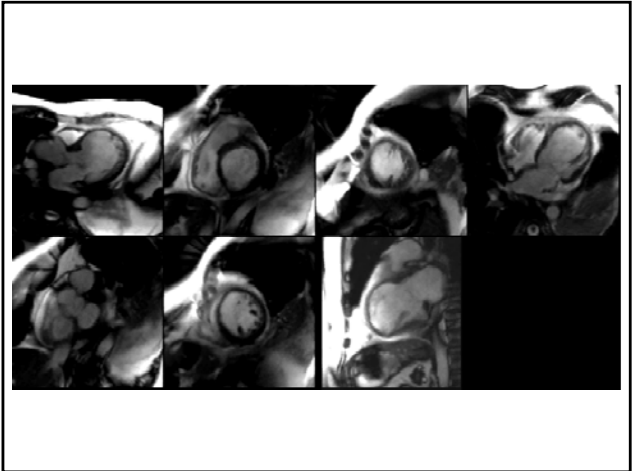
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## Gadolinium Contrast: Two Phases of Myocardial Enhancement



## Patterns of Hyperenhancement

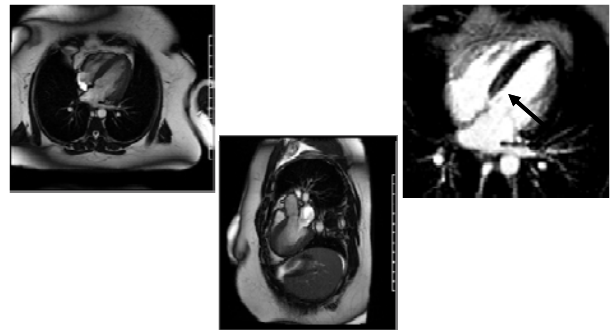
- Transmural
  - Involves entire wall
  - Consistent with myocardial infarction/ischemic event
  - If more than 50% of wall involved, felt to be non-viable
- Non-transmural
  - Endocardial, epicardial, mid-wall
  - Non-ischemic myopathies, infiltrative diseases



## DME: LAD-territory infarct scar



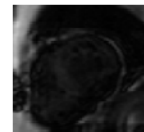
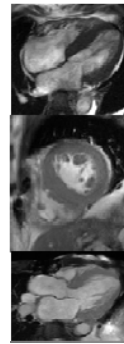
## Mid-Myocardial Hyperenhancement



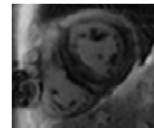
## Infiltrative Cardiomyopathies

- Myocardial biopsies subject to sampling error
- CMR 'samples' the entire myocardium
- Sarcoidosis
- Amyloidosis
- Hemochromatosis
- Chagas disease
- Gaucher's disease, Anderson-Fabry disease, etc.

## Cardiac Amyloid



DME TI Scout



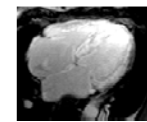
DME TI  
70msec



Congo red

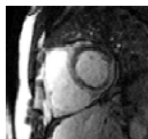


Polarized light  
with congo red

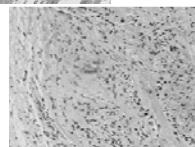
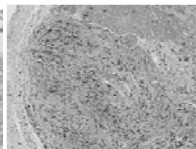
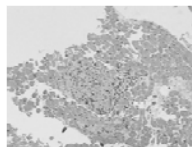


DME TI 200msec

## Myocarditis: Giant Cell



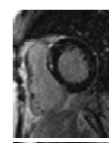
DME with extensive  
epicardial  
hyperenhancement



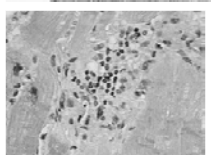
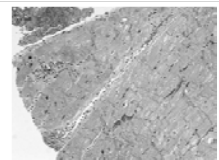
## Myocarditis



CMR Cine  
Images



Markedly abnormal  
DME-CMR



Small focus of  
mononuclear cells

## Limitations of MRI

- Long acquisition times
  - 45-60 min
- Most imaging sequences require breath holding
  - 10-30 sec breath holds per image sequence
  - 10-16 images required to image entire heart
- Contraindications to MRI
  - Pacemakers/ICDs
  - Any ferrous material within body
  - CKD→Nephrogenic systemic fibrosis (NSF)

## Nephrogenic Systemic Fibrosis (NSF)

- Diffuse systemic fibrosis involving skin, skeletal muscle, GI tract, cardiovascular system
  - Skin lesions symmetrical and extend distal to proximal
- After the administration of gadolinium in patients with renal failure (GFR<60)
  - No cases reported in patients with GFR >30
- Diagnosis: skin biopsy
  - Lab testing non-specific
- Treatment supportive
  - Restore renal function (HD not effective once patient develops NSF)
  - Pain management
- For further questions, refer to OSU Radiology Departmental website on OneSource

## Overview of Cardiac MRI Stress Testing

- Pharmacologic
  - Adenosine/Regadenoson
  - Dobutamine
- Exercise (Treadmill)
  - Functional data
  - NIH supported research at Ohio State



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**Sharon Roble, MD**

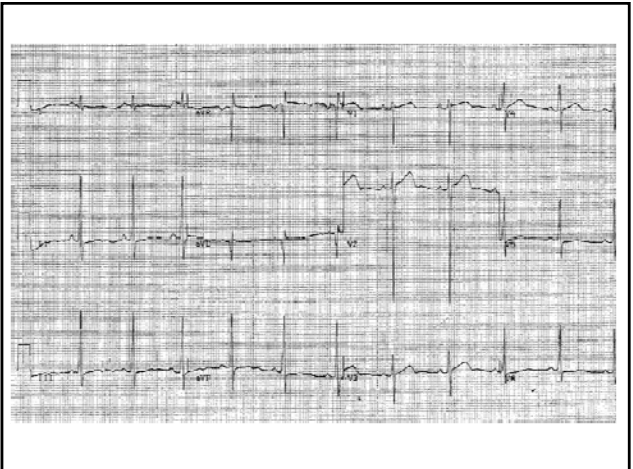
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## Clinical Case 1

- 16 year-old asymptomatic basketball player
- ROS: no syncope, palpitations, DOE, etc.
- PMH: negative
- FH: unremarkable

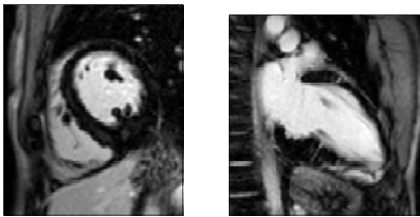
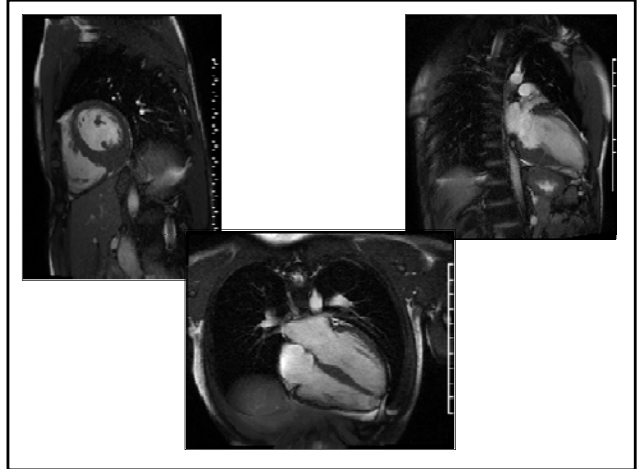
## Physical Examination

- Height 182 cm, weight 71 kg
- BP 118/54, HR 45-60
- Symmetric pulses
- II/VI SEM at LUSB, no positional change
- Rest of PE unremarkable



## Diagnostic Testing

- Normal echocardiogram ('1cm LV walls')
- Because of abnormal ECG, patient referred for cardiac magnetic resonance
- CMR exam included:
  - 3D cine
  - Post-gad DME for scar/infiltrate
  - Non-contrast MRA for coronary artery origins/ prox course and aorta

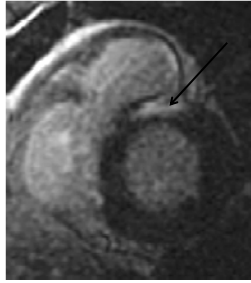


## Clinical Case 2

- 36 y/o African-American male with palpitations, near-syncope
- PMH: sarcoidosis
- PE, echocardiogram unremarkable

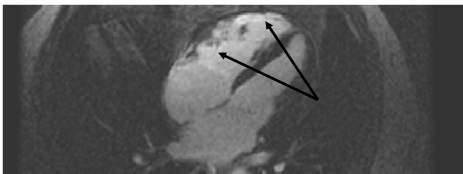


- CMR to assess myocardium



## Clinical Case 3

- 42 y/o male with atrial fibrillation refractory to drug therapy
- FH: no known cardiovascular disease
- PE: unremarkable
- Echocardiogram: low-normal EF
- CMR exam to delineate pulmonary veins pre-ablation



**Dx: arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D)**

**Change in management:**

- RFA plus ICD placement
- Screening of family members

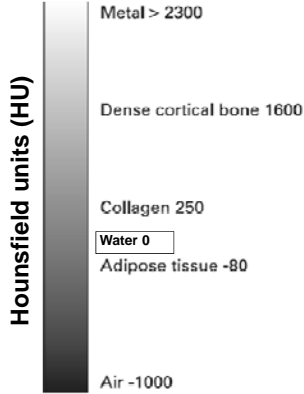
## Introduction to Cardiac CT

- Calcium scoring
  - No contrast
  - Primarily for risk stratification
- Coronary angiography
  - Contrast administered
  - Calcium scoring typically done with this study
  - Symptomatic patient with low to intermediate risk for CAD
  - Symptomatic with indeterminate stress test
  - Coronary artery anomalies



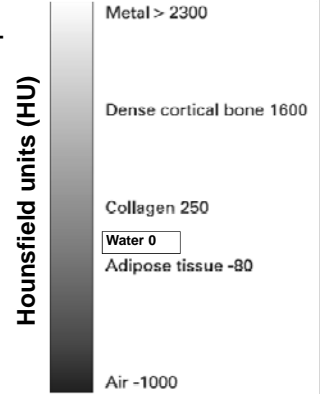
## Calcium Scoring

- Calcium has high signal intensity in CT; based on x-ray attenuation relative to water
- Threshold for calcium scoring typically 130
- Agatston score: weighted sum of HU over slices covering the heart
- Calcification is one aspect of atherosclerosis
- Calcium score indicates:
  - Plaque burden? Yes
  - Luminal stenosis? No



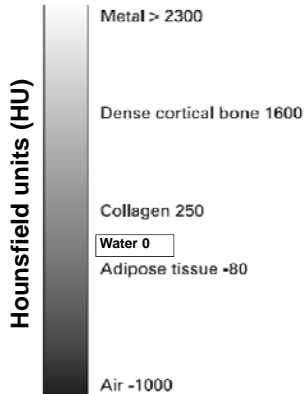
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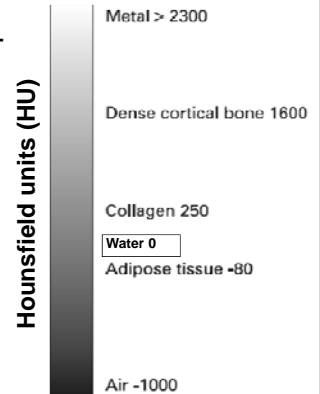
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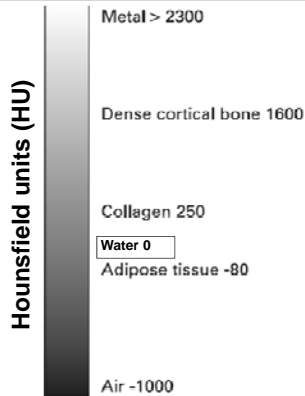
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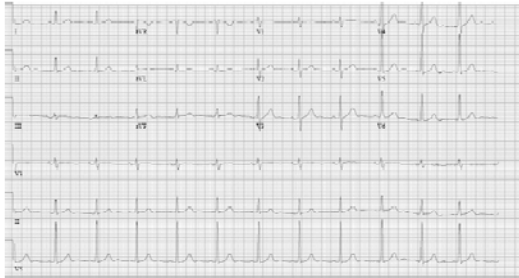
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## Clinical Case 4

- 65yo Male presents for an annual physical
  - Exercises 5 days a week without any concerning symptoms
    - PMHx: Hyperlipidemia
    - Medications: 20mg Simvastatin, 325mg Aspirin
    - SoHx: 2ppd tobacco x 20 years (quit in 2009)
      - Cigar use 1-2 times a month
    - FmHx: Father with MI age 53, PGM, PGF and mother with MI in their 60s.

## Clinical Case 4 Continued

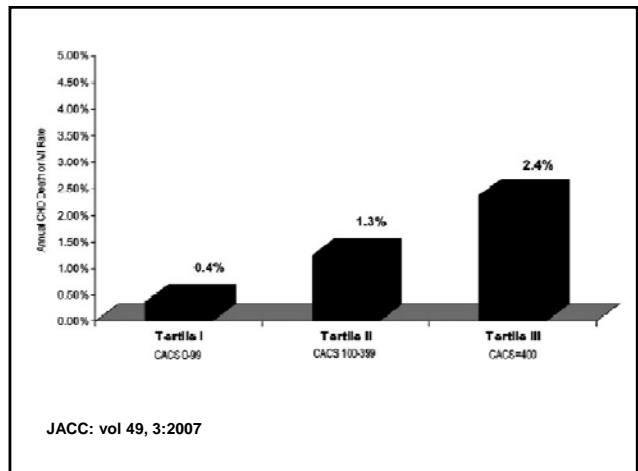
- PE: BP 168/83 HR 65, BMI 29
  - Unremarkable physical findings.
- Lipid
  - Total cholesterol 221
  - LDL 145
  - HDL 41
  - Triglycerides 176



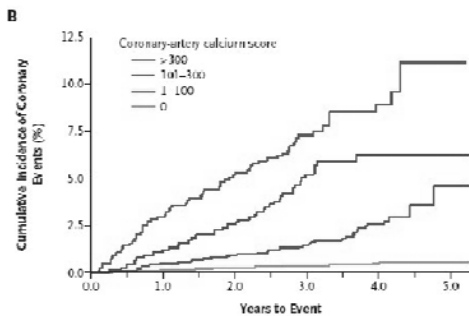
• “So Doc, how’s my heart doing? I don’t want to end up like my parents.”

Risk Category	LDL Goal	LDL Level at Which to Initiate Therapeutic Lifestyle Changes (TLC)	LDL Level at Which to Consider Drug Therapy
CHD or CHD Risk Equivalents (10-year risk >20%)	<100 mg/dL	≥100 mg/dL	≥130 mg/dL (100-129 mg/dL: drug optional)*
2+ Risk Factors (10-year risk ≤20%)	<130 mg/dL	≥130 mg/dL	10-year risk 10-20%: ≥130 mg/dL 10-year risk < 10%: ≥160 mg/dL
0-1 Risk Factor†	<160 mg/dL	≥160 mg/dL	≥190 mg/dL (160-189 mg/dL: LDL-lowering drug optional)

**ATPIII Executive summary**



## Multi-Ethnic Study of Atherosclerosis



NEJM 2008; 358:13:1336-45

## Patient selection for Calcium scoring

- CAC for intermediate risk patients (10-20% 10 year risk) without symptoms (IIa)
- CAC may be reasonable for low to intermediate risk patients (6-10%) (IIb)
- No data to support use in low risk (<6% 10-year risk). Typically young population of men less than 40 and women less than 50.

Greenland et al JACC vol 56, 25, 2010



## Clinical Case 4 Continued

- Calcium score
  - RCA 237
  - LAD 298
  - LM none
  - Cx none
- Change treatment to secondary prevention guidelines
- Ideal patient is in the Intermediate risk (10-20% 10 yr) risk strata
  - asymptomatic patient
  - Result might reclassify patient to higher risk status

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## **Contraindications for calcium scoring**

- Known CAD
- Symptomatic patient
- Cardiac “hardware”: pacemakers, stents, prosthetic valves

## **Clinical Case 5**

- 12 year old female with no significant past medical history had syncopal event while playing in basketball game
- No prodrome
- Awoke spontaneously

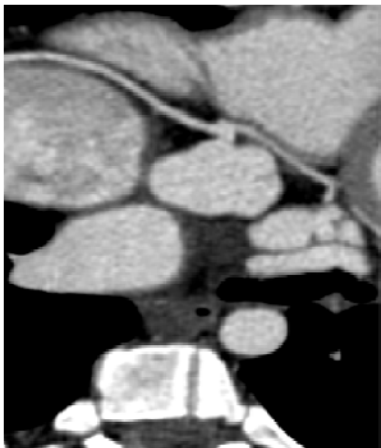
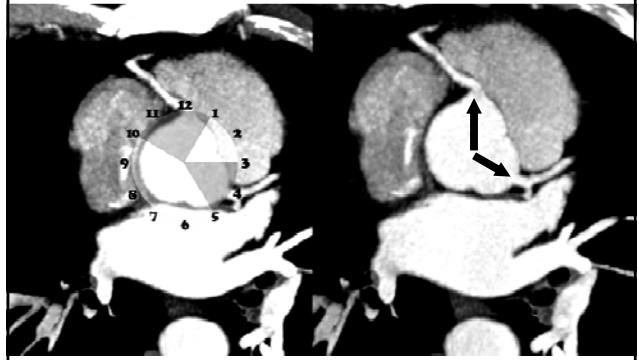
## **Physical Examination**

- Afebrile, P-80, BP 90/50
- Quiet precordium, I/IV short systolic ejection murmur, no diastolic murmur, gallop or rubs
- Abdomen unremarkable

## Diagnostic Testing

- ECG showed sinus rhythm with 0.5 mm ST elevation in precordial leads.
- Echo showed normal biventricular function, no significant valvular disease, unable to visualize coronary arteries
- Referred for coronary CTA

## Normal Anatomy



## Clinical Case 6

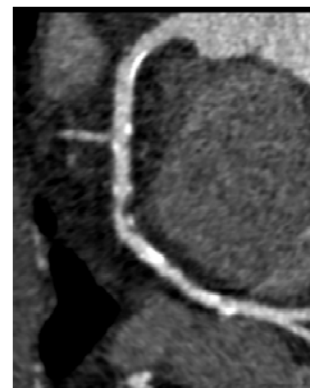
- 45 year old perimenopausal female with hypertension presents with dyspnea on exertion
- PMH: HTN, obesity
- Meds: Lisinopril/HCTZ 10/12.5mg
- Non-smoker
- Family history of coronary artery disease in her mom (60's) and dad (60's)

## Clinical Case 6: Physical Exam

- PE: P-70; BP 132/75, BMI 30
- HEENT: Normocephalic, +acanthosis nigrans, no carotid bruits
- CV: Quiet precordium, RRR, no murmurs, gallops or rubs. 2+ peripheral pulses.
- Ext: No edema

## Clinical Case 6: Treadmill Nuclear Stress Testing

- Exercised for 9 minutes no Bruce protocol achieving 10.1 METs and 96% of age-predicted maximal heart rate
- Baseline ECG: Sinus rhythm with 0.5 mm ST depression in anterior leads
- Stress ECG: Sinus tachycardia with 1.5 mm horizontal ST depression in precordial leads (indeterminate due to baseline abnormalities)
- Imaging: Mild perfusion defect in anterior wall likely due to breast attenuation although ischemia cannot be excluded. Normal function, EF 55%



## References

- ACC/AHA Cardiovascular CT Appropriateness Criteria, *Journal of the American College Cardiology*. 2012; 59 (9): 857-881.
- ACC/AHA Guidelines for Exercise Testing: Executive Summary, *Circulation*. 1991; 96: 345-354.
- OSU Department of Radiology website.  
<https://onesource.osumc.edu/departments/radiology>