RC997: Essentials of Cardiovascular Imaging

Cardiac MR Imaging: What You Need to Know

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Disclosures

- Off-label: gadolinium MR of the heart and vessels, adenosine MRI
- Research support: Epix Medical
- Consultant: Bracco, Berlex
- Speaker: Toshiba, GE Healthcare

Essentials of Cardiac MRI

- MRI cardiac pulse sequences
- Evaluation of myocardial masses
- Evaluation of coronary heart disease
- Evaluation of the right ventricle

Pulse sequences for cardiac MRI*

Purpose	Type	Sequence
morphology	Black blood T1, T2	double IR FSE/TSE
function	cine	steady state free precession (SSFP)
tissue characterization	*gadolinium*	*IR prepared gradient echo*

*"all" are gated to the cardiac cycle

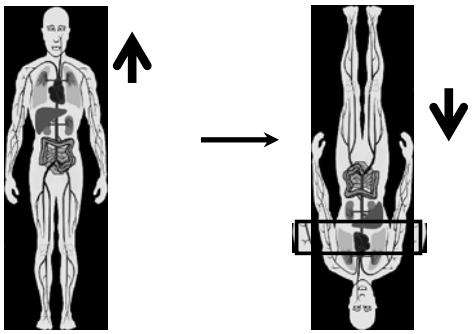
"Double IR" black blood FSE

Breath-hold high resolution, intracardiac detail

- "T1" weighted, where TR = 1 R-R interval
- PD (TR 1000, TE 20), T2 weighted (TR 2000, TE 80)

"Double IR" FSE: 1st inversion pulse

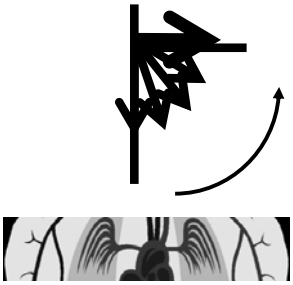
nonselective 180° inversion pulse



"Double IR" FSE: 2nd inversion pulse

2nd *selective* 180° inversion pulse

"Double IR" FSE: wait for the TI time

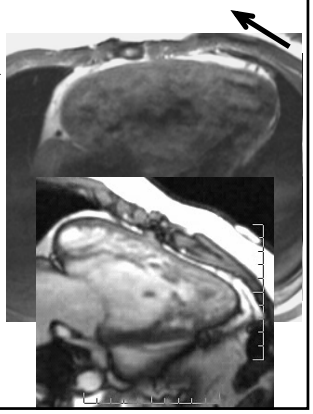


- The inversion time for blood varies based on heart rate, from 400-600 msec
- If gadolinium present, use TI 200 msec

"Double IR":

TI = 600 msec, inflowing blood now nulled (dark)

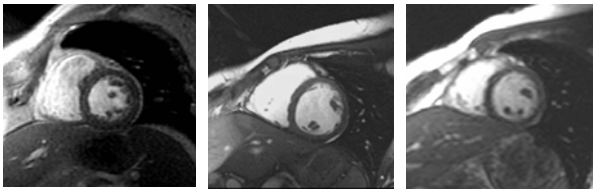
Perform a gated FSE acquisition



Cine: Steady state free precession (SSFP)

-balanced FFE®
-TruFISP®
-Fiesta®

ALL THE SAME

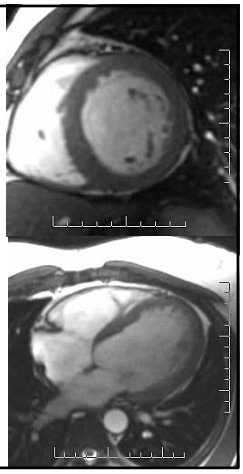


Fast GRE (16 sec) | SSFP (6 sec) | Real time SSFP

T. Foo

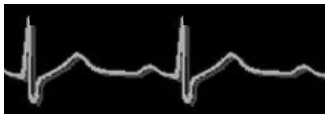
SSFP Cine

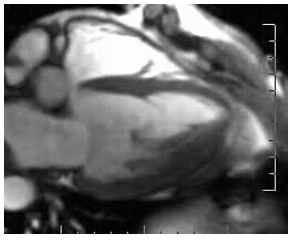
- fast gradient echo pulse sequence, balanced gradients in x,y,z
- Contrast $\sqrt{T2^* / T1}$

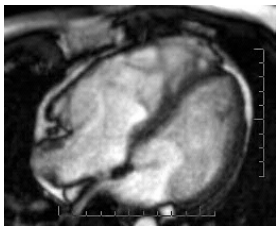


CINE images

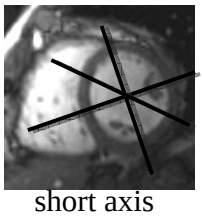
Retrospective Triggering
Prospective Triggering
Real-time Imaging





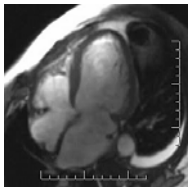


Imaging planes

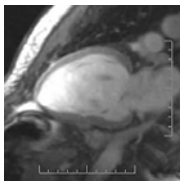


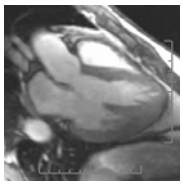
short axis

HLA



VLA



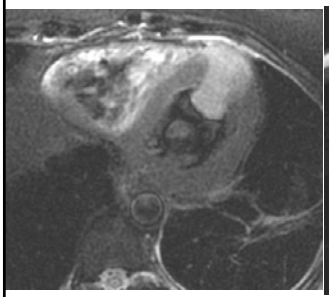


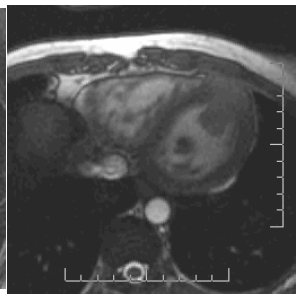
5 chamber

Essentials of Cardiac MRI

- MR cardiac pulse sequences
- Evaluation of myocardial mass
- Evaluation of coronary heart disease
- Evaluation of the right ventricle

Metastatic disease 20x more common than primary cardiac tumors



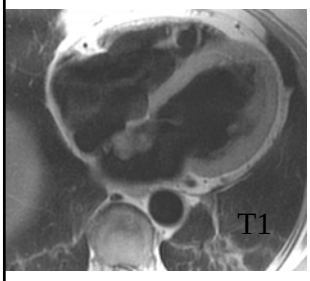


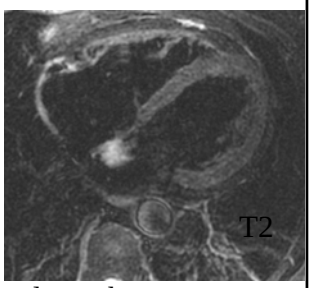
T2 Leiomyosarcoma metastasis

Primary benign tumors:

1. Myxoma 41%
2. Lipoma 14%
3. Papillary fibroelastoma 13%
4. Rhabdomyoma 11%

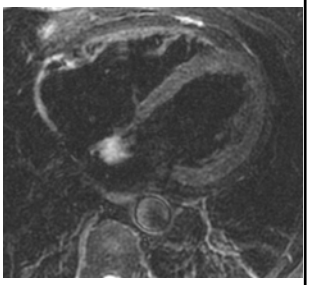
Myxoma





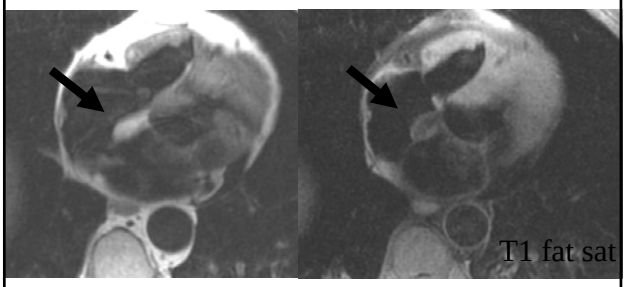
- interatrial septal attachment
- 4:1 left vs. right sided

Myxoma



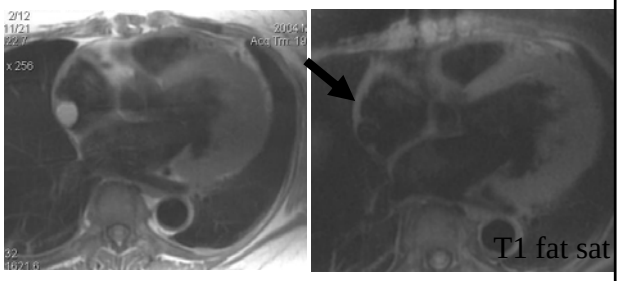
- high T2 signal

Lipomatous atrial septal hypertrophy

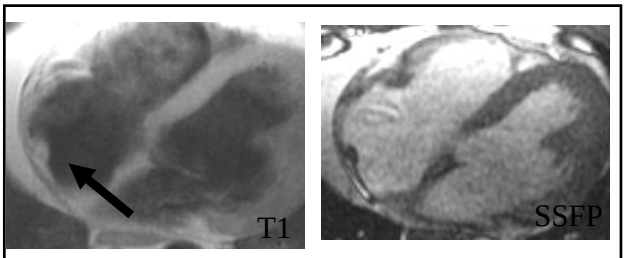


- echogenic mass on echocardiogram
- low association with arrhythmia, obesity

Right atrial lipoma



- T1 fat sat is diagnostic
- Associations: obesity, steriod use



Crista terminalis

- normal RA finding, may be confused with clot or mass

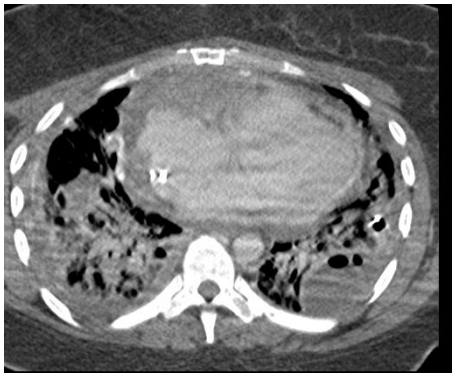
Crista terminalis

- Smooth ridge within the right atrium
- Related to embryonic development of the right atrium

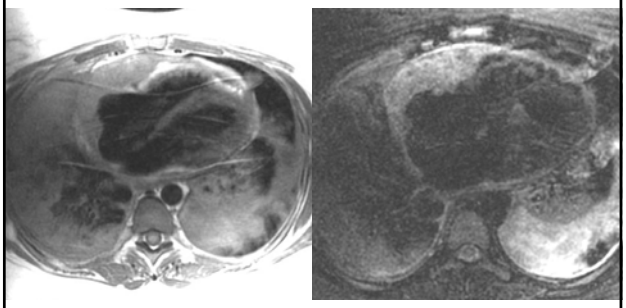
Primary malignant tumors:

1.	Angiosarcoma	31%
2.	Rhabodmyosarcoma	20%
3.	Other sarcoma	16%
4.	Mesothelioma	15%
5.	Primary Lymphoma	6%

62 yo female, CHF and abnormal CT

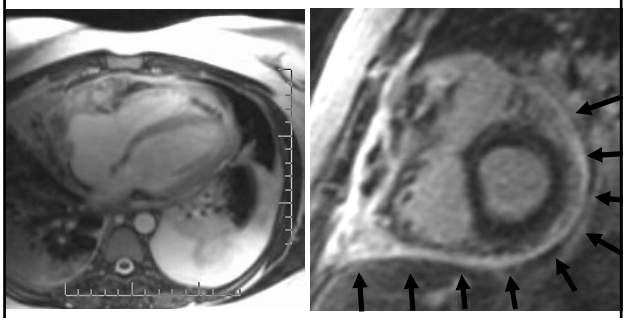


CHF, soft tissue mass by CT



Axial T1 Axial T2, fat sat

CHF, soft tissue mass by CT: angiosarcoma



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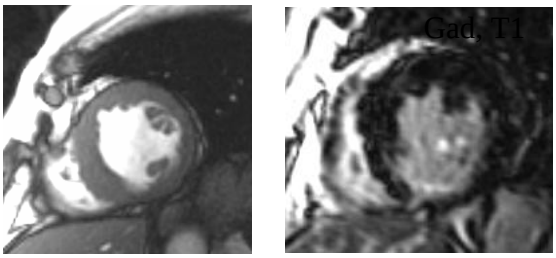
Myocardial Delayed Enhancement (MDE)

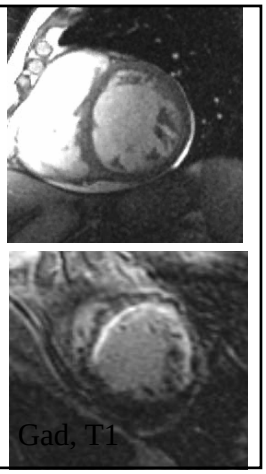
Coronary Heart Disease, valvular abnormality

Delayed washout (@10-20 mm) of gadolinium in areas of infarction/scar.



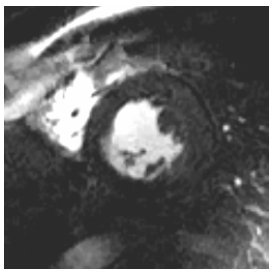
Non viable Myocardium (scar)

1. Lack of contraction, *and*
2. Lack of recovery of normal function after revascularization (CABG).



Chronic MI

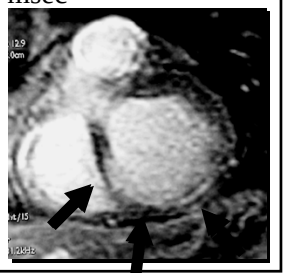
- Images every 1 minute after gadolinium injection



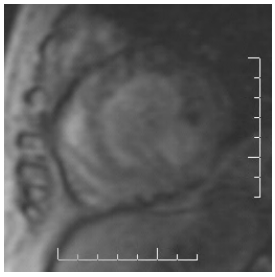
M. Friedrich, AHA 2002

Use an inversion pulse to suppress normal myocardium

- Optimal TI time depends on clearance of gadolinium from the *normal* myocardium
- Typical range: 175-250 msec
- Lower TI time when more gad is present:
  - decreased renal function
  - CHF

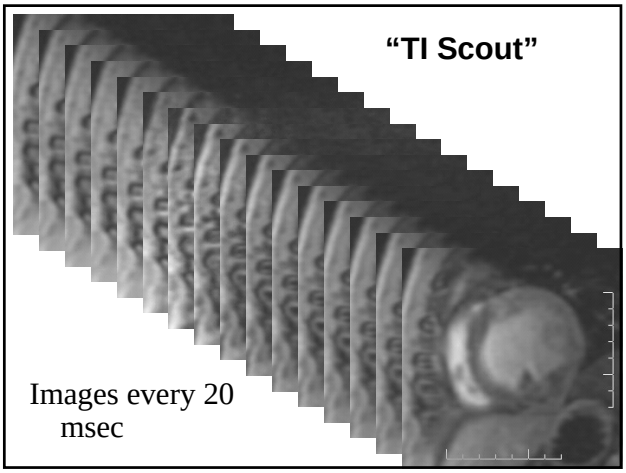


"TI Scout"



Single breath-hold, 50 phases, 20 msec temporal resolution

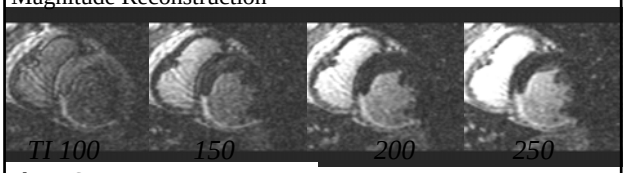
"TI Scout"



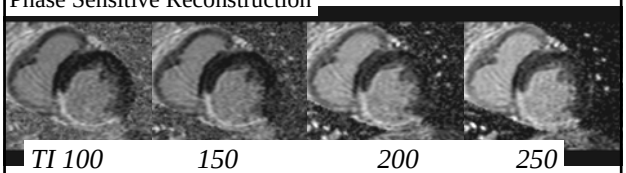
Images every 20 msec

Phase Sensitive Inversion Recovery

Magnitude Reconstruction

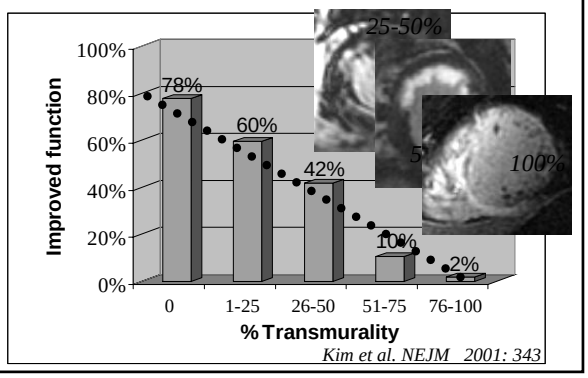


Phase Sensitive Reconstruction



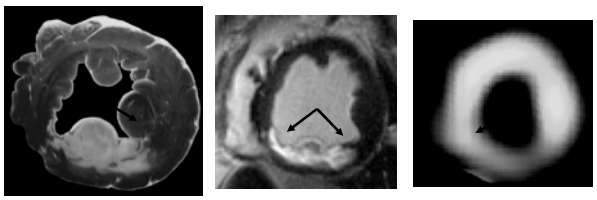
Arai, AHA 2002

Key factor: *transmurality* of the gadolinium enhancement



Kim et al. NEJM 2001: 343

MRI is higher resolution than SPECT

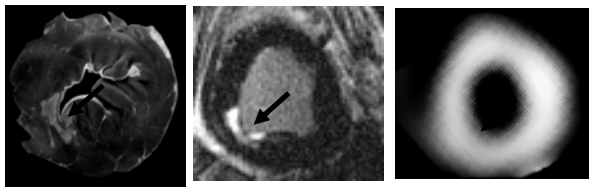


TTC MRI SPECT

Canine model

Wagner A. et al., Lancet. 2003 Feb 1;361(9355):374-9

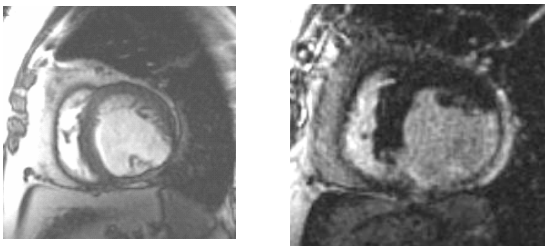
MRI is more sensitive than SPECT



TTC MRI SPECT

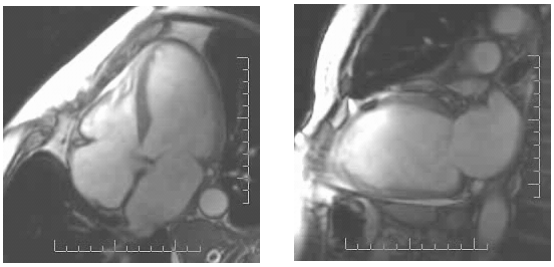
Wagner A. et al., Lancet. 2003 Feb 1;361(9355):374-9

MR Viability imaging aids in pre-surgical planning

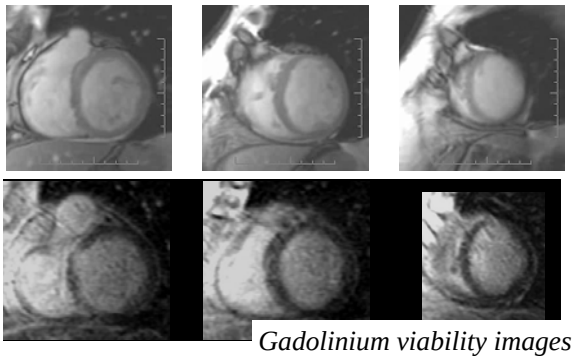


SSFP short axis Gad- delayed

Left ventricular remodeling after MI reduces effectiveness of contraction



MR Viability imaging aids in bypass surgical planning



Gadolinium viability images

Coronary Heart Disease

1. No delayed enhancement
   = no myocardial scar/ fibrosis.

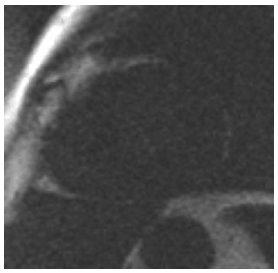
2. T*ransmural* delayed enhancement
   = no functional recovery even after treatment by bypass or stent.

Coronary Heart Disease: *Acute* coronary blockage (infarct)

- Initially, there is myocardial necrosis (cell death) than enhances with gadolinium.
- If the blockage is not rapidly opened and the patient survives, the capillary blood supply may also be damaged.

Q-Wave Acute MI

- Images every 1 minute after gadolinium injection
- Capillary blockage is termed "microvascular obstruction"

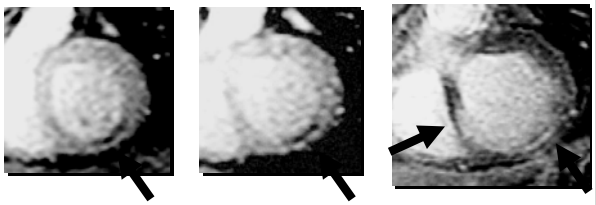


images every 1 minute after gadolinium

M. Friedrich, AHA 2002

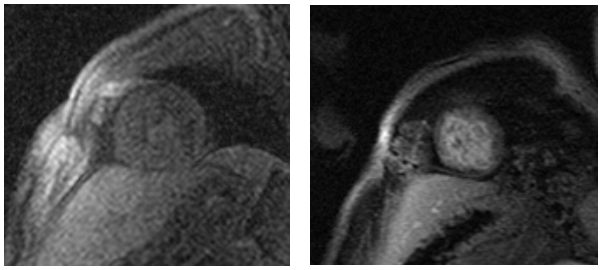
Acute infarct with microvascular obstruction (at the infarct core)

1st pass image | Filling in | Infarct



25 sec | 40 sec | 10 min

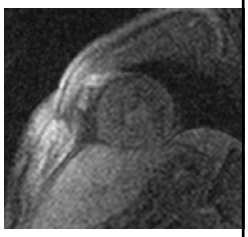
Acute LAD infarction



1st pass | delay

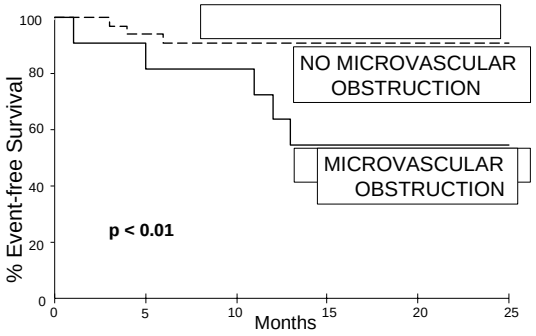
Microvascular Obstruction (MO)

MO predicts significantly increased rate of cardiovascular complications after MI (unstable angina, reinfarction, CHF, embolic stroke, death).



Wu KC, et al. *Circulation* 1998;97:765-772

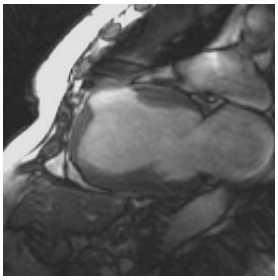
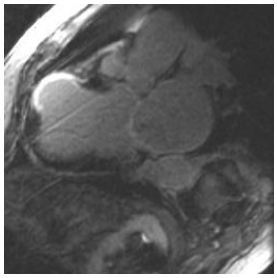
Microvascular Obstruction (MO)



Wu KC, et al. *Circulation* 1998;97:765-772

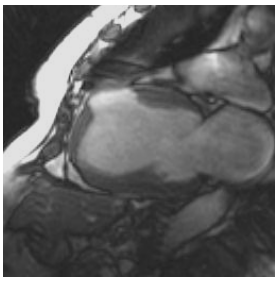
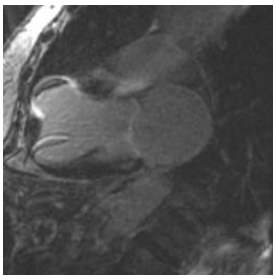
Examples: Coronary Heart Disease

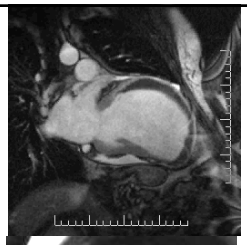
New onset CHF

pseudoaneurym (rupture) vs. true aneurysm

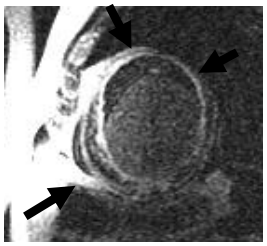
True LV aneurysm + clot due to old infarct

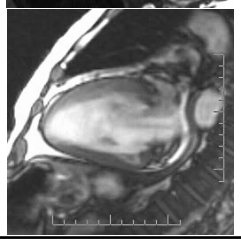





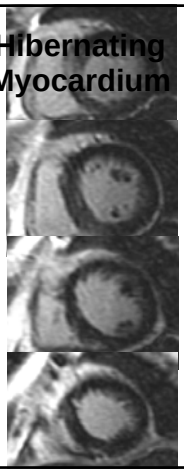

LV aneurysm/ infarct and clot

LV EF 8% LV volume 820 ml



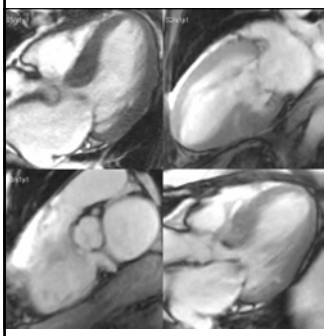
Hibernating Myocardium



Delayed Enhancement is nonspecific

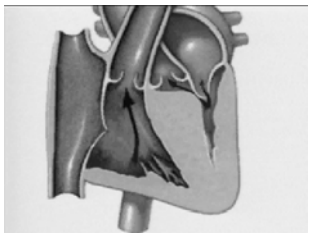
- Fibrosis (MI, hypertrophy)
- Tumor
- Inflammation – myocarditis
- Amyloid
- Chagas disease (fibrosis)
- Sarcoid

Hypertrophic Cardiomyopathy (HOCM)



- Most common cause of sudden cardiac death <30 yrs old
- Obstruction of outflow tract
- Genetic abnormality: sarcometric contractile proteins
- Autosomal dominant

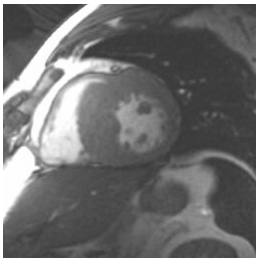
HOCM - pathophysiology

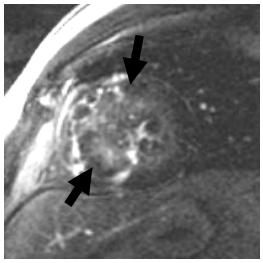


© *Mayo Clinic*

Systolic anterior motion of the mitral valve, resulting in aortic outflow obstruction

HOCM: MRI shows collagen deposition associated with “myocardial disarray”



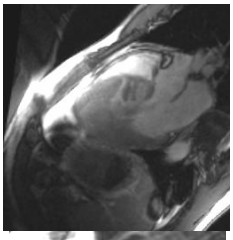


Cine

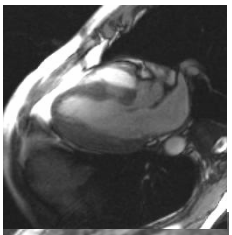
Delayed contrast

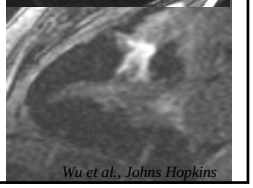
HOCM: minimally invasive Rx (EtOH)

Pre Treatment



2 mths Post Treatment

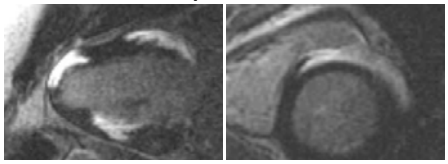




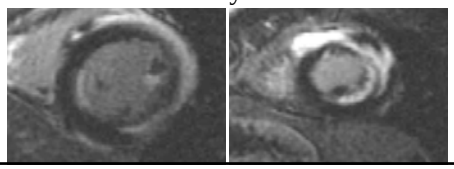
Wu et al., Johns Hopkins

Acute Onset Ventricular Tachycardia, Fever, Malaise

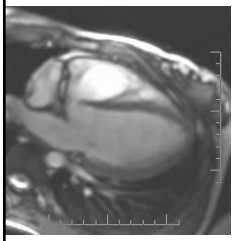
(Courtesy, J. Tadeja, MD)

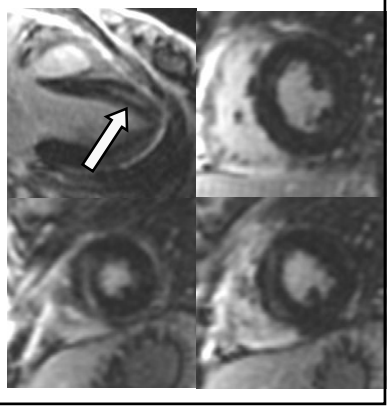


Patchy epicardial enhancement, noncoronary distribution



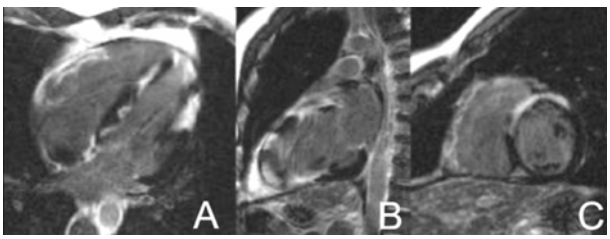
25 y/o, acute chest pain 2 wks ago



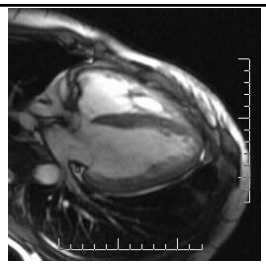


Cardiac Sarcoidosis

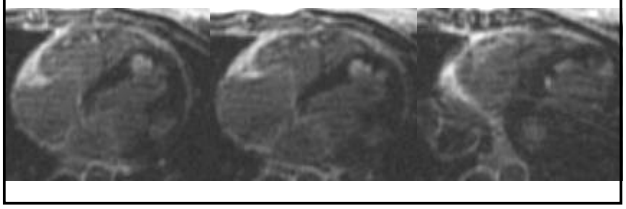
Patchy myocardial enhancement, especially septal/ basal/ epicardial regions



Acute Sarcoidosis: Hunold, J. Barkhausen, AJR 2005; 184



Progressive RV failure
Giant Cell Myocarditis



Essentials of Cardiac MRI

- MR cardiac pulse sequences
- Evaluation of myocardial masses
- Evaluation of coronary heart disease
- Evaluation of the right ventricle

Arrhythmogenic right ventricular dysplasia/ cardiomyopathy (ARVD/C)

- MRI is the most important noninvasive imaging test for diagnosis.
- 71% of cases referred for 2nd opinion were overdiagnosed by MRI* (?high sensitivity, low specificity)

**Bomma et al, J Cardiovasc Electrophysiol 2004; 15*

Arrhythmogenic RV Dysplasia

- Fibrofatty infiltration of RV resulting in ventricular tachycardia
- Palpitations, syncope, sudden death
- Age 33 ± 14 yrs.
- 30-50% cases are familial. MRI used to screen family members.

"McKenna" Criteria*:*
2 major, 1 major+2 minor, 4 minor*

Criteria	Major
Abnl structure/ function by echo, ventriculography, MRI or nuclear	Severe dilatation and reduction of RV EF Localized RV aneurysms Severe segmental dilatation of RV
ECG Repolarization or depolarization/ abnormalities	QRS prolongation
Arrhythmias	
Family history	Confirmed at necropsy or surgery

Br Heart J 1994:71

ARVD MRI Diagnostic Findings

1. Abnormal RV morphology
2. Abnormal RV function

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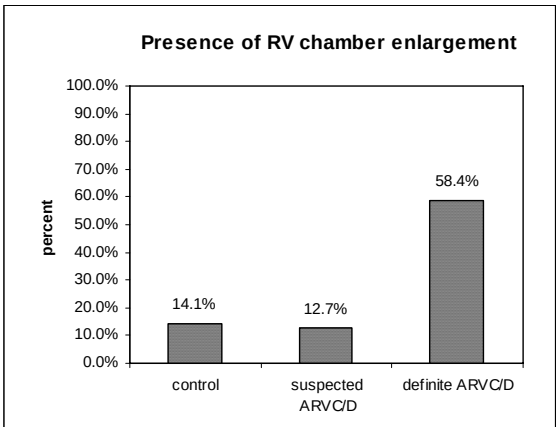
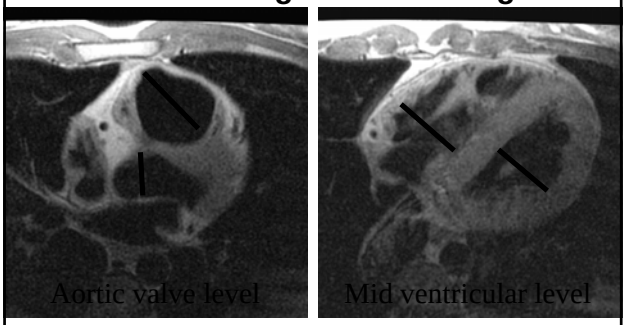
3. Abnormal signal intensity (fat)
4. Enhancement in the RV wall (fibrosis)



Bluemke et al., Cardiology, 2003:99:153

ARVD: findings on axial images

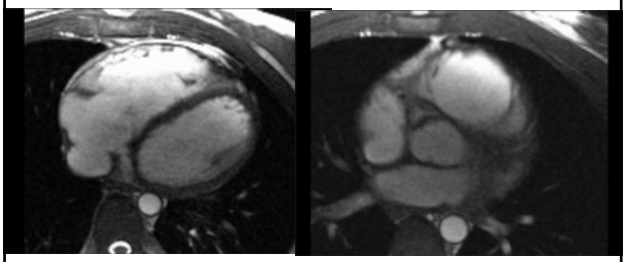


38 yo F, athlete with ventricular tachycardia

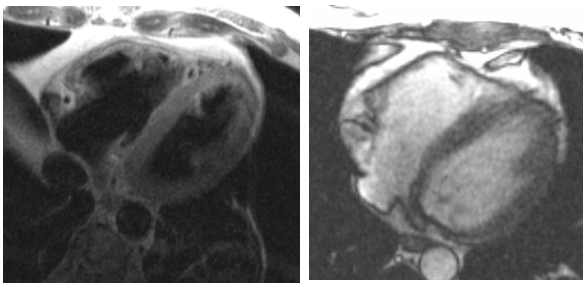
RV enlargement: differential diagnosis in the setting of suspected ARVD

1. Normal variant (young age)
2. Pulmonary Hypertension
3. PAPVR
4. Intracardiac cardiac shunt or valve dysfunction

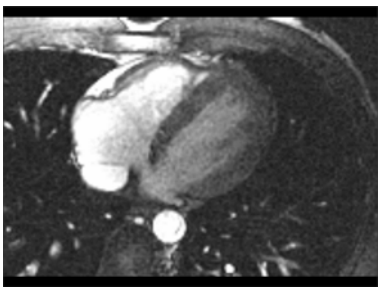
RV and Pulmonary outflow tract enlarged, poor function



Right ventricular aneurysm

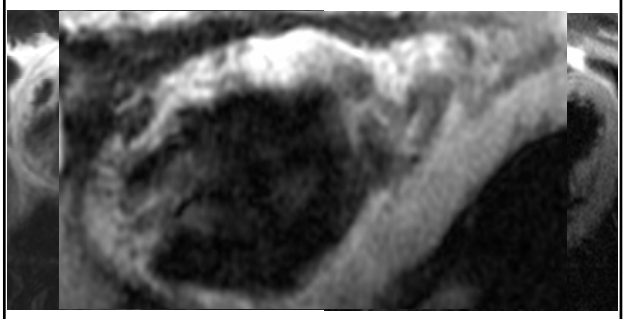


Typical ARVD

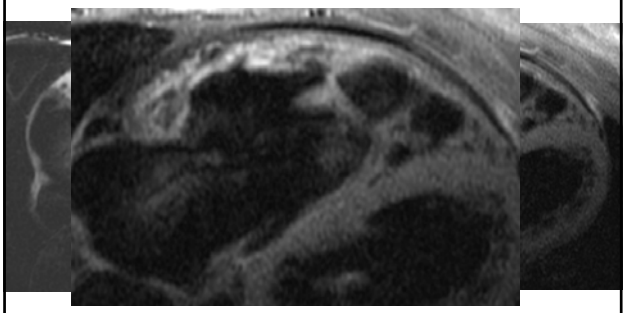


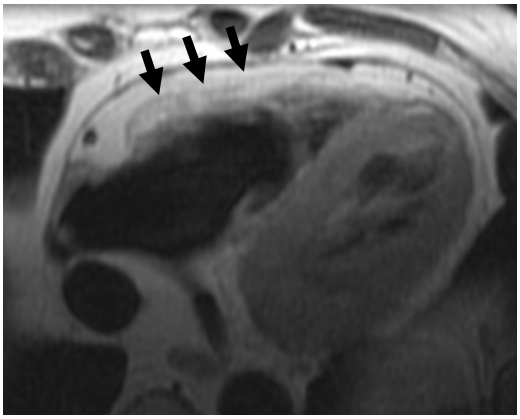
37% of normal volunteers

Tissue Characterization: RV fat

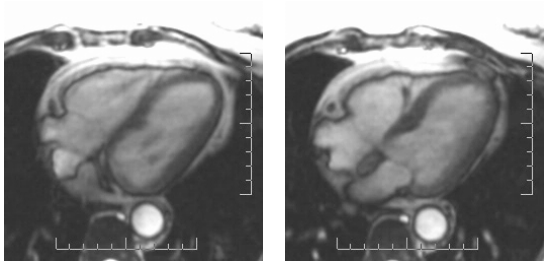


Right ventricle fat





Fat alone is insufficient for ARVD/C diagnosis: not arrhythmogenic



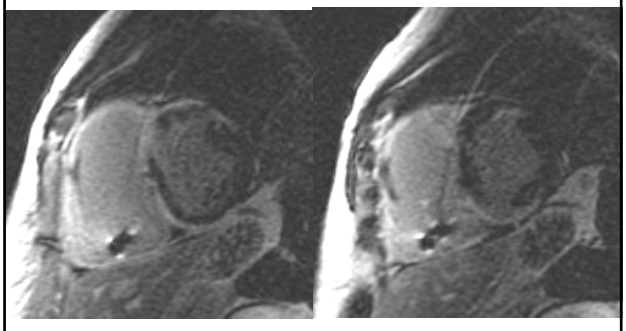
LV EF 68.5% EDV 120 ml
RV EF 71% EDV 124 ml

Detection of RV fibrosis in ARVD

- Delayed enhancement due to fibrosis present in 60% of ARVD patients.
- All patients had other RV abnormalities (wall motion, morphology).

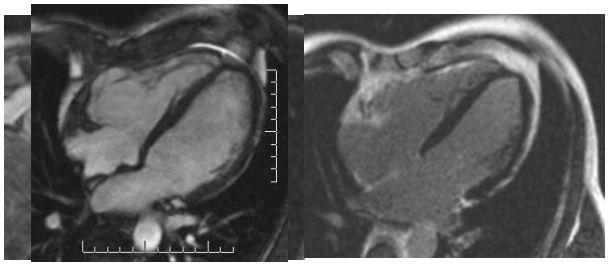
Tandri, JACC 2005; 45

RV delayed enhancement



**ICD, investigational*

RV delayed enhancement



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www.heartMRI.com

Acknowledgments

- João Lima, MD
- Dara Kraitchman, PhD
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