Screening of Children and Adolescents at Risk of Sudden Cardiac Arrest:

What Is the Utility of Non-Invasive Imaging?

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Question:

- Echocardiograms should be included in screening of all athletes for SCA risk
  1. TRUE
  2. FALSE

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Outline

- What cardiac abnormalities a/w SCA can be screened by non-invasive imaging?
- What do we mean by a 'screening echo program?'
- Echocardiography for SCA screening
- Cardiac MRI or CT as adjunct to echo
- Risks, benefits, and other issues of screening for SCA using non-invasive imaging

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What Diagnoses Can Be Screened by Non-Invasive Imaging?

- Hypertrophic cardiomyopathy (HCM)
- Arrhythmogenic right ventricular CMP (ARVC)
- Coronary artery anomalies:
  - Anomalous origin from the opposite coronary sinus
  - Coronary abnormalities s/p Kawasaki Disease
- Aortic valve and root pathology
- Other diagnoses:
  - Dilated cardiomyopathy, myocarditis, mitral valve prolapse

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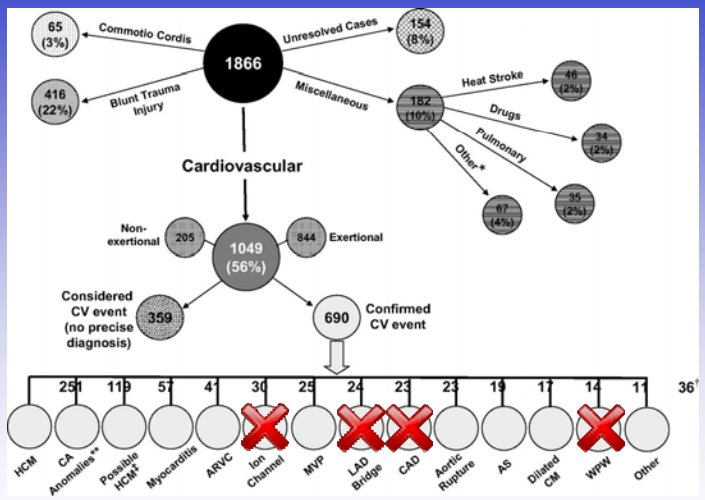
Flow diagram summarizing causes of death in 1866 young competitive athletes



Maron, B. J. et al. Circulation 2009;119:1085-1092

Circulation

American Heart Association
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What Do We Mean by Echo Screening?

'Universal' Echocardiographic Screening
(Limited study with a portable device?)
vs.
Echocardiographic imaging of those at risk on basis of history, physical examination and/or EKG (Italy, ~10%)
(Complete study?)
vs.
Something in between

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When are Echos Included in Screening for SCA Risk?

- *Current US guidelines do not include routine echocardiographic screening for athletes*
- European and Olympic guidelines also do not include routine echo screening
- NBA instituted annual screening of all players, including echocardiograms (*rest and stress*), in 2006
- NFL considering including echos this year
- Most community echo screening is currently underwritten by private organizations with support from imaging companies
  - Both non-profit and for-profit screening initiatives

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HeartScreen America®
Screening Hearts, Saving Lives™

young hearts for life YH4L

A Heart for Sports

Cardiac Risk in the Young

2-D Echo Screening for SCA Risk: Hypertrophic Cardiomyopathy

- Left Ventricular Dimensions
  - LV wall thickness or mass
  - LV mass (or wall thickness): volume ratio
- LV Systolic Function
  - Global (ejection fraction)
  - Regional
  - Pre- vs. post-exercise
- Left Atrial Imaging
  - Left atrial size (volume)
    - Dilation has been associated with diastolic dysfunction
  - Left atrial function
- LV Diastolic Function, Strain and Torsion

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HCM vs. Athlete's Heart

- Sport-specific cardiac characteristics have been demonstrated in elite athletes
  - Increased LV cavity size in endurance athletes (runners)
  - Concentric hypertrophy in static sports athletes (body builders)
  - Eccentric hypertrophy (combination of increased LV wall thickness and increased cavity size) in 'combined' sports athletes (cyclists, rowers)
  - Increased vagal tone in some professional athletes (soccer players), may be a/w LA dilation and 'diastolic dysfunction' (Wilhelm, et al. Am J Cardiol. 2010 106:569-74)

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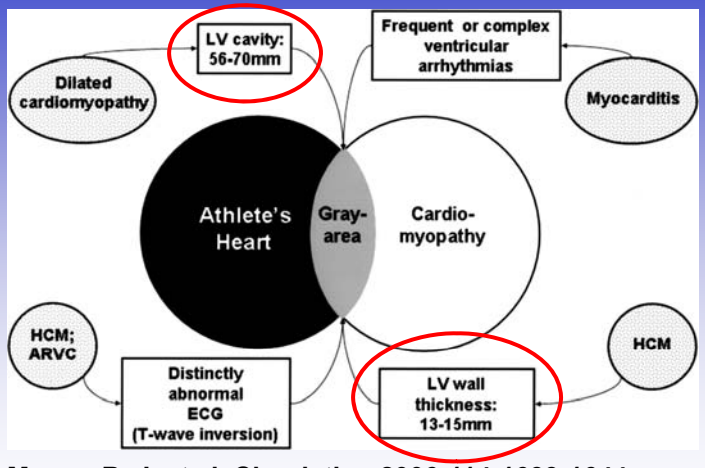
Differential diagnosis between athlete's heart and cardiac disease



Maron, B. J. et al. Circulation 2006;114:1633-1644

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Doppler and Strain: What Can These Add in Differentiating HCM?

- Diastolic and systolic assessment
- Doppler imaging:
  - Mitral inflow or myocardial velocities
  - May be abnormal in HCM carriers before LVH develops (Ho, et al. Circulation 2002 105:2992-7)
- Strain imaging
  - Assessment of twist of left ventricle

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LV Strain: Can it Help Differentiate HCM from Athlete's Heart?

- Compared 15 HCM, 20 athletes and 18 sedentary controls
- All LV strain indices were decreased in HCM vs. athletes or controls
- DTI were also lower in HCM vs. athletes or controls
- No overall difference between athletes and controls

(Butz, et al. Int J Cardiovasc Imaging 2010)

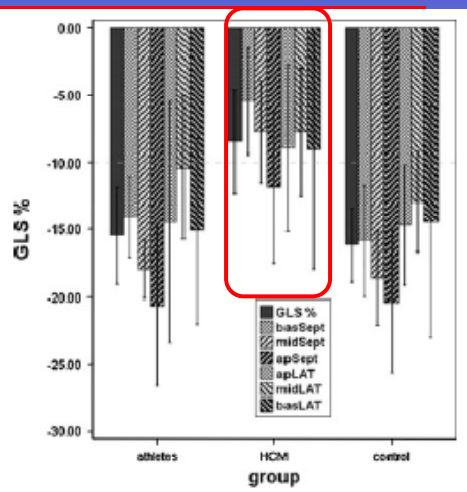


Fig. 1 Mean values ± SD of the global longitudinal strain (*GLS*) and the regional peak systolic strain (*PSS*) in the 6 LV segments

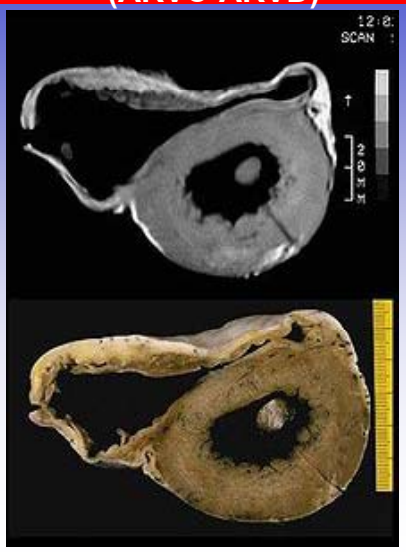
What Else Do We Know re: Differentiating HCM vs. Athlete's Heart?

- Genetic differences are important:
  - Gender differences:
    - Study of elite white female athletes demonstrated mildly increased LV volume and wall thickness *but no abnormal LVH*
    - *'Clinical differentiation of athlete's heart from HCM appears to be a diagnostic dilemma limited to male athletes'*

      (Pelliccia, et al. JAMA 1996 276:211-5)
  - Racial differences:
    - Black male athletes have greater LV mass and wall thickness vs. matched white athletes
    - Black female athletes *also* have greater LV mass and wall thickness as well as increased left atrial size

      (Rawlins, et al. Circulation 2010 121:1078-85)
- Detraining, echo stress testing can be used to differentiate 'normal' from HCM

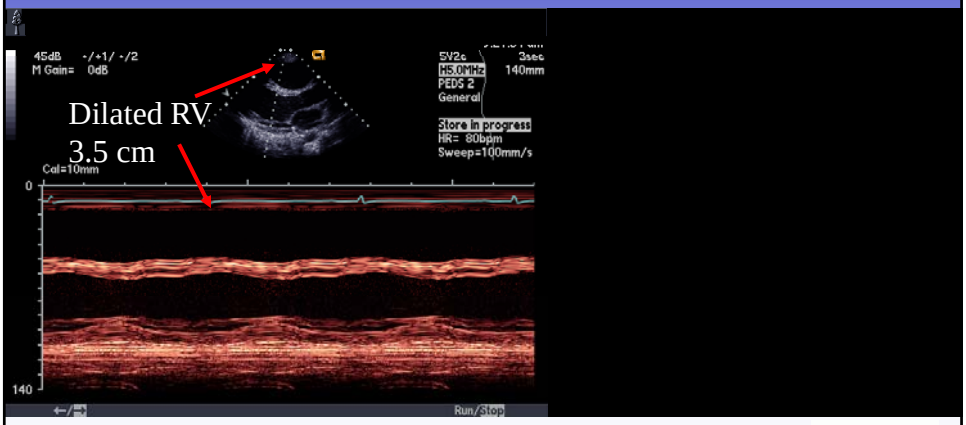
Arrhythmogenic Right Ventricular Cardiomyopathy-Dysplasia (ARVC-ARVD)



2-D Echo: Screening for ARVC/D (From arvd-arvc-info.org)

- **Revised echo criteria:**
  - **Major:**
    - **Regional RV akinesia, dyskinesia or aneurysm *AND***
    - **One of the following (end-diastole)**
      - **PLAX RVOT ≥32 mm or PLAX/BSA ≥ 19 mm/m2**
      - **PSAX RVOT ≥36 mm or PSAX/BSA ≥ 21 mm/m2**
      - **FAC ≤33%**
  - **Minor:**
    - **Regional RV akinesia or dyskinesia *AND***
    - **One of the following:**
      - **PLAX RVOT ≥29 to <32 mm or PLAX/BSA ≥16 to <19 mm/m2**
      - **PSAX RVOT ≥32 to <36 mm or PSAX/BSA ≥18 to <21 mm/m2**
  - **Hypokinesis no longer included as criteria**
- **How often does screening need to be repeated?**

Example-ARVD Echo



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2-D Echo Screening for SCA: Coronary Artery Anomalies

- **Coronary artery origin and proximal course**
  - **May be technically limited in older/larger pts**
  - **Prospectively screening of 3500 asymptomatic athletes by echo (Zeppilli, et al. Chest 1998 114:89-93)**
    - **'Clearly visualized ostia and 1st tracts of RCA and LCA' in 90%**
    - **3 (0.09%) suspected of AOCA (2 R, 1 L); all confirmed by angiogram (All three previously had 'normal echos')**
    - **Compare this to higher incidence on autopsies or by coronary angiography: were there false negative?**
    - **Color Doppler not included**
- **Coronary artery abnormalities s/p Kawasaki Disease**
  - **May have been undiagnosed in early childhood**
  - **Sudden death and ischemic symptoms well-described**

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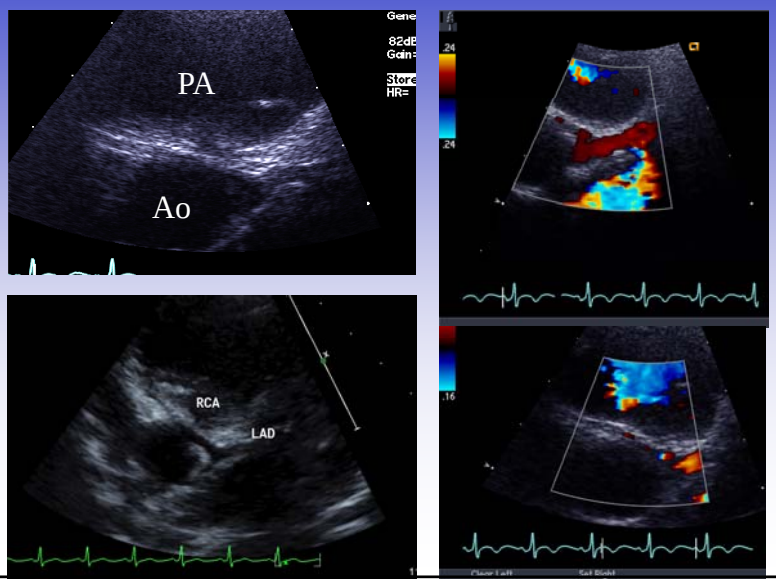
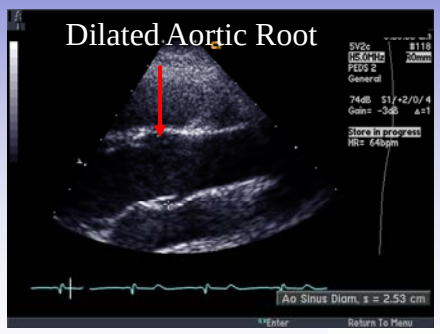
Example-Anomalous RCA from LCA



2-D Echo Screening for SCA: Aortic Morphology

- **Aortic stenosis**
  - **Usually is associated with heart murmur**
- **Aortic dilation**
  - **Marfan syndrome and other connective tissue disorders**
  - **Bicuspid aortic valve with ascending aorta dilation (may have no significant stenosis or regurgitation)**
  - **Importance of adjusting for BSA**
  - **Serial assessment**



When is Echocardiography Not Enough?

- Screening echo suggests LVH, but is it HCM or 'athlete's heart'?
  - Despite certain echo criteria, is diagnosis certain without genetic testing?
- Screening echo suggests but does not confirm another abnormality:
  - Coronary artery abnormality
  - ARVC-D
  - Dilated cardiomyopathy or myocarditis
  - Aortic root dilation/connective tissue disorder

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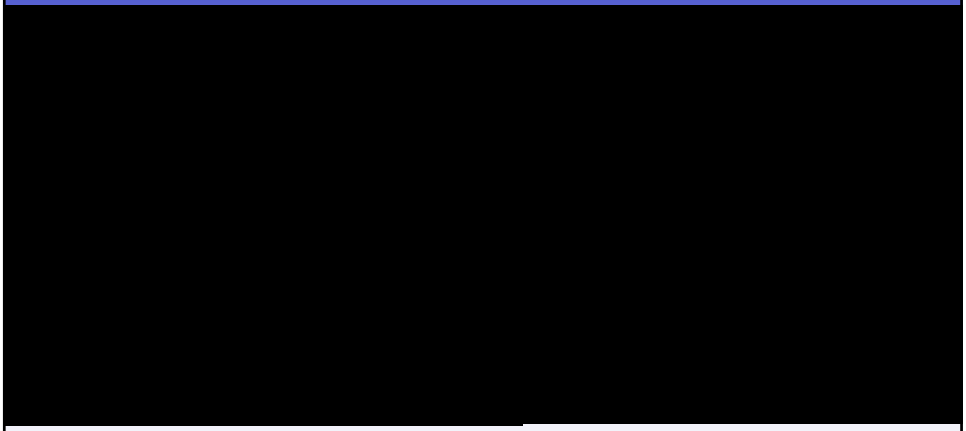
What's the Diagnosis?



1. Hypertrophic Cardiomyopathy
2. Marfan Syndrome
3. New England snow storm

What if Screening Echo is of Suboptimal Quality to Rule Out Abnormalities?

- Study may have been very limited:
  - Portable echo devices may not generate images of sufficient quality to rule out certain anomalies
  - Imaging technologists, readers may lack adequate experience
  - Pt body habitus (esp. in older/larger pts) may prohibit adequate imaging by 2-D echo
- Is echo worth repeating?
  - Need to assess if different equipment or circumstances will yield sufficient additional information to exclude cardiac pathologies
  - If not clear, should turn to alternative non-invasive imaging modality

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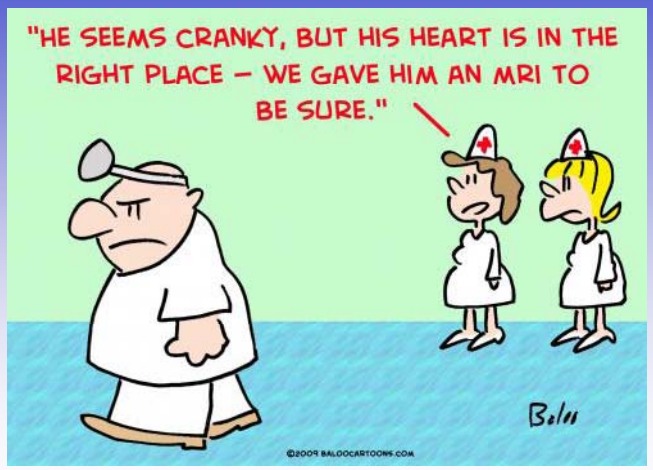

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Why Cardiac MRI?

- 3-D tomographic technique:
  - Any imaging plane possible
  - No (appreciable) size/imaging limitation
    - 1.5 – 200+ kg
- Noninvasive
  - Usually need peripheral IV for contrast or sedation
- No ionizing radiation
  - Increased lifetime cancer risk, esp. with early or repeated radiation exposure
  - Radiation can be significantly decreased via technical CT advances

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Why *Not* Cardiac MRI?

- Requires patient cooperates with scan:
  - Pt typically in scanner for 45-60 minutes
  - Sedation (anesthesia) generally required for children younger than 6 years of age
  - Older children and adults: 'virtual reality' movie system increases compliance, even if pt claustrophobic
- Certain contra-indications to MRI:
  - Pacemakers or pacing wires current exclusion criteria
- Not portable
- Limited availability and expertise

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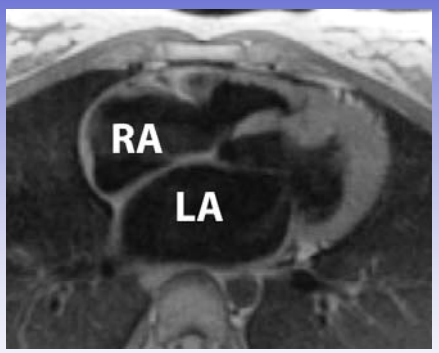
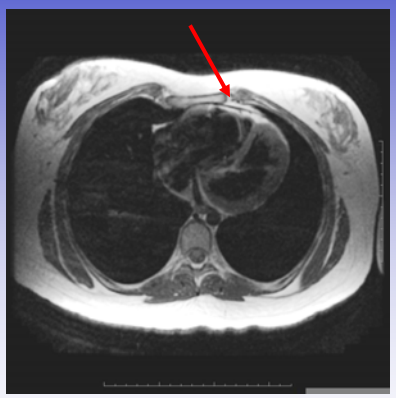
MRI-compatible Audio and Video System

What Can Cardiac MRI Add?

- **Anatomy:**
  - Thoracic vasculature
  - Intracardiac structures
  - Coronary artery origin/branching/aneurysms
  - Intracardiac masses/tumor characterization
- **Physiology**
  - Ventricular function, volumes and mass
  - Flow and cardiac output measurements
- **Myocardial perfusion and viability**
  - Assess for regions of infarct, inflammation, or fibrosis
  - Can be combined with stress imaging (usually in adults)

Examples: MRI Black Blood Imaging





HCM: Note the dilated atria

ARVD: Abnormally bright right ventricle due to fatty infiltration

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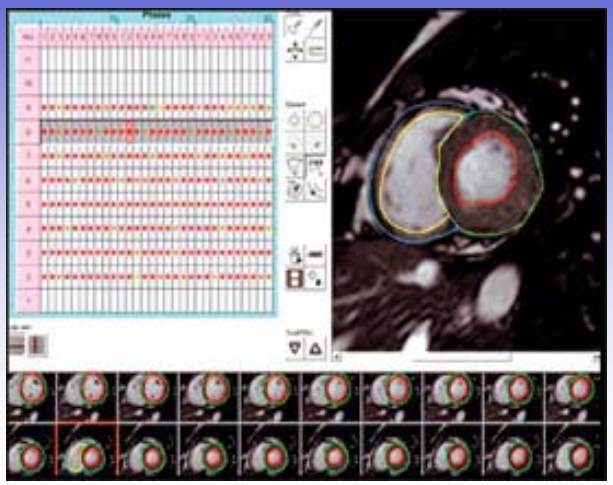
MRI Ventricular Volume and Function Analysis



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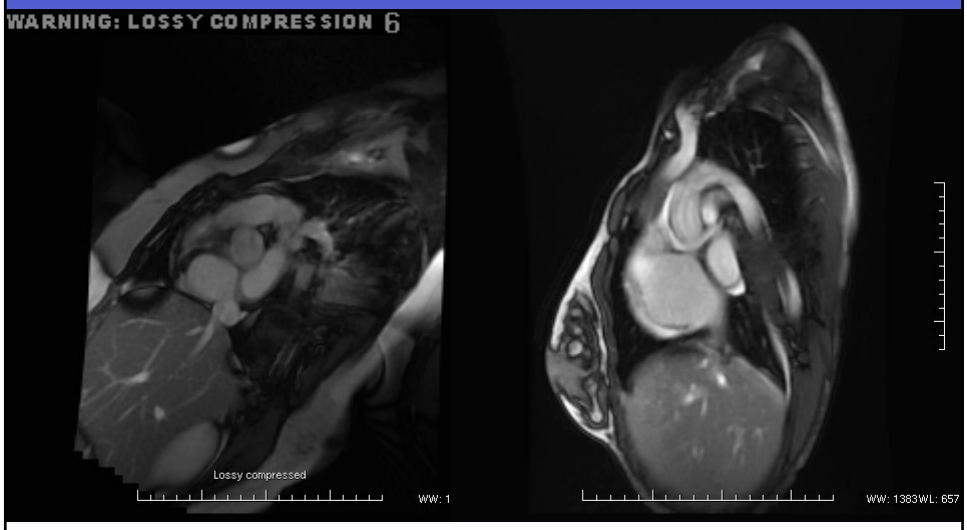
MRI: Bright Blood Imaging

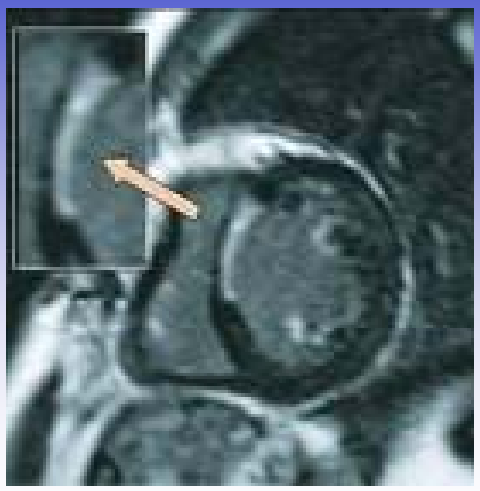


Hypertrophic CMP **ARVC**

How to Assess for Infarct or Fibrosis? Myocardial Viability Imaging

- ***Normal*** **myocardium: Gd perfuses in and washes out rapidly**
- ***Abnormal*** **myocardium isn't perfused early: 'bright' signal 10 minutes post-Gd c/w infarct/fibrosis**

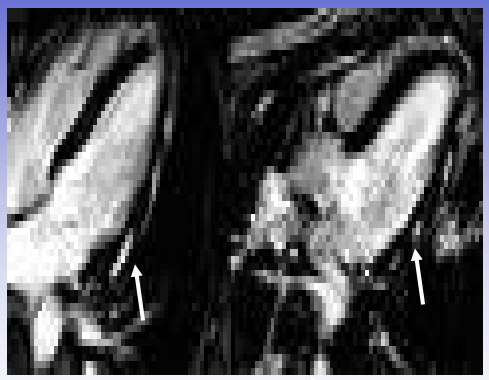
Examples of Delayed Enhancement



Septal Infarct

ARVC: RV and LV MDE

Examples of Delayed Enhancement: Myocarditis- Can Have Normal Function



Myocarditis-subepicardial MDE

Myo-Pericarditis

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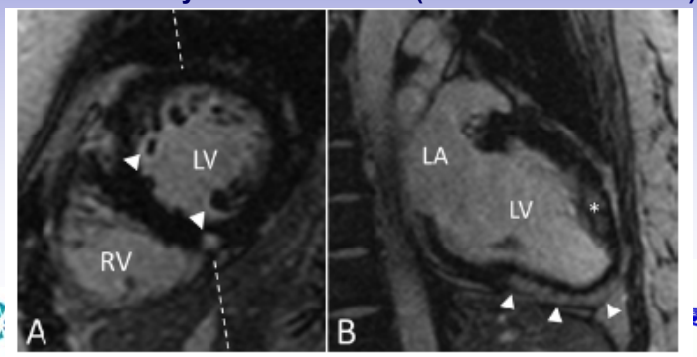
MRI in HCM- Screening

- MRI may be able to detect HCM gene+ carriers prior to development of ventricular hypertrophy
  - Abnormal myocardial strain (by tagging)
  - Abnormal LV torsion (Russel, et al. JCMR 2011)
  - Abnormal delayed enhancement (Germans JCMR 2010)



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CT Imaging for SCA

- Coronary artery origin, course, and dilation (s/p KD)
- Aortic dilation
- Must be cognizant of radiation exposure:
  - Great variation in dosing depending on equipment and expertise of imaging specialist (radiologists, cardiologists)

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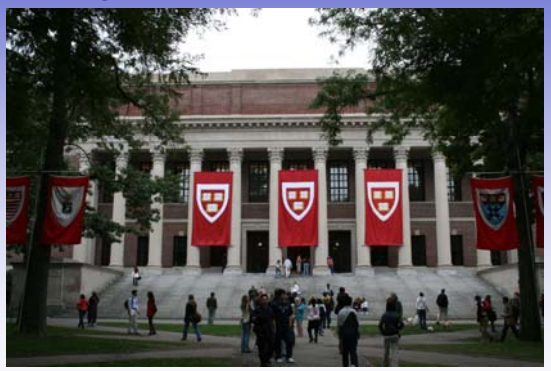
Example: CT Imaging of Anomalous RCA from Left Coronary Sinus

Cost vs. Risk Assessment: Is Testing All Good?

- What is the monetary cost of a screening echo?
  - Marked variability in cost/echo: $50-$2000
  - Decreased total cost if screening echo only performed on those at highest risk
    - College or professional athletes?
- What is the cost of additional studies that are ordered based on abnormalities detected on the screening echo?
  - Cardiac MRI is currently not reimbursed by MediCal
- How often do we need to screen?

Utility of Echo for SCA Screening

- Study of Harvard Athletes

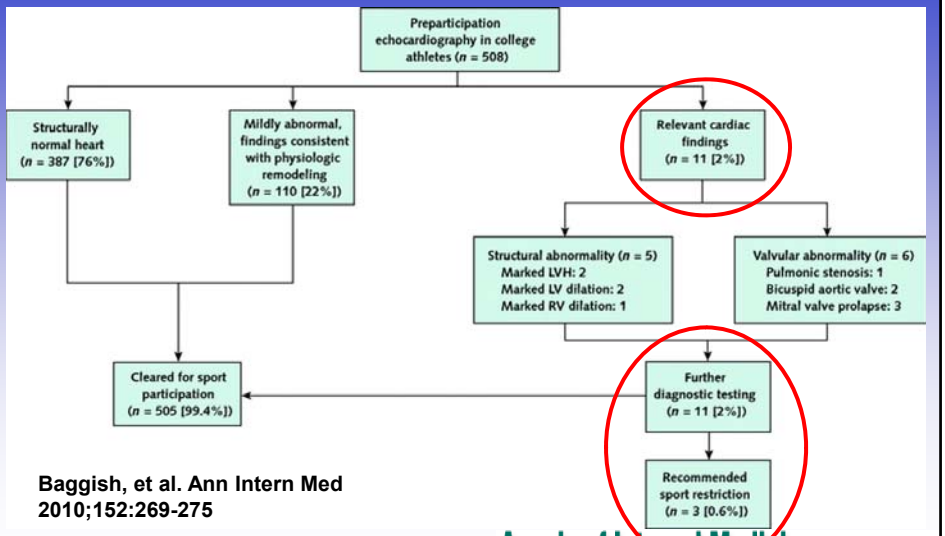


Baggish, et al. Ann Intern Med 2010 152:269-75

Study Methods and Results

- 510 athletes screened
  - History and physical
  - ECGs
  - Echocardiograms
- H&P's done by MDs blinded to ECG/Echo
- 11 of 510 athletes had abnormal echocardiograms (2.2%); *10/11 abnl EKG*
- 3 restricted from sports participation

Study flow diagram: Results of Screening Echocardiograms



Baggish, et al. Ann Intern Med 2010;152:269-275

Annals of Internal Medicine

Cost vs. Risk Assessment: Is Testing All Good?

- How many will be restricted from sports participation despite unclear risk?
  - May *still* be difficult to differentiate pathology vs. exercise-related ventricular changes despite all imaging tests
  - Uncertain risk of incidentally diagnosed 'disease'
- What is liability if screening echo does not detect an abnormality that is later found?

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Other Ethical Issues Re: Imaging as Screening for SCA Risk

- Potential systems abuses:
  - Screening echos can be turned into lucrative practice
- Web search 'echocardiographic screening for sudden death',

  Company X states,
  - 'Are your team players at risk for HCM, the sudden killer? (We) are the best and most affordable method of detecting HCM'
  - Go to their company website, this is what they say:

    'The SAME TESTS you send your patients to have performed in an outpatient imaging center can generate well in excess of $60,000 or more in annual income for you.'

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Conclusions

- Current US recommendations for SCA risk reduction do *not* include echo screening
- Screening echo may be especially helpful in those cases where history, exam, and EKG all may be nl (eg. anomalous coronary artery origin)

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Conclusions

- Cardiac MRI or CT can assist in clarification of diagnosis in questionable cases or when echo is non-diagnostic
- Unclear if risk/benefit assessment *for society* is toward inclusion of non-invasive imaging as part of SCA screening

Question:

- Echocardiograms should be included in screening of all athletes for SCA risk
  1. TRUE
  2. FALSE

Thank You

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MRI in ARVD

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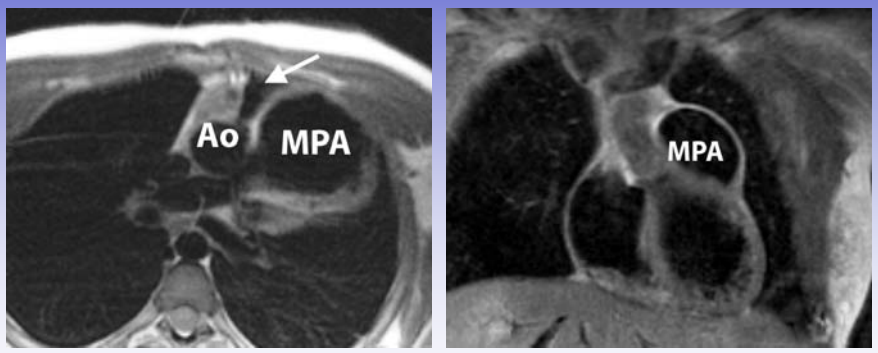
MRI Assessment of Coronary Artery Anomaly

MRI in Dilated Cardiomyopathy or Myocarditis

Example – MRI Black Blood Imaging: Congenital Partial Absence of Pericardium



Note rim of lung tissue between aorta and dilated MPA

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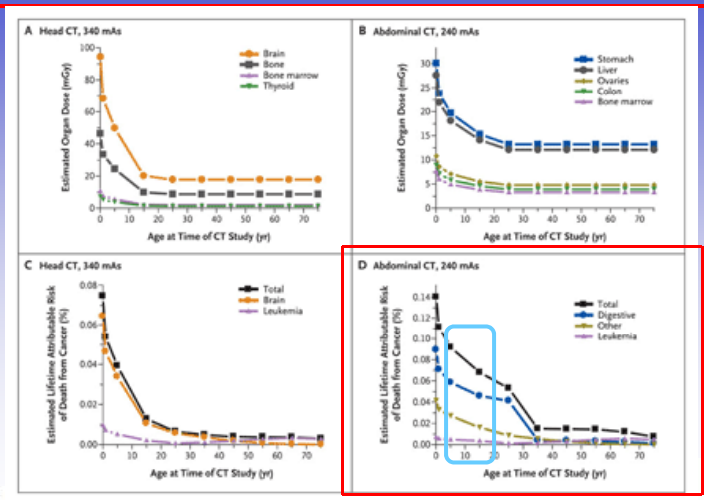
Estimated Cancer Risk from Head or Abdominal CT vs. Age at Time of CT



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Brenner and Hall. Computed Tomography — An Increasing Source of Radiation Exposure. ***New England Journal of Medicine 2007***

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How do we Assess Anatomy?
A. Black Blood Imaging

- Blood (vascular spaces) is black, cardiac and vascular tissue is white
- Still images, gated to cardiac cycle
- Good resolution for vessels and other thoracic structures
  - Tissue characterization (fatty infiltration)
  - Visualization of masses (tumors, etc.)

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Anatomy and Physiology:
B. Bright Blood (Cine) Imaging

- Blood whiter (brighter) than surrounding vascular structures
- Motion pictures through cardiac cycle
- Enables assessment of ventricular function, mass and volume
  - 'Gold standard' for RV and LV volumetric and mass assessment
  - Normative data for ventricular volumes and mass *are not available* for young children and adolescents

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