

# Cardiac MRI: Appropriateness

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# Approaches to Appropriateness

- The indication
- The patient
- The scanner and technologists
- The interpreting physician
- The report content

# The Inappropriate Patient

- **Contraindications**
  - Ferrous intracranial vascular clips
  - Ball & cage mechanical valve (Starr-Edwards)
  - Certain implanted devices
    - Shellock provides comprehensive list
  - Iron fragments in or near orbits
- **Potentially (likely) inappropriate**
  - ICD and pacemaker recipients
  - Claustrophobia
  - Atrial fibrillation, or very frequent ectopy (A or V)
  - Very low GFR ( $\leq 30$ ml/min) for gd-requiring sequences

# The *Not* Inappropriate Patient

- Coronary stents
- Sternal wires
- Cardiac valves
- Orthopedic hardware

# Scanner Requirements

- 1.5 T (or 3 T scanner)
- ECG gating
- Interactive, real-time
- Parallel receiving coil
- High gradient slew

# Technologist Requirement

- Cardiac anatomy and physiology
  - For most part, virtually all other scanning is along primary radiological planes- axial, sagittal and coronal
  - Moving objects are unfamiliar to most technologists
  - SSFP sequences not very common outside of cardiac imaging... although rapid growth in these sequences is underway

# Physician Training

- COCATS
- ACC/AHA/SCMR Level II
  - 3 months fellowship in CMR
  - 150 cases, 50 as primary acquisition and read
  - 30 hr MRI general or CMR specific coursework
  - Maintain: 50 cases/year, 30 hr CME/3 yr
- ACC/AHA/SCMR Level III
  - 12 months fellowship in CMR
  - 300 cases, 100 as primary acquisition and read
  - 60 hr MRI general or CMR specific coursework
  - Maintain: 100 cases/year, 60 hr CME/3yr

# Brief Overview of CMR Applications

- Morphology Imaging
  - Ventricular atrial, vascular, valvular, pericardial, masses
- Functional Imaging
  - Left and right ventricular, valvular, pericardial, shunt significance ( $Q_p:Q_s$ ), flow
- Stress Imaging
  - Dobutamine- contractile; adenosine- perfusion
- Scar Imaging

# CMR Applications Rated Inappropriate

- Chest Pain Syndrome, Detect CAD (Stress CMR)
  - Low pretest probability of CAD, ECG interpretable and able to exercise
  - High pretest probability, evidence myocardial injury
- Risk Assessment (Stress CMR)
  - Normal stress within 1 yr, high clinical risk
  - Low risk operation, intermediate clinical risk
- Chest Pain Syndrome, Detect CAD (Coronary MRA)
  - Including post PCI or CAB grafts

# CMR Applications Rated Uncertain

- Chest Pain Syndrome, Detect CAD (Stress CMR)
  - Intermediate pretest probability of CAD, ECG interpretable and able to exercise
  - High pretest probability of CAD
  - Acute CP, intermediate probability of CAD, negative ECG changes, ischemia biomarkers

# CMR Applications Rated Uncertain

- Risk Assessment (stress CMR)
  - Intermediate clinical risk, and equivocal stress ECG, SPECT or echocardiography (use dob cmr slide)
  - Intermediate clinical risk, and intermediate to high risk surgery
- Structure and Function
  - Evaluate LV function after MI
  - Evaluate LV function in heart failure
  - Evaluate myocardial necrosis after PCI

# CMR Applications Rated Appropriate

- Chest Pain Syndrome, Detect CAD (stress CMR)
  - Intermediate probability of CAD, uninterpretable ECG, or unable to exercise
- Risk Assessment (stress CMR)
  - Known stenosis of uncertain significance
- Coronary MRA
  - Suspected symptomatic coronary anomaly

# CMR Applications Rated Appropriate

- Morphology and Function
  - Complex congenital heart disease
  - LV Function after MI or heart failure, with technically difficult echocardiography
  - Valve function with technically difficult echo
  - LV function with discrepant LV assessments
  - Evaluate specific cardiomyopathies
  - Evaluation for ARVC with ventricular arrhythmia
  - Evaluation for MI or myocarditis without CAD, and with myocardial necrosis

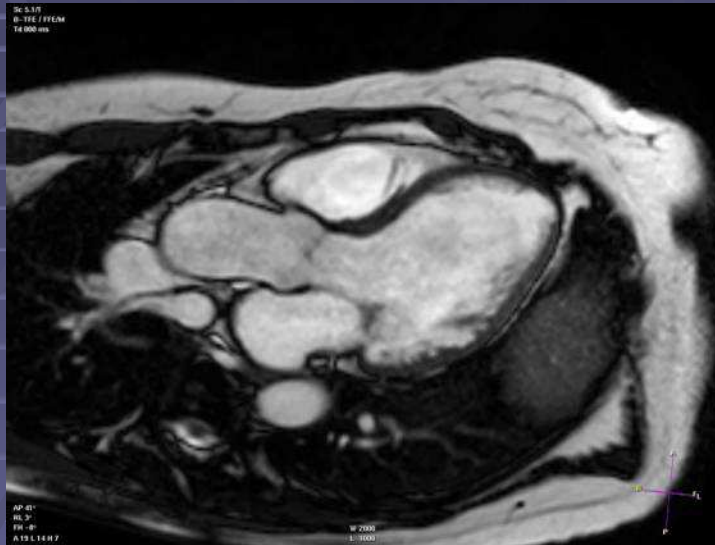
# CMR Applications Rated Appropriate

- Structure and Function
  - Evaluation of cardiac mass/thrombus
  - Evaluation of pericardial conditions
  - Evaluation for aortic dissection
  - Evaluation of pulmonary veins prior to ablation/isolation for atrial fibrillation
- Structure and Function, with gadolinium
  - Post-MI extent of necrosis and/or no-reflow
  - Determine pre-revascularization viability

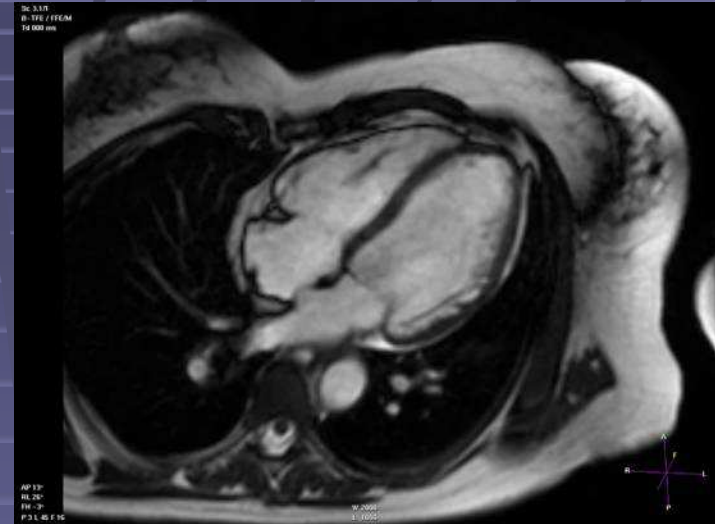
# Some CMR Applications Not Emphasized in the Appropriateness Document

- RV Size and Function
- LV evaluation for iron overload (thalassemia, hemochromatosis)
- Evaluation of cardiac shunts
- Evaluation of endocarditis
- Prediction of sudden cardiac death

# CMR... doing what established non-invasive techniques can do



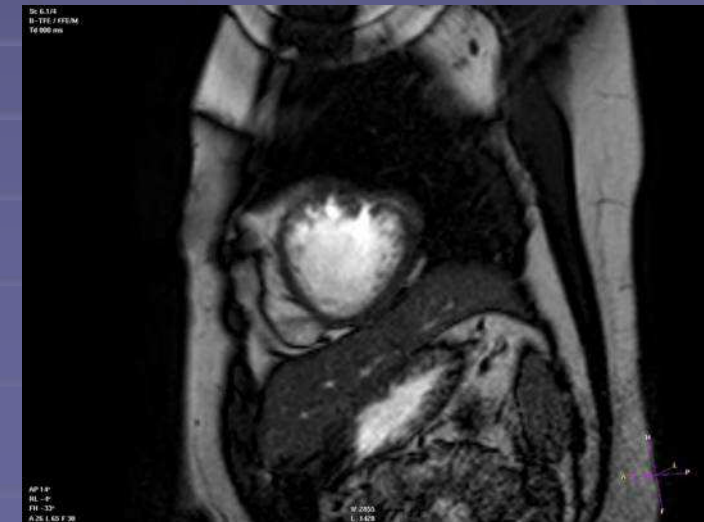
LVOT



HLA



VLA



SA

Workhorse sequence is Breath-held SSFP

# Adding Quantitation

**PHILIPS**

Scan  
7.1: SHORT AXIS SENSE

Application  
LV analysis

Session  
s5

3 x 8 Phases

SI  
5  
10  
15  
16

Ph. 5 10 15 20

Image alignment

Draw  
Endo contour

Computer assistance

Results

Report

FFE/M  
SI 9/Ph 1/000 ms

FFE/M  
SI 9/Ph 2/050 ms

FFE/M  
SI 9/Ph 3/100 ms

FFE/M  
SI 9/Ph 4/151 ms

FFE/M  
SI 9/Ph 5/201 ms

FFE/M  
SI 9/Ph 6/251 ms

FFE/M  
SI 9/Ph 7/301 ms

FFE/M  
SI 9/Ph 8/352 ms

FFE/M  
SI 9/Ph 9/402 ms

FFE/M  
SI 9/Ph 10/452 ms

FFE/M  
SI 9/Ph 11/502 ms

FFE/M  
SI 9/Ph 12/553 ms

FFE/M  
SI 9/Ph 13/603 ms

FFE/M  
SI 9/Ph 14/653 ms

FFE/M  
SI 9/Ph 15/703 ms

FFE/M  
SI 9/Ph 16/744 ms

FFE/M  
SI 9/Ph 17/804 ms

FFE/M  
SI 9/Ph 18/854 ms

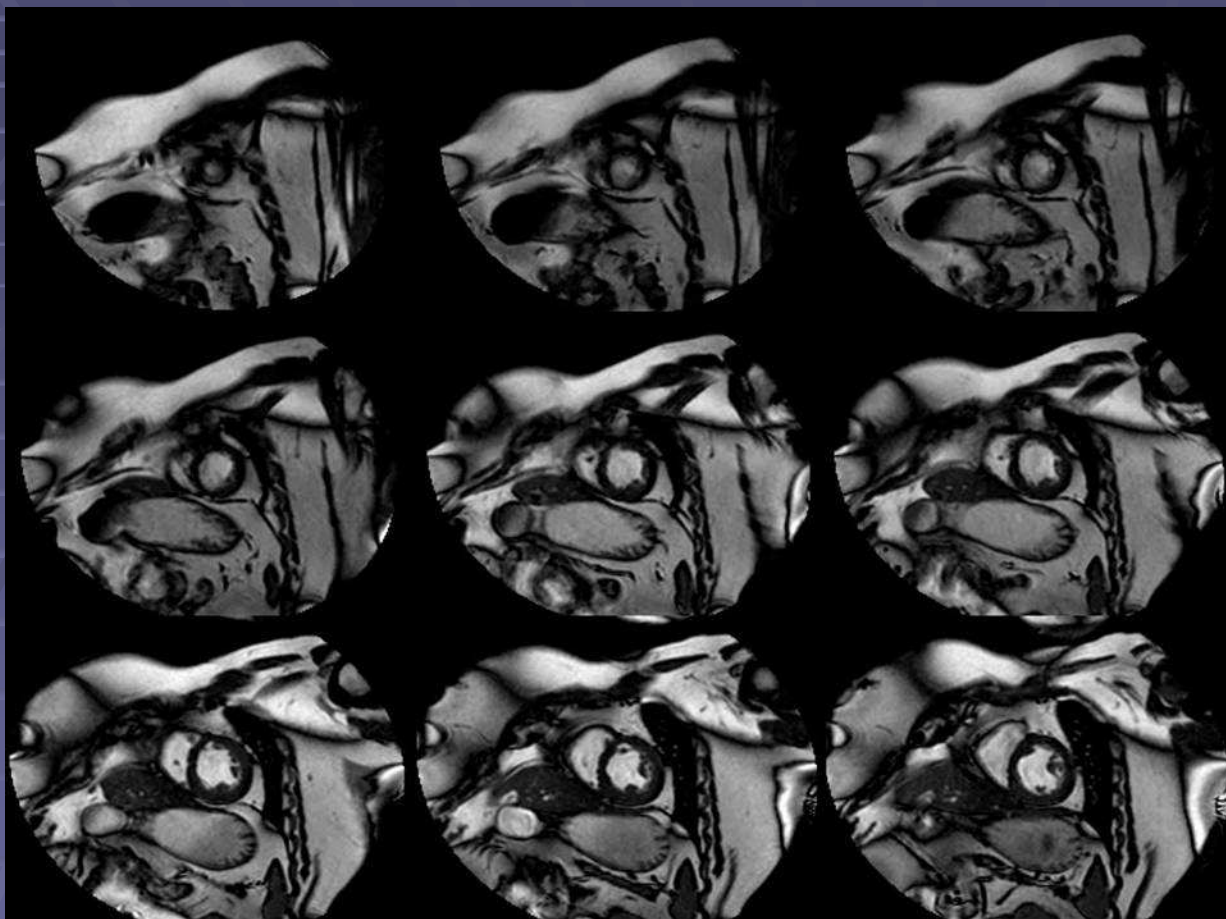
FFE/M  
SI 9/Ph 19/904 ms

FFE/M  
SI 9/Ph 20/955 ms

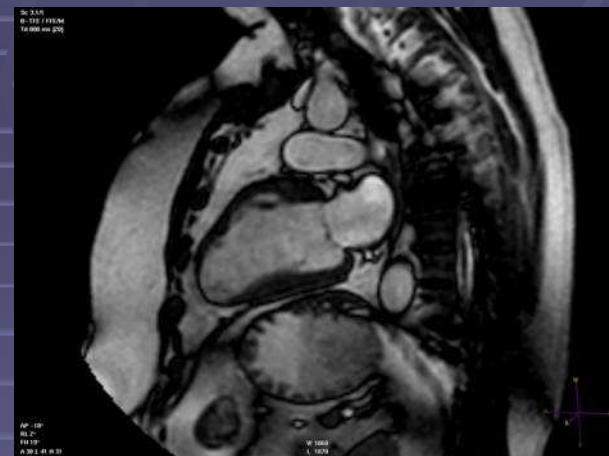
FFE/M  
SI 8  
Ph 7 / 301 ms

FFE/M  
SI 8  
Ph 20 / 953 ms

# TDS Echo



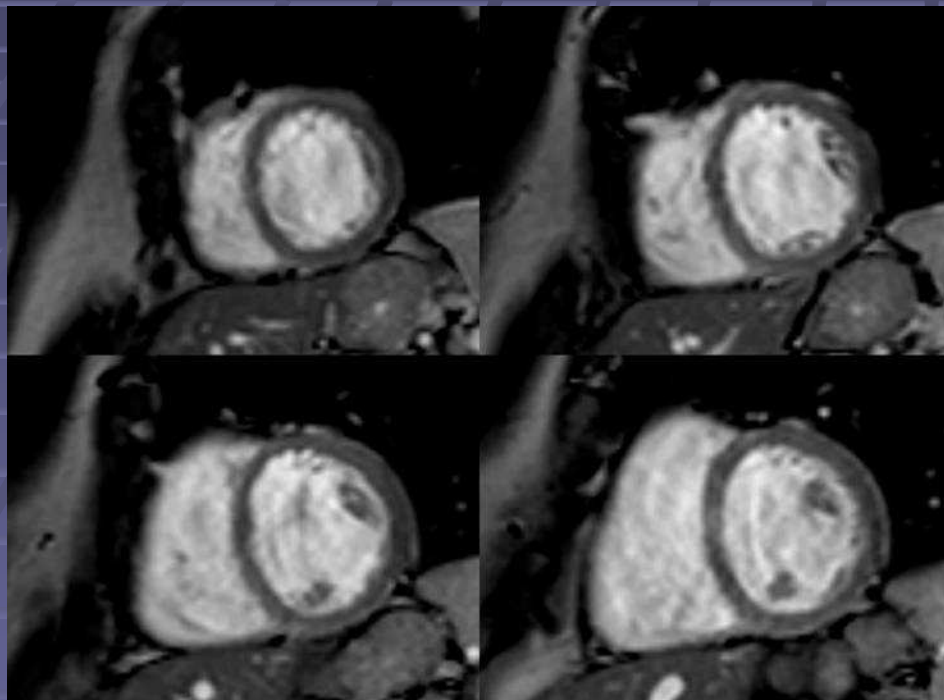
SA Stack, cine bTFE body coil



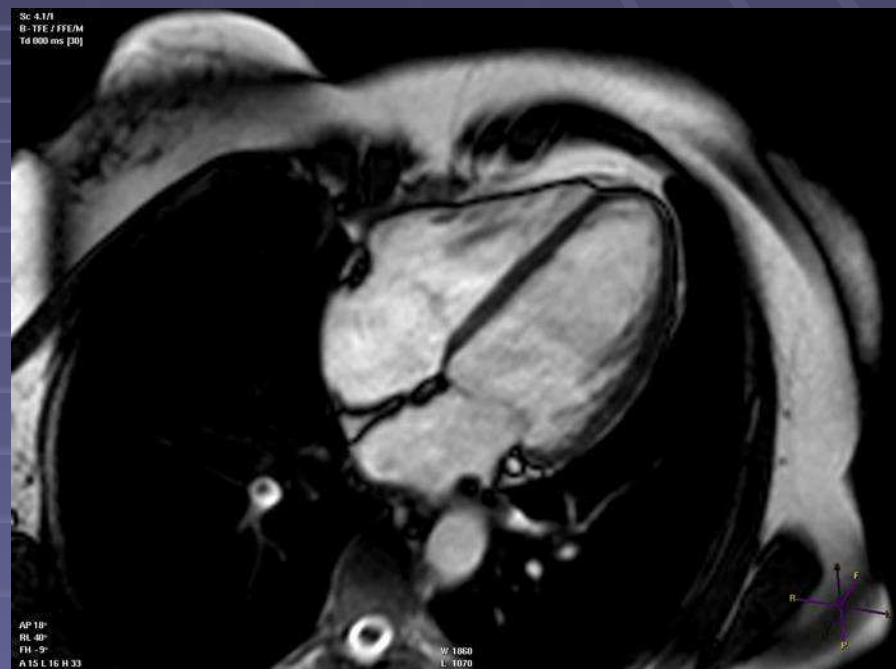
VLA, cine bTFE body coil

Pt with Extreme Obesity, SOB, non-diagnostic contrast echo and unsuspected WMA suggestive of anterior MI

# Negative Predictive Value



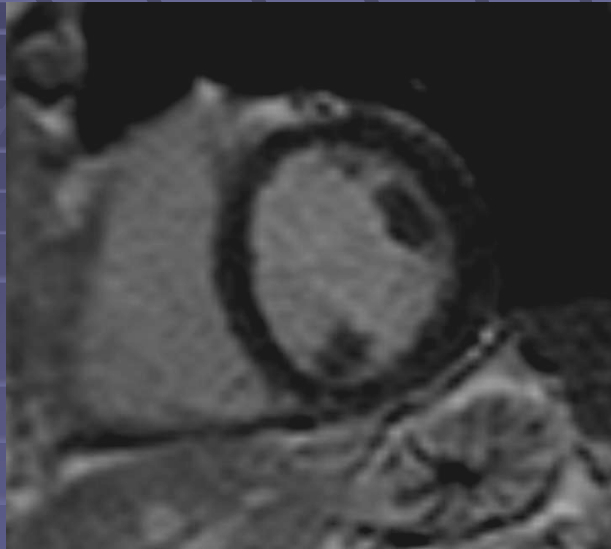
SSFP cine CMR, SA series



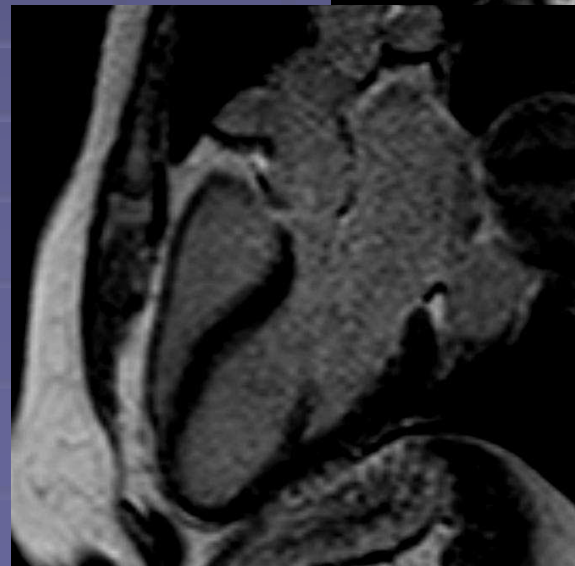
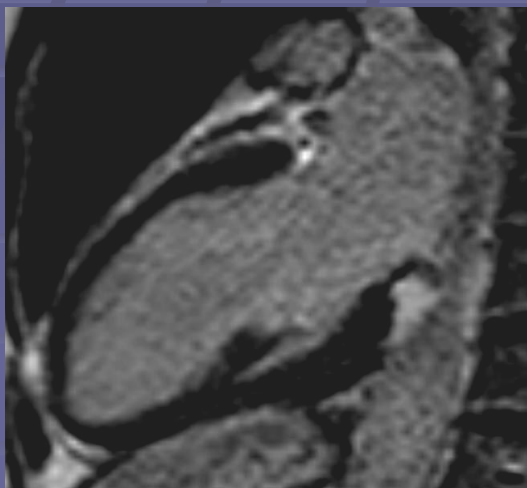
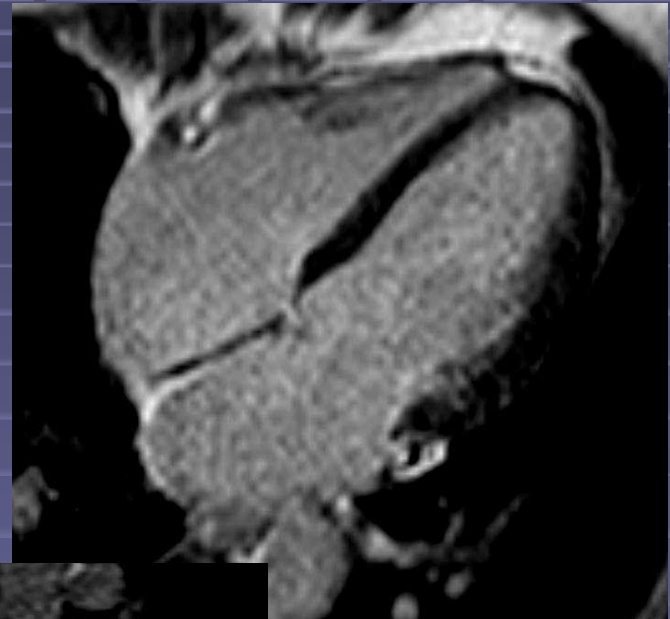
SSFP cine CMR, HLA

Pre-surgical evaluation in pt without strong clinical features for CAD, but 2 SPECT studies read as prior anteroseptal MI (performed for LBBB hx)

# No Scar



IR DHE,  
demonstrating  
uniform  
myocardial  
nulling, and  
excluding MI



# Dobutamine CMR



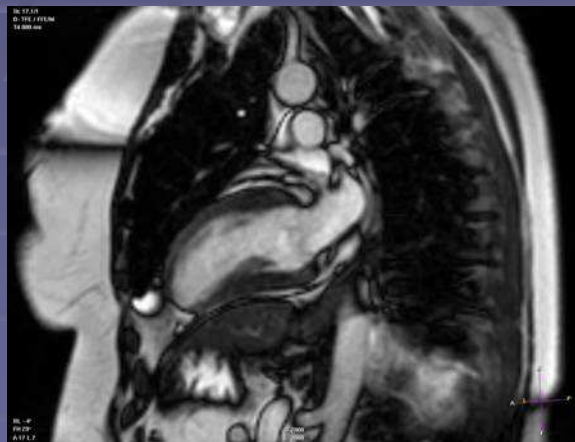
rest



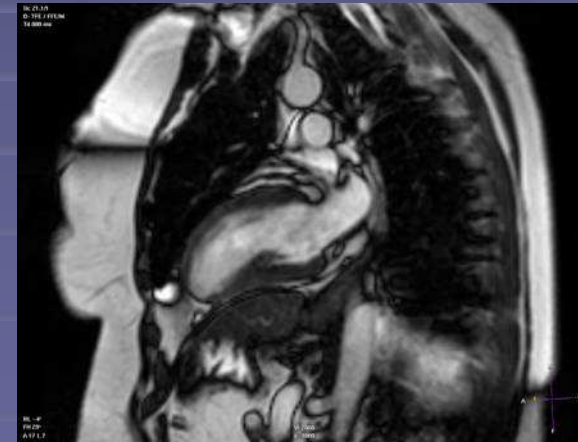
10 mcg/kg



20 mcg/kg



30 mcg/kg



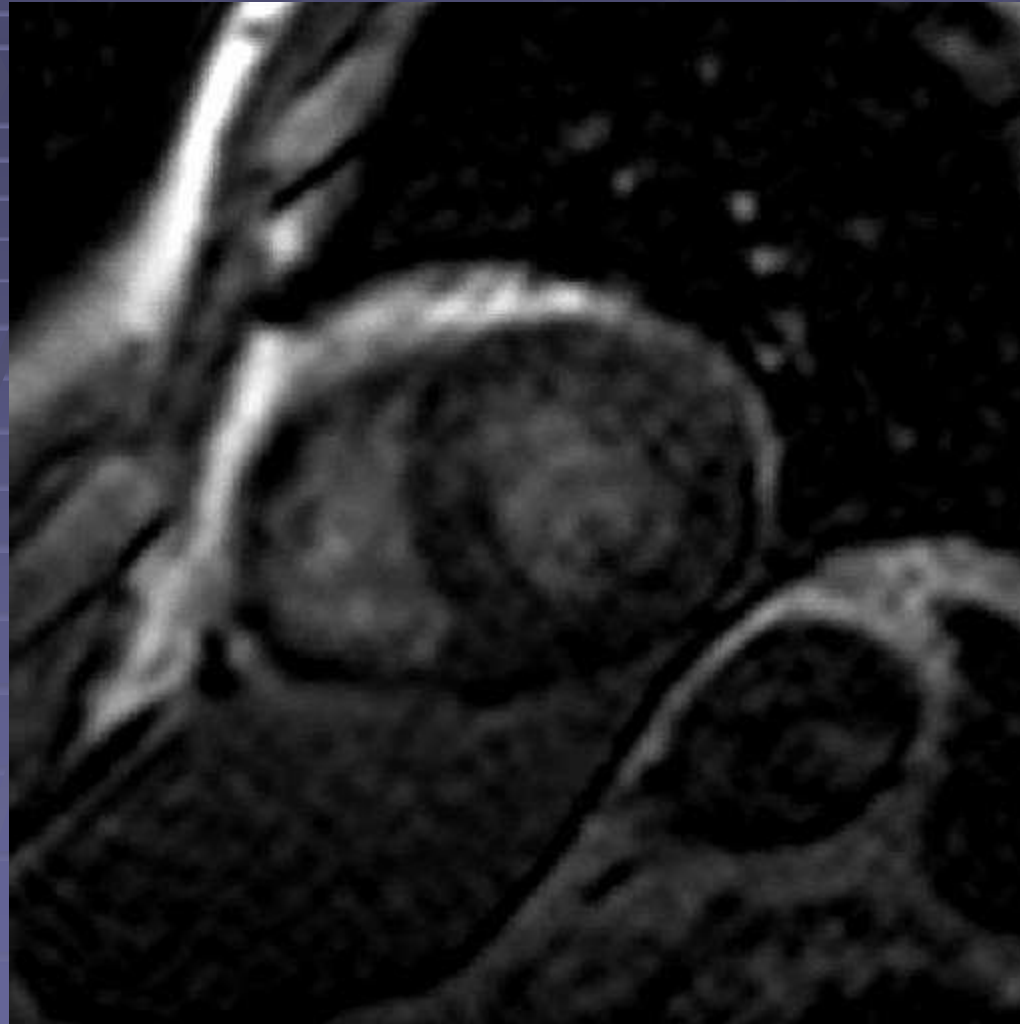
early recovery

48 year old pt with persistent CP despite negative SPECT MPI

# Dobutamine CMR

- Strengths
  - High reproducibility of segments
  - Outperforms dobutamine stress echo
- Limitations
  - Requires detection of ischemic WMA as study progresses
  - Complications occur in magnet environment

# Stress Perfusion CMR

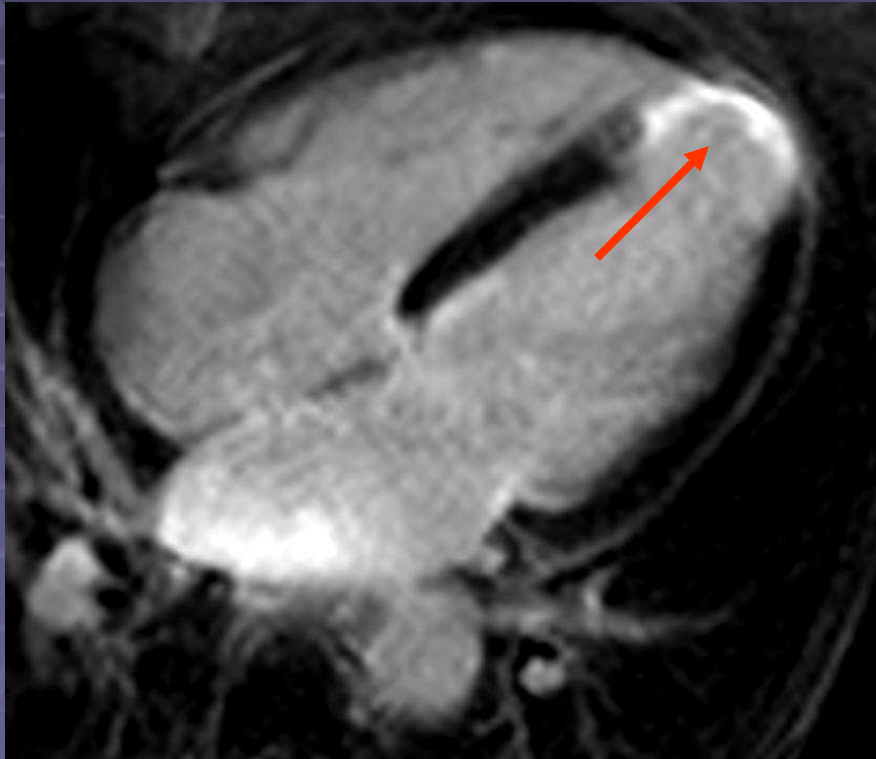


Adenosine induced inferior perfusion abnormality

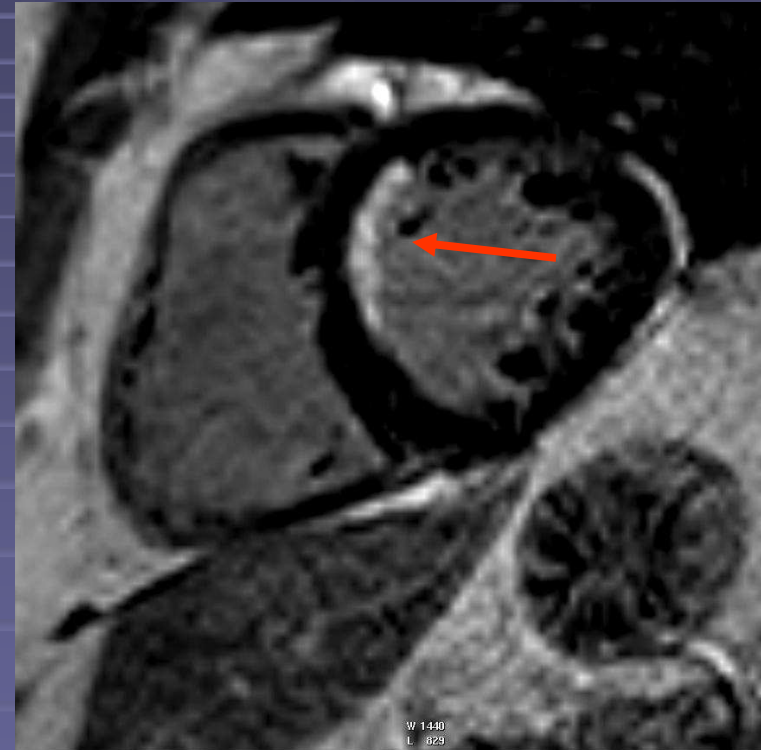
# Stress Perfusion CMR

- Strengths
  - Improved ability to detect subendocardial perfusion defects, c/w SPECT MPI
  - Post-gd delayed hyperenhancement, sensitive MI detection
- Weaknesses
  - Subject to pt movement
  - Quantitative perfusion software not yet widely available
  - Lacks volume of outcome data c/w SPECT MPI

# Characterization of MI and Viability

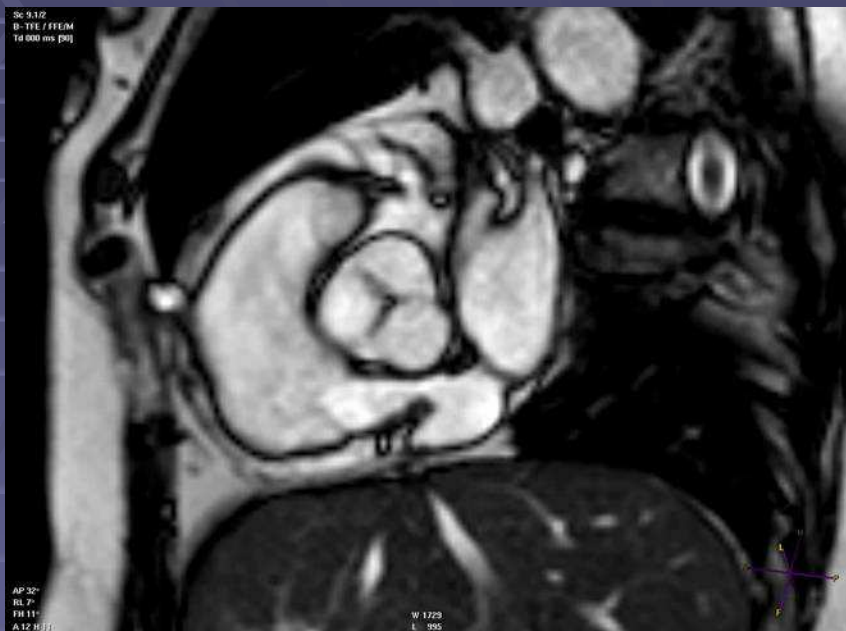


Transmurular Anterolapical MI; HLA IR-DHE. Non-Viable Segment



Non-Transmurular Septal MI; mid SA IR-DHE. Viable Segment

# Valvular HD

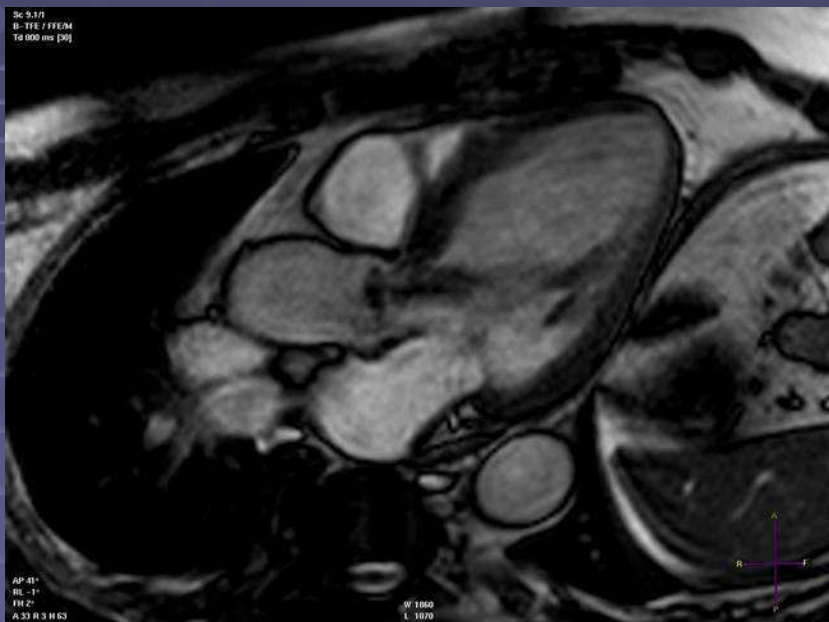


AoV Sclerosis; cine SSFP  
SA-AoV

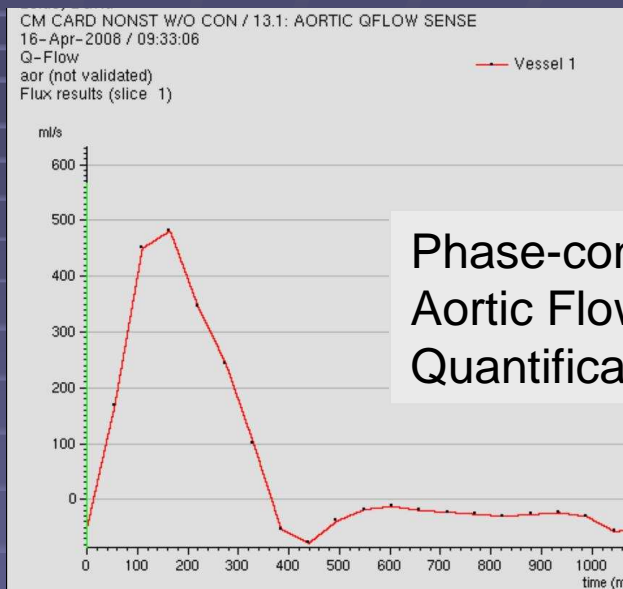


AoV Stenosis; cine SSFP  
SA-AoV

# Valvular HD



Aortic regurgitation; cine SSFP LVOT



Phase-contrast  
Aortic Flow  
Quantification

ANALYSIS RESULTS:

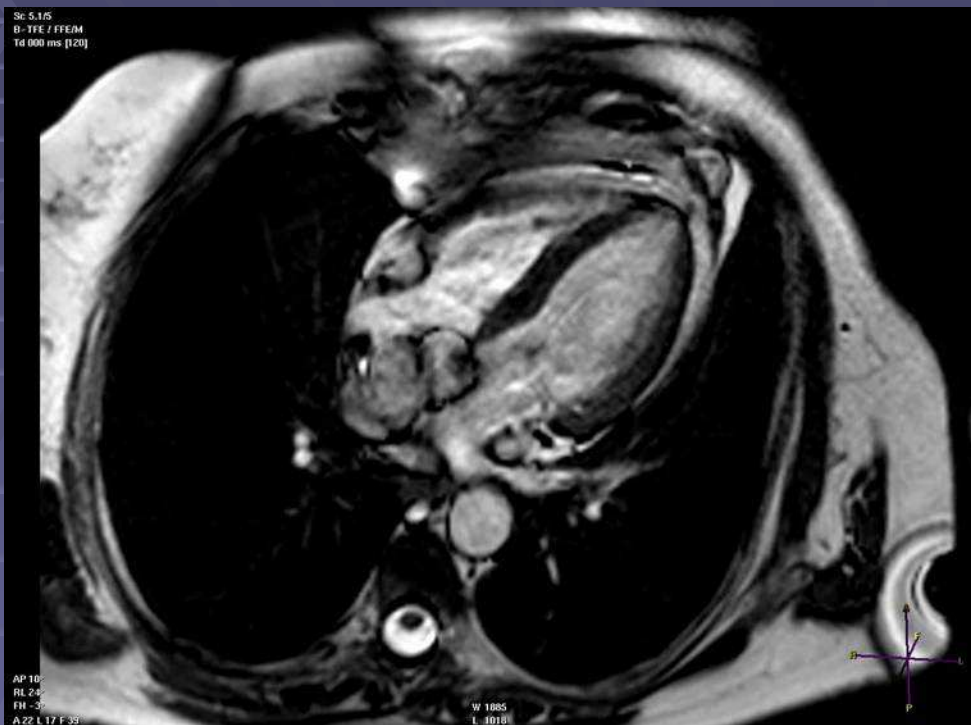
slice 1	Vessel 1
Stroke volume (ml)	71.8
Forward flow vol. (ml)	96.3
Backward flow vol. (ml)	24.5
Regurgitant fract. (%)	25.4
Abs. stroke volume (ml)	120.8
Mean flux (ml/s)	65.8
Stroke distance (cm)	3.8
Mean velocity (cm/s)	3.4

# More than just a Pretty Picture

## EuroCMR Registry Pilot

- Goal to determine value of clinical CMR
  - 11,040 consecutive pts at 20 German sites
  - Image quality at least diagnostic 98.2% pts
  - Severe complications in 0.05% pts (no death)
  - 62% studies directly impacted pt care
    - 16% entirely unsuspected diagnoses
  - 86% pts had enough information from CMR that additional imaging was unnecessary

# CMR... Adding Clinical Utility outside ability of usual Non-Invasive Methods

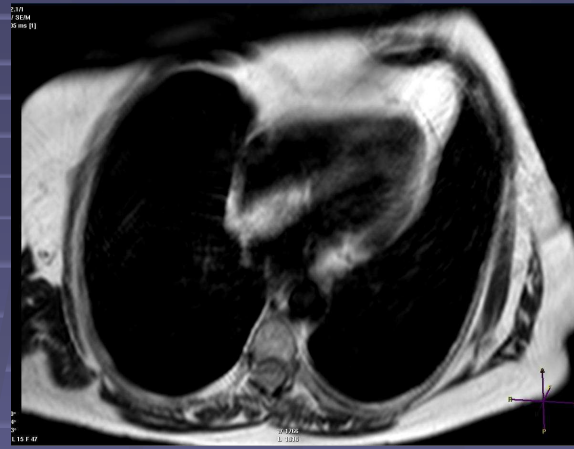


SSFP cine CMR, HLA, with RA-septal structure seen on echo

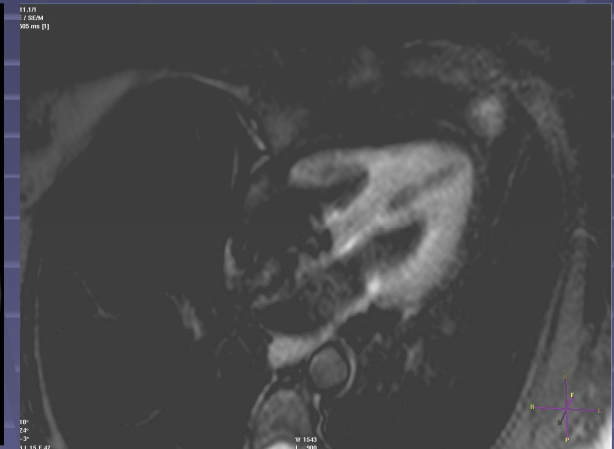
# Tissue Characterization



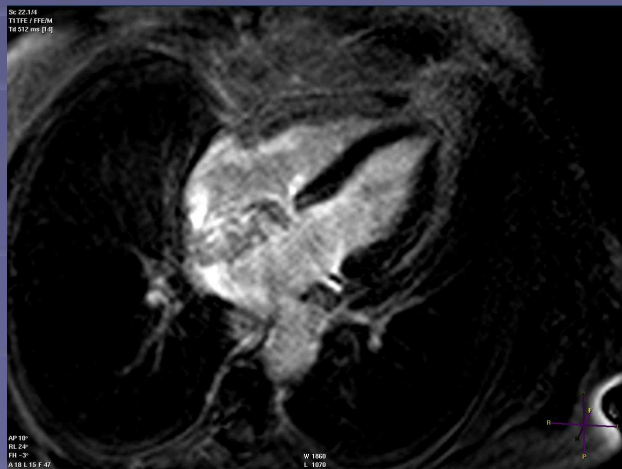
t1 black-blood SE, HLA



t2 black-blood SE, HLA



t2 Fat-saturated SE, HLA



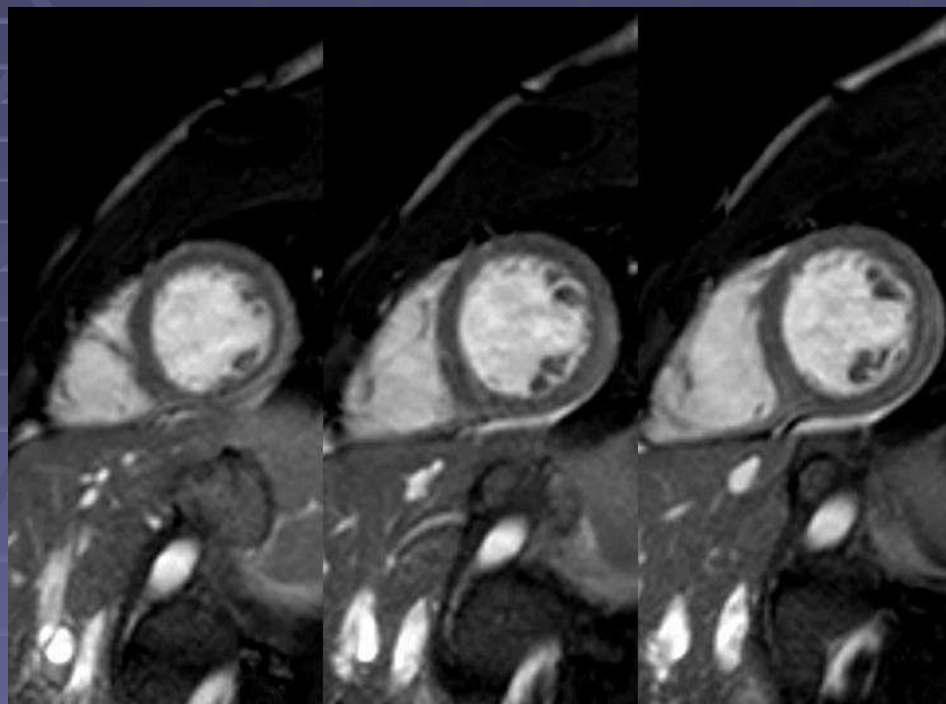
IR DHE, HLA, myocardial nulling



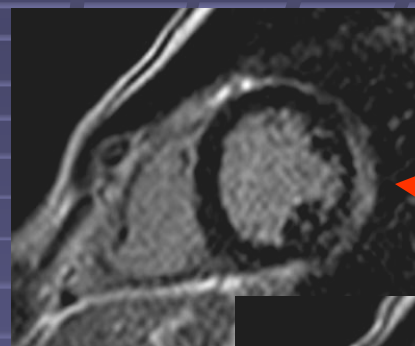
IR DHE, HLA, non-cardiac fat nulling



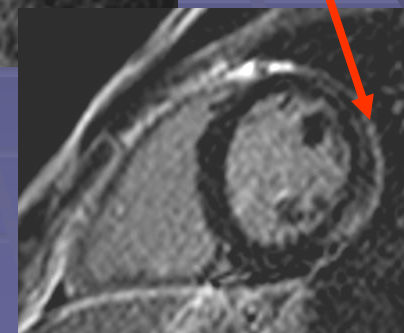
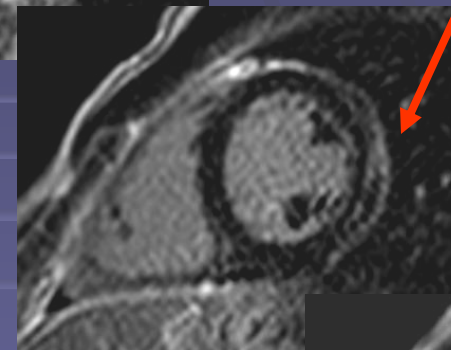
# Acute Myocardial Injury



SSFP cine CMR, SA (after gd)

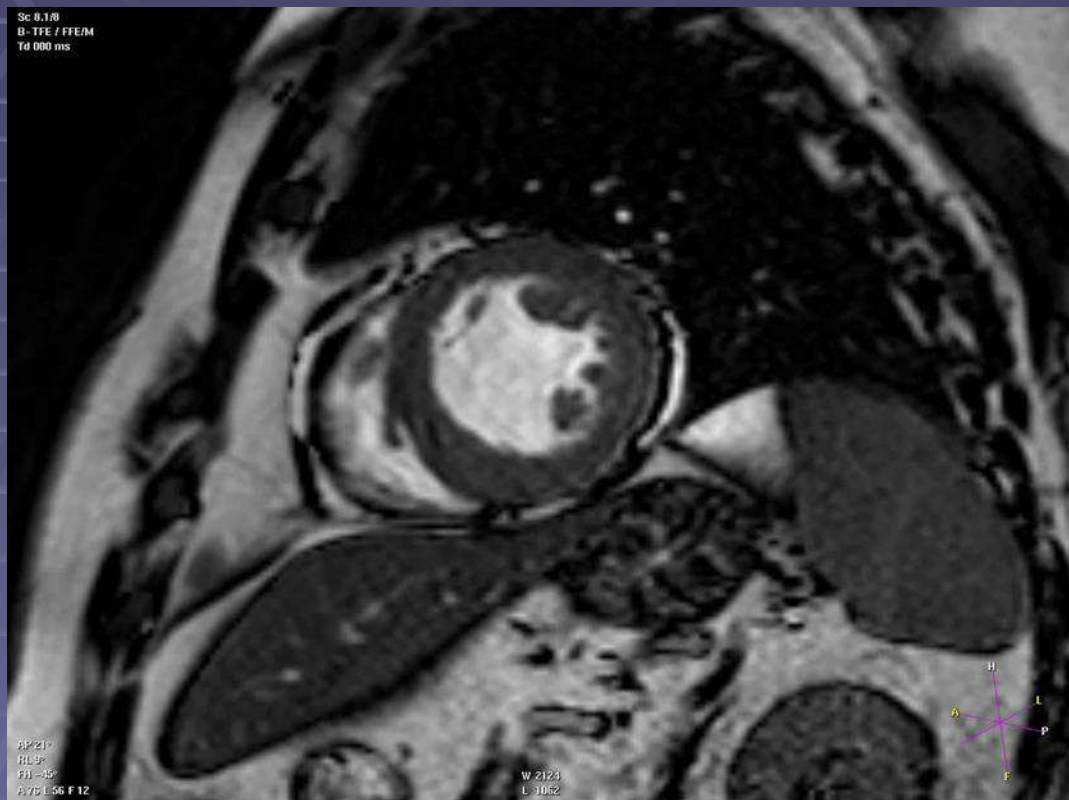


IR DHE SA

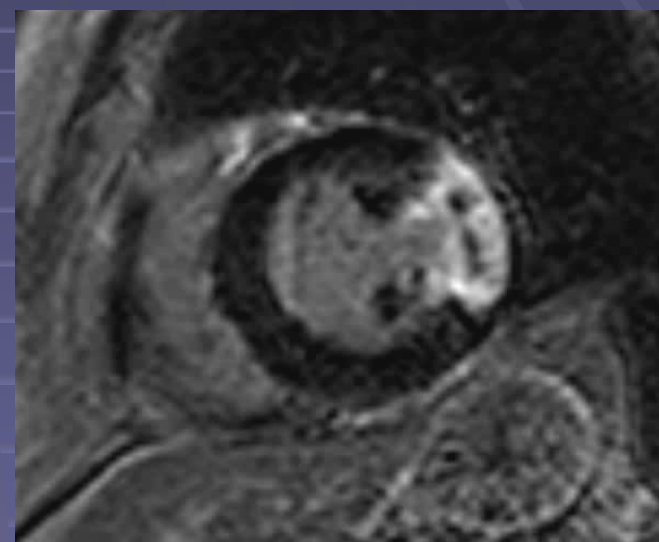


Acute Myopericarditis, with epicardial enhancement far remote from endocardium

# Acute Myocardial Injury



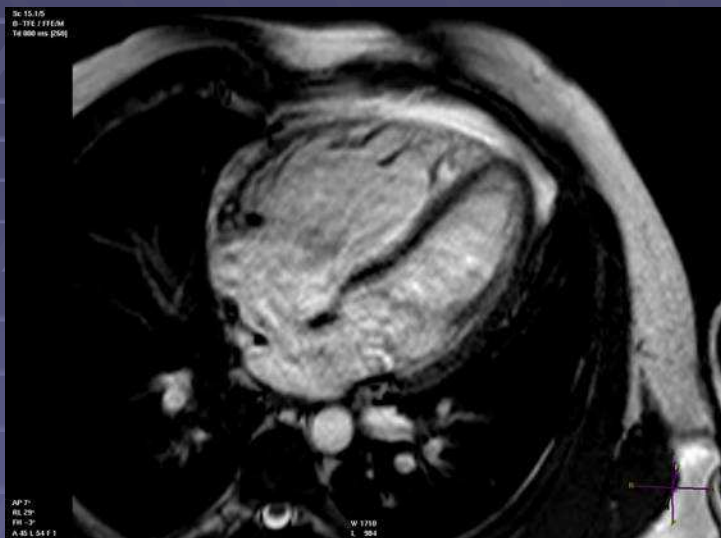
SSFP cine CMR, mid SA



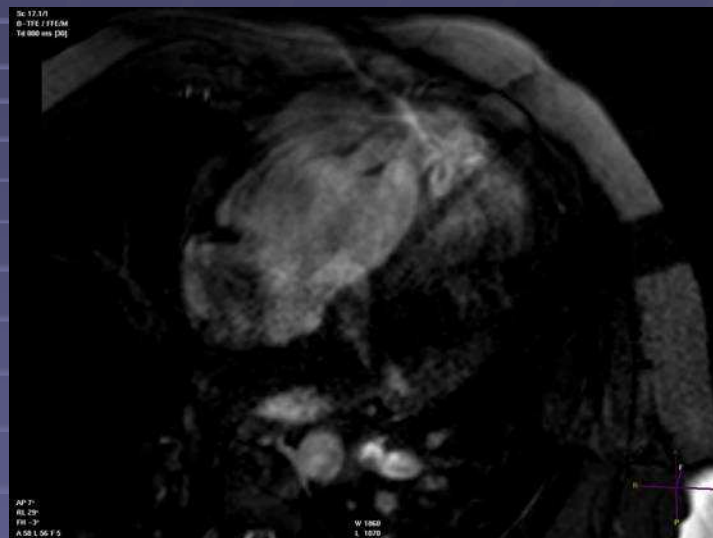
IR DHE, mid SA

44 year old with acute CP, markedly elevated troponin I, and minimal CAD. IR DHE consistent with MI and no-reflow. Reassessment of angiogram- flush OM occlusion.

# Large Secundum ASD



Cine SSFP CMR, HLA



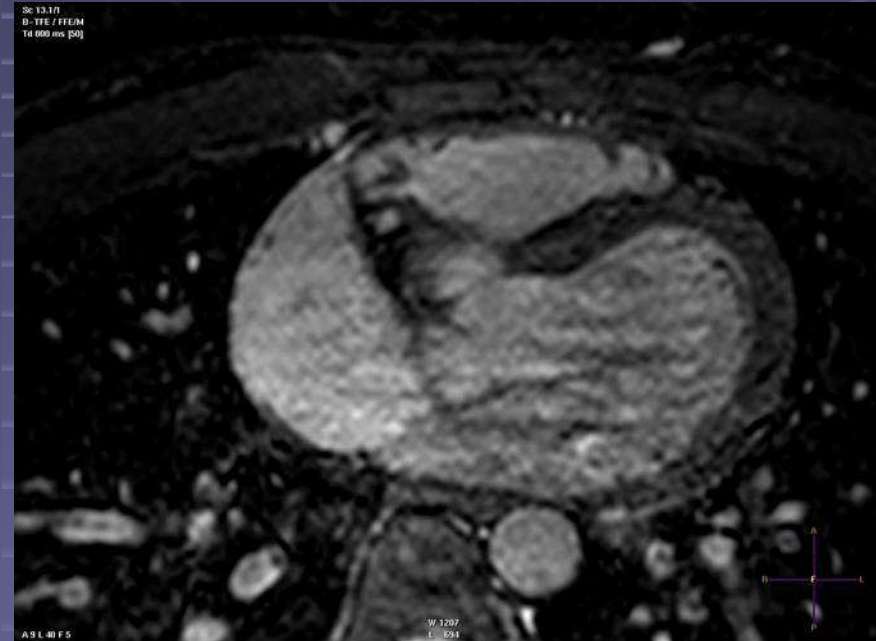
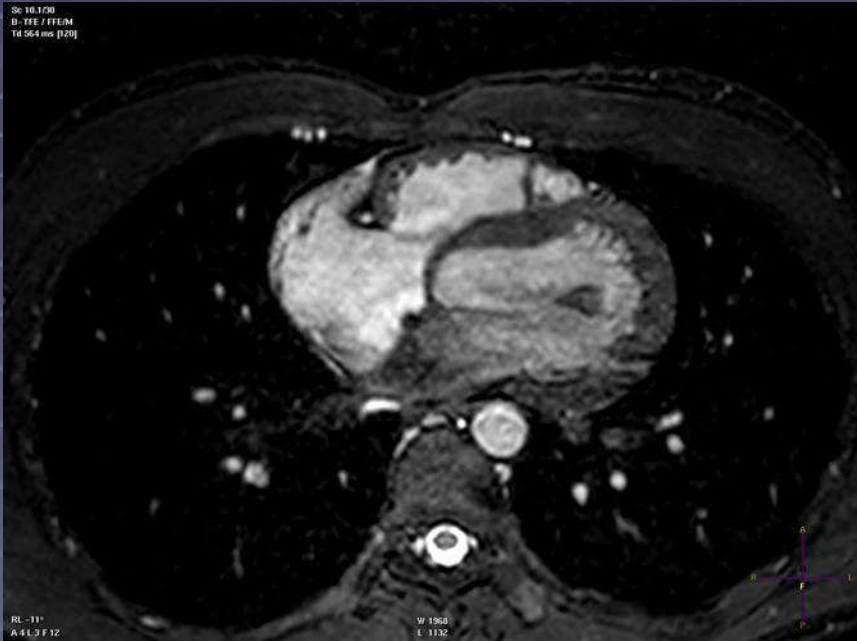
Saturation band applied left heart

Stroke volume (ml)		87.6
Forward flow vol. (ml)		88.9
Backward flow vol. (ml)		1.2
Regurgitant fract. (%)		1.4

Stroke volume (ml)		165.8
Forward flow vol. (ml)		167.8
Backward flow vol. (ml)		2.0
Regurgitant fract. (%)		1.2

Phase contrast derived aortic (left) and pulmonary artery (right) flow, demonstrating a Qp:Qs of 1.9

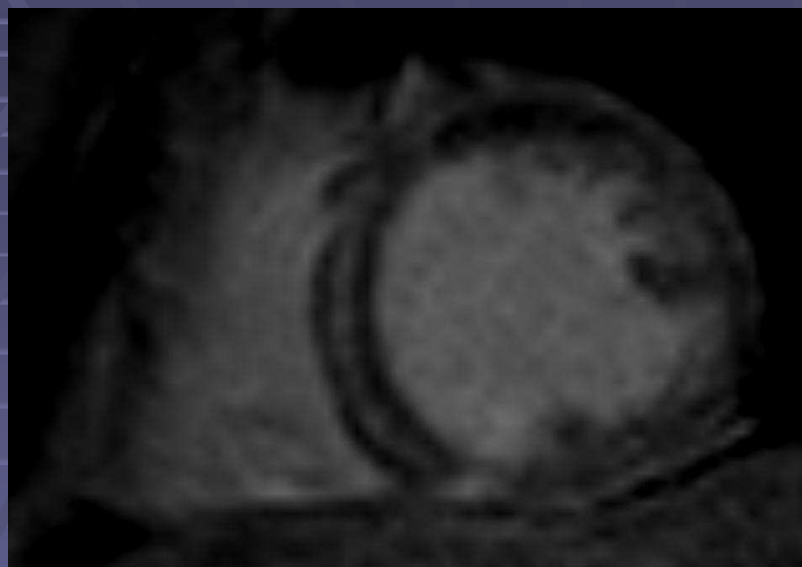
# Coronary MRA



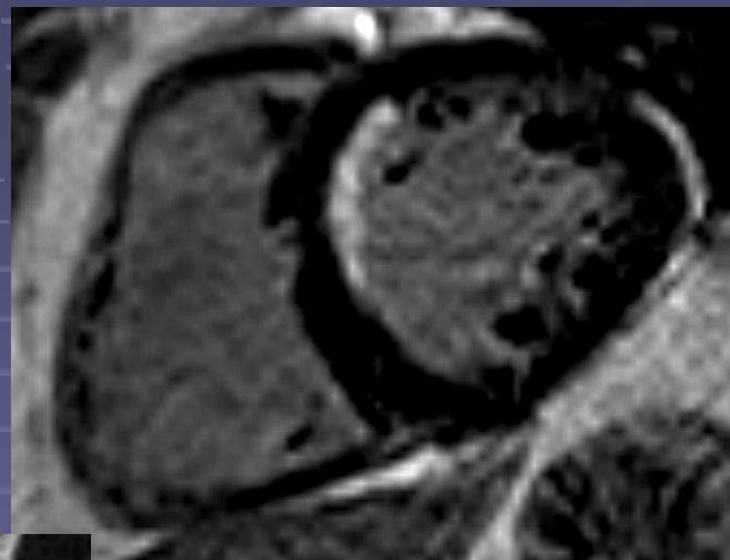
Free-breathing, Navigator-based whole heart coronary MRA, axial acquisitions, reconstructed to 0.55 x0.55 x0.7mm resolution

Whole heart coronary MRA. Normal subject (left). 29 year old tennis teaching pro, with exertional CP (right).

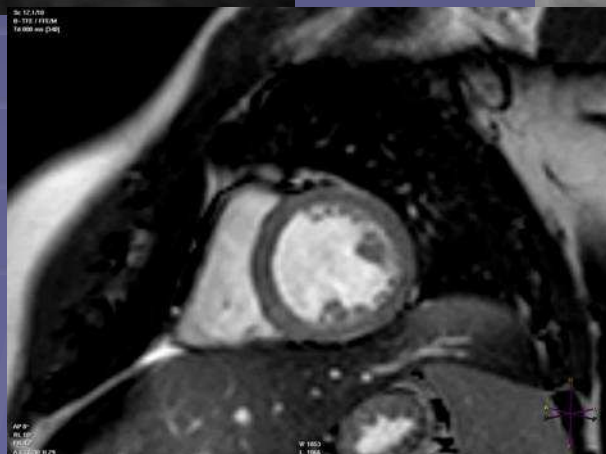
# DHE Assists in Differentiating Ischemic and Non-Ischemic HD



IR DHE, septal mid-myocardial enhancement; non-ischemic cm



IR DHE, septal endocardial enhancement; MI



45 year old male with heart failure, LV systolic dysfunction (SSFP SA, bottom)

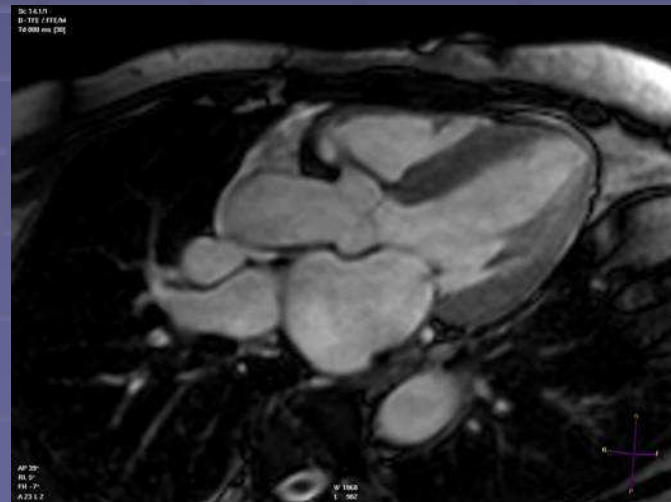
# Usefulness of CMR in Evaluation of Cardiomyopathy Etiologies



SSFP Cine LVOT



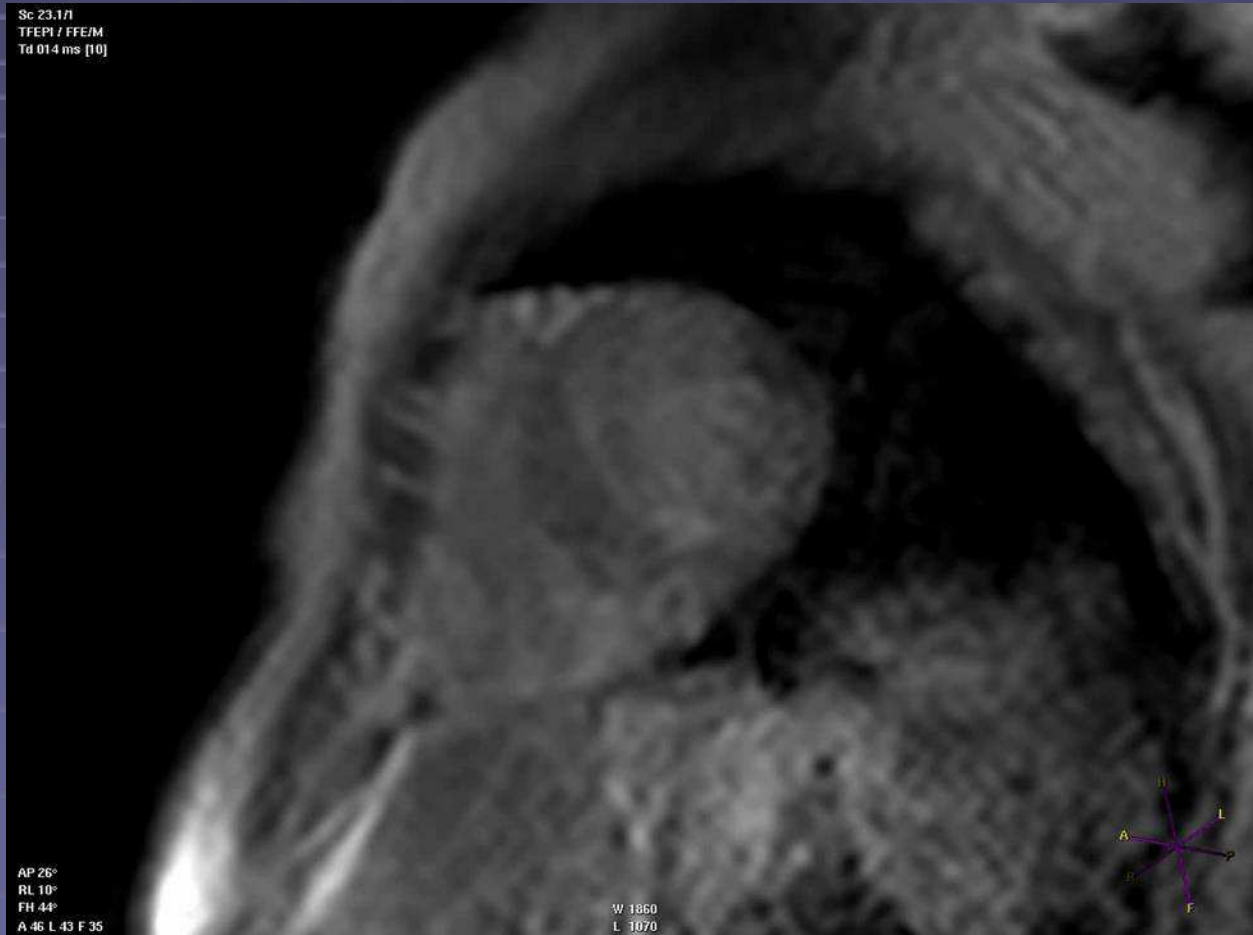
SSFP Cine HLA



SSFP Cine VLA

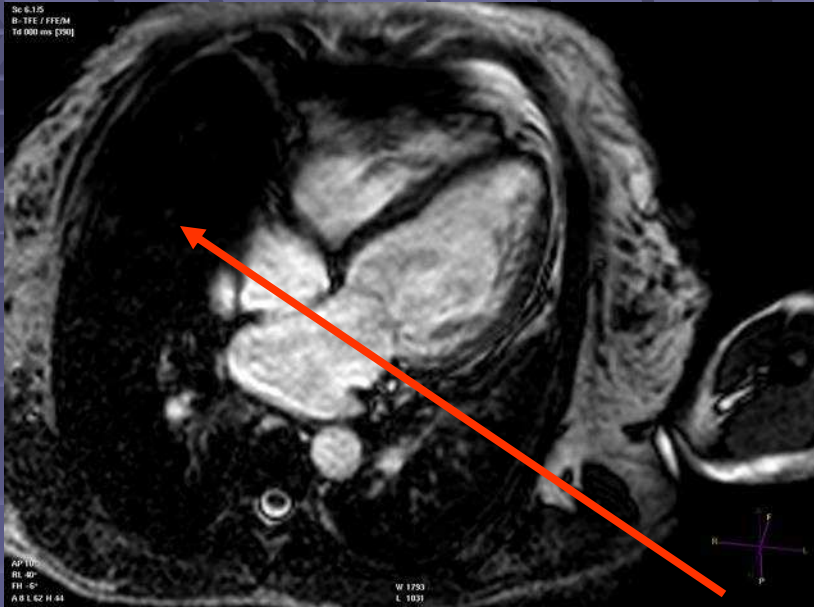
Pt with progressive SOB, referred to evaluate CHF

# Some of the Most Important Information comes from Ugly Pictures



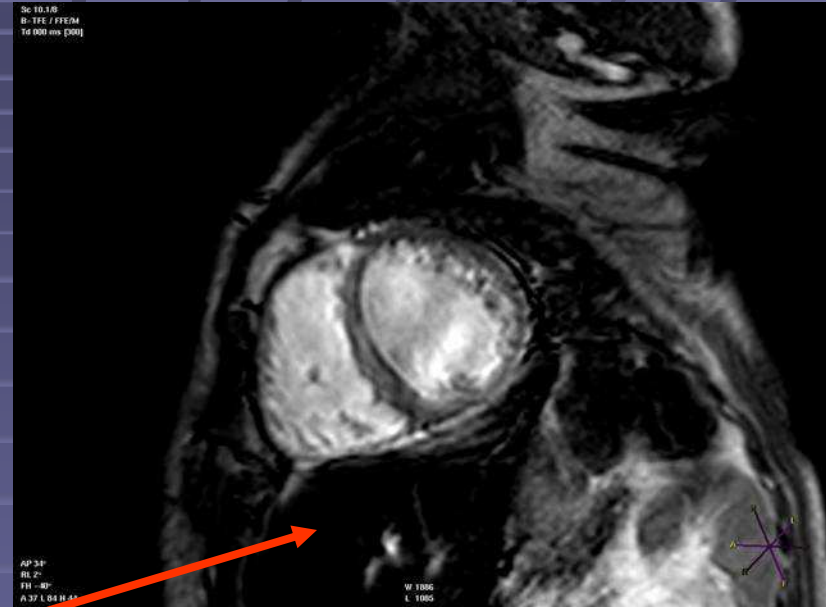
IR Look Locker Sequence, demonstrating poor myocardial nulling effect over all inversion times

# Hemochromatosis



SSFP cine CMR, HLA

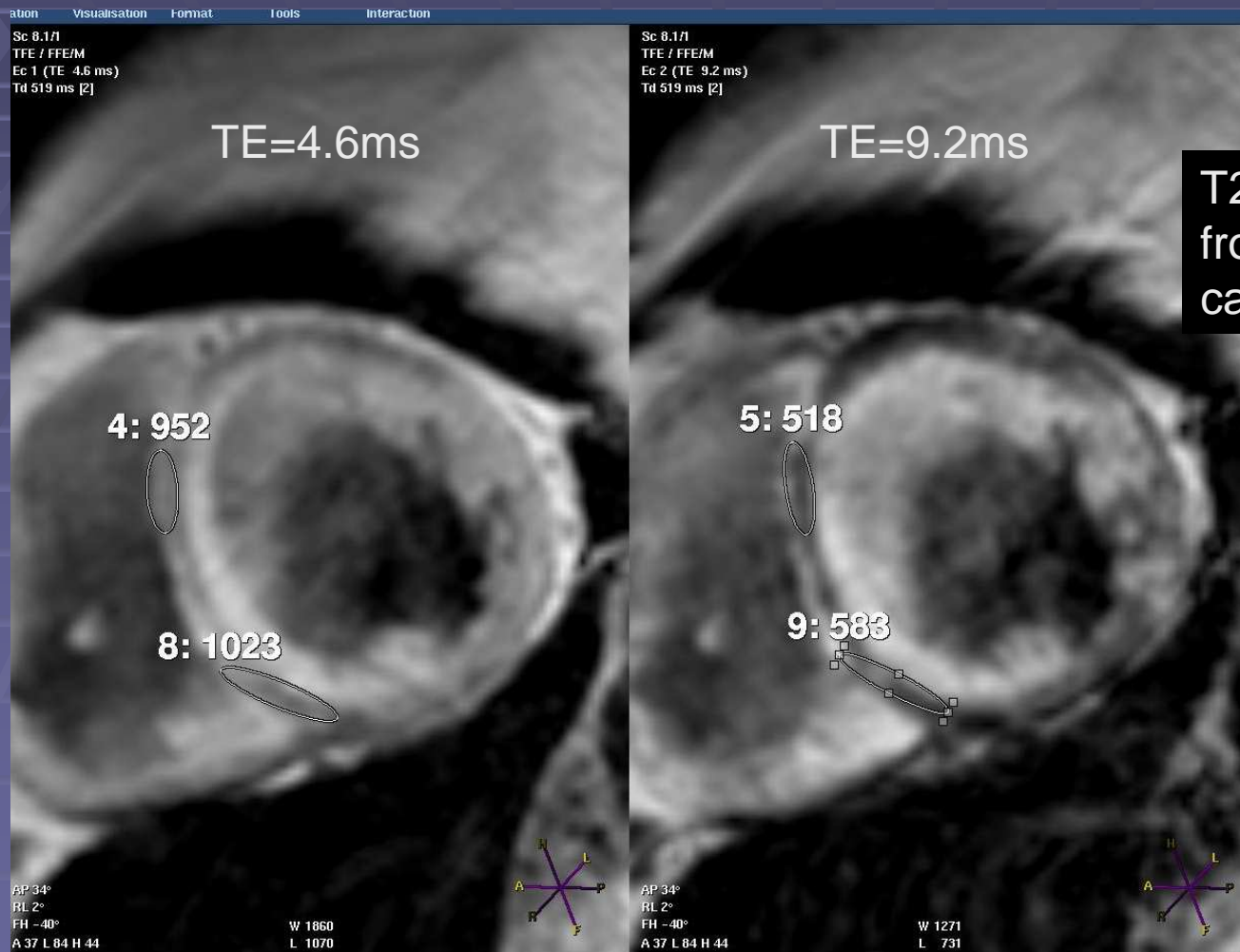
Liver



SSFP cine CMR, SA

CHF in patient with hemochromatosis. SSFP is a T2/T1 weighted method; note dark signal from liver.

# Evaluation of Myocardial Iron Overload



T2 intensity samples from septum for use in calculating T2\* value

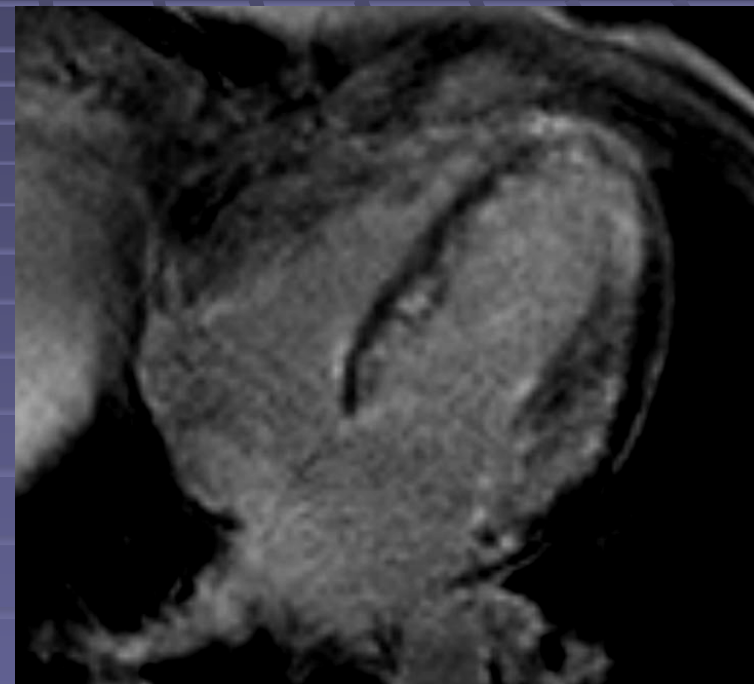
T2\*=7.9  
(normal>20)

Calculation of T<sub>2</sub>\* value demonstrating myocardial iron deposition in hemochromatosis

# Subendocardial Enhancement, non-ischemic etiology



SSFP cine CMR HLA



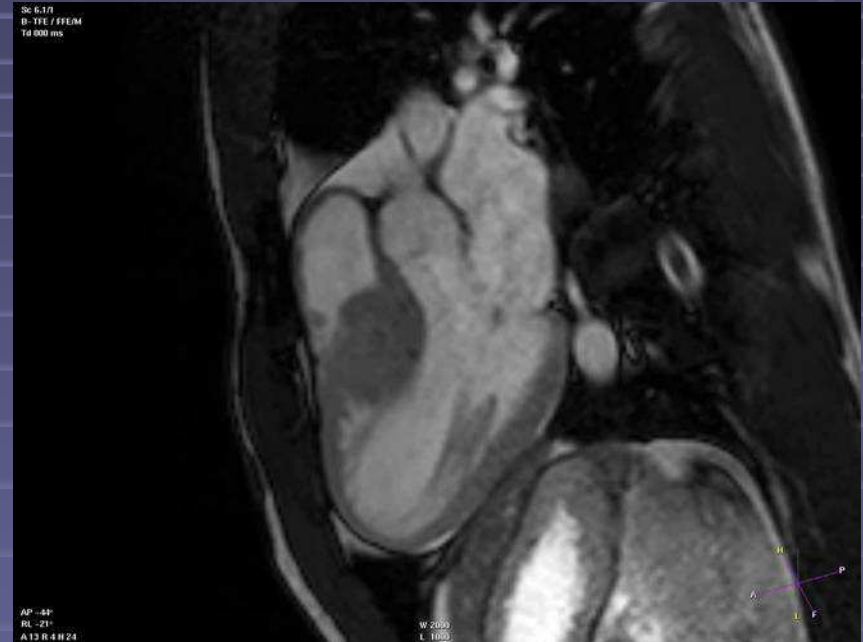
IR DHE HLA

Evaluation of myocardial injury and SOB in marked hypereosinophilia

# Hypertrophic CM



SSFP cine CMR HLA



SSFP cine CMR LVOT

# Myocardial Tissue Tagging in HCM

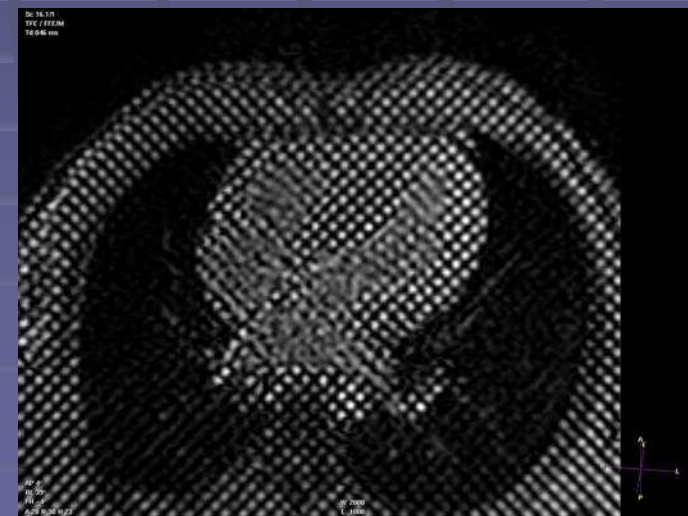


C-spamm  
SA HCM



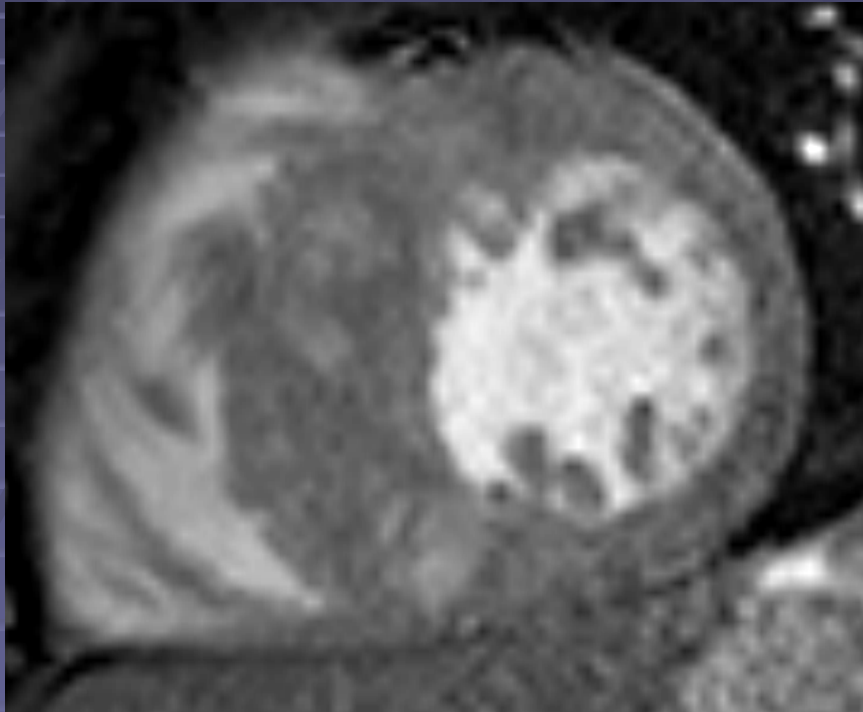
c-spamm SA normal subject

C-spamm  
HLA HCM

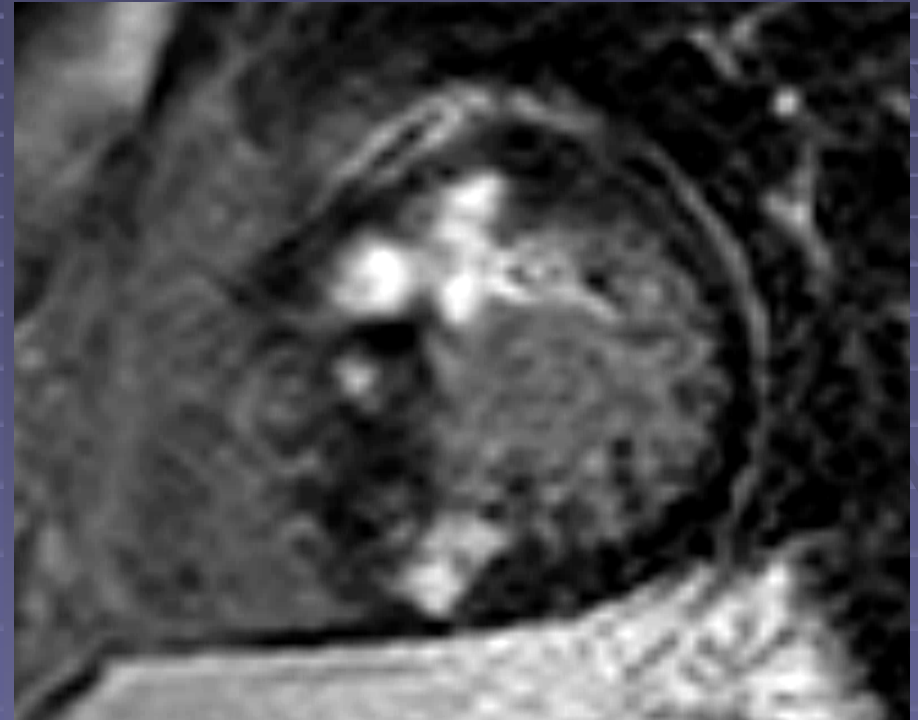


Methods that demonstrate abnormal myocardial mechanics may assist to identify pathological hypertrophy from adaptive

# Late Myocardial Enhancement in HCM



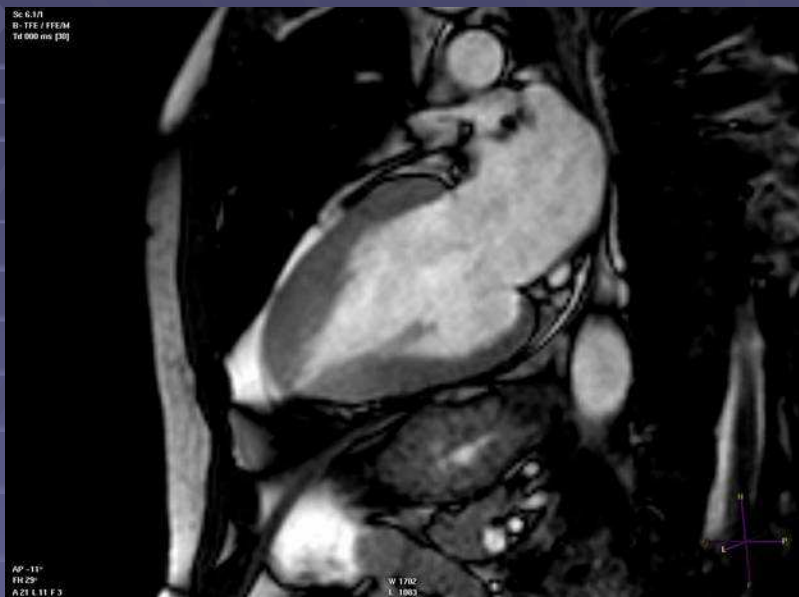
SSFP cine CMR, SA diastole



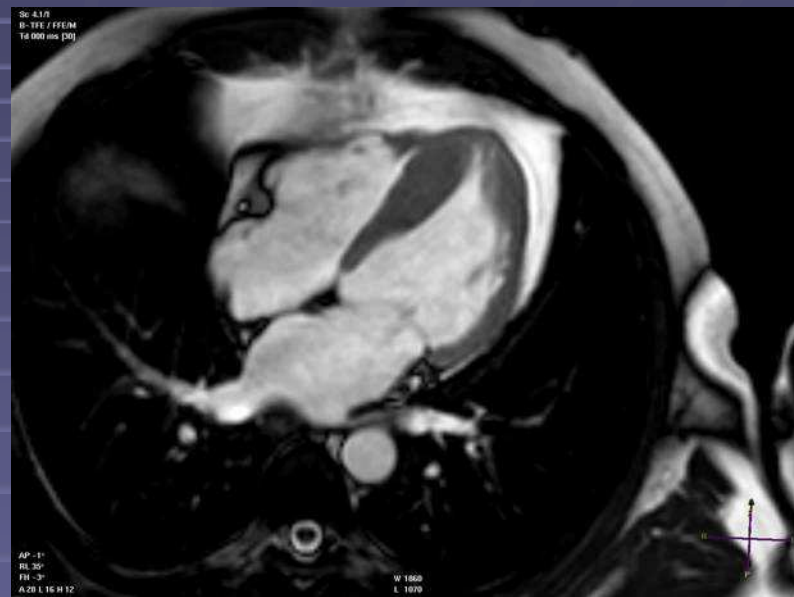
IR DHE, SA

Extent of late myocardial enhancement correlates with arrhythmia hazard in HCM

# Apical Hypertrophic CM



SSFP VLA



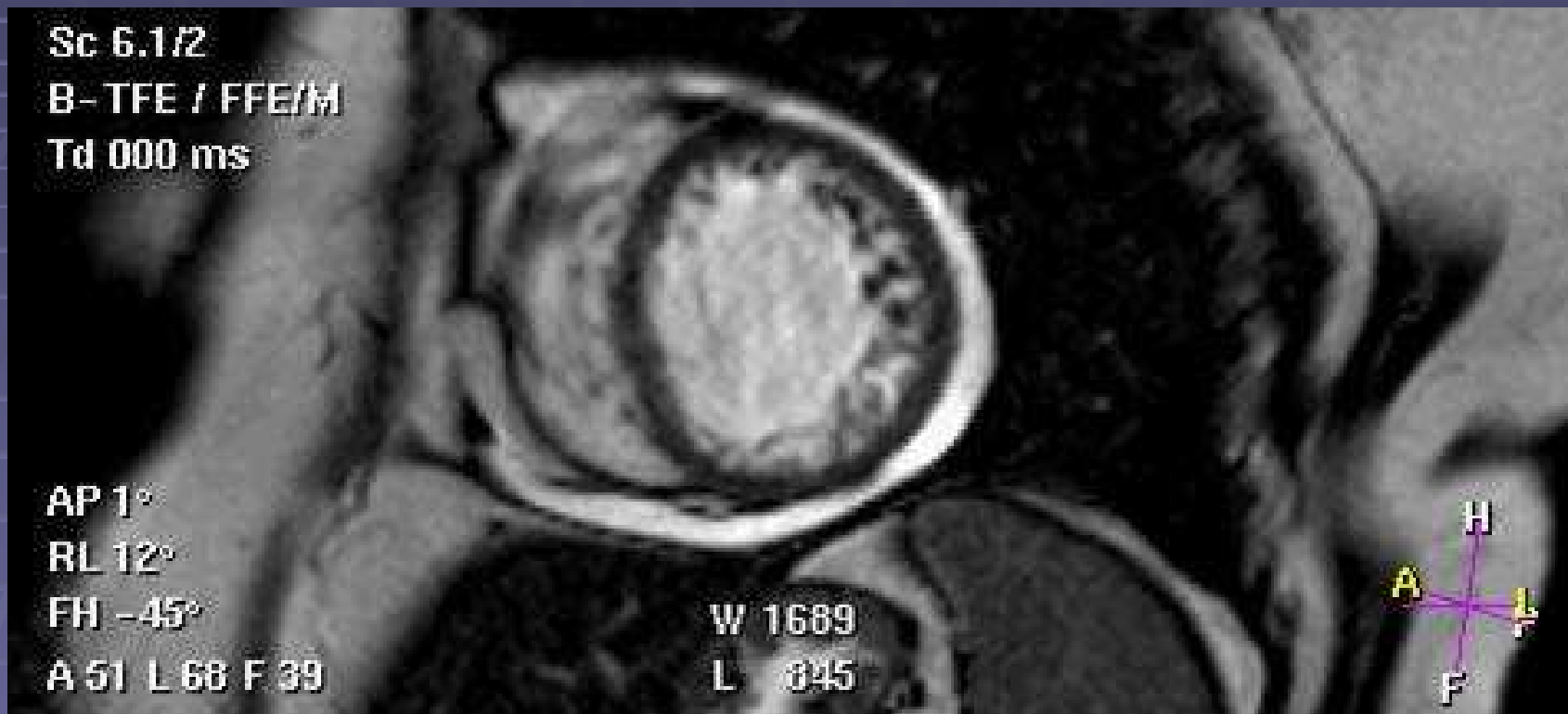
SSFP HLA

IR DHE  
VLA



Cardiac MRI affords accurate determination of extent/location of hypertrophy in HCM

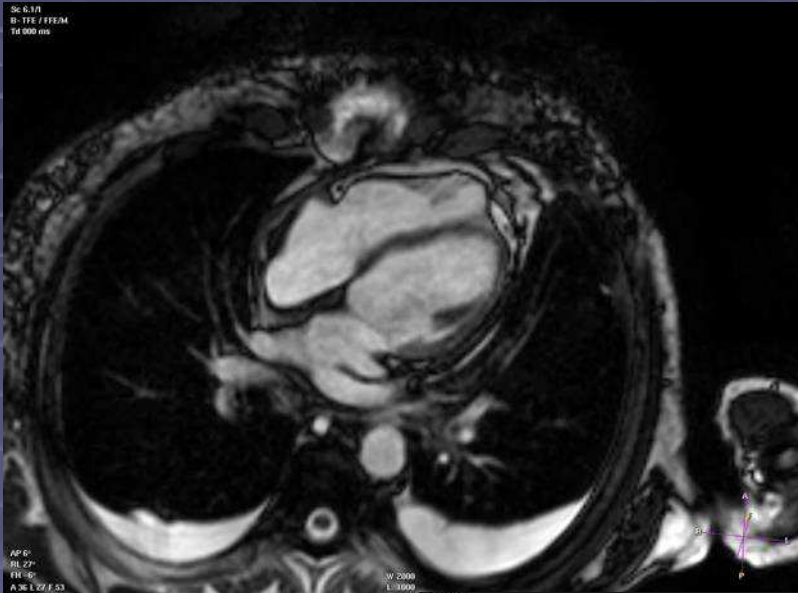
# Non-Ischemic CM



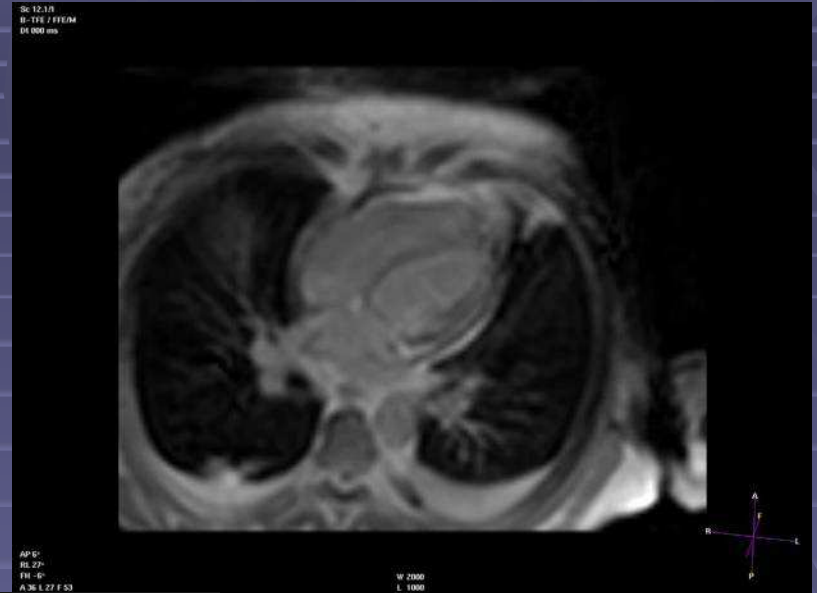
SSFP cine CMR mid SA

Deep recesses persist in systole, consistent with non-compaction cardiomyopathy

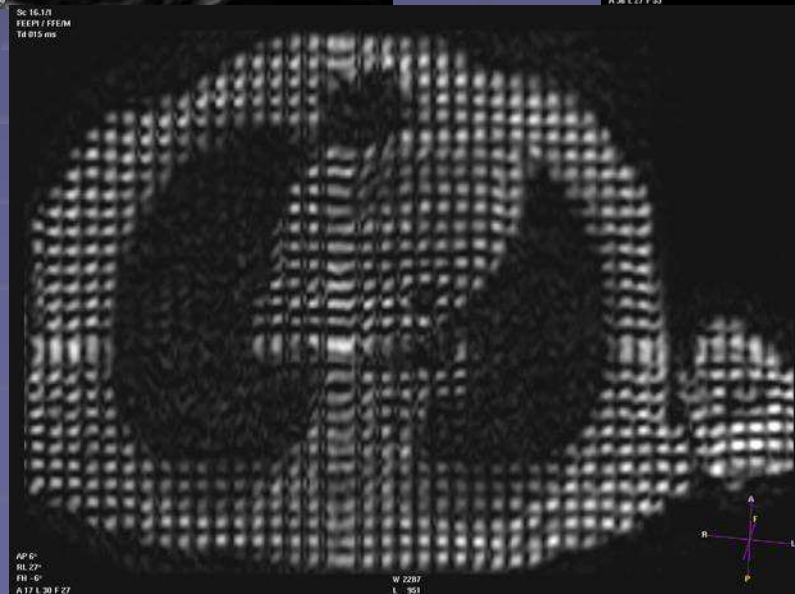
# CHF after CABG: Constrictive Pericarditis



HLA cine CMR



Real-Time HLA



Tissue Tagging HLA

# Application of CMR in Community Medical Centers

- Challenges facing implementation
  - Economics
    - Magnet
    - Volume
  - Performing Physicians
    - Sufficient training
    - Investment in technologists, nursing
    - Availability
      - Non-uniformity of protocols
  - Educating referral physicians

# CMR Appropriateness-Summary

- CMR is a robust, reasonably mature imaging method, with wide clinical applicability
- Appropriate utilization depends upon
  - Familiarity with the appropriate patient
  - Availability of an appropriate CMR service
  - Awareness of the strengths and limitations of CMR compared with alternative methods
  - Framing an appropriate clinical question so that a high probability exists that the result will influence patient care