RC429: Optimize Your Body MR Practice:

Optimize Your Body MR Imaging Protocols: Cardiovascular

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Disclosures

- Off-label: gadolinium MR of the heart and vessels, adenosine MRI
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- Speaker: Toshiba, GE Healthcare

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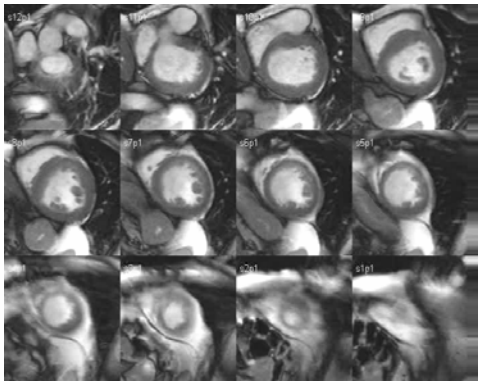
- Tom Foo, PhD, GEMS
- Christine Lorenz, PhD, Steve Shea, PhD, Siemens

Topics

Heart:
- LV function
- Viability
- Perfusion
- Cardiac Mass
- Pericardium
- ARVD

Vascular:
- Coronary
- Chest
- Abdomen
- Peripheral vascular

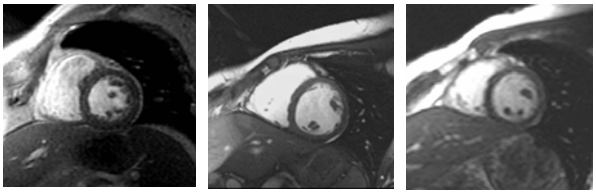
LV Function



Steady state free precession (SSFP) cine

balanced FFE – Philips
TruFISP – Siemens
Fiesta – GE

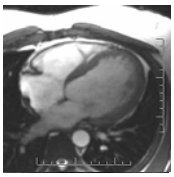
ALL THE SAME



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

T. Foo, GEMS

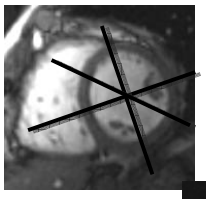
LV function

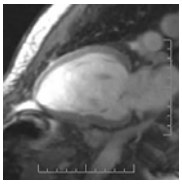


1. HLA chamber cine
2. Short axis cine
   8 mm thick, 2 mm spacing
3. VLA cine
4. 5 chamber cine (optional, for HOCM)

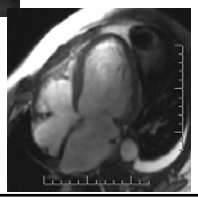
15 minutes (use parallel imaging n=2)

Imaging planes

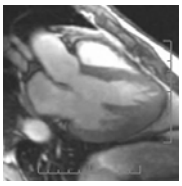




VLA



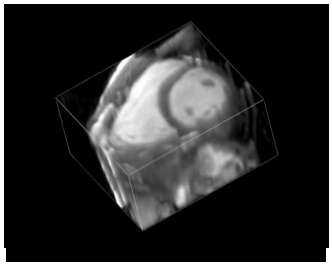
HLA



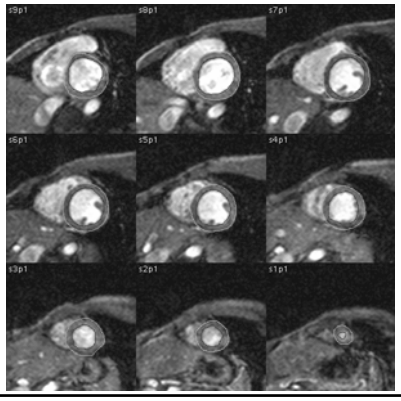
5 chamber

4D SSFP: use parallel imaging

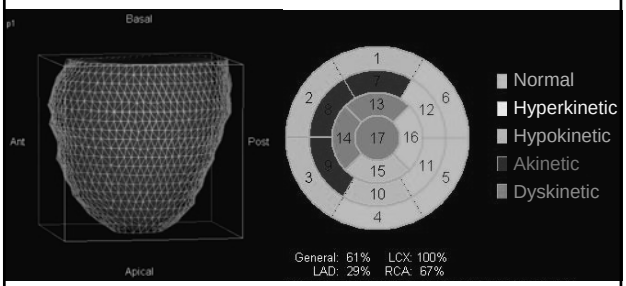
Full 3d recon + cine; 1 breath-hold



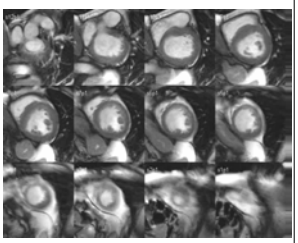
LV Function - Segmentation



Regional Wall Motion Analysis



Data courtesy of Fujita Health University, Aichi, Japan



LEFT VENTRICULAR VOLUME RESULTS

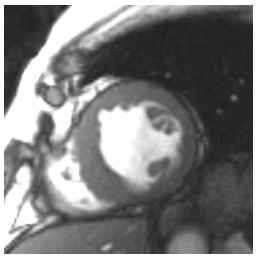
Body Surface Area:	1.89	m²
ED volume:	357.65	ml
ED volume/BSA:	189.04	ml/m²
ES volume:	241.32	ml
ES volume/BSA:	127.55	ml/m²
Stroke volume:	116.33	ml
Stroke volume/BSA:	61.49	ml/m²
Ejection fraction:	32.53	%
LV mass ED:	175.24	g
LV mass ED/BSA:	92.62	g/m²
LV mass ES:	190.67	g
LV mass ES/BSA:	100.78	g/m²
PER:	281.68	ml/s
PER/EDV:	0.79	EDV/s
TPER:	400.00	ms
TPER phase number:	5	
PFR:	203.55	ml/s
PFR/EDV:	0.57	EDV/s
TPFR:	300.00	ms
TPFR phase number:	11	

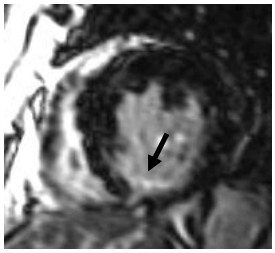
Cardiac Protocols

- ✓ LV function
- ✓ Viability
- Perfusion
- Cardiac Mass
- Pericardium
- ARVD

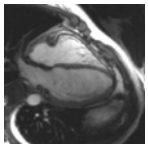
Viability Protocol

- Purpose: evaluate delayed washout of gadolinium in infarction, inflammation, infiltrative disease





Viability Protocol



Time

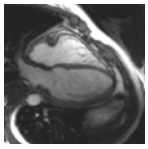
15 min 1. LV Function protocol

Long, short axis cine images

2. Administer 0.15-0.2 mmol/kg gadolinium*, wait...

15 { 3. TI scout
4. Delayed images, short and long axis, begin 10 min after gad was given

Viability Protocol Alternative



Time

10 min 1. LV Function protocol

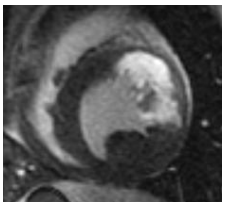
Long axis cine images

2. Administer 0.15-0.2 mmol/kg gadolinium*,

15 { 3. *Short axis cines,* then TI scout
4. Delayed images, short and long axis, begin 10 min after gad was given

IR-prepared segmented fast GRE

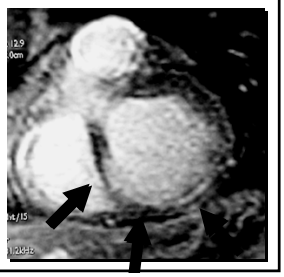
- segmentation factor: 24 OR single shot SSFP
- *TD:* 300 ms (diastole)
- *TI:* 200-250 ms (adjust)
- 2 NEX
- 8 mm thick/0 mm spacing.



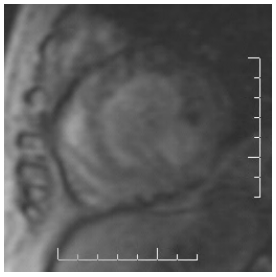
- acquire images ~10-20 min after 0.2 mmol/kg gadolinium, 12 hb/ slice

Adjust the TI time for each patient

- 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

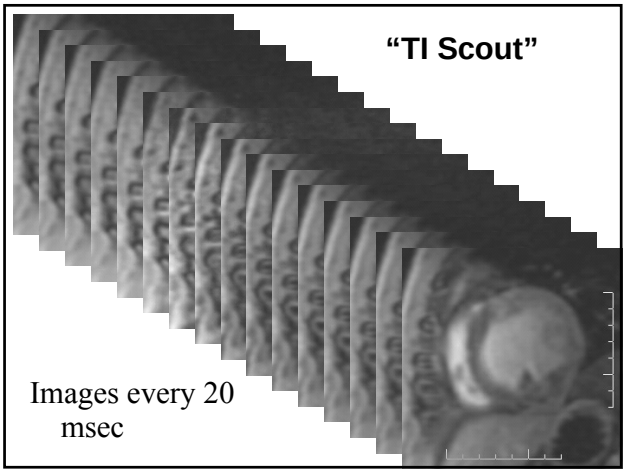


"TI Scout"



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

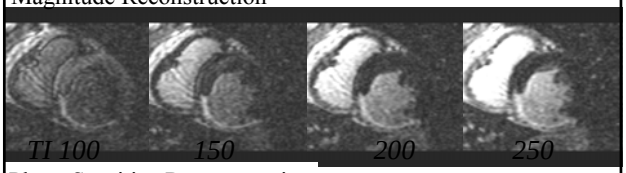
"TI Scout"



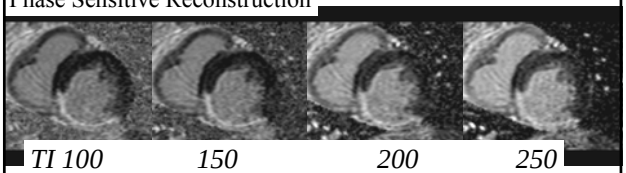
Images every 20
msec

Phase Sensitive Inversion Recovery

Magnitude Reconstruction



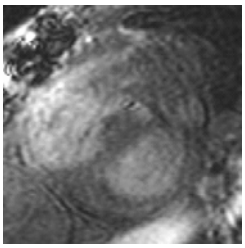
Phase Sensitive Reconstruction



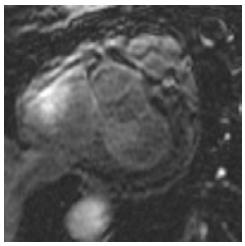
Arai, AHA 2002

3D Viability Sequence

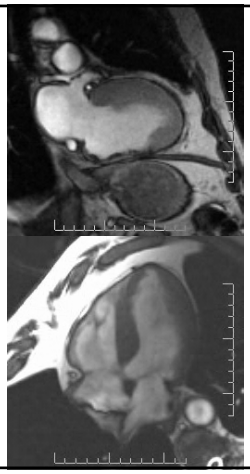
Septal MI



Antero- Septal MI

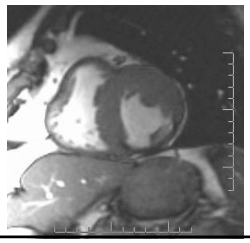


Foo et al, Radiology 2004; 230:845



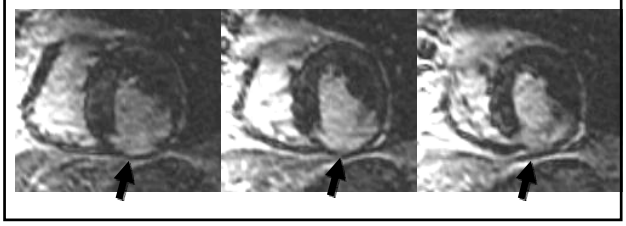
Viability Protocol: Increasing Dyspnea

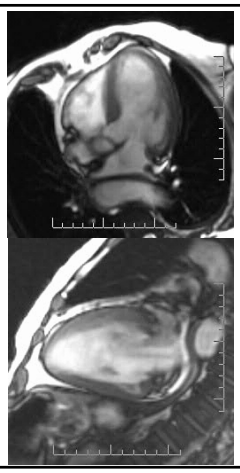
14% EF
EDV 210
LV mass 232g



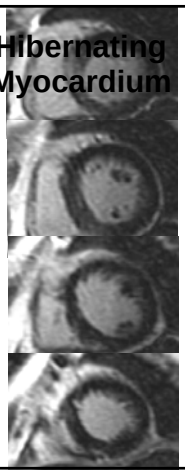
RCA Infarct (old)

14% EF
EDV 210
LV mass 232g





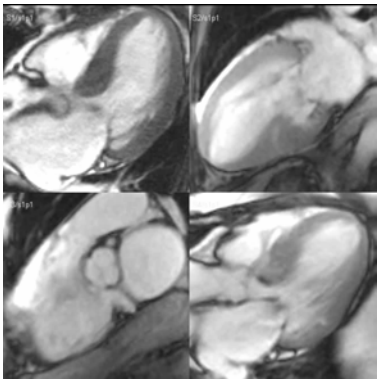
Hibernating Myocardium



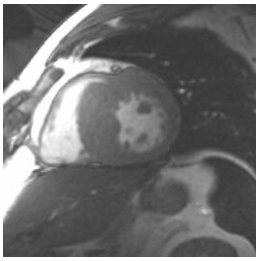
Viability Protocol: also for Nonischemic Cardiomyopathy

- Hypertrophic cardiomyopathy
- Myocarditis – inflammation
- Amyloid
- Sarcoid
- Drug toxicity
- Chagas disease (fibrosis)

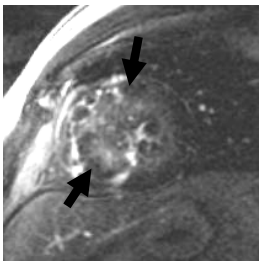
Hypertrophic Cardiomyopathy: Septum



HOCM: Myocardial Fibrosis



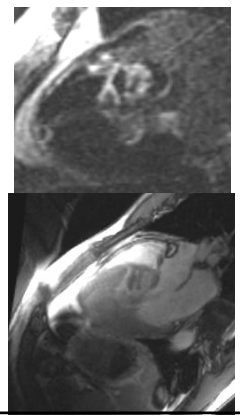
Cine



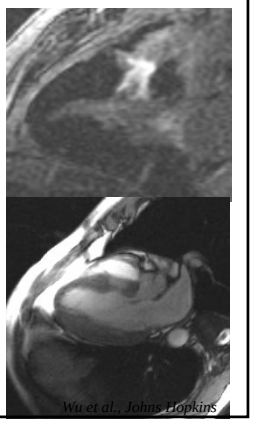
Delayed contrast

HOCM, EtOH ablation

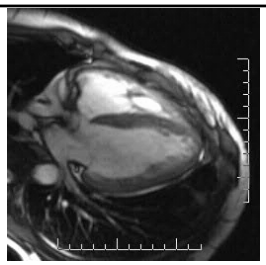
Pre Treatment



2 mths Post Treatment

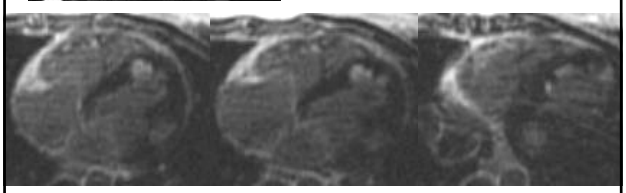


Wu et al., Johns Hopkins

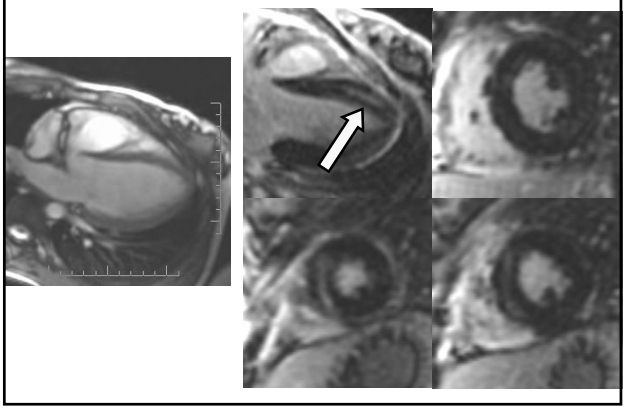


Progressive RV failure

Giant Cell Myocarditis



Myocarditis with scar
28 yo, acute chest pain



Cardiac Protocols

- ✓ LV function
- ✓ Viability
- ✓ Perfusion

Cardiac Mass

Pericardium

ARVD

Adenosine Stress MRI - requirements

1. Equipment

   Infusion pump

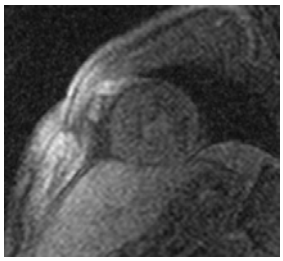
   2 IV's (gadolinium and adenosine)

2. Patient prep: withhold caffeine, methylxanthines

3. Antidote (AV block, $T_{1/2}$ = 2 min)

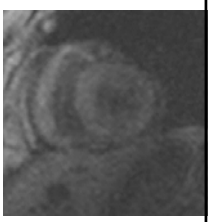
   (aminophylline 125 mg IV over 3 min)

MRI perfusion



- 0.05-0.1 mmol gad, 5 ml/ sec
- (Notched-interleaved) EPI-FGRE acquisition
- 6-8 images / 2 R-R
- 128x128 matrix
- 8 mm thick, 2 mm gap
- 40 phases

Protocol – Stress Portion



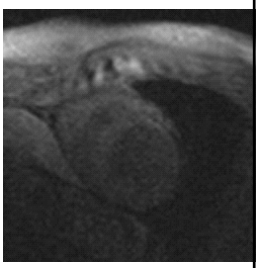
- Localize short axis:

  - 3 min adenosine @140 ug/kg/min OR,

  - 2 min dipyridamole @0.56 mg /kg over 4 min

- 0.05 mmol/kg gadolinium bolus, 5 ml/sec
- Short axis perfusion for 1 min

Protocol – Rest Portion



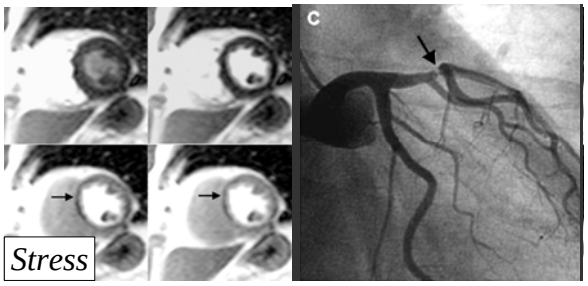
- Administer additional 0.1 mmol/kg gadolinium
- ~15 min delay:

  LV function protocol

- Viability protocol

- *Optional: Repeat perfusion at rest, 0.1 mmol/kg gadolinium @ 5 ml/sec (optional)*

Saturation recovery SSFP



from Fenchel et al AJR 2005: 185

Cardiac Protocols

- ✓ LV function
- ✓ Viability
- ✓ Perfusion
- ✓ Cardiac Mass
- ✓ Pericardium

} ARVD

Cardiac mass protocol

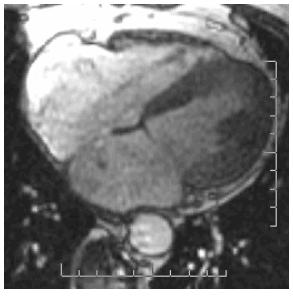
1. Axial T1 images (find the mass!)
2. Axial T2 images
3. +/- fat suppressed T1 images
4. Axial cine images
5. Pre/ post gadolinium T1 images
   - fat sat double IR FSE (1x gadolinium) or "viability" T1 images with 2x dose gadolinium

Primary benign tumors:

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

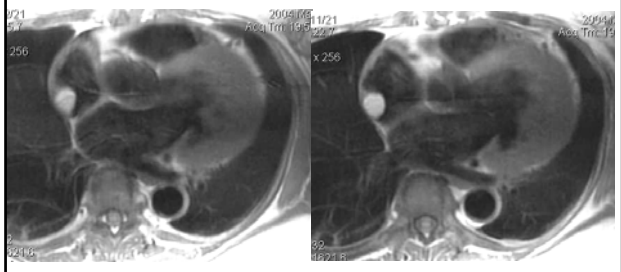
(clot)

Syncope, mass by echo: myxoma



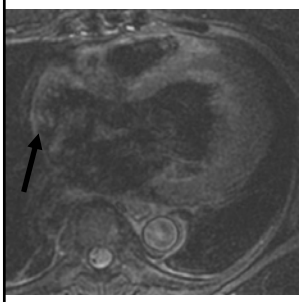
Axial T1 Axial SSFP cine

Emergency transfer for cardiac mass on echo

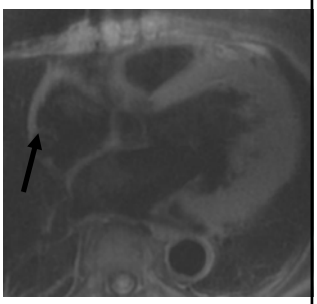


Axial T1 Axial T1

Emergency transfer for cardiac mass on echo

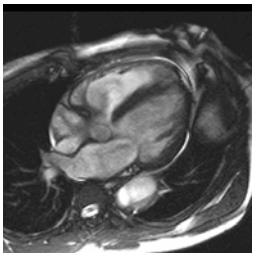


Axial STIR images
(fat is dark, edema is bright)

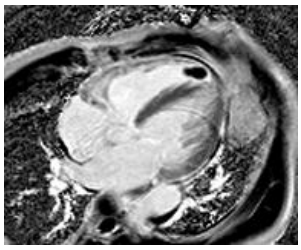


Axial T1 images with fat suppression

Pulmonary hypertension, RV dysfunction



cine SSFP



viability image

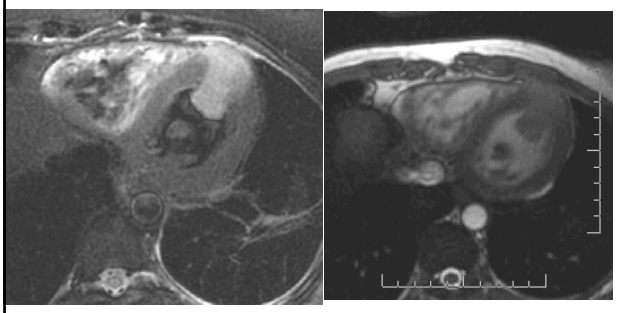
Malignant tumors:

Secondary tumors 20x more common:
Metastatic disease, lymphoma

Primary:

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

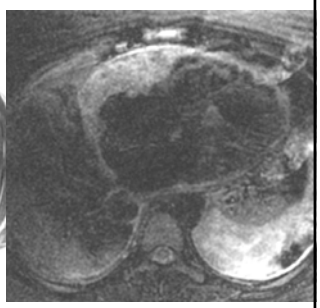
Leiomysarcoma metastatsis



T2

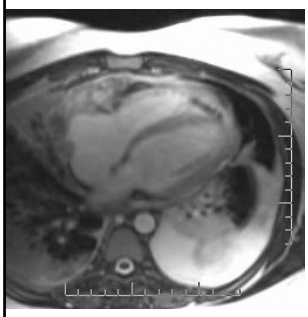
CHF, soft tissue mass by CT

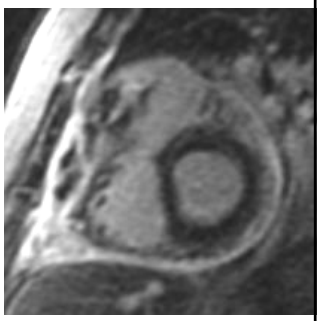
Axial T1



Axial T2, fat sat

CHF, soft tissue mass by CT: angiosarcoma

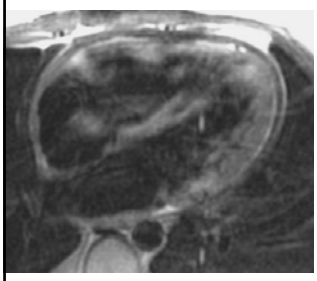




Pericardium - Protocol

1. LV mass protocol
2. Short axis cines for constriction quantitate LV/ RV function
3. Axial tagging

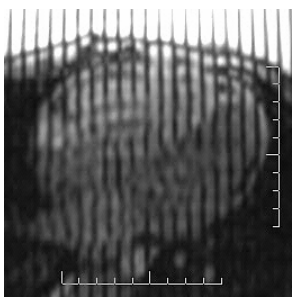
Constrictive pericarditis

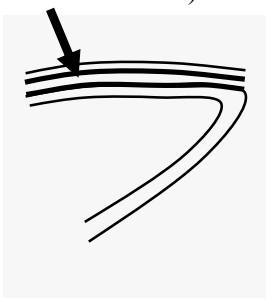


- ≥4mm pericardial thickness
- Equalization of left/ right heart pressures
- Tubular right ventricle
- Reduced diastolic filling
- Enlarged right atrium, IVC

3429369

Pericardial line + mediastinal fat (chemical shift artifact)





MRI tagging, axial images, stripe tags

Cardiac Protocols

- ✓ LV function
- ✓ Viability
- ✓ Perfusion
- ✓ Cardiac Mass
- ✓ Pericardium
- ✓ ARVD

Arrhythmogenic RV Dysplasia

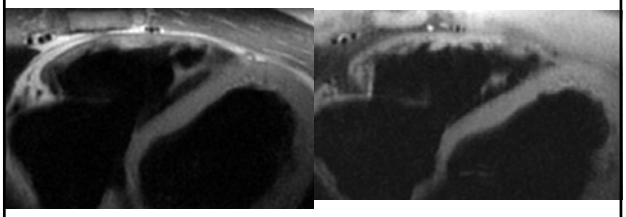
- Fibrofatty infiltration of RV resulting in ventricular tachycardia
- Palpitations, syncope, sudden death
- Age 33 ± 14 yrs.
- 30-50% cases are familial. MR screening of family members?

RV dysplasia - Protocol

1. Axial / short axis "T1" images, blood suppression (double IR FSE)
   - 5 mm slice thickness, ETL 24-32
   - Anterior coil, FOV 24-28
2. same as (1), with fat suppression
3. Cine: axial and short axis, HLA
4. Delayed gadolinium images, form the viability protocol, axial and short axis

Black blood images

- Axial "T1" images, blood/ **±fat suppression**
  - TE min, ETL 24-32, 256x256, ZIP
  - 5x3 mm
  - Anterior coil, FOV 24-28



Common protocol questions:

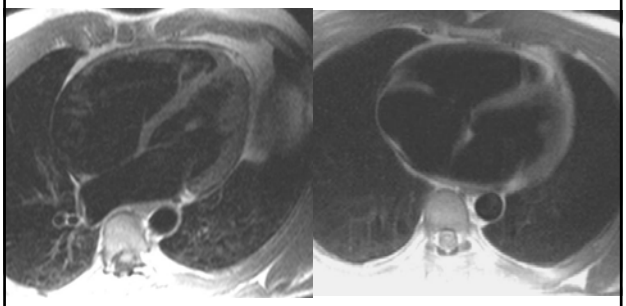
1. What about prone imaging?
   - not necessary with breath-hold imaging.
   - difficult for patients to sustain for the duration of this protocol (45 + minutes).

Common protocol questions:

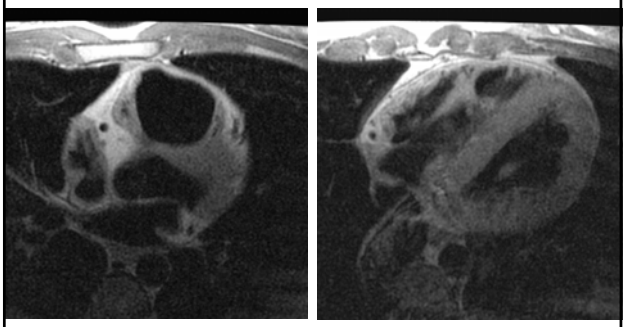
2. We have a double IR single shot sequence (ssfse, HASTE) that is much faster – should I use this?

"Double IR" single shot (HASTE) FSE

2 sec per image – do not use for heart MRI

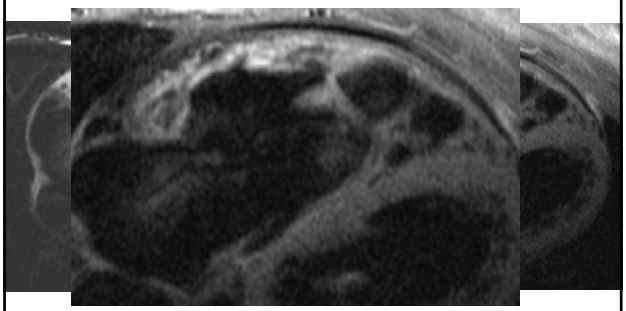


ARVD: morphology

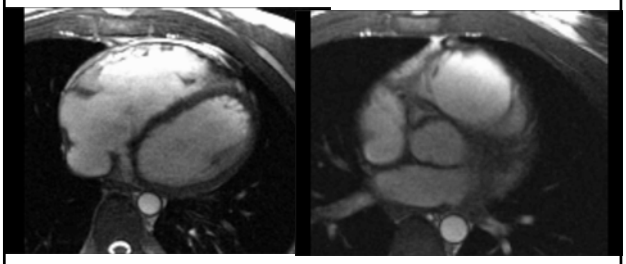


38 yo F athlete, ventricular tachycardia

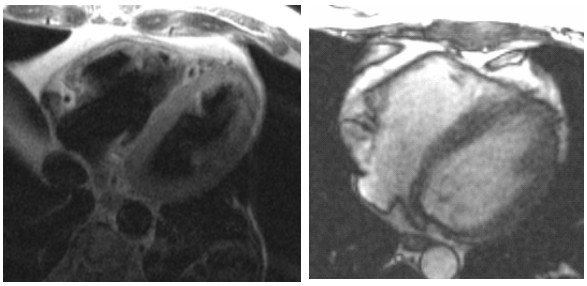
Right ventricle fat



RV and Pulmonary outflow tract enlarged, poor function



Right ventricular aneurysm



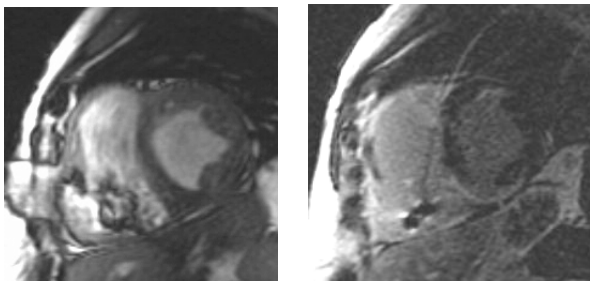
Typical ARVD

Delayed Gadolinium Enhancement

- Delayed enhancement present in 8/13 (61%) of ARVD patients.
- 7 patients had biopsy, all showed fibrosis.
- All of patients had other RV abnormalities (wall motion, morphology)

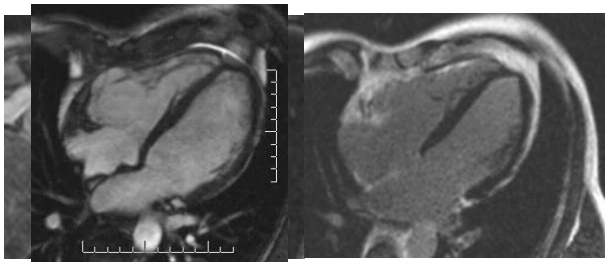
Tandri, JACC 2005; 45

RV delayed enhancement



**AICD, investigational*

RV delayed enhancement



Topics

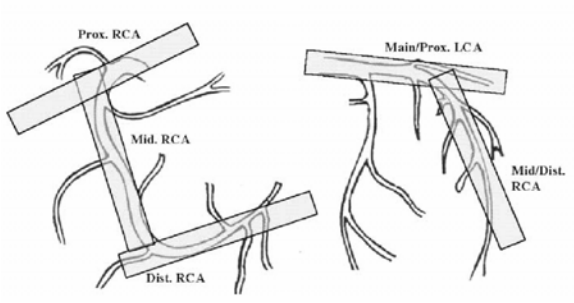
✓ Heart:
- LV function
- Viability
- Perfusion
- Cardiac Mass
- Pericardium
- ARVD

•Vascular
- Coronary
- Chest
- Abdomen
- Peripheral vascular

Coronary MRA Protocols

1. Targeted MRA (VCATS)
   - breath-hold 3d SSFP technique
   - double oblique images, oriented along the course of each coronary artery
2. Whole heart coronary MRA

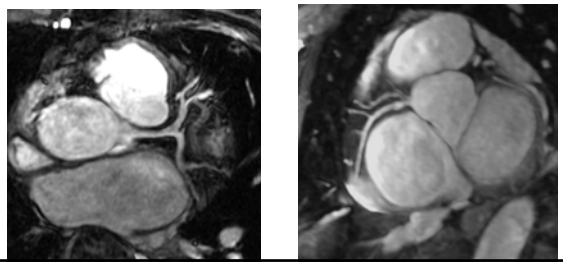
VCATS: volume coronary angiography using targeted scans



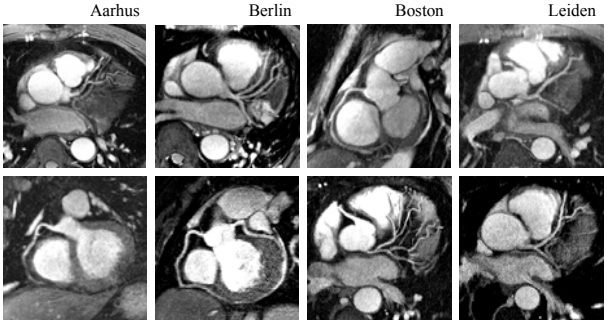
Dirksen et al JCMR 2003 5: 365

Breath-hold 3D SSFP of RCA

- Advantages: quick, 20 sec, repeatable
- Disadvantages: breath-hold time limits resolution, difficult at high heart rates, complex for technologist

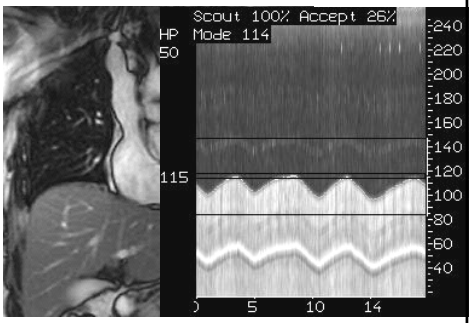


Multicenter Coronary MRA Study 1.5T: targeted MRA with navigator

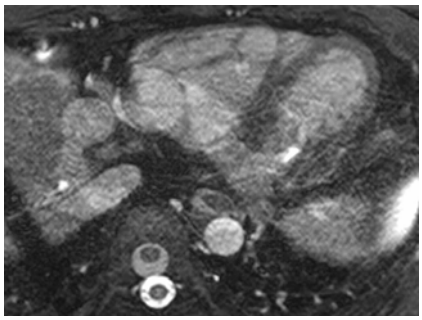


Kim WY et al.: N Engl J Med;345(26):1863-1869 (2001).

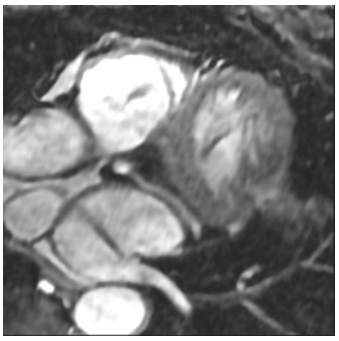
Whole Heart 3d axial MRA: diaphragm tracking



Whole Heart 3d MRA



Whole Heart 3d MRA



Vascular Protocols

- ✓ Coronary
- ✓ Chest
- ✓ Abdomen

} Peripheral vascular

Abdomen, Chest Protocols

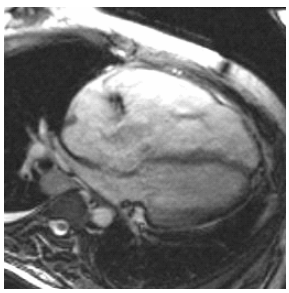
Sequence	Chest	Abdomen
3D MRA	≤ 3mm	≤ 2mm (fat suppression)
Pre	Ax, Sag T1 (gated)	SSFSE (cysts, fluid)
Post	Post T1 (fat sat, gated)	VIBE, 3d T1 GRE (liver, kidney, etc)

MRI/A Chest: Contrast allergy

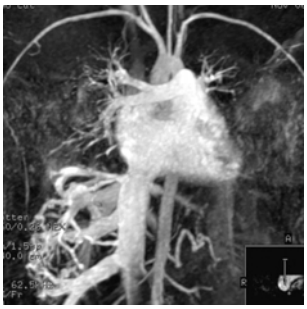
History: septic emboli, cardiac failure

- Black Blood: double IR breath-hold FSE
- Option: single shot technique

MRI/A Chest: combine with function

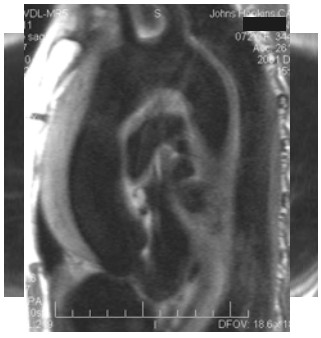


Cardiac Fiesta cine



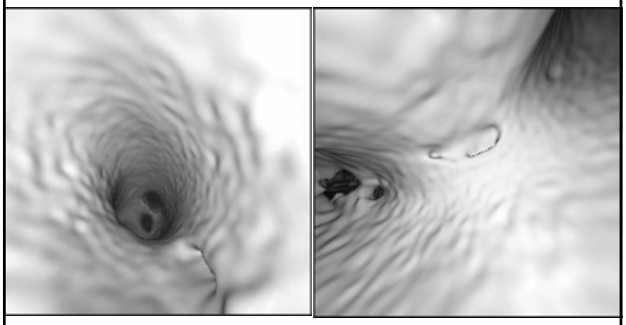
3d Gad MRA

Thrombosed Aortic Dissection

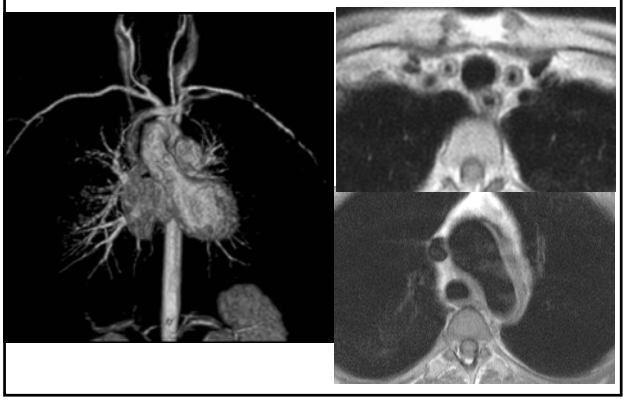


"double IR" black blood FSE MRA

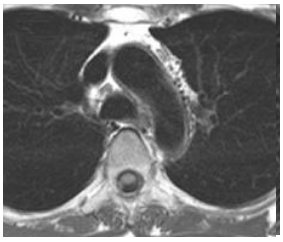
Aortic Dissection - intraluminal view



Takayasu arteritis



Takayasu arteritis



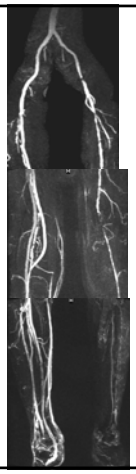
T1 double IR

Renal MRA (3T): with 3d T1

Vascular Protocols

- ✓ Coronary
- ✓ Chest
- ✓ Abdomen
- ✓ Peripheral vascular

Bolus Chase: Stepping Table MRA



1 — 9 - 12 sec

2 — 9 - 11 sec

3 — 11-13 sec x 2 runs

F. Scott Pereles MD

Hybrid pMRA Approach

3 stations BUT 2 Injections

- Calf and foot station
  - 20 ml Gad and 2 or 3 acquisitions
- Pelvis & Thigh stations with step table
  - 25 – 35 ml Gad bolus chase style
- Improved resolution at all stations
- Avoids venous contamination in the feet and calves.

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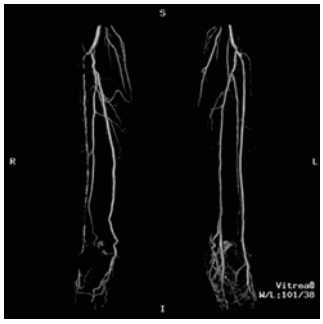
Hybrid pMRA



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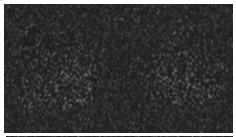
Hybrid Approach

3 stations BUT 2 Injections

- 2 separate timing runs (pelvis & calves)

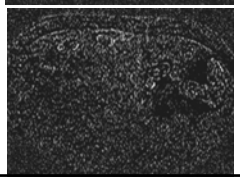
- Axial timing run, proximal calf

  2 ml Gad @ 2 ml/sec (20ml saline flush @ 2ml/sec)



- Axial timing run, aortic bifurcation

  2 ml Gad @ 2 ml/sec (20ml saline flush @ 2ml/sec)



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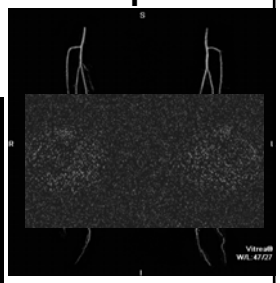
Hybrid Technique



2nd Acquisition, better visualization of foot vessels

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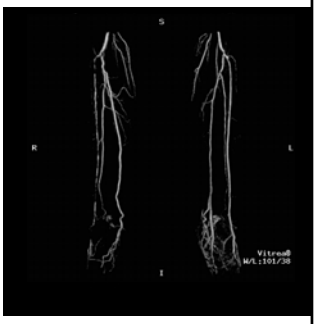
Time Resolved MRA
(TREAT, TRICKS)



F. Scott Pereles MD

Summary

Heart:	Vascular:
- LV function	- Coronary
- Viability	- Chest
- Perfusion	- Abdomen
- Cardiac Mass	- Peripheral vascular
- Pericardium	
- ARVD	

Thank you