



## Case Based Review of Cardiovascular MRI

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## Disclosures

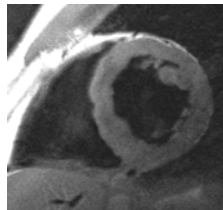
Consultant: Berlex, GE-Healthcare

Research support: Epix Medical

Off-label use: gadolinium enhanced  
MRI of the heart  
and vessels

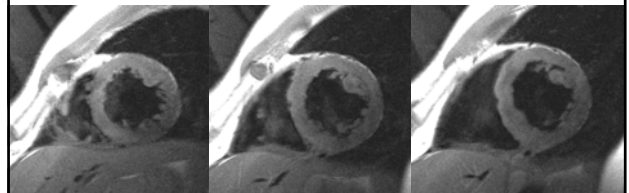
### Which is the current best method for obtaining T1 or T2 weighted images of the heart?

1. Spin echo
2. Double inversion recovery fast / turbo spin echo
3. Diffusion MRI
4. SSFP cine (eg, TruFISP)



### “Double IR” black blood FSE/TSE

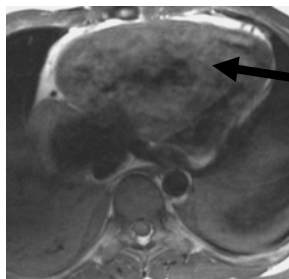
Breath-hold high resolution, intracardiac detail



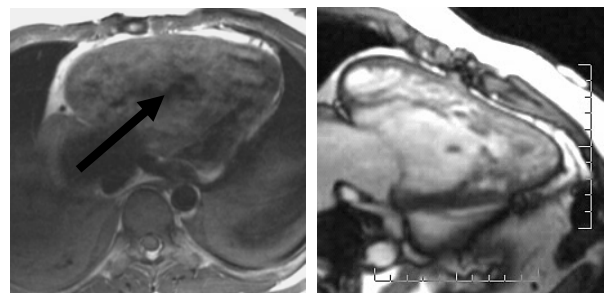
- “T1” weighted, where TR = 1 R-R interval
- PD (TR 1000, TE 20), T2 weighted (TR 2000, TE 80)

### You are evaluating a suspected RV cardiac mass and protocol a long axis double IR black blood image – but the blood is not black: why?

1. Usually this is due to poor technologist scanning.
2. The tech gave gadolinium; its impossible to get black blood after gad.
3. Blood flow must be perpendicular for this sequence to work.



### Blood flow on the long axis image is in-plane (slow flow)

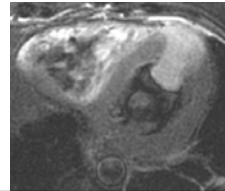


## Review of Cardiac MRI

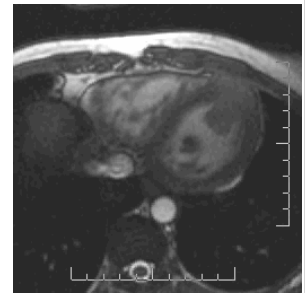
- MR cardiac pulse sequences
- **Evaluation of myocardial mass**
- Evaluation of coronary heart disease
- Evaluation of the right ventricle

## 67 yr old female with LV cardiac mass: which is most likely?

1. Myxoma
2. Blood clot
3. Rhabdomyosarcoma
4. Metastasis

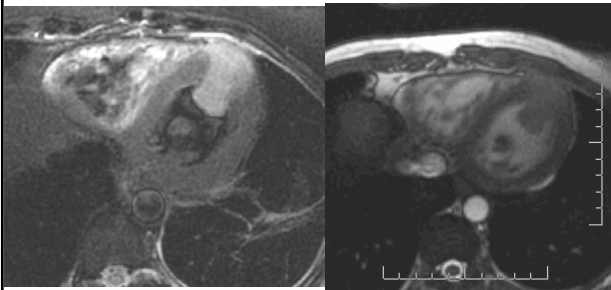


T2



cine

## Metastasis 20x more common than primary disease.



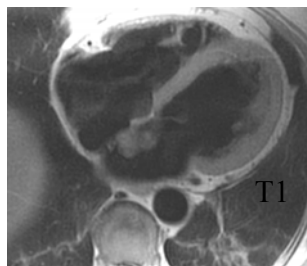
Leiomyosarcoma metastasis

## Primary malignant tumors:

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

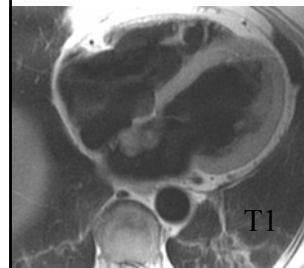
## 43 yo woman with TIA's, mass discovered on echocardiography. Most likely diagnosis?

1. Myxoma
2. Blood clot
3. Rhabdomyosarcoma
4. Metastasis

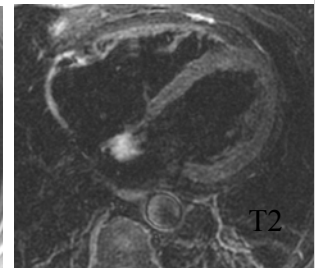


T1

## Myxoma



T1



T2

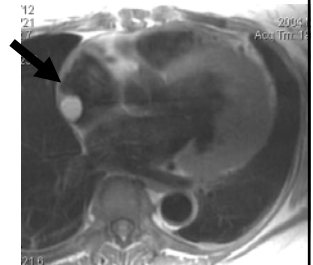
- interatrial septal attachment
- 4:1 left vs. right sided

### Primary benign tumors:

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

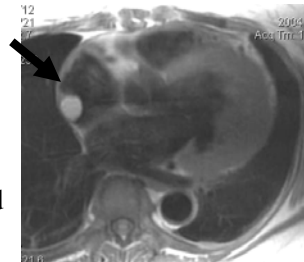
**23 yo female, ambulance transfer from community hospital for RA mass on echocardiography. Which is not bright on T1?**

1. Blood clot
2. Myxoma
3. Melanoma met
4. Lipoma
5. Proteinaceous cyst

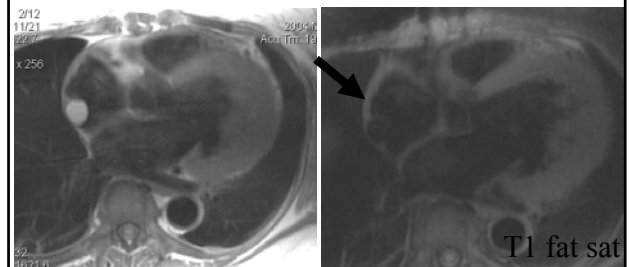


### 5 high signal masses on T1:

1. Blood clot
2. Melanoma met
3. Lipoma
4. Proteinaceous cyst
5. Gadolinium enhanced mass



### Right atrial lipoma



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

### Review of Cardiac MRI

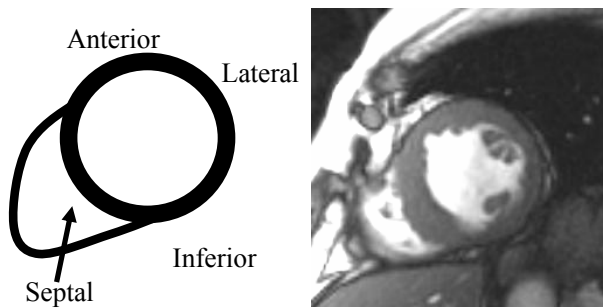
- MR cardiac pulse sequences
- Evaluation of myocardial mass
- **Evaluation of coronary heart disease**
- Evaluation of the right ventricle

**62yo with prior non-Q wave myocardial infarction. Where is the abnormality?**

1. Anterior
2. Inferior
3. Septal
4. Lateral

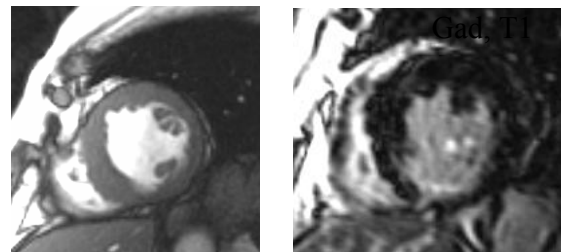


**62yo with prior non-Q wave myocardial infarction. Where is the abnormality?**

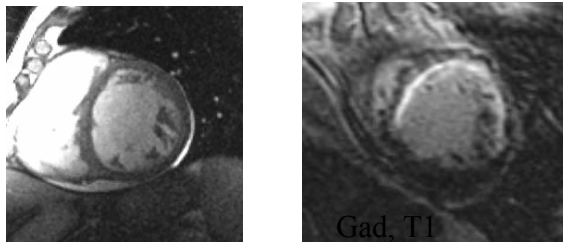


## Myocardial Delayed Enhancement (MDE)

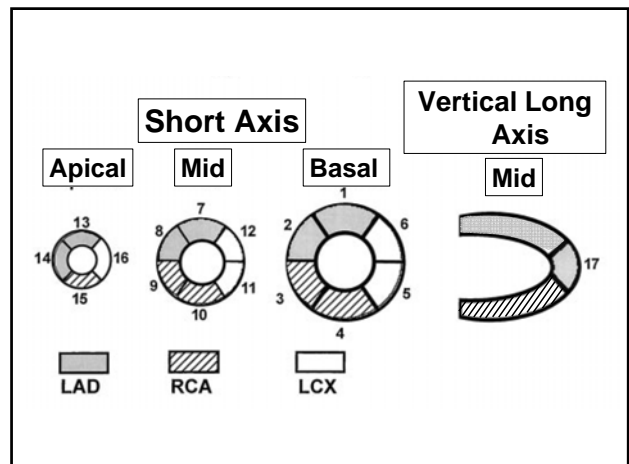
Delayed washout (@10-20 min) of gadolinium in areas of infarction/scar.



**80 yo, CHF, best diagnosis**



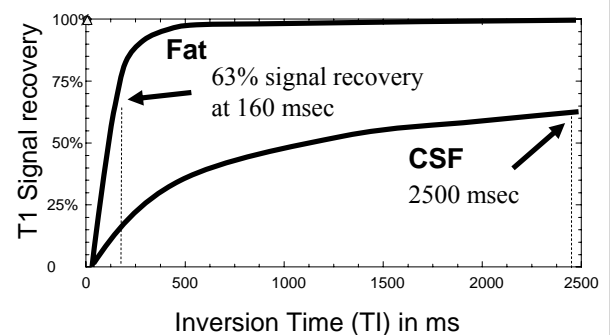
1. Hibernating myocardium
2. Left main infarction
3. LAD infarction
4. RCA infarction



**What are the inversion times at 1.5 T for fat (STIR) and CSF (FLAIR sequences)**

1. 160 msec (fat), 2500 msec (CSF)
2. 160 msec for both fat and CSF
3. 2500 msec for both fat and CSF

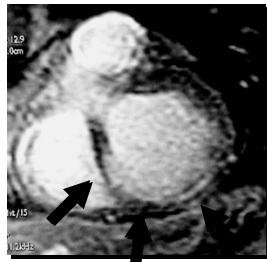
**T1 times for fat/ water (CSF) at 1.5 T**



### Using an inversion pulse to suppress normal myocardium

If gadolinium level in the heart/ blood pool is higher (eg, renal failure), what value of TI is needed to suppress the myocardium?

1. a smaller (shorter) TI
2. a larger (longer) TI
3. makes no difference

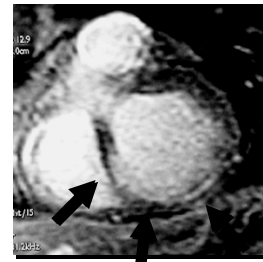


### Using an inversion pulse to suppress normal myocardium

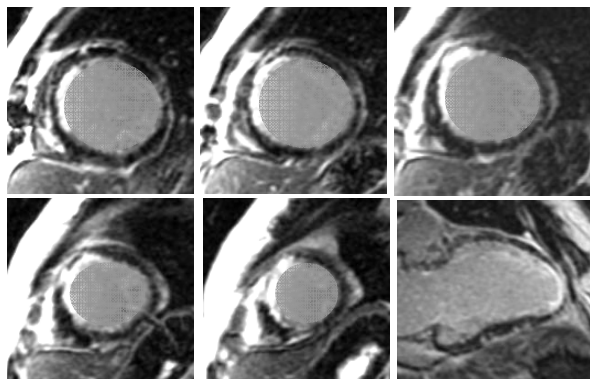
• Typical range: 175-250 msec

- Smaller (shorter) TI time when more gad is present:

- decreased renal function
- CHF
- shorter delay time



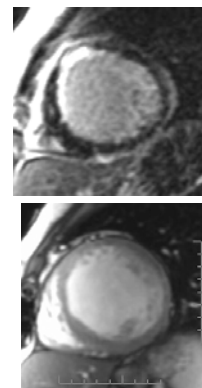
### 72yo male with heart failure: delayed gadolinium images



### 72yo male with heart failure

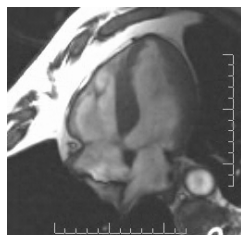
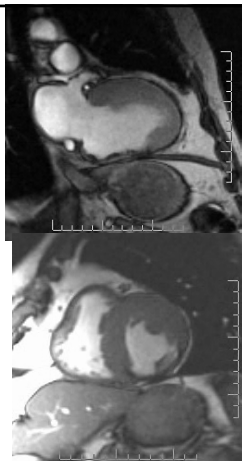
Diagnosis:

1. Prior RCA infarction
2. Prior LAD infarction
3. Prior myocarditis
4. Nonspecific cardiomyopathy



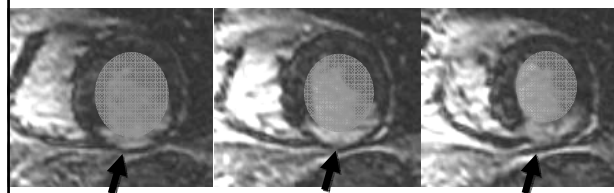
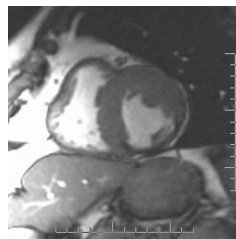
### 73 yo male, increasing dyspnea

14% EF  
EDV 210  
LV mass 232g



### Best diagnosis

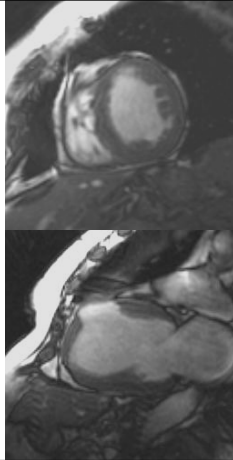
1. Old RCA infarction
2. Old LAD infarction
3. Prior myocarditis
4. Nonspecific cardiomyopathy



## 65 yo female

Best diagnosis

1. Pseudoaneurysm of the left ventricle (rupture)
2. True LV aneurysm
3. Mycotic aneurysm



### Which is typical of true aneurysm:

1. “wide” neck with diameter comparable to the aneurysm diameter
2. Typically RCA distribution
3. Late rupture is common

### Which is typical of true aneurysm:

- A) “wide” neck with diameter comparable to the aneurysm diameter
- B) Typically ~~RCA~~ LAD distribution
- C) Late rupture is **not** common



### Which is typical of pseudo aneurysm:

1. Disruption of the pericardium
2. Wide necked appearance
3. 45% incidence of rupture

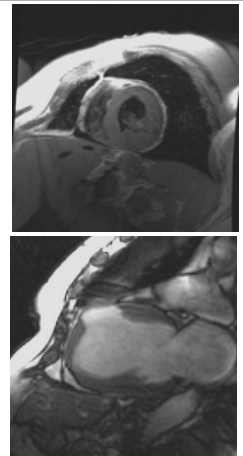
### Typical of pseudo aneurysm:

1. Disruption of *all myocardial* layers; contained by pericardium
2. *Narrow* ( $\leq 40\%$  of diameter) neck appearance
3. 45% incidence of rupture

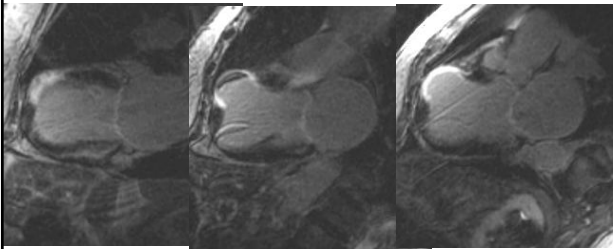
## 65 yo female, new onset CHF

Most appropriate next step:

1. Immediate surgery
2. Repeat cardiac cath for stenting
3. MRI with contrast (delay)
4. MRI with hemosiderin sensitive sequences



**Delayed long axis images after 0.2 mmol gad**

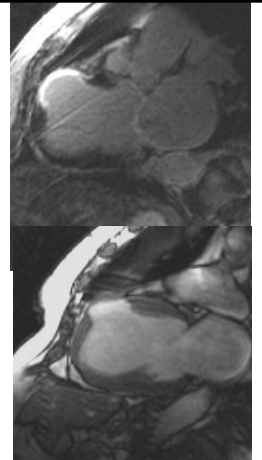


TI set to suppress myocardium (200 msec)

**65 yo female, CHF**

Best diagnosis

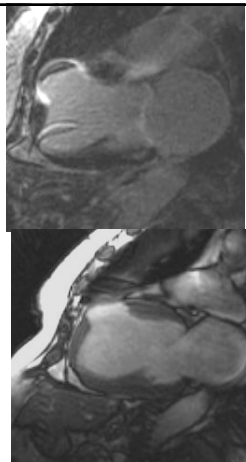
1. Pseudoaneurysm of the left ventricle (rupture)
2. True LV aneurysm
3. Mycotic aneurysm



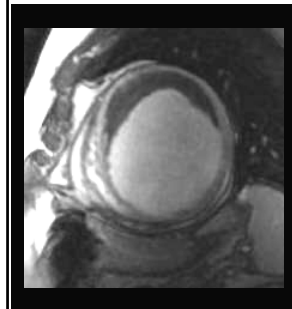
**65 yo female, CHF**

Additional finding:

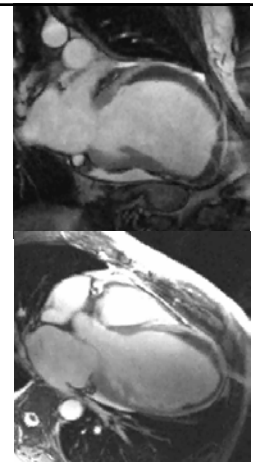
- clot formation in the aneurysm
- suggests long standing aneurysm
- MRI the most sensitive method for clot detection



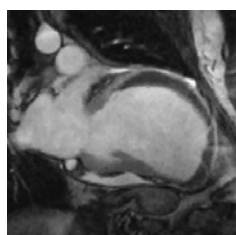
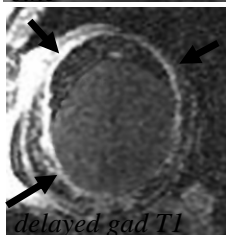
**Elderly male, CHF,  
9% EF, 820 ml EDV**



short axis cine

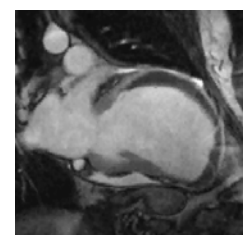
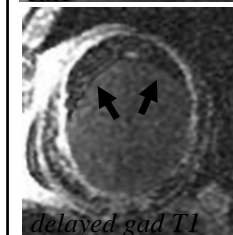
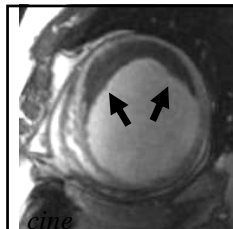


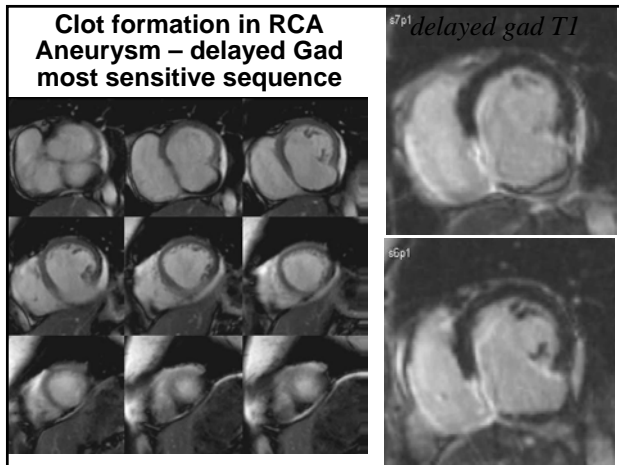
**Delayed Gadolinium Image**



**What is the dark area in the aneurysm?**

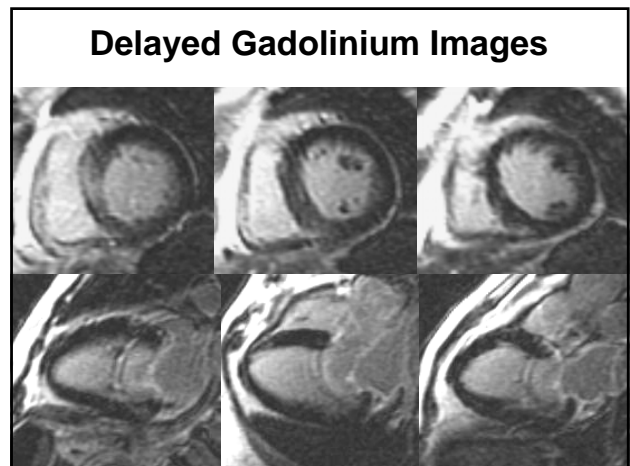
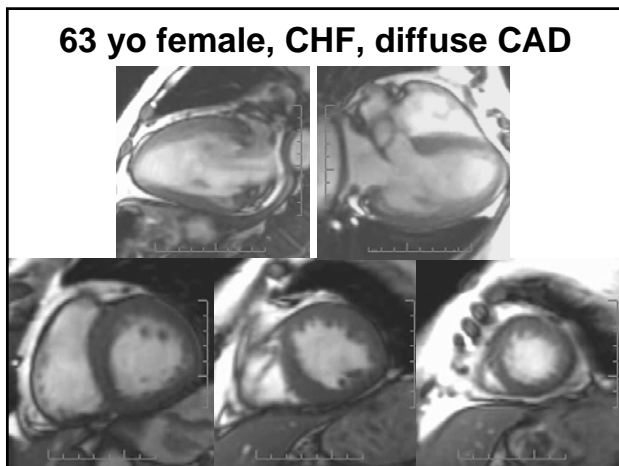
1. Thickened infarct
2. Blood clot
3. High concentration of Gad





### 63 yo female, CHF

- Known diffuse coronary artery disease
- ECG: nonspecific T wave changes
- MRI ordered for treatment planning



**63 yo female, CHF, known CAD, low ejection fraction, no delayed enhancement that would otherwise be seen in infarction**

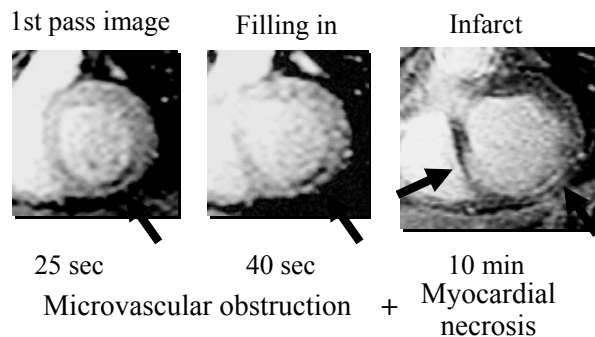
Best diagnosis:

1. Prior myocarditis or other nonischemic cardiomyopathy
2. Small infarcts too small to be seen on MRI
3. Hibernating myocardium

### Hibernating Myocardium

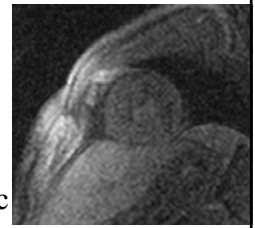
- *reduced* contraction at rest
- chronically reduced blood flow
- function can improve after CABG or stent revascularization

### Acute infarct with microvascular obstruction (at the infarct core)



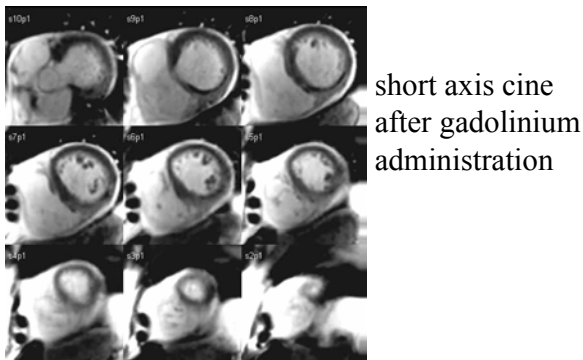
### Microvascular Obstruction (MO)

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

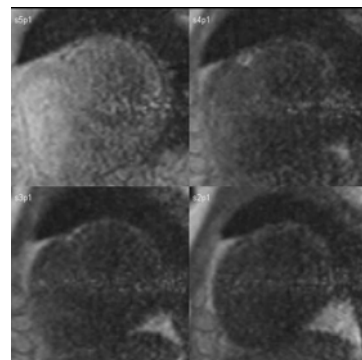


Wu KC, et al. *Circulation* 1998;97:765-772

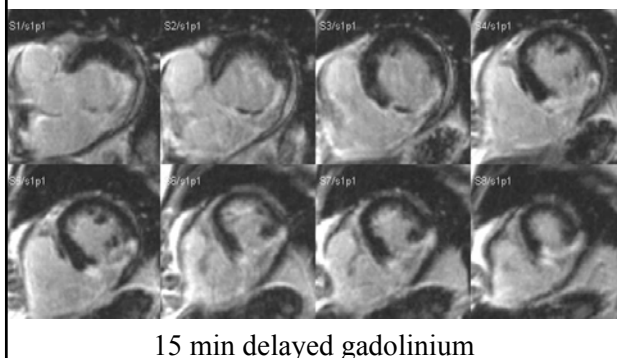
### 52 yo male, acute chest pain, emergent cath/ stent. MRI for extent of disease.



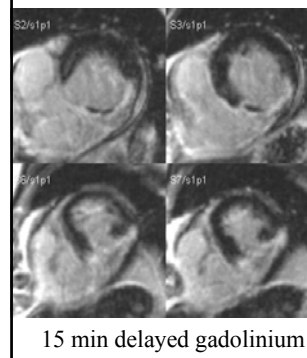
### 52 yo male, acute chest pain, emergent cath/ stent. MRI for extent of disease.



### 52 yo male, acute chest pain, emergent cath/ stent. MRI for extent of disease.



### 52 yo male, acute chest pain, emergent cath/ stent. MRI for extent of disease.



Best diagnosis:

1. RCA infarct with microvascular obstruction
2. Old RCA infarction 6 months ago
3. Hibernating myocardium

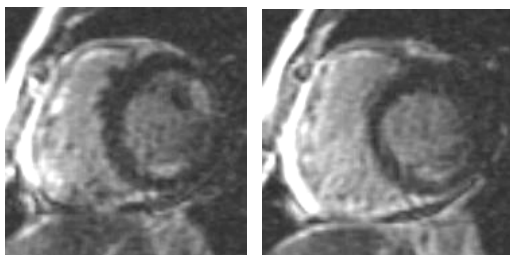
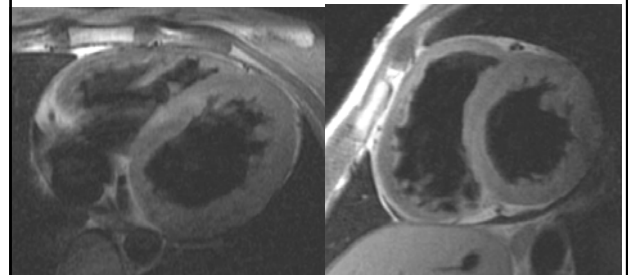
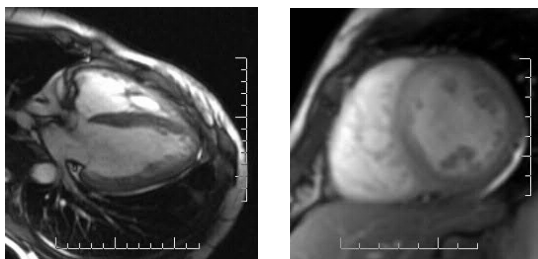
**33 yo OF, transferred for suspected right heart failure and arrhythmia**

- Palpitations, syncope, ER with VT
- Cath: normal coronaries
- Echo: normal LV, poor RV function
- LVgram: hypokinetic LV, 30% EF
- RVgram: global dysfunction

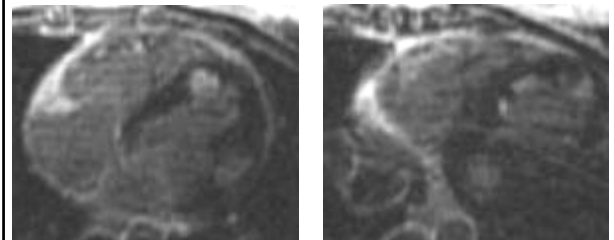
**33 yo OF, transferred for suspected right heart failure and arrhythmia**

MRI obtained to evaluate the right ventricle, in particular to consider ARVD (arrhythmogenic right ventricular dysplasia).

LV EF: 48%, RV EF: 25%



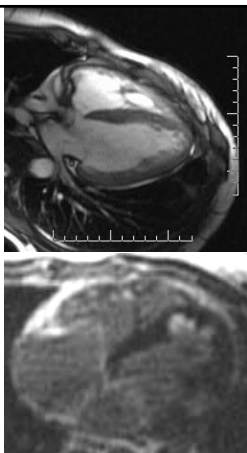
Delayed images after  
gadolinium (15 min)



Delayed images after  
gadolinium (15 min)

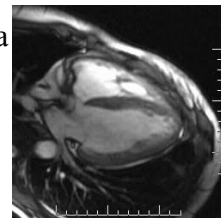
## Best Diagnosis

1. ARVD
2. Sarcoidosis
3. Chagas
4. Non specific myocarditis



## Giant Cell Myocarditis

- Path: giant cells, inflammatory infiltrate
- Average age in largest series: 37-48 yrs
- 81% occur in otherwise healthy persons
- 89% mortality in 3 yrs
- CHF, refractory arrhythmia
- 8% had IBD
- 88% whites

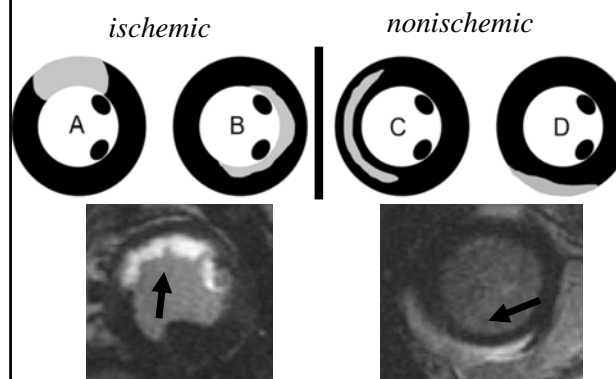


Cooper LT NEJM 1997;336

## Delayed Gadolinium enhancement of the heart is not specific for infarction:

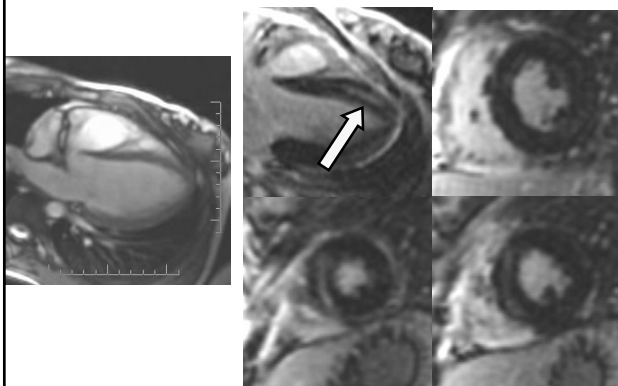
- Fibrosis (old MI)
- Myocardial necrosis (acute MI)
- Tumor
- Inflammation – myocarditis
- Amyloid
- Sarcoid
- Chagas disease (fibrosis)

## Gadolinium is a nonspecific contrast agent

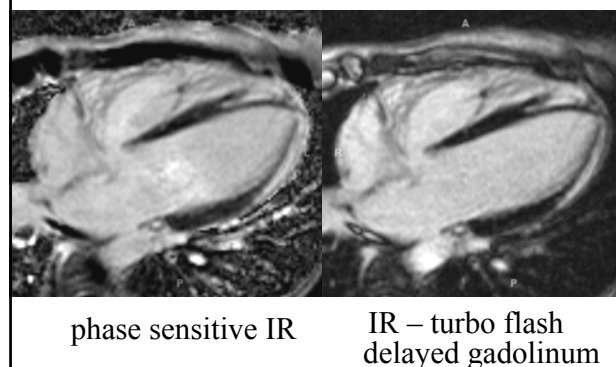


Hunold, J. Barkhausen, AJR 2005; 184

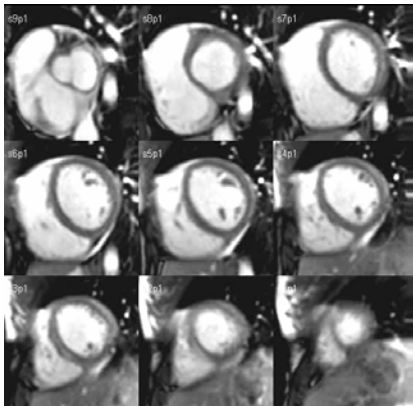
## 25 yo, acute chest pain 2 mos previously



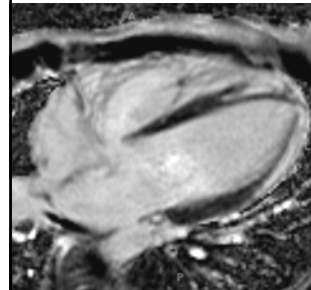
## 25 yo, 1 yr f/u. Persistent elevated ESR.



**25 yo, 1 yr f/u. Persistent elevated ESR.**



**25 yo, 1 yr f/u. Persistent elevated ESR.**

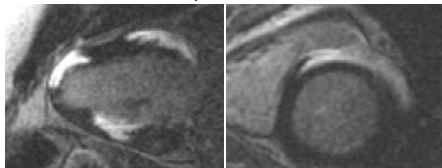


phase sensitive IR

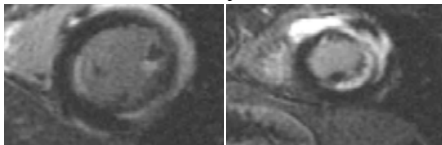
Best diagnosis:

1. Circumflex infarction
2. ARVD
3. Myocarditis
4. Congestive heart failure

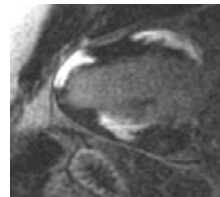
**Acute Onset Ventricular Tachycardia,  
Fever, Malaise**



Patchy epicardial enhancement,  
noncoronary distribution



**Acute fever, malaise, arrhythmia**

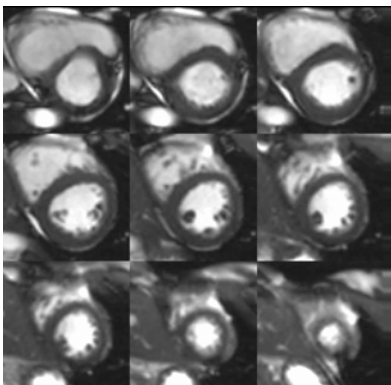


Best diagnosis:

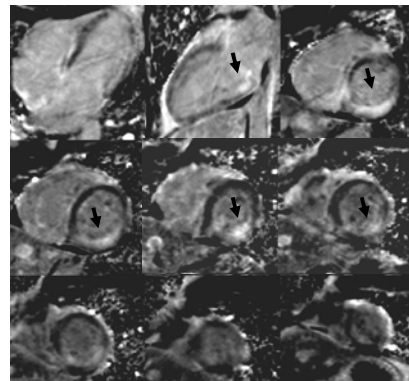
1. Sarcoid
2. Myocarditis
3. Chagas
4. Amyloid

(courtesy, J. Freeby, MD)

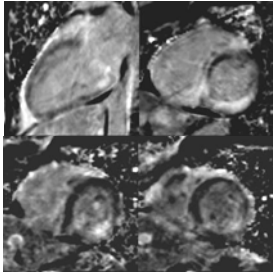
**45 yo male, dialysis, abnormal echo**



**45 yo male, dialysis, abnormal echo**



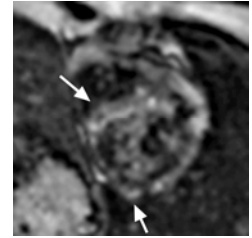
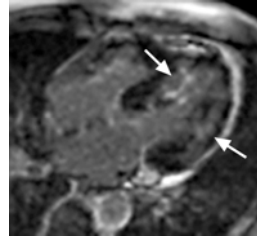
### 45 yo male, dialysis, abnormal echo



Best diagnosis:

1. Sarcoid
2. Myocarditis
3. Chagas
4. Amyloid

### Amyloidosis



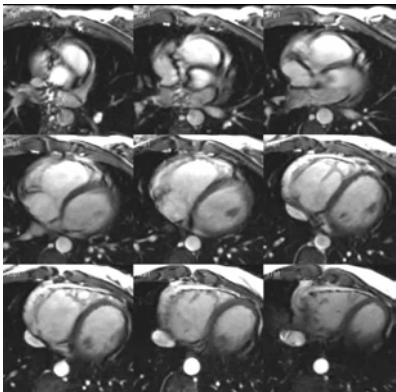
- report difficulty in suppressing the myocardium
- both ventricles, atrial involvement
- dialysis history

### Essentials of Cardiac MRI

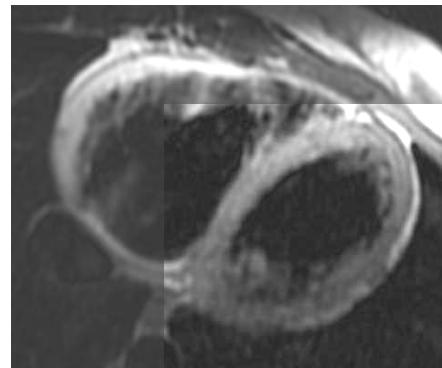
- MR cardiac pulse sequences
- Evaluation of myocardial masses
- Evaluation of coronary heart disease
- Evaluation of the right ventricle

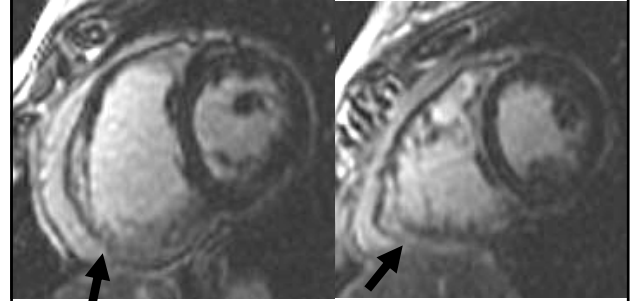
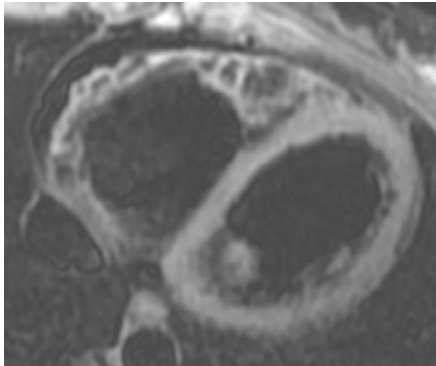
### 19 yo woman

- Syncope, irregular heart beat
- Hx: significant for high level of physical activity (triathlon participation)
- ECG has TWI in V1 to V3, no epsilon wave
- Stress testing: had rare PVCs with LBBB
- Echo was normal, SAECG normal



RV EF 52%, EDV 172 ml (155)





MRI: decreased EF, regional motion abnormality, RV and LV fat, RV delayed gad enhancement.

### 19 yo female, arrhythmia: best diagnosis

1. Sarcoidosis
2. Anomalous coronary artery
3. ARVD (arrhythmogenic RV dysplasia)
4. Amyloidosis

### Arrhythmogenic RV Dysplasia

- Fibrofatty infiltration of RV resulting in ventricular tachycardia
- Palpitations, syncope, sudden death
- Age  $33 \pm 14$  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

### Which is the least common reason for RV enlargement?

1. ARVD
2. Pulmonary Hypertension
3. PAPVR
4. Intracardiac cardiac shunt or valve dysfunction

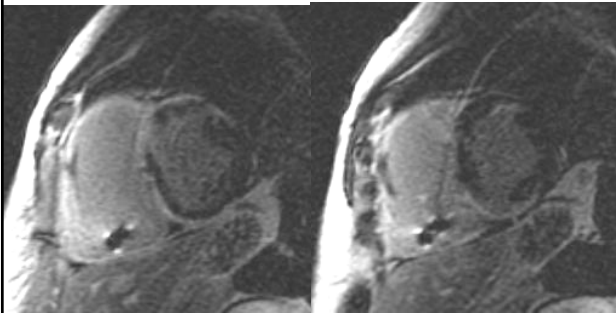
### Which best describes fat association with ARVD?

1. Fibrofatty RV replacement tissue is a histologic criterion for ARVD
2. RV fat always indicates ARVD
3. RV fat is a normal variant
4. LV fat is seen only with ARVD

### What is the potential role of gadolinium MRI in ARVD?

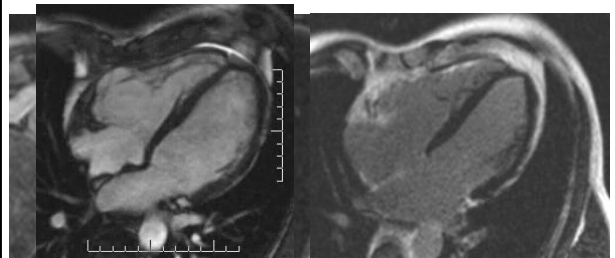
1. RV enhancement supports ARVD diagnosis
2. RV enhancement does not occur (fat does not enhance)
3. It is not a McKenna criterion, and thus there is no role for gadolinium MRI
4. If I knew the answer, I would not be in this seminar...

### RV delayed enhancement



*\*ICD, investigational*

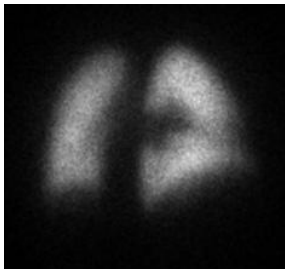
### RV delayed enhancement



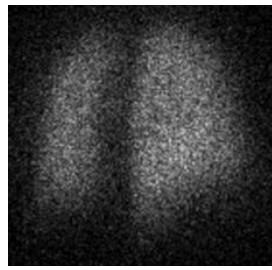
- 39-year old male with a 3-year history of highly symptomatic paroxysmal atrial fibrillation, referred for catheter ablation.
- AF ablation was performed using the segmental ostial ablation.
- No reduction of AF as a result of this procedure; ablation was repeated.

- Evening of hospital discharge, the patient started to cough up bright red blood; went to local ER
- Chest X-ray performed showed an infiltrate in the right lower lobe.
- Spiral CT scan showed no evidence of pulmonary embolism
- Presumptive diagnosis of pneumonia; the patient was discharged on antibiotic therapy.

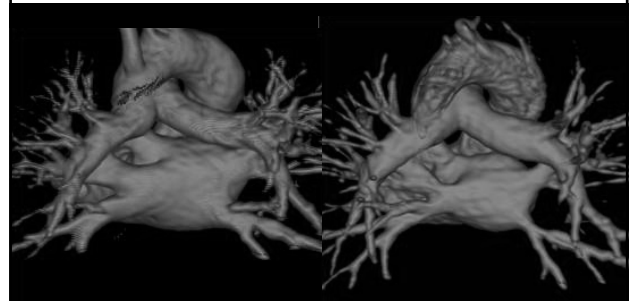
- Returned to our institution: V/Q scan performed: segmental perfusion defect in the RLL. Normal ventilation



Perfusion



Ventilation



Baseline

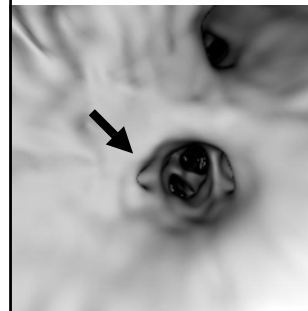


Follow-up

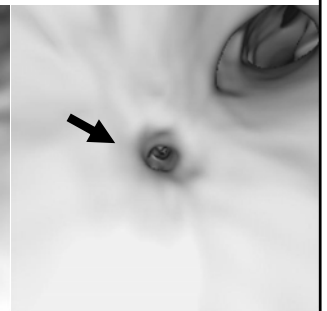
### Best Diagnosis

1. Esophageal perforation
2. Aspiration pneumonia
3. Pulmonary vein stenosis
4. Congenital pulmonary vein absence

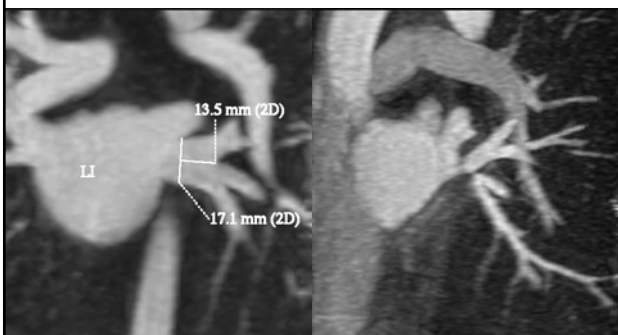
### Inferior pulmonary venous ostia



Baseline



Follow-up



Baseline



Follow-up

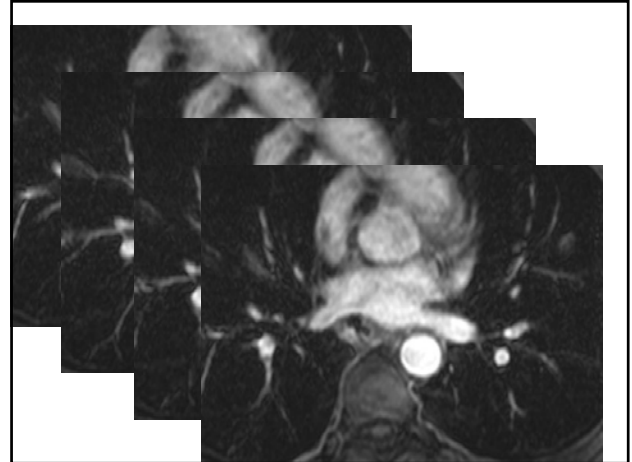
### Chest pain after PV ablation



### Esophagram, same day



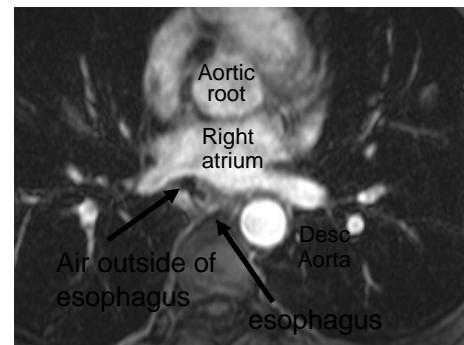
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### Best Diagnosis

1. Esophageal perforation
2. Aspiration pneumonia
3. Pulmonary vein stenosis
4. Congenital pulmonary vein absence

### Esophageal perforation



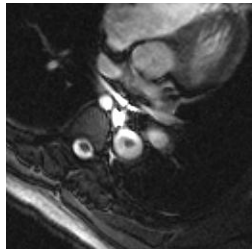
### 45 yo female:

- Insulin dependent diabetes, hypertension
- Hx significant for bilateral lower extremity and upper extremity deep venous thrombosis
- She was admitted to another hospital with left sided chest pain, left arm numbness and dyspnea 5 months before.
- Her cardiac enzymes and ECG were normal.

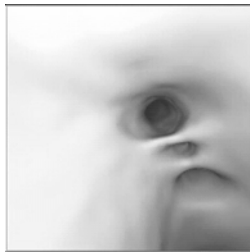
### 45 yr old female, chest pain: triple rule out: aortic mass on CT



**45 yr old female, aortic mass**

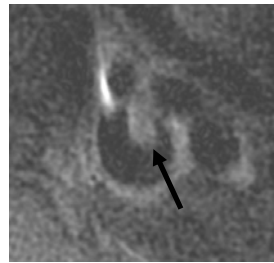


*cine*

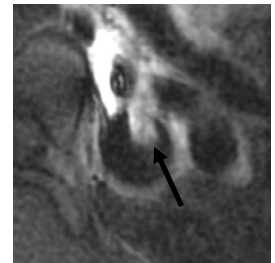


*MRA*

**45 yr old female,  
transesophageal MR coil**



*pre-contrast*



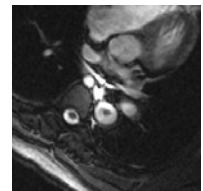
*post contrast*

**Best diagnosis:**

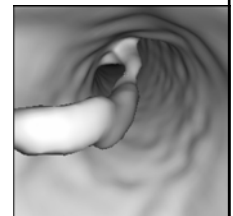
1. Gadolinium enhancement indicates malignant lesion
2. Floating aortic thrombus
3. Metastatic disease
4. Primary leiomyosarcoma of the aorta

**Protein S deficiency**

Clinical course:  
Anticoagulated for 4 weeks  
Repeat MRI: similar findings  
Surgery to remove aortic clot

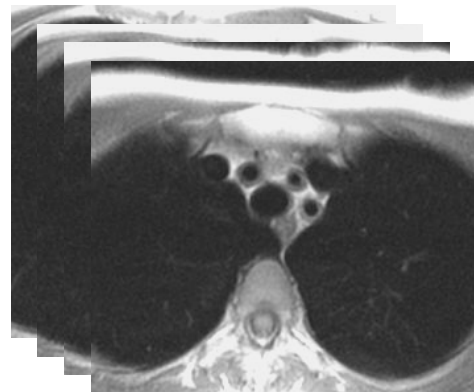


Subsequent multiple  
readmissions for both upper  
extremity clots despite concurrent  
warfarin therapy

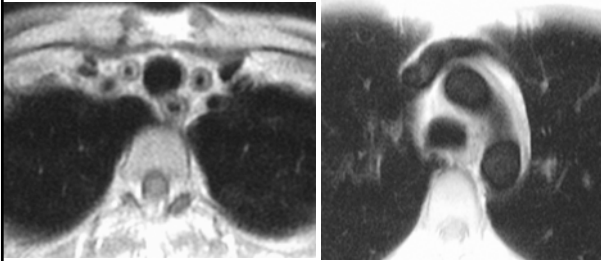


**Vascular Aunt Minnies**

**2 cases, same diagnosis**

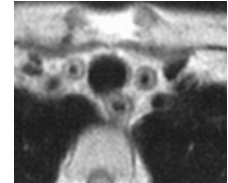


### Case 2:



### Best diagnosis:

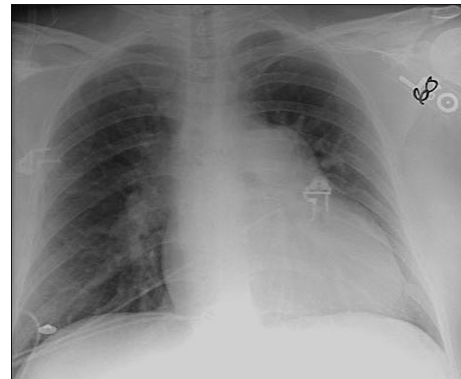
1. Takayasu vasculitis
2. Syphilitic aortitis
3. Intramural hematoma



### 36 yo adult male

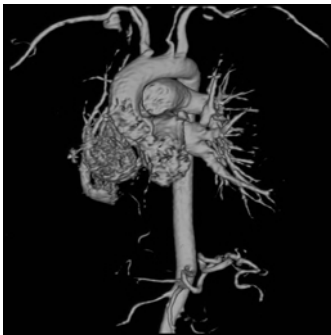
- Increasing short of breath
- History of valvular repair at age 2
- CXR: small right hemithorax
- Suspect arch abnormality

### 36 yo adult male

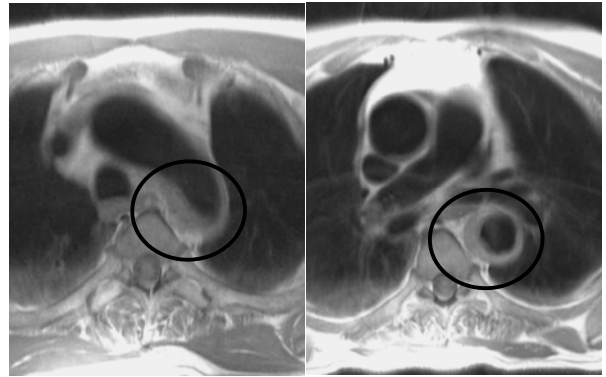


**Best diagnosis:**

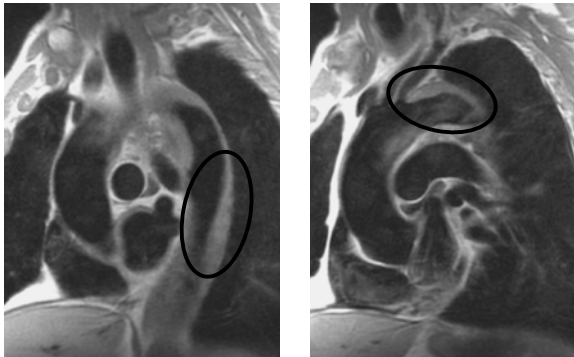
1. Absent pulmonary artery
2. Coarctation
3. Scimitar syndrome (PAPVR)



**Acute Chest Pain**



**Acute Chest Pain**

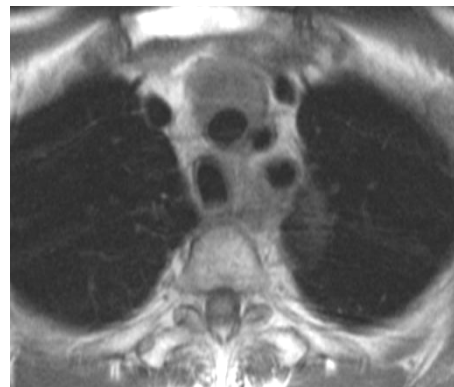


**Best diagnosis:**

1. Aortic dissection
2. Aortic rupture
3. Intramural hematoma

**Last case...**

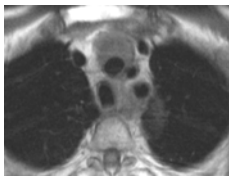
- 61 yo male with H/N cancer
- Prior neck radiation
- Now with skin breakdown over the left chest, persistent fever
- MRI to assess for disease extent, source of fever and complications.





**Best diagnosis:**

1. Post-op seroma
2. Nodal metastasis
3. Pseudoaneurysm innominate artery



**Thank you!**

