Assessing Cardiac Masses with Cardiac Magnetic Resonance Imaging

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Differential Diagnosis of a Cardiac Mass

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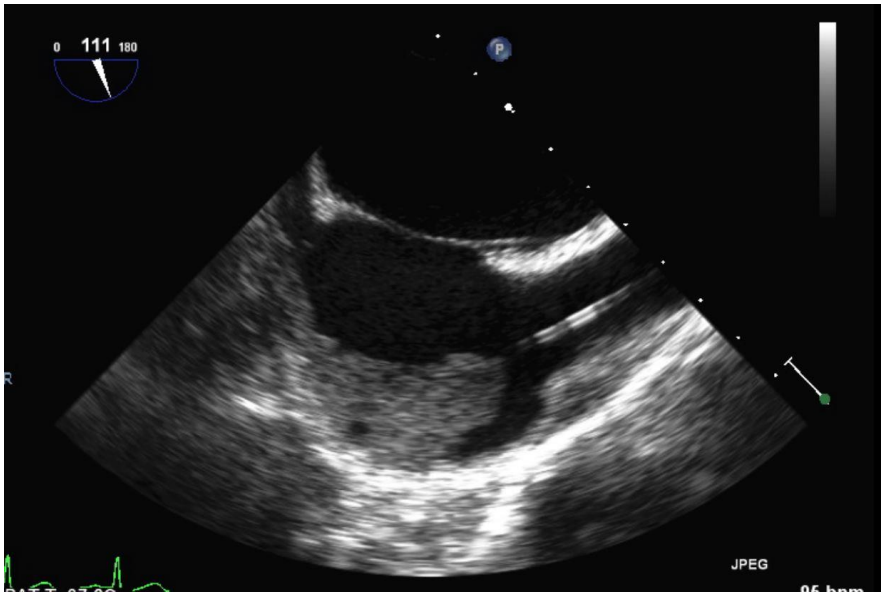

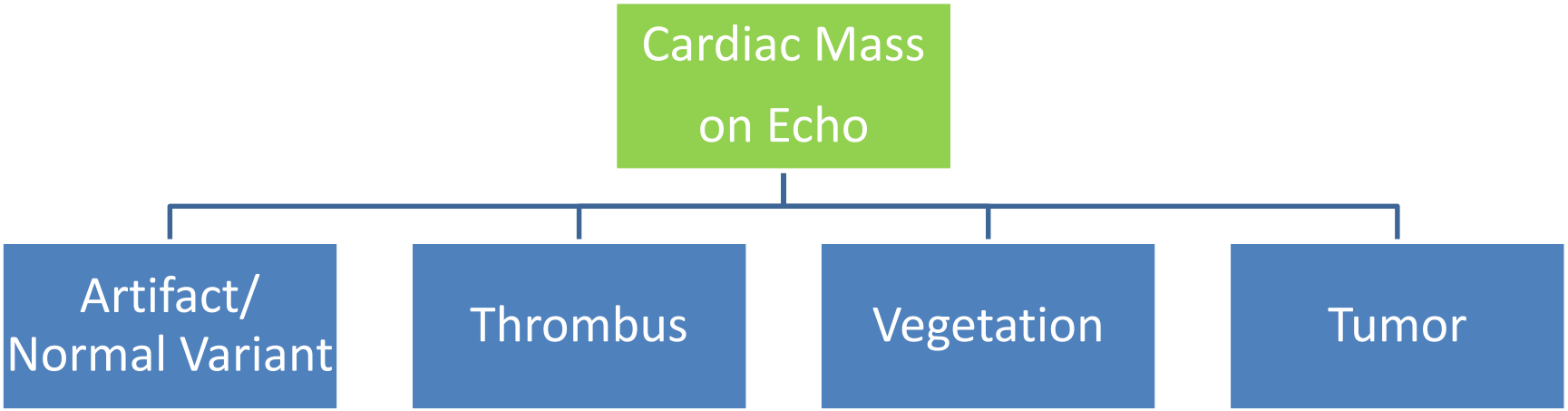

Echocardiography:
Primary Modality for Imaging Intracardiac Disease

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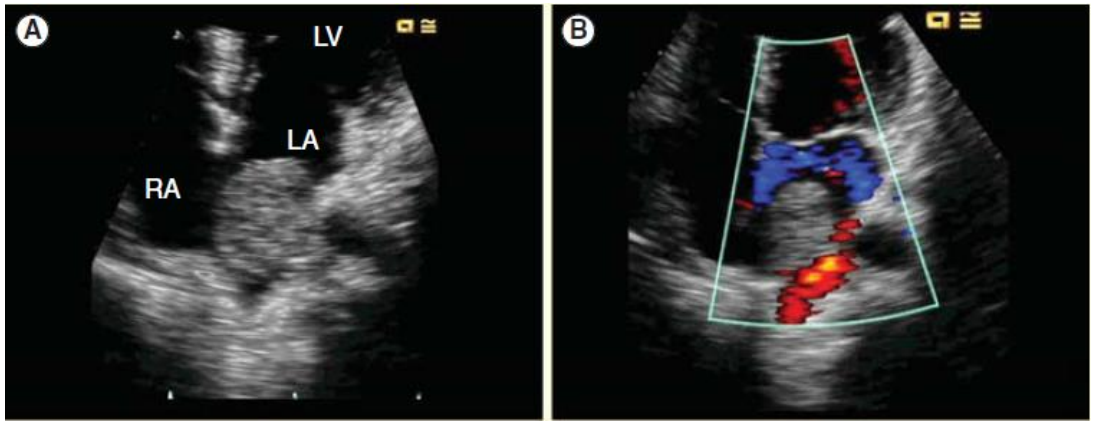
Advantages

- Readily available
- Identifies morphology, location
- Doppler identifies altered hemodynamics
- Many cases, characteristic features permit a differential diagnosis

Disadvantages

- Operator dependent
- Acoustic window restrictions (restricted FOV)
  - Limited imaging of the right heart
  - Mediastinal/extra-cardiac structures
  - Obesity / COPD
- Poor soft tissue characterization
- TEE is invasive



Advanced Imaging of Cardiac Masses

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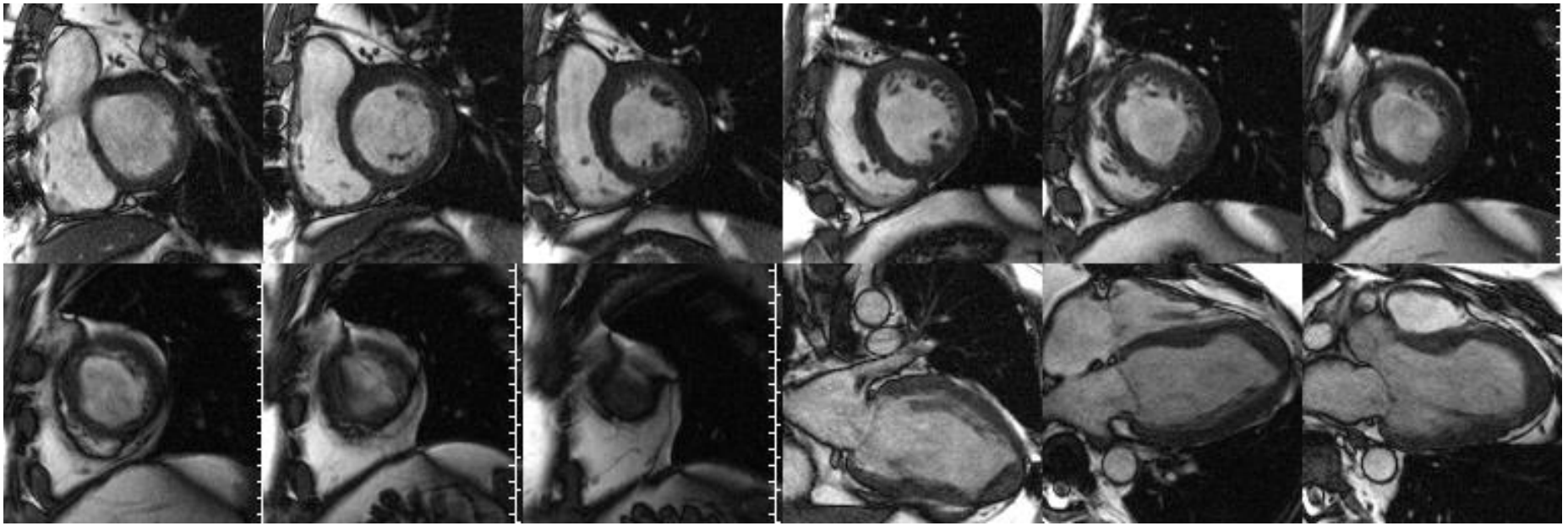

Modality	Echocardiography	Cardiac MRI	Cardiac CTA
Field of view	++	+++	+++
Tissue characterization	+	+++	++
Temporal resolution	+++	++	+
Perfusion assessment	++	+++	+
Spatial resolution	+	+++	+++

CMR Provides Incremental Value

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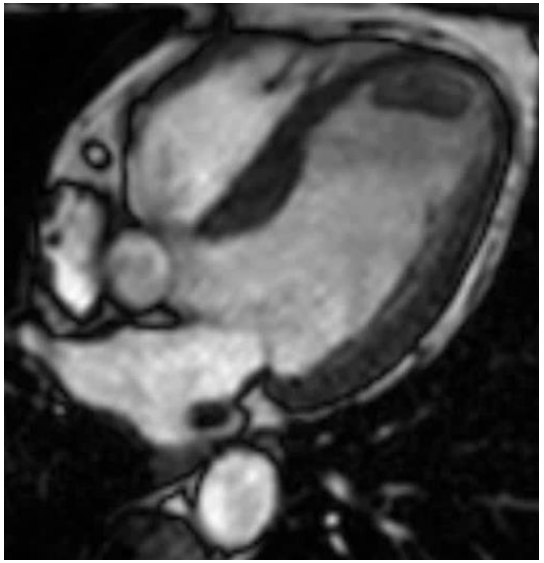
Accurate description of:

- Tumor anatomy (shape, size, location)
- Tumor extension
- Vascularity
- Tissue contrast (fat, thrombus, fluid, iron)



Added value:

1) Detail its relationship to other cardiac and extra-cardiac structures
2) Identify & contribute to differential diagnosis of a cardiac mass
3) Plan therapy (eg. surgery or chemotherapy)
4) Monitor tumor regression after therapy with serial studies

2019 Appropriate Use Criteria for Multimodality Imaging

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Indication	TTE (With or Without 3D; With Contrast as Needed)	TEE (With or Without 3D)	Stress Echo*	Strain/Strain Rate Imaging by Speckle or Tissue Doppler	F-18 FDG PET	Tc-99m PYP	MPI (SPECT/PET)	CMR	CT†	ANG	RVG
Other											
40. Suspected pericardial diseases	9 (A)	4 (M)	1 (R)	5 (M)	1 (R)	1 (R)	1 (R)	7 (A)	7 (A)	1 (R)	1 (R)
41. Initial evaluation of cardiac mass, suspected tumor or thrombus, or potential cardiac source of emboli	9 (A)	7 (A)	1 (R)	1 (R)	1 (R)	1 (R)	1 (R)	7 (A)	7 (A)	1 (R)	1 (R)

Doherty. J Am Coll Cardiol 2019;73:488–516

CMR Imaging Protocol: Cardiac Masses

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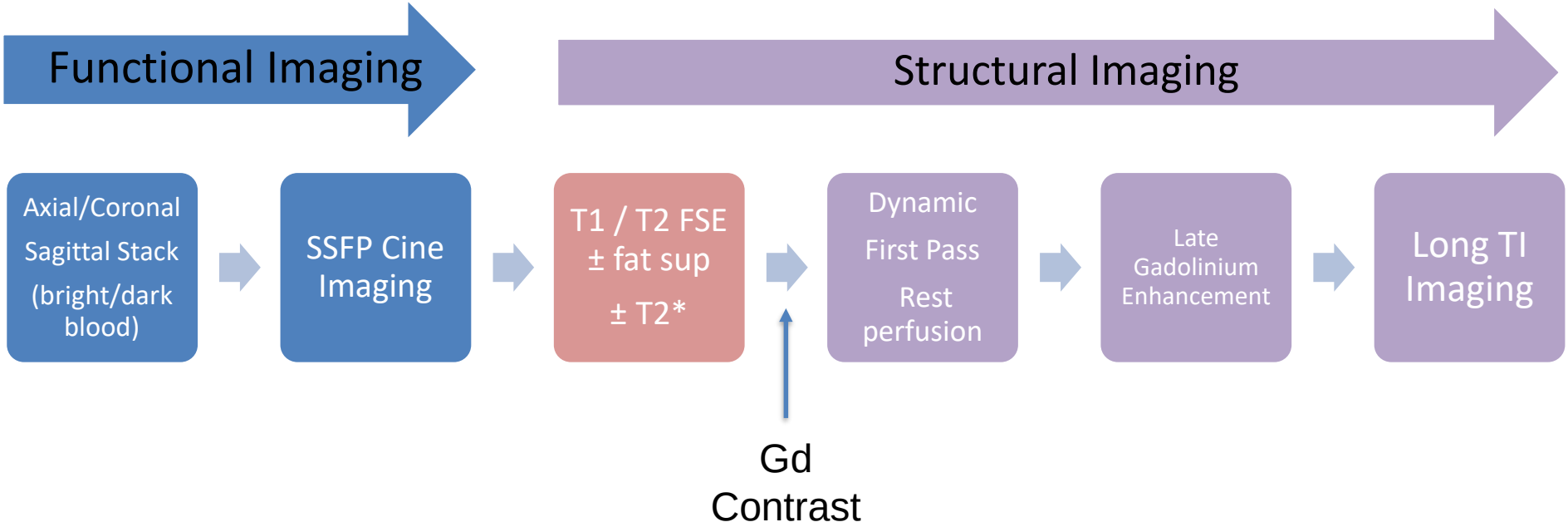

CMR Imaging Protocol: Functional Imaging with Cine SSFP

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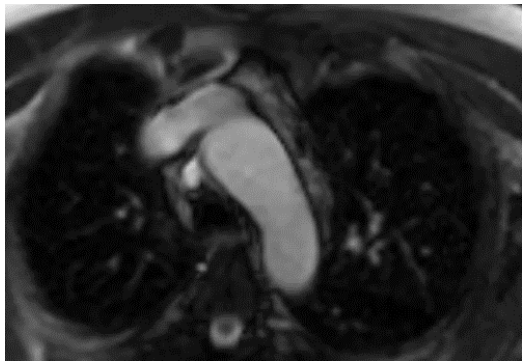

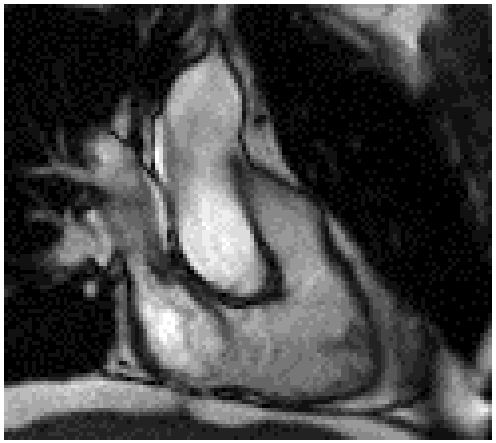

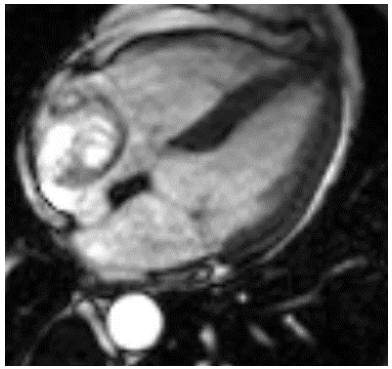

- Standard cine imaging of the heart from base to apex in both short- and long-axis views
- Targeted non-standard imaging planes for optimal visualization
- Value:
  - Confirm location, size & morphology
  - Assess mobility
  - Assess physiological impact
  - Assess tumor extension or involvement of the pericardium, mediastinum, lungs, lymph nodes and vascular bed

CMR Imaging Protocol: Structural Assessment

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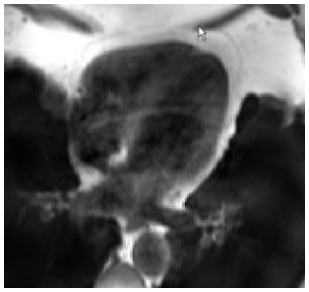
Superior Ability to Discriminate Tissue Characteristics

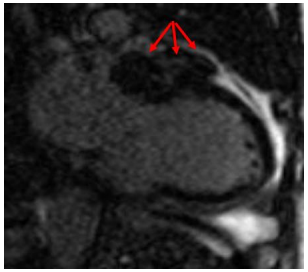
Pre-Contrast Images

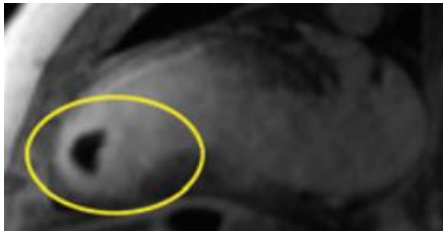


- T1 Weighted sequences
  - Fat
  - Acute blood
- T2 Weighted sequences
  - Edema (water)
- T2* sequence
  - Iron / blood breakdown products

Contrast Enhanced Images

- Dynamic first pass rest perfusion
  - Vascularity
- Delayed hyperenhancement
  - Fibrosis / necrosis / inflammation
- Long TI Imaging
  - Thrombus





Contribute to differential diagnosis of a cardiac mass

CMR Imaging Protocol: Structural Assessment

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

Superior Ability to Discriminate Tissue Characteristics

Pre-Contrast Images

- **T1 Weighted**
  - Fat
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- **T2 Weighted**
  - Edema (water)
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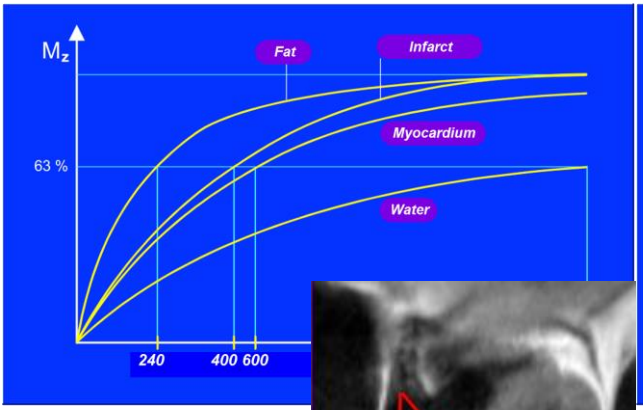
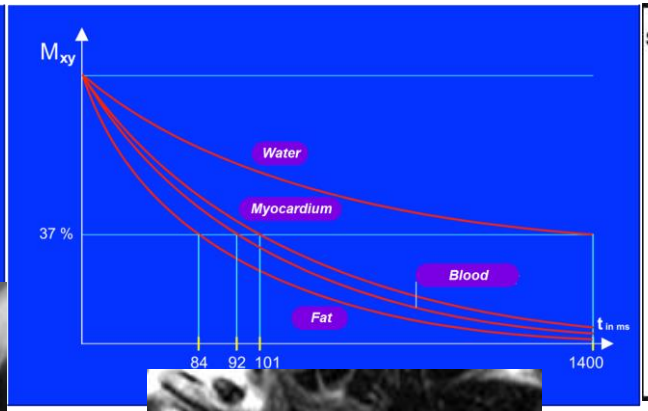
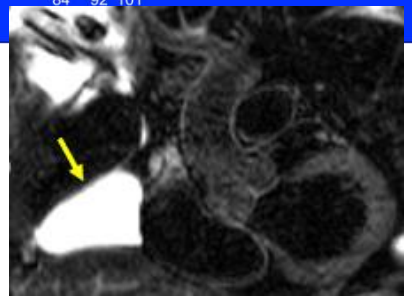
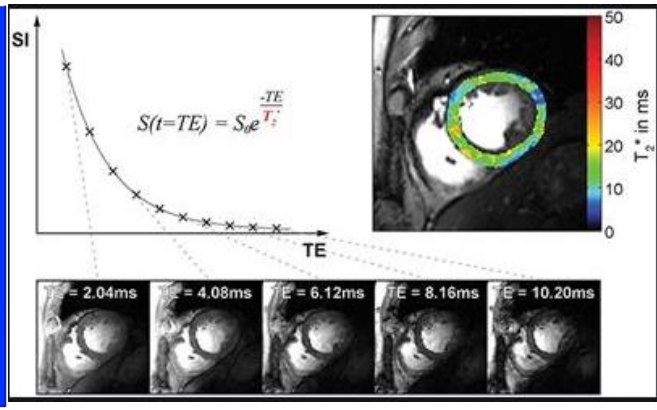
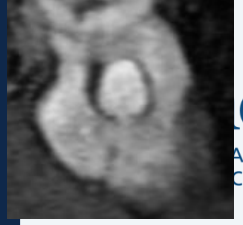








CMR Imaging Protocol: Structural Assessment



Superior Ability to Discriminate Tissue Characteristics

Contrast Enhanced Images

- **Dynamic Rest Perfusion**
  - Vascularity
- **Delayed hyperenhancement**
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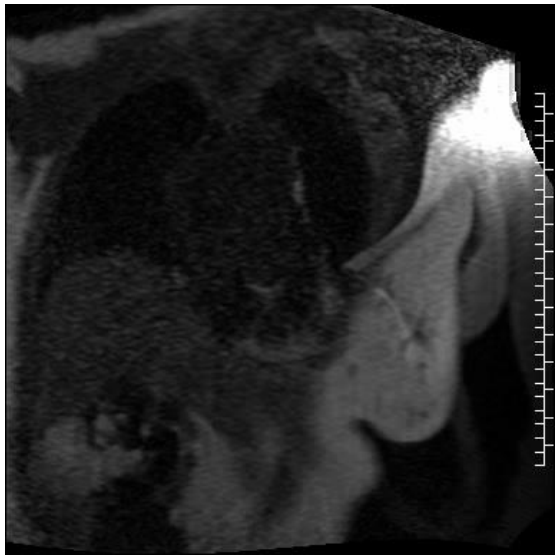

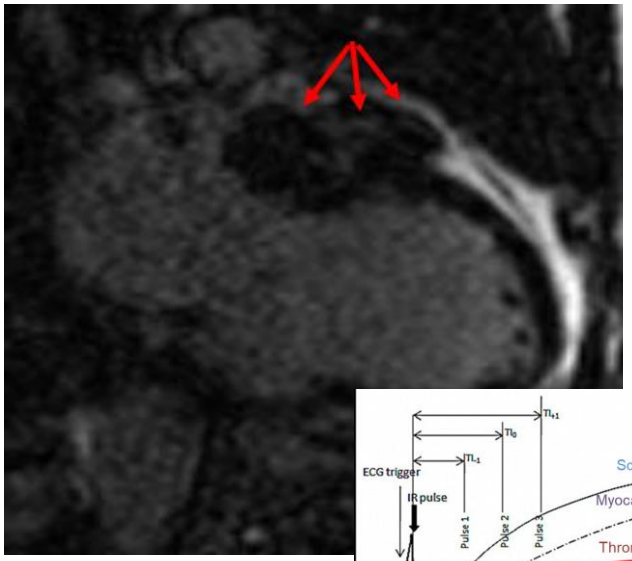

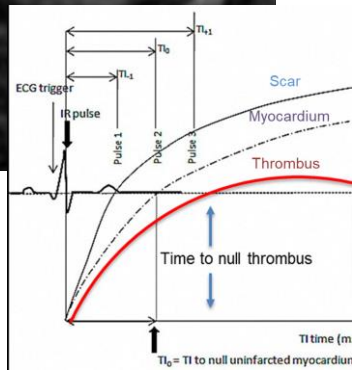

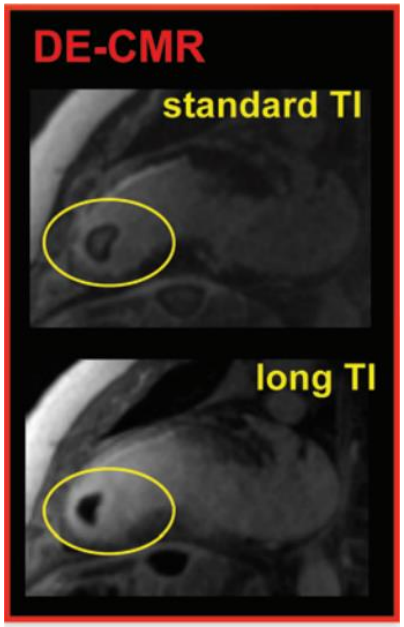

Contribute to differential diagnosis of cardiac mass

Step Wise Cardiac Mass Evaluation

STEP 1

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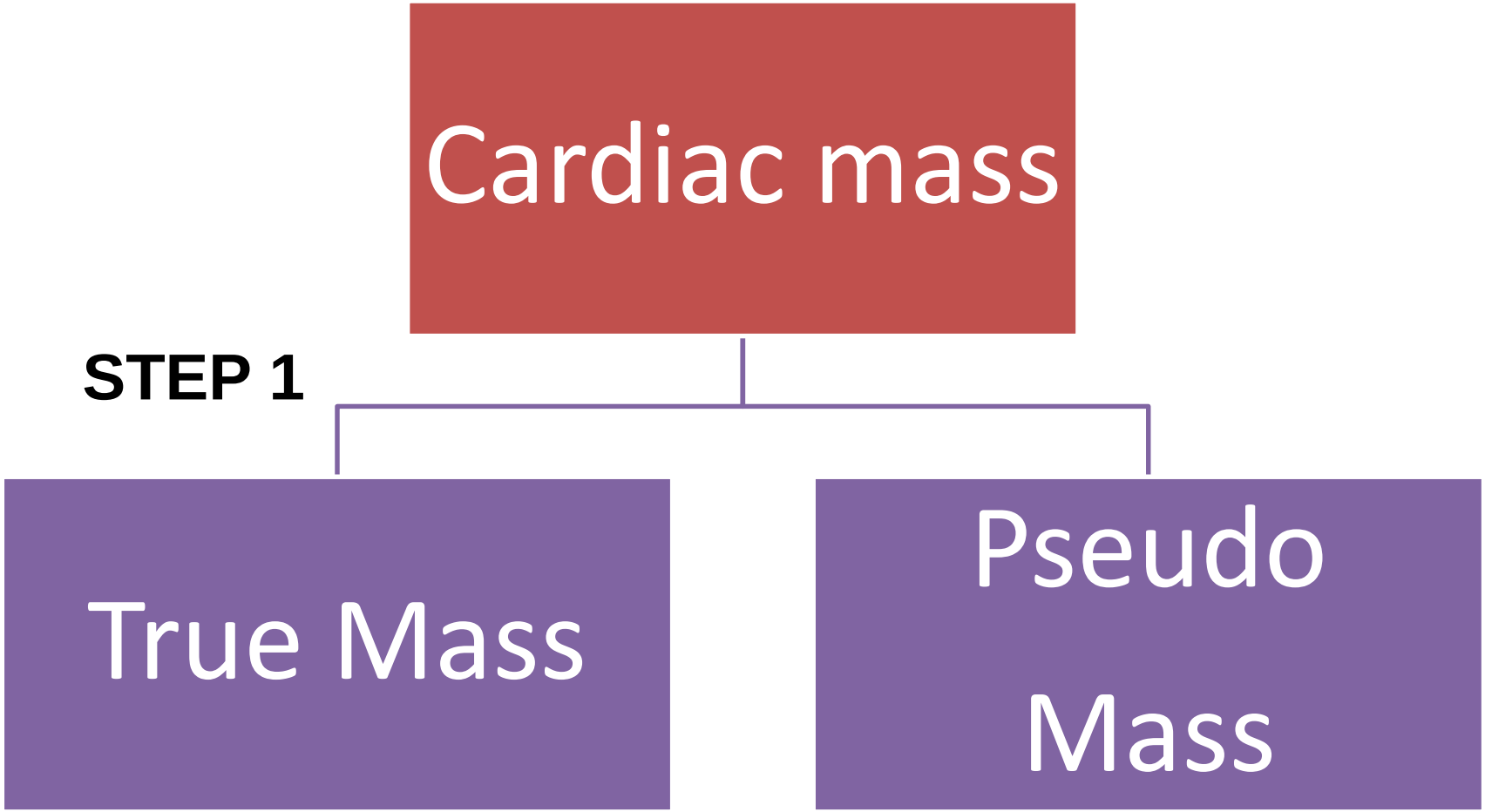

Tumor vs Pseudo-Mass

Case 1

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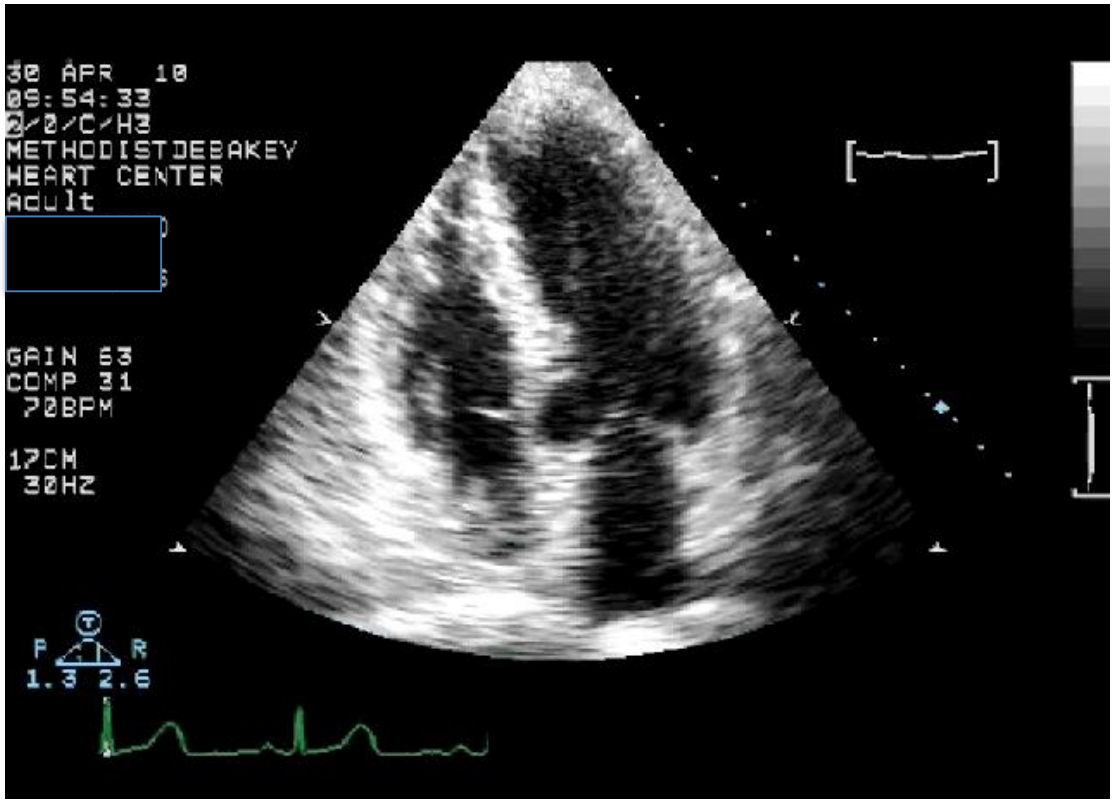
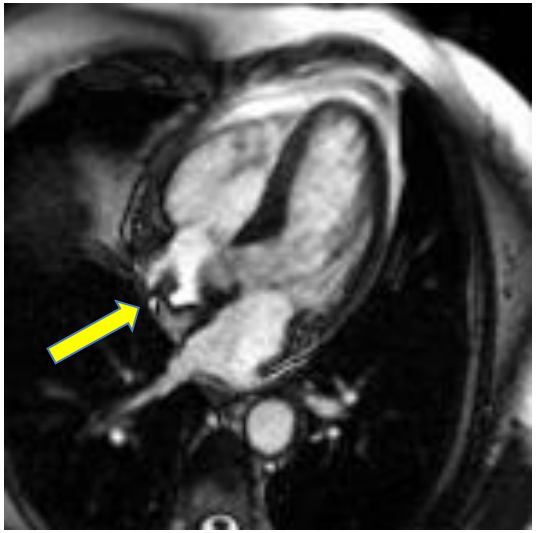
74M with CVA found to have RA mass





Prominent christa terminalis

Tumor vs Pseudo-Mass

Case 2

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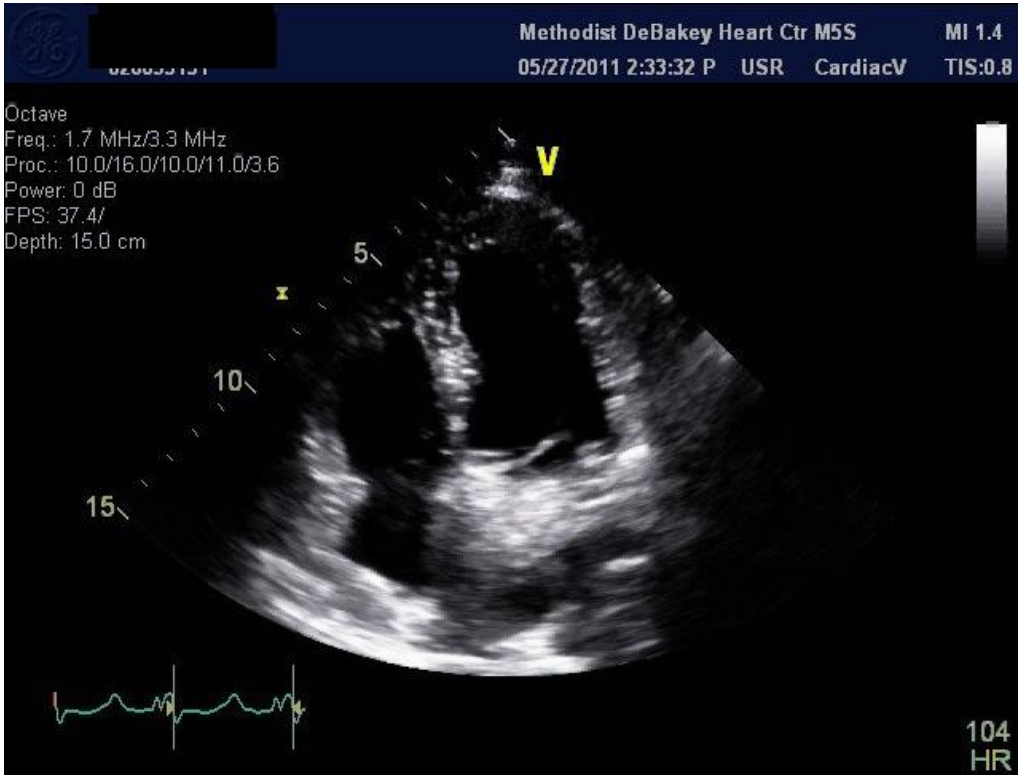
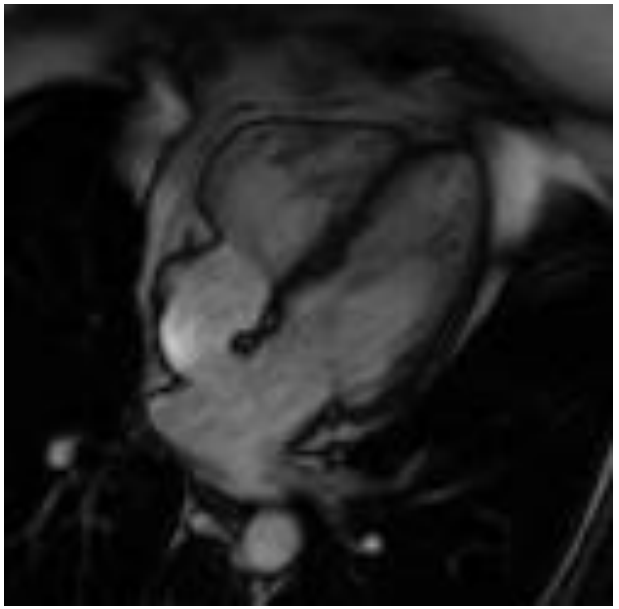
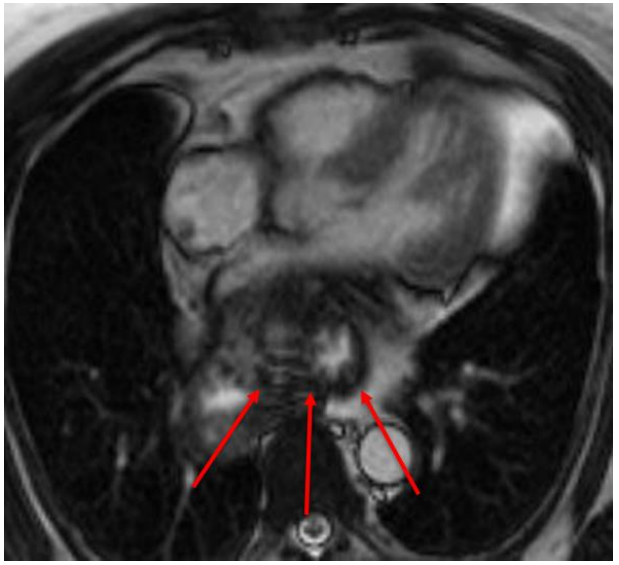
51F CAD admitted with epigastric pain







Hiatal hernia

Normal Structures that can be Mistaken for an Abnormal Cardiac Mass

Left atrium	Dilated coronary sinus (persistent left superior vena cava) Raphe between left superior pulmonary vein and LA appendage Atrial suture line after cardiac transplant Beam-width artifact from calcified aortic valve, aortic valve prosthesis, or other echogenic target adjacent to the atrium Interatrial septal aneurysm
Right atrium	Crista terminalis Chiari network (Eustachian valve remnants) Lipomatous hypertrophy of the interatrial septum Trabeculation of RA appendage Atrial suture line after cardiac transplant Pacer wire, Swan-Ganz catheter, or central venous line
Left ventricle	Papillary muscles LV web (aberrant chordae) Prominent apical trabeculations Prominent mitral annular calcification
Right ventricle	Moderator band Papillary muscles Swan-Ganz catheter or pacer wire
Aortic valve	Nodules of Arantius Lambl excrescences Base of valve leaflet seen *en face* in diastole
Mitral valve	Redundant chordae Myxomatous mitral valve tissue
Pulmonary artery	LA appendage (just caudal to pulmonary artery)
Pericardium	Epicardial adipose tissue Fibrinous debris in a chronic organized pericardial effusion

Otto. Textbook of Clinical Echocardiography. 2014

Step Wise Cardiac Mass Evaluation

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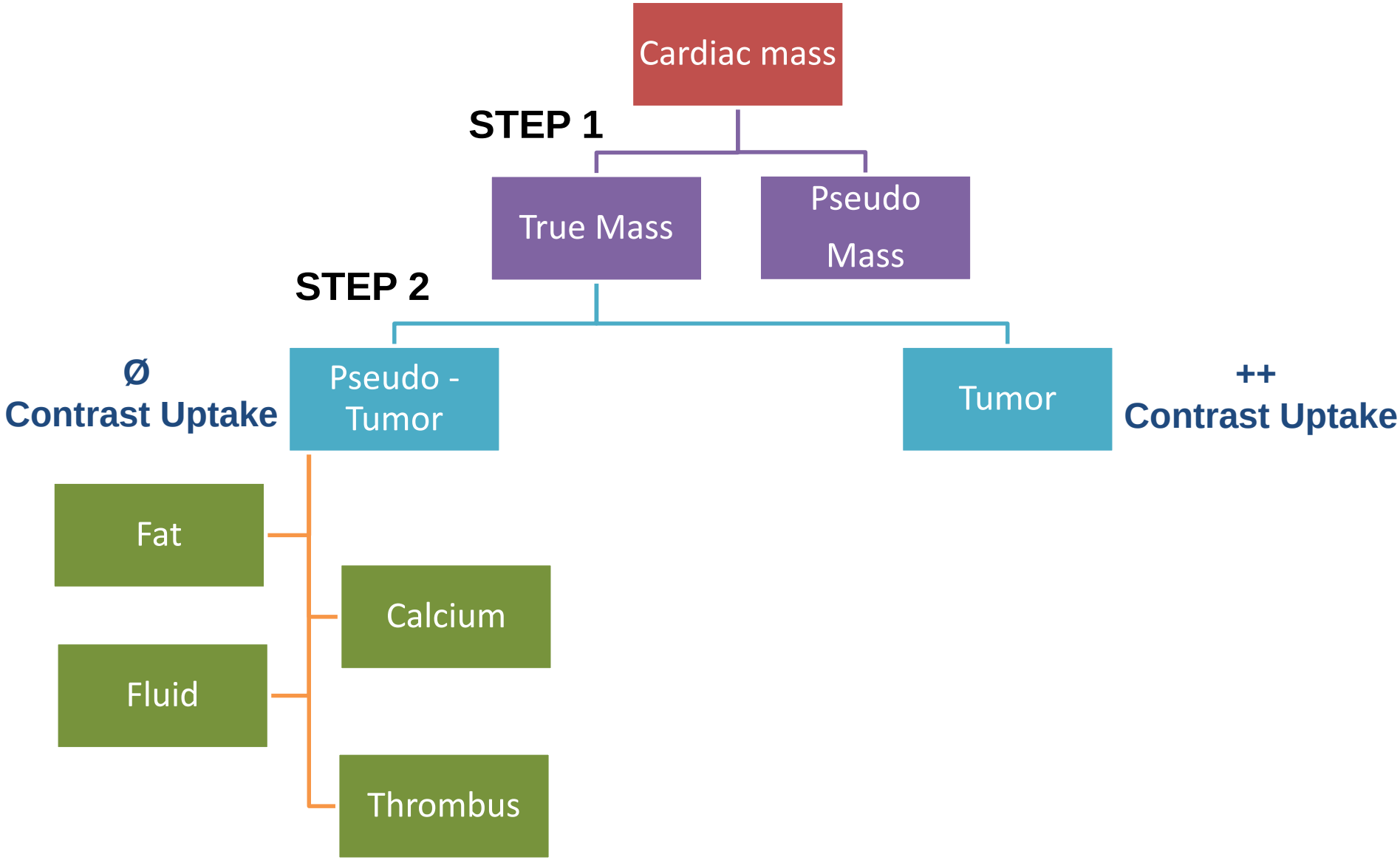

Tumor vs Pseudo-tumor

Case3

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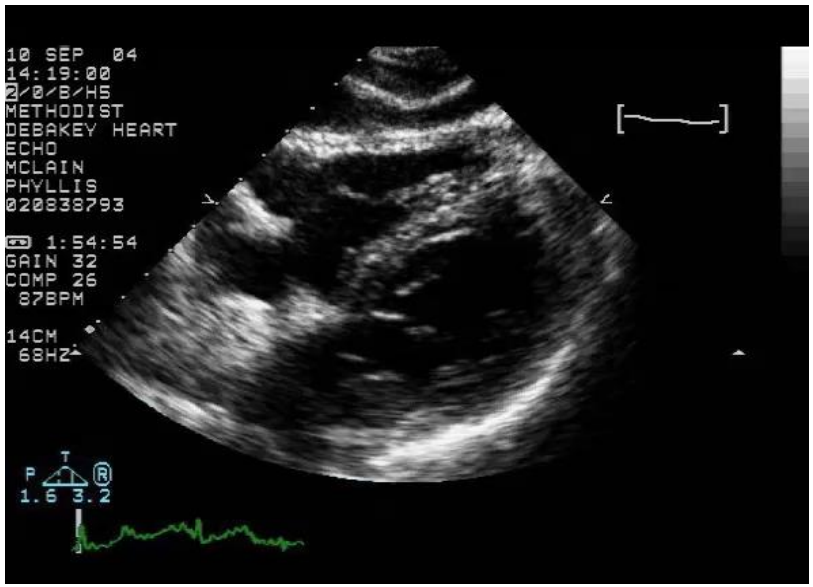
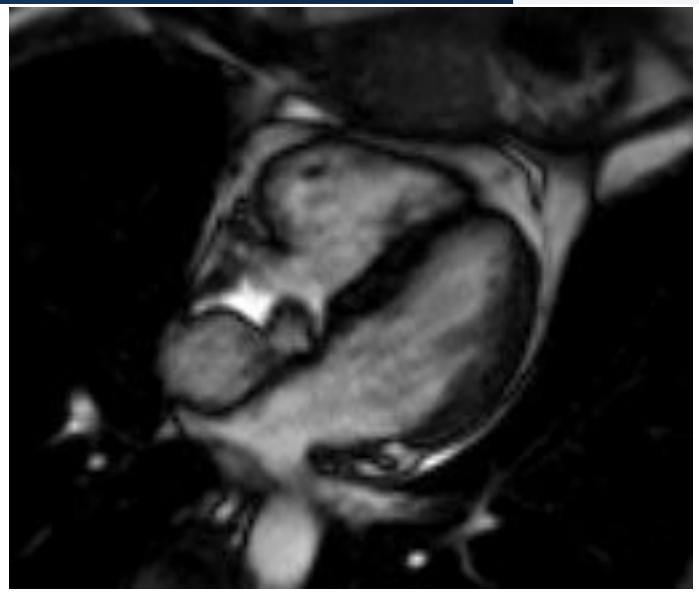
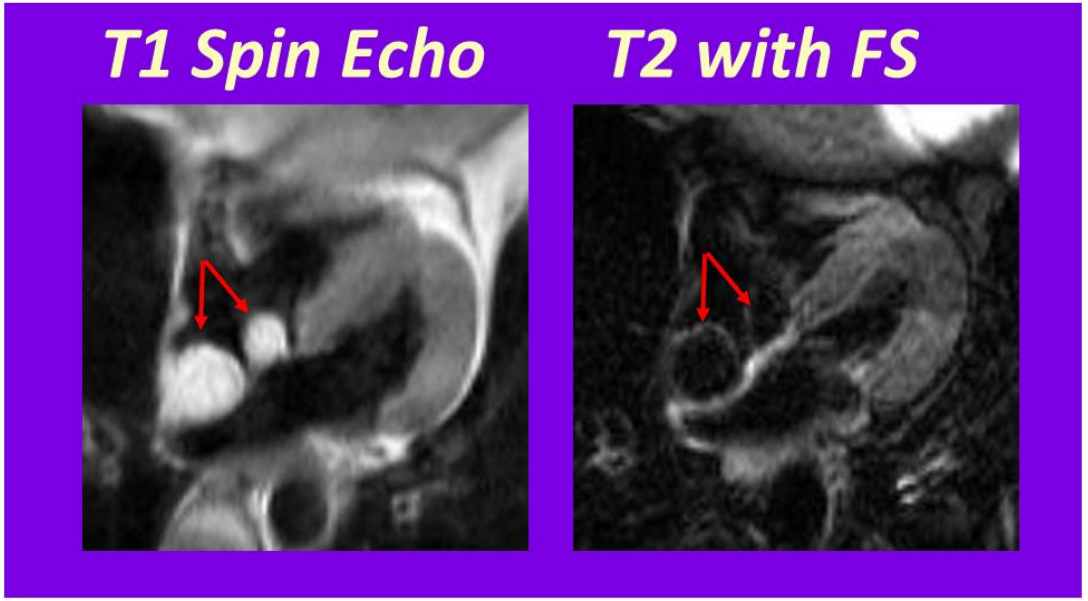




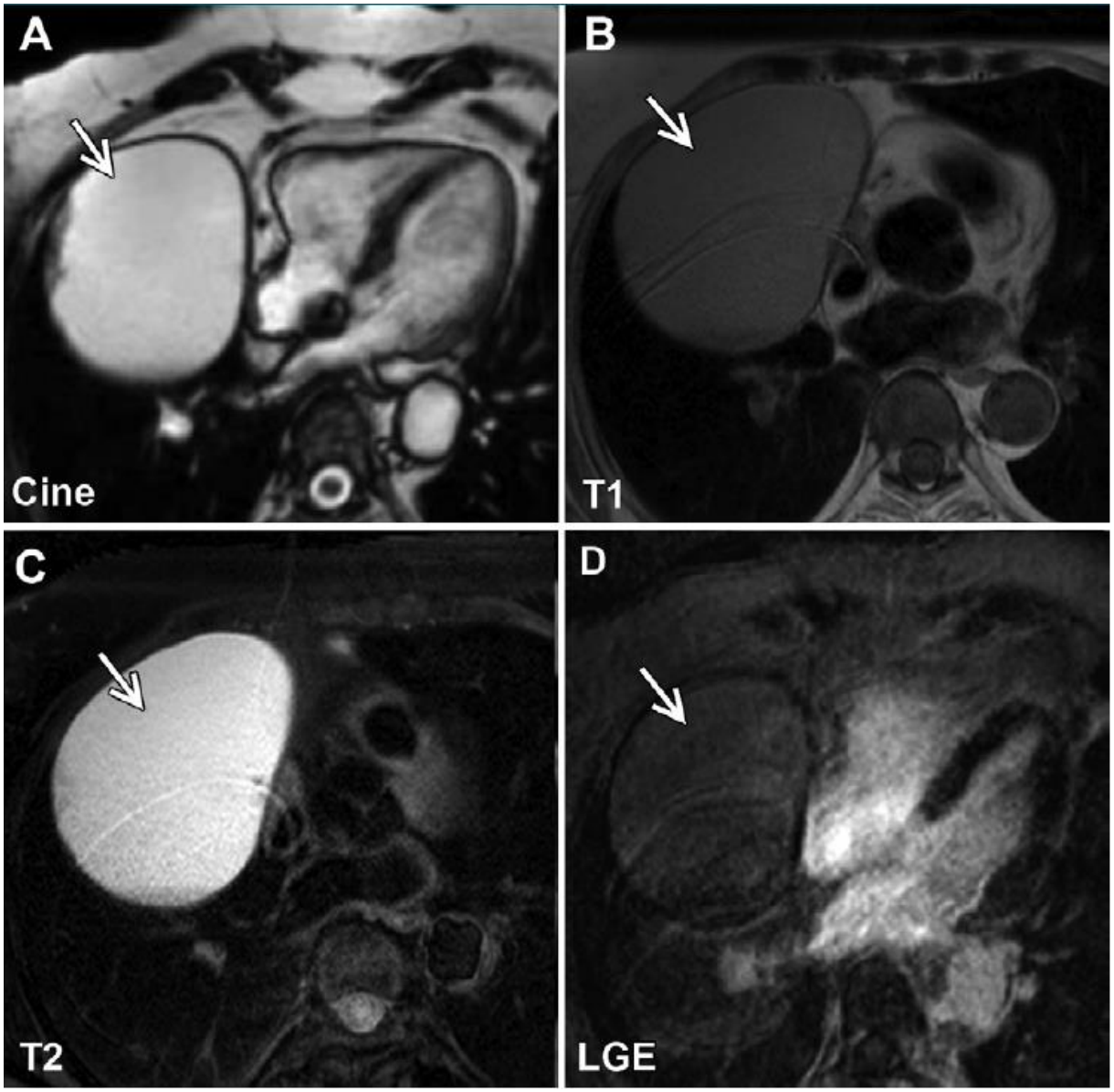
Lipomatous hypertrophy of the IAS



Tumor vs Pseudo-tumor

Case 4

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER



Pericardial Cyst

Tumor vs Pseudotumor

Case 5

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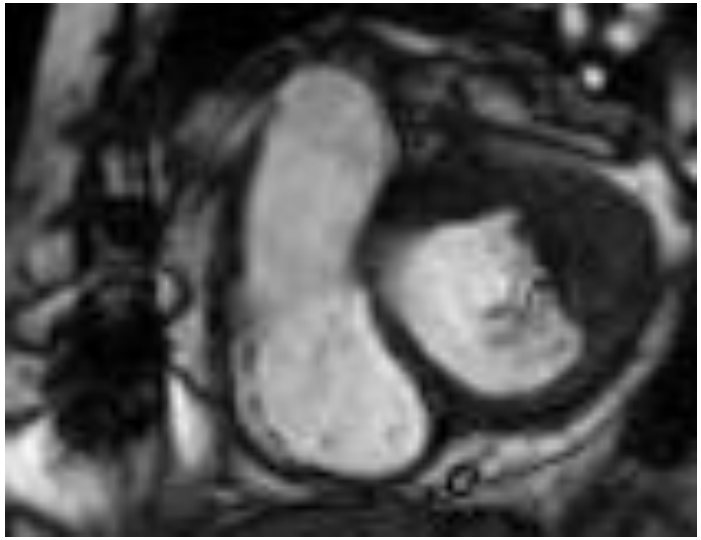
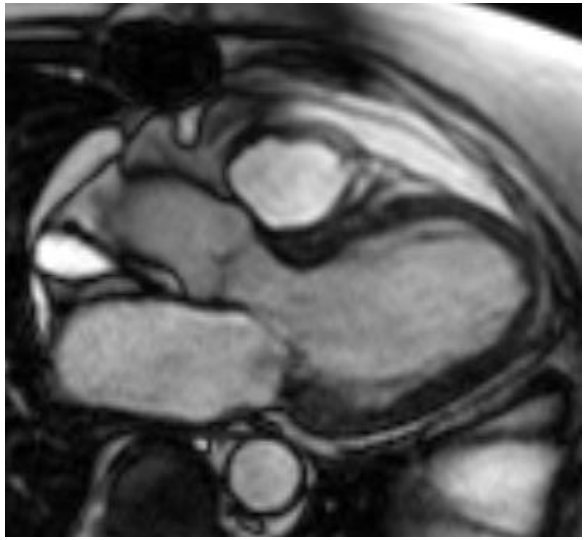
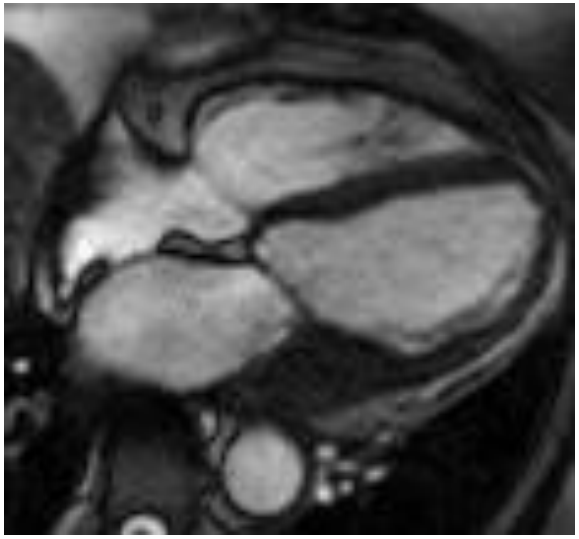
A 77 year-old asymptomatic female with a history of a very recent 2V-CABG referred from OSH for surgical removal of a new LA mass found on a post-op TTE

Tumor vs Pseudotumor

Case 5

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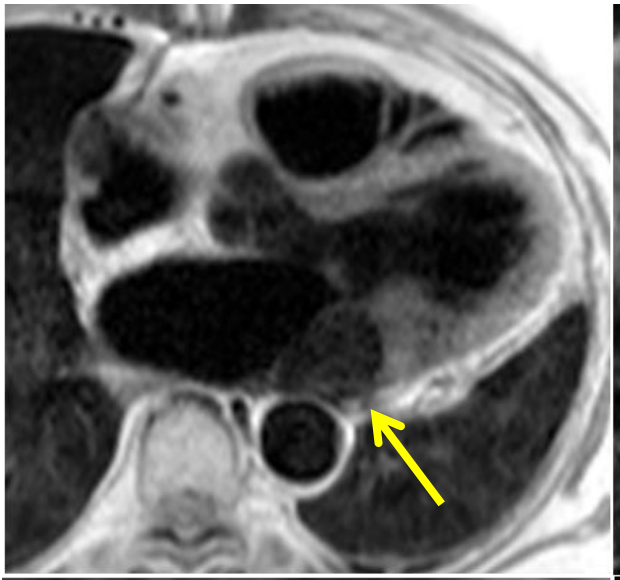
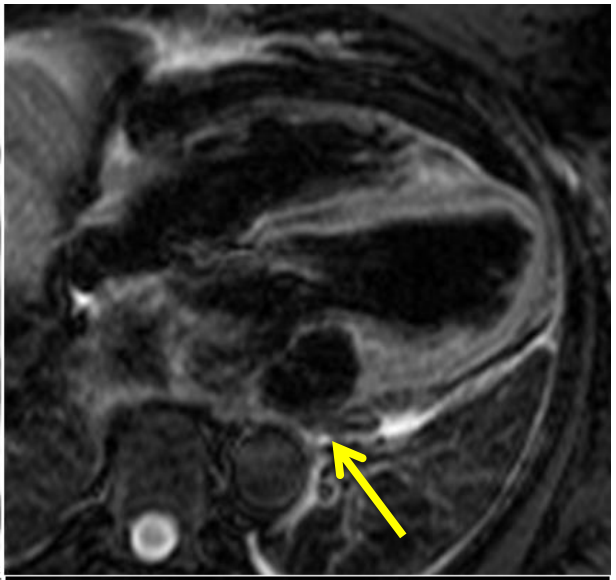
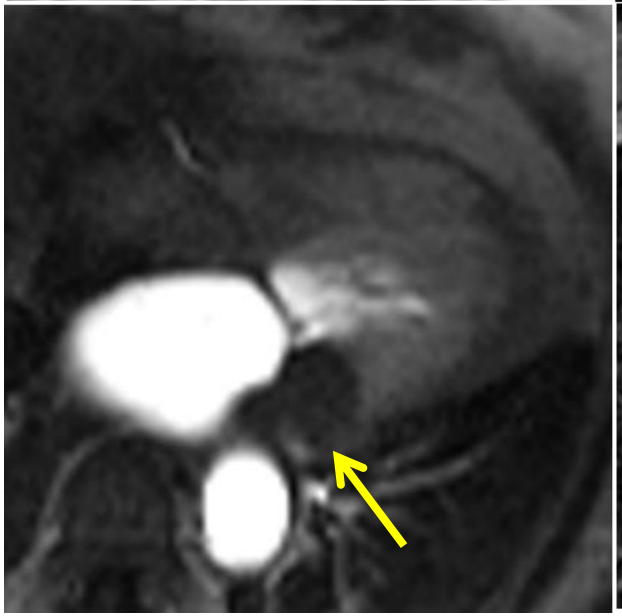
T1

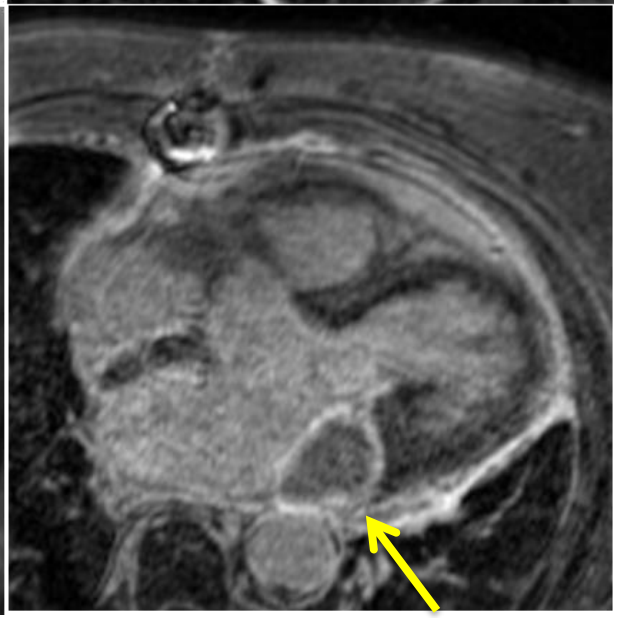




T2 with fat sat

First pass rest perfusion





LGE

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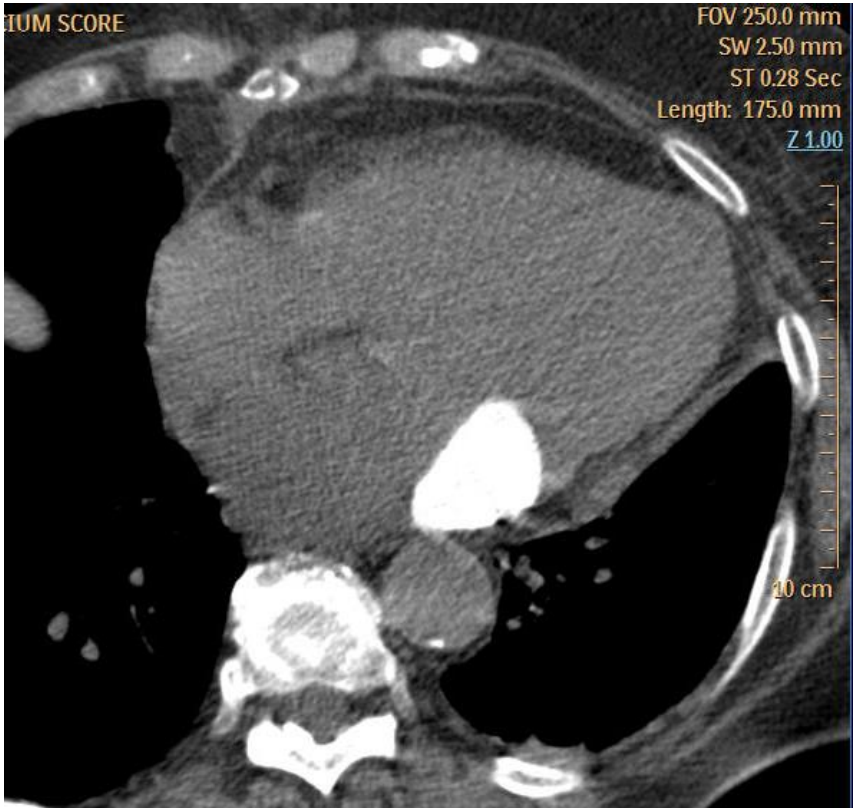
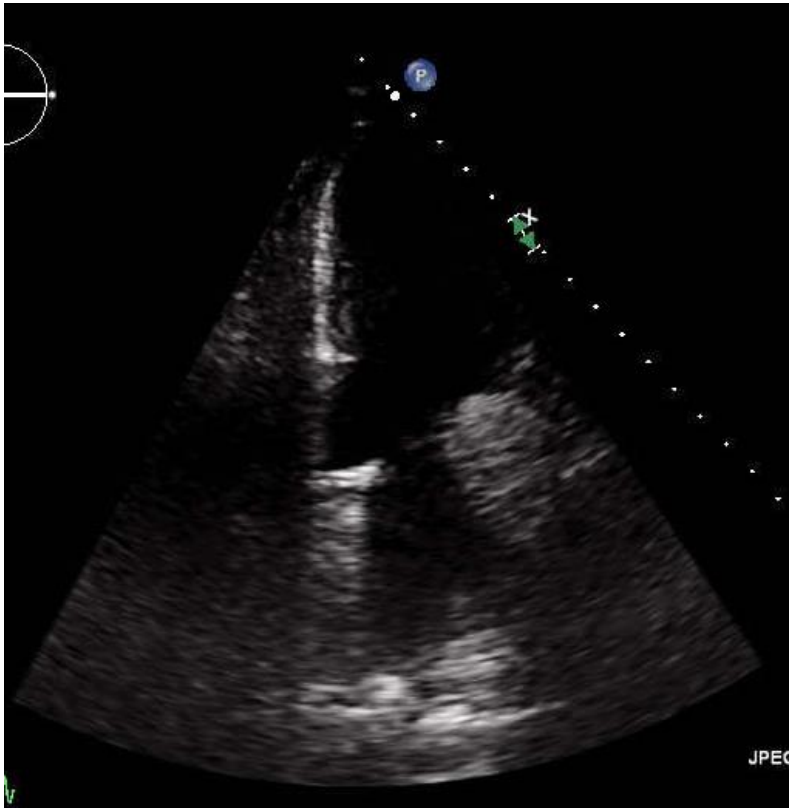
Non-contrast Cardiac CT



TTE – Apical 4 CH



Caseating Mitral Annular Calcification

Thrombus vs Tumor

Case 1

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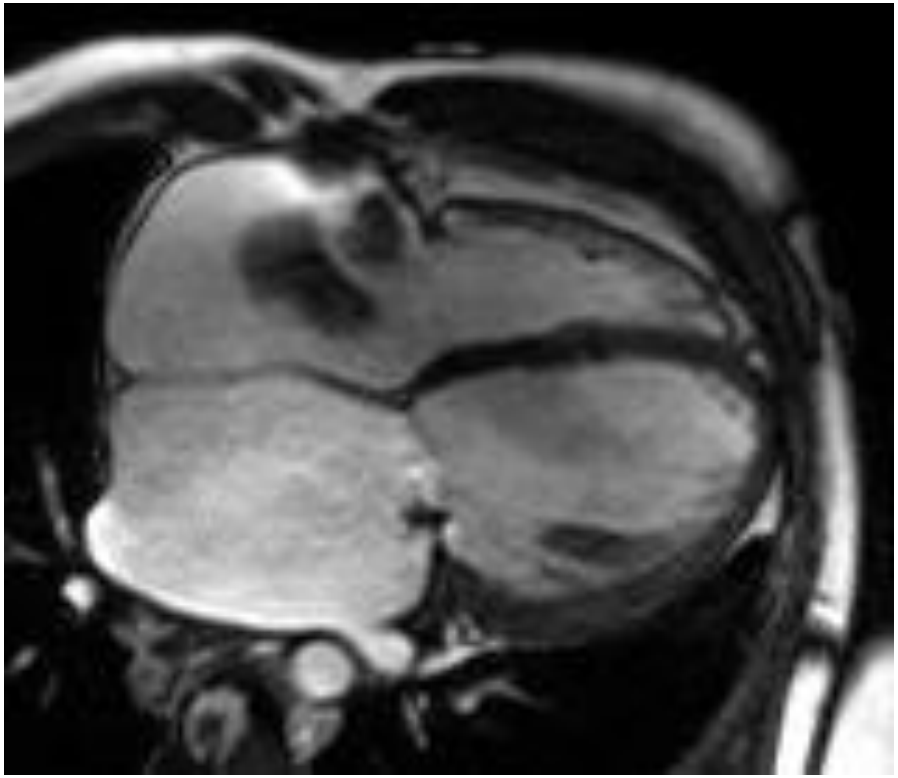
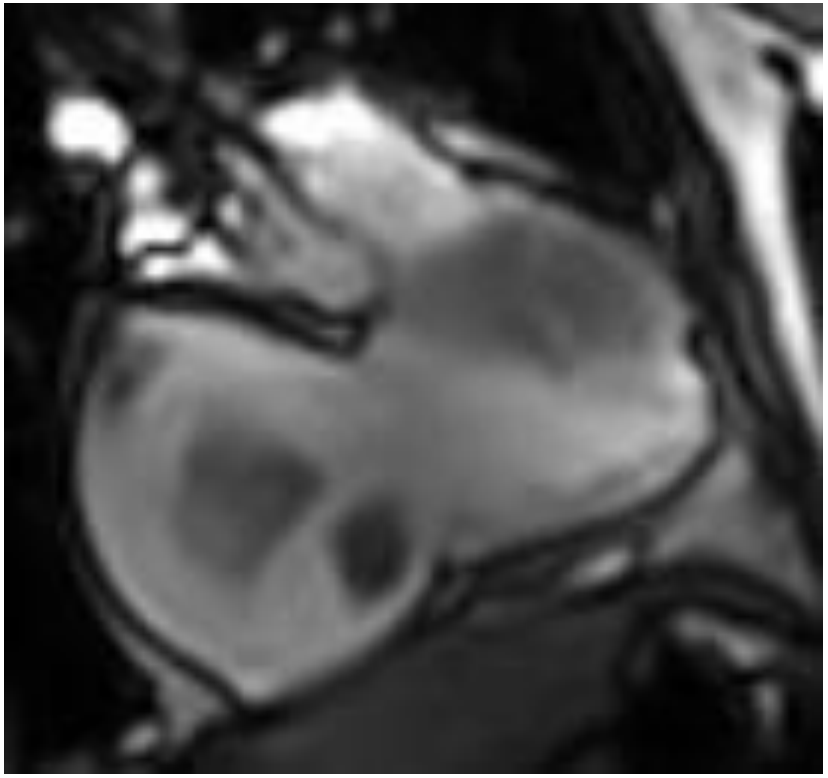
52M DM, MVR’09, chronic afib on anti-coagulation, nl EF, admitted with DHF





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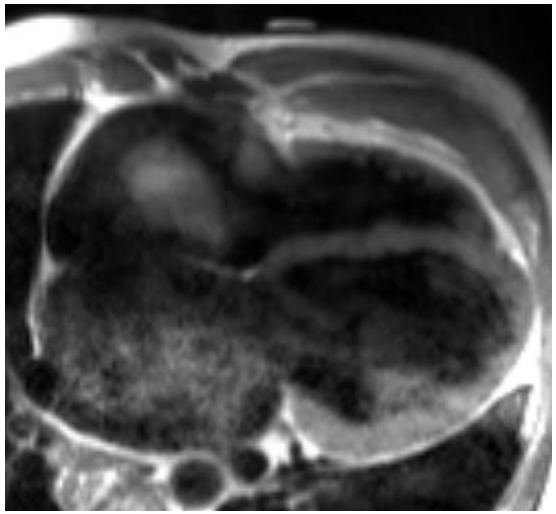
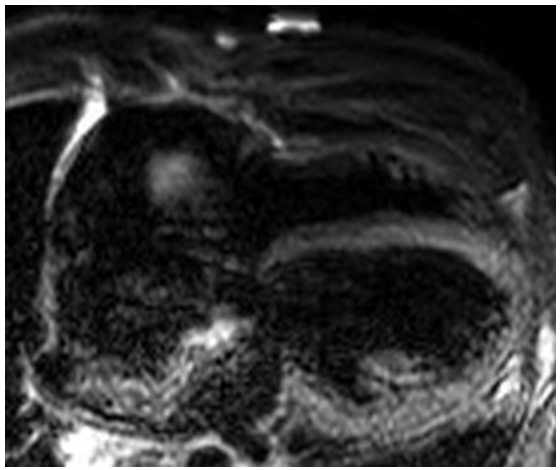
T1/T2





Rest Perfusion

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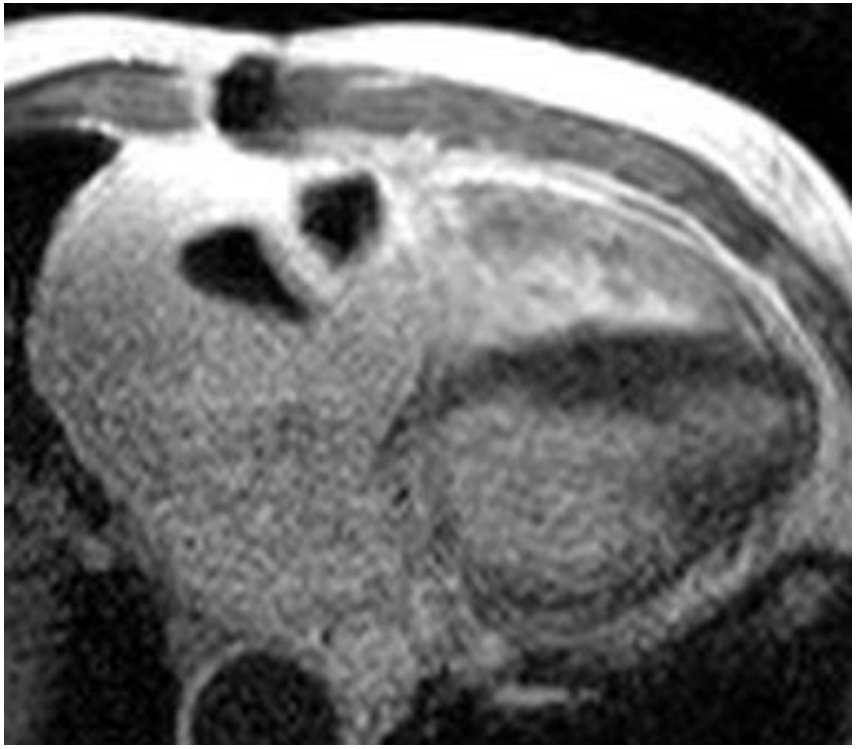
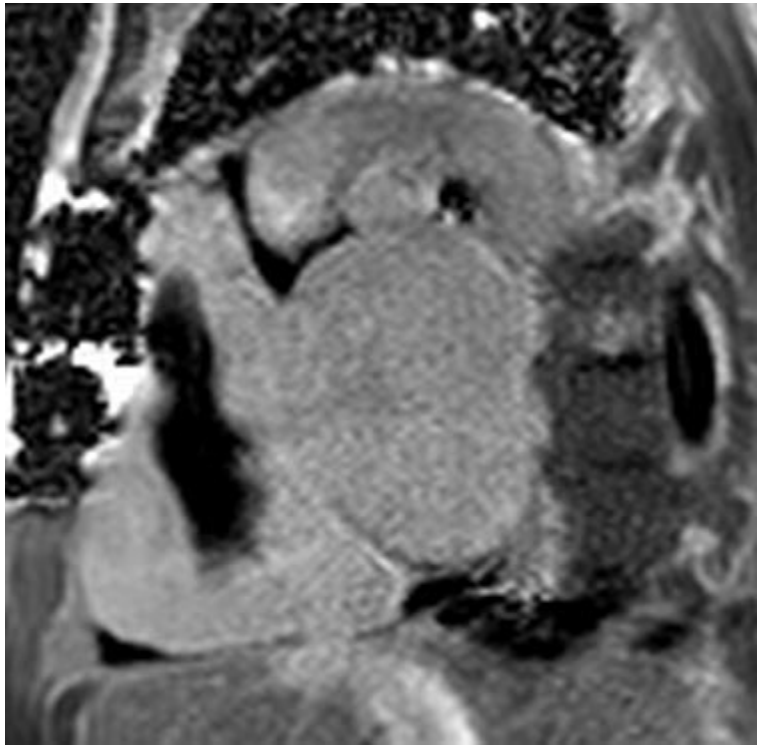
Long TI Imaging





Thrombus
-confirmed on surgery-

CMR imaging enables thrombus to be detected based on intrinsic tissue characteristics related to avascular tissue composition

Thrombus vs Tumor

Case2

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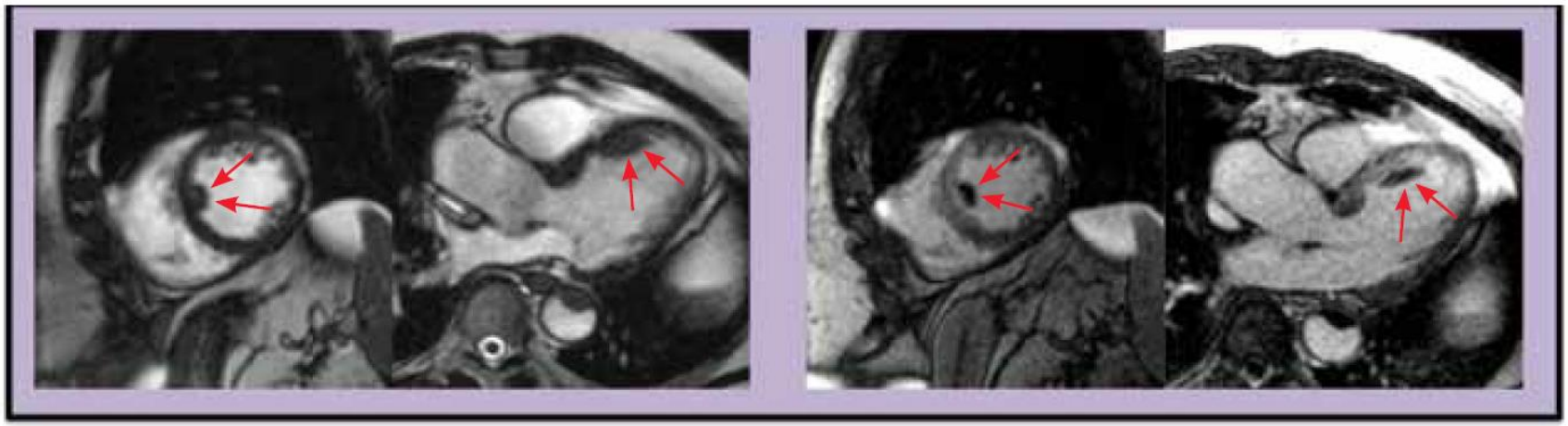
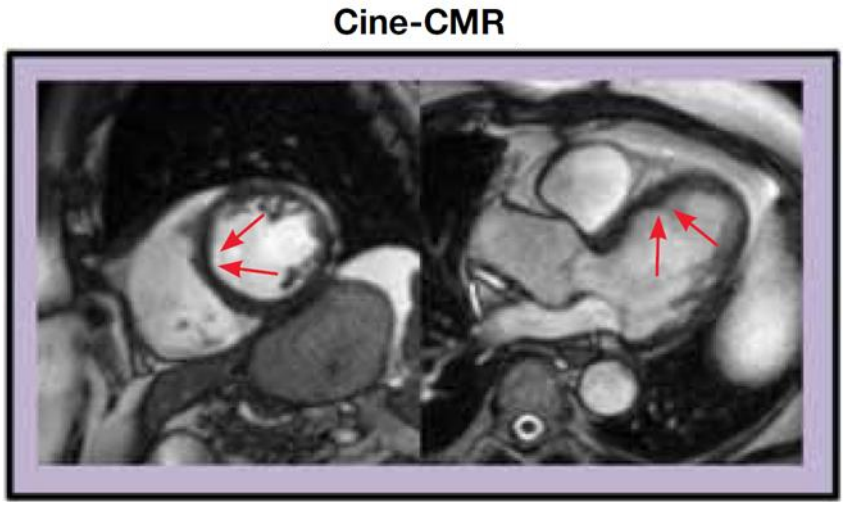
Baseline



After anti-coagulation



LV Thrombus

Shah. Debakey Cardiovasc J. Jul-Sep 2010;6(3):4-11

CE- MRI Provides High Sensitivity & Specificity for LV Thrombus

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- 160 patients with IHD had TTE/TEE/CMR within 30d of LV reconstruction surgery and pathological confirmation of presence or absence of LV thrombus
- Left ventricular thrombus was present in 29%

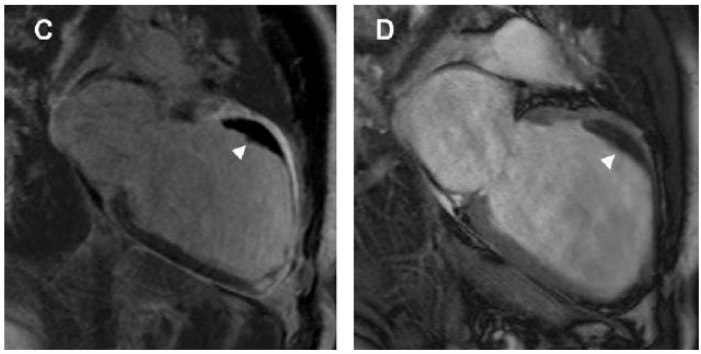

Table III. Sensitivity and specificity for subgroup with all 3 imaging modalities

	Total (n)	MRI	TTE	TEE
Sensitivity	48	88% (79%-97%)	23% (11%-35%)	40% (26%-54%)
Specificity	112	99% (97%-100%)	96% (92%-99.6%)	96% (92%-99.6%)

Srichai. Am Heart J 2006;152:75-84

Diagnostic Performance of Routine Imaging for LV Thrombus

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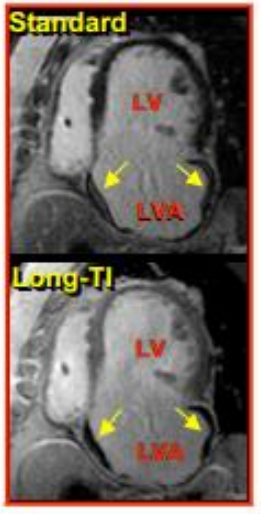
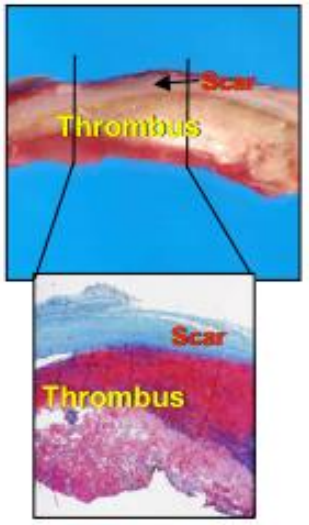
- Mixed cohort of heart failure and post-MI patients (n=121)
- Calculated using DE-CMR as the standard for LV thrombus (20%)

	Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
Noncontrast Echo	33%	94%	82%	57%	85%
Contrast Echo	61%	99%	92%	93%	91%
Cine-CMR	79%	99%	95%	95%	95%

- Cine-CMR more sensitive than echo
- Sensitivity of Echo & CMR is significantly improved with IV contrast
- Thrombi missed by echo were more likely to be:
  - small in size
  - mural in shape





Weinsaft. JACC Cardiovasc Imaging. 2009 Aug;2(8):969-79.

Hypointensity with Long TI Has the Highest Accuracy for Thrombus

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

116 patients: 84 thrombi, 17 benign tumors, & 25 malignant tumors

TABLE 3 Accuracy of CMR Features for the Diagnosis of Thrombus (Versus Tumor)

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Pre-contrast visualization (-)	23	100	100	39	48
Diameter <2.4 cm	84	78	88	72	82
Area <4.1 cm^2	89	80	89	79	86
Homogeneous (+)	99	54	81	96	84
Motility (-)	87	33	72	56	69
T2w-TSE hyperintensity (-)	58	85	81	65	71
FPP (-)	96	70	81	93	85
LGE (-)	95	71	86	88	87
Typical TI scout pattern*	94	98	98	91	95
T1 time ≥422 ms	67	80	77	71	73

Pazos-Lopez. J Am Coll Cardiol Img 2014;7:896–905

CMR Useful in Identifying Structural Risk Factors That Predispose to LV Thrombus

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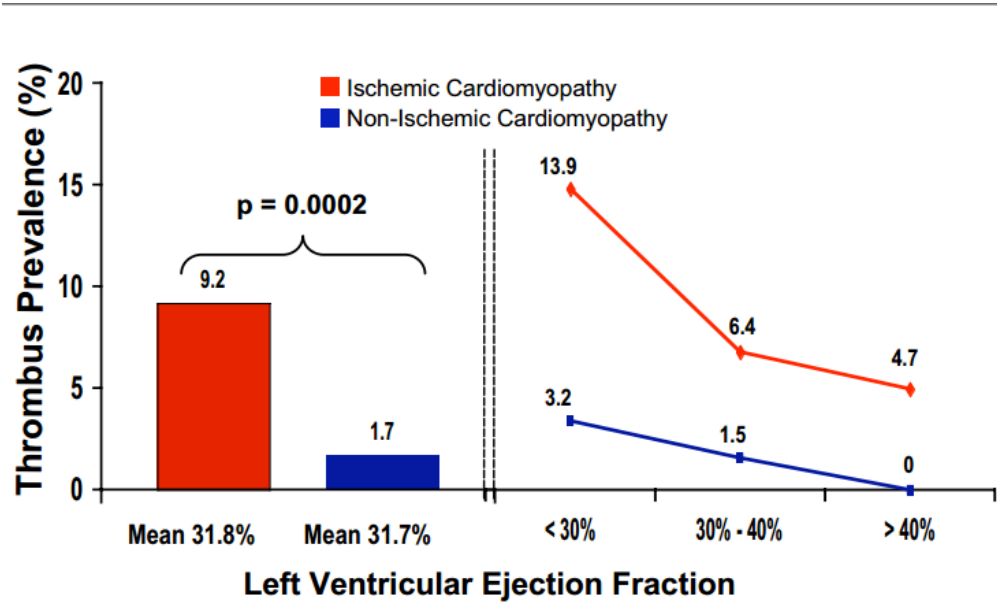
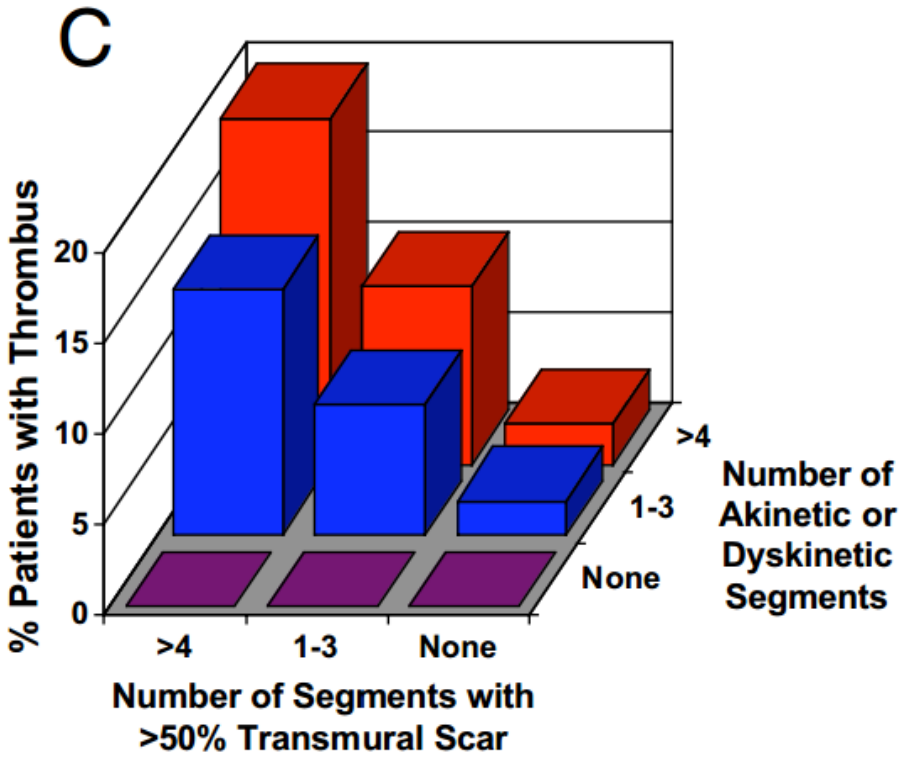
784 pts with LVEF <50%



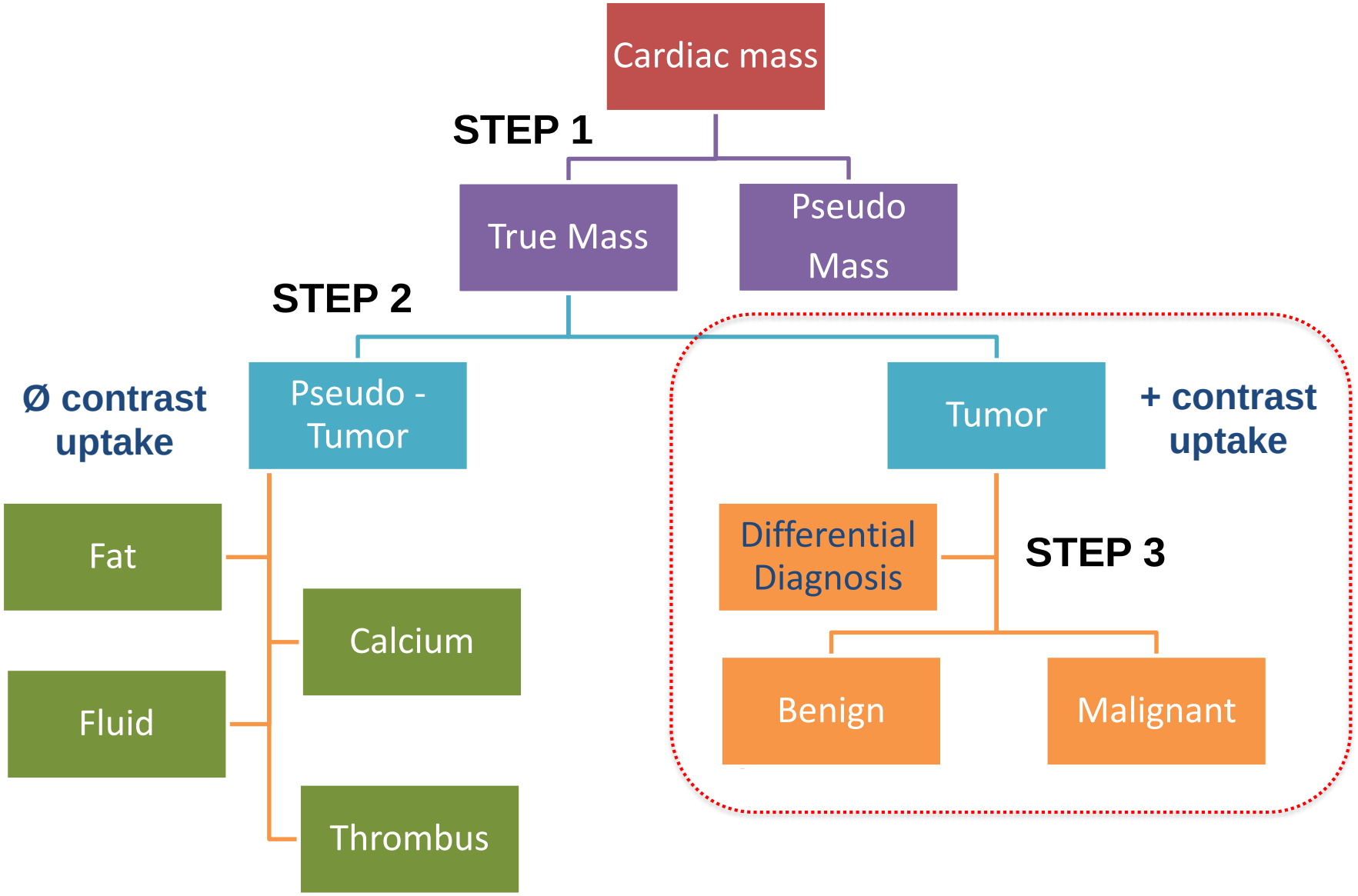


CMR also identifies structural risk factors for LV thrombus, including infarct size/distribution and contractile dysfunction

Weinsaft. J Am Coll Cardiol 2008;52:148–57

Step-Wise Cardiac Mass Evaluation

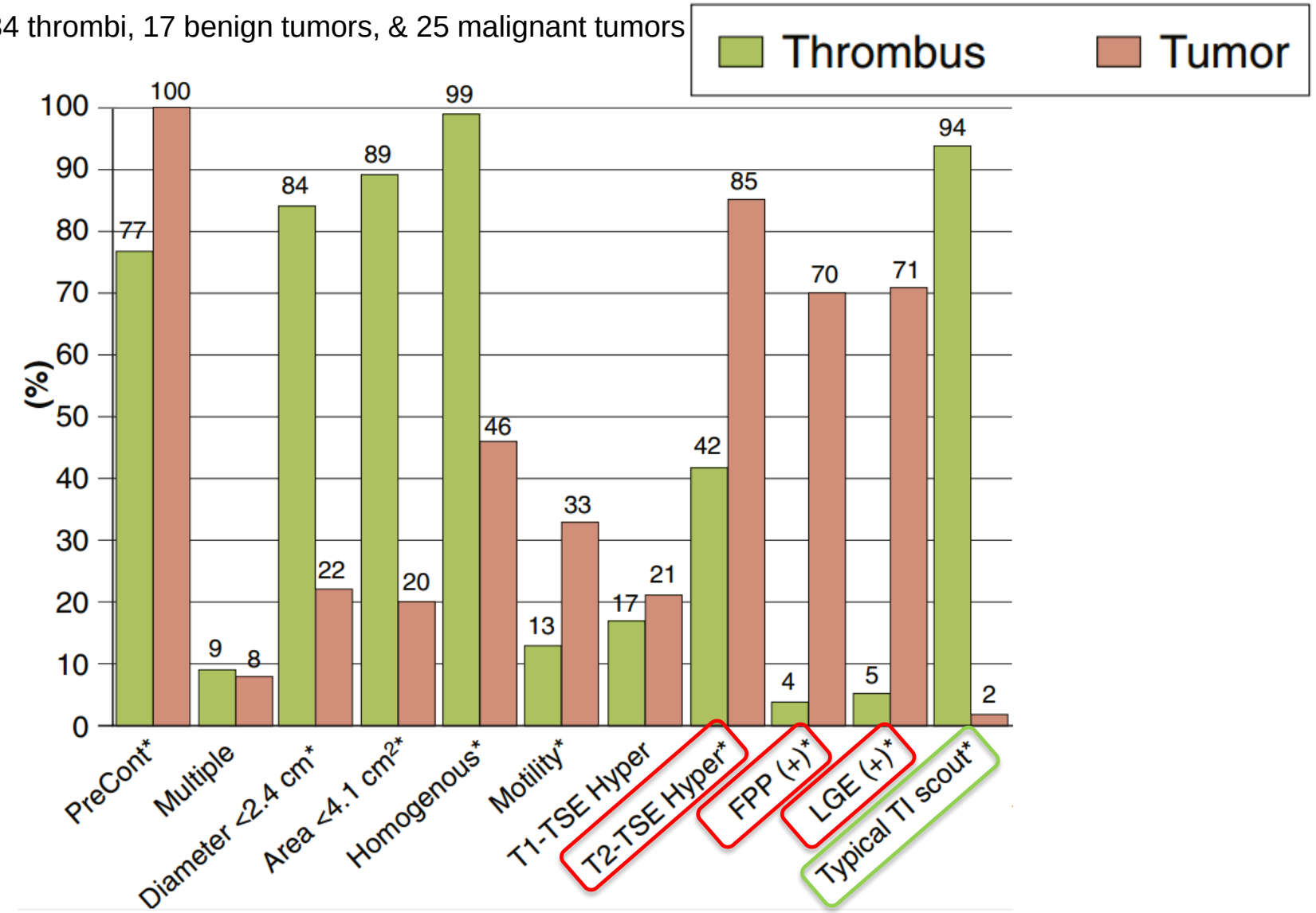
HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER



Tumors are Hyperintense on T2, FPP, LGE, & Long TI

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

116 patients: 84 thrombi, 17 benign tumors, & 25 malignant tumors



Pazos-Lopez. J Am Coll Cardiol Img 2014;7:896–905

Contrast Uptake = Tumor

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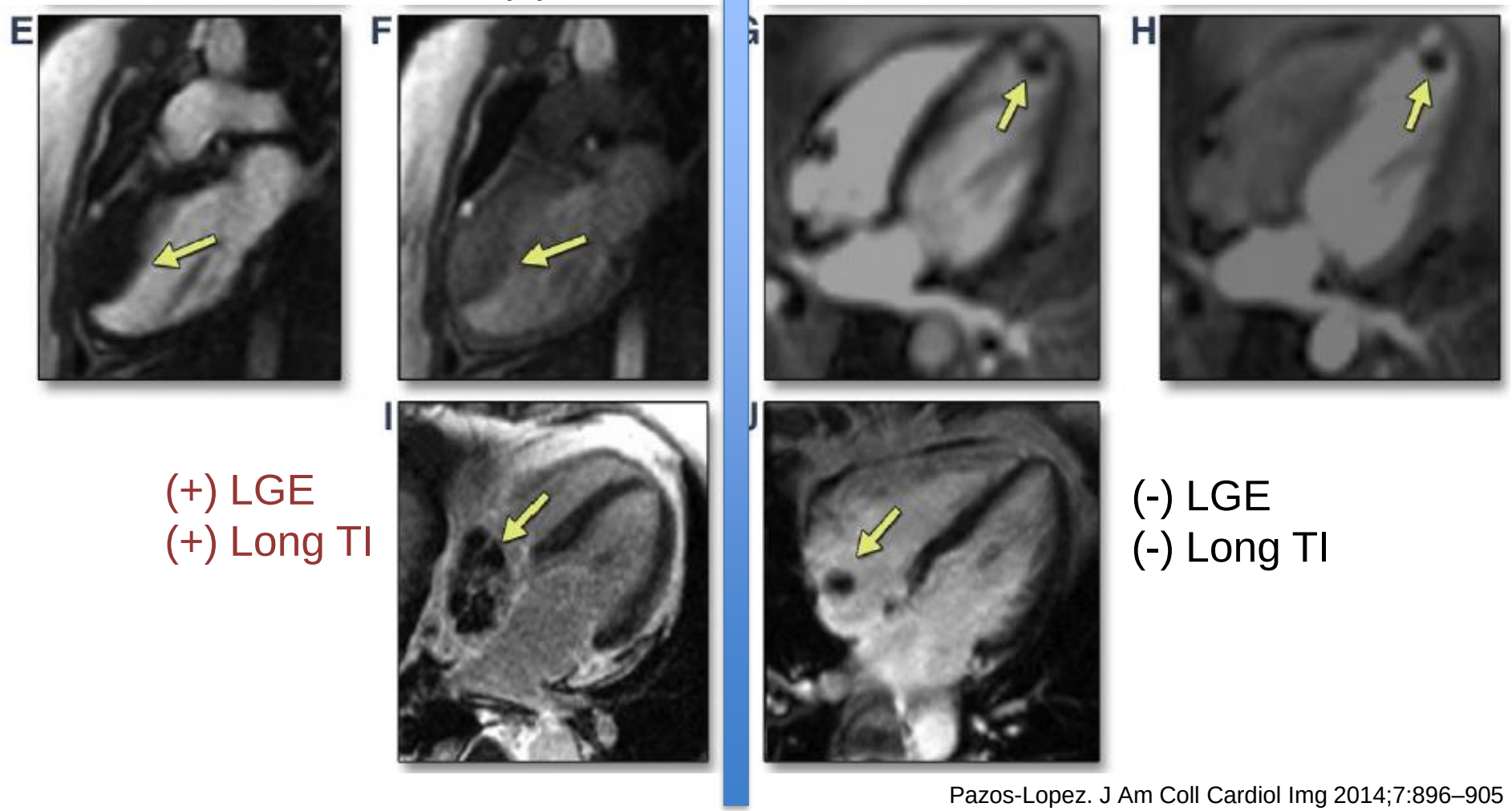
Tumor (+) FPP

Thrombus (-) FPP



(+) LGE
(+) Long TI

(-) LGE
(-) Long TI

Pazos-Lopez. J Am Coll Cardiol Img 2014;7:896–905

Benign vs Malignant

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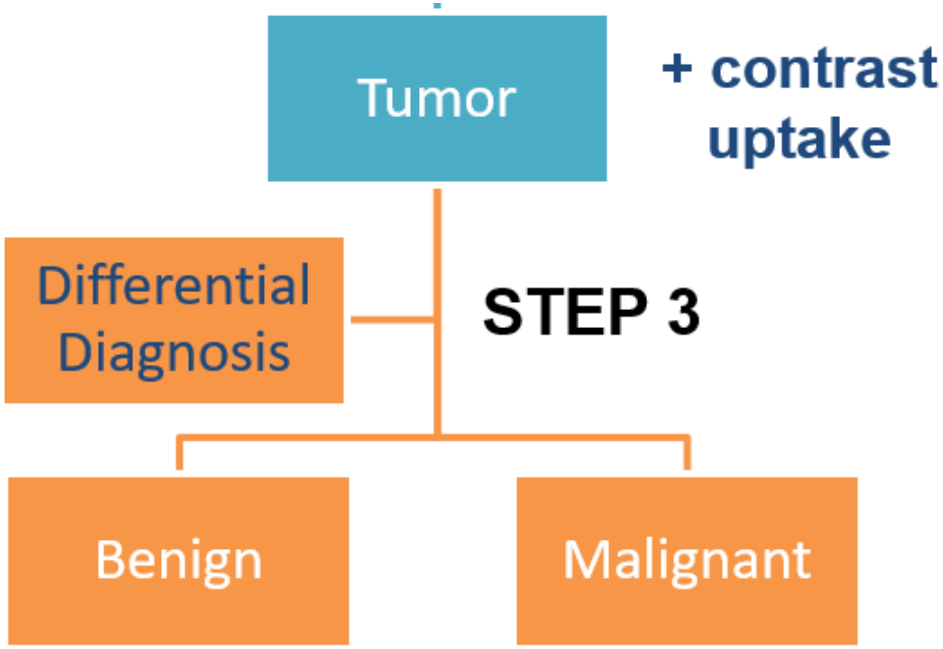
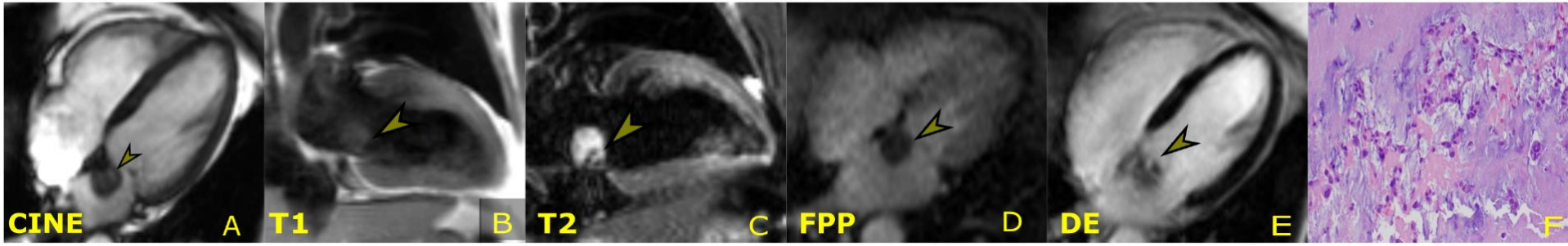
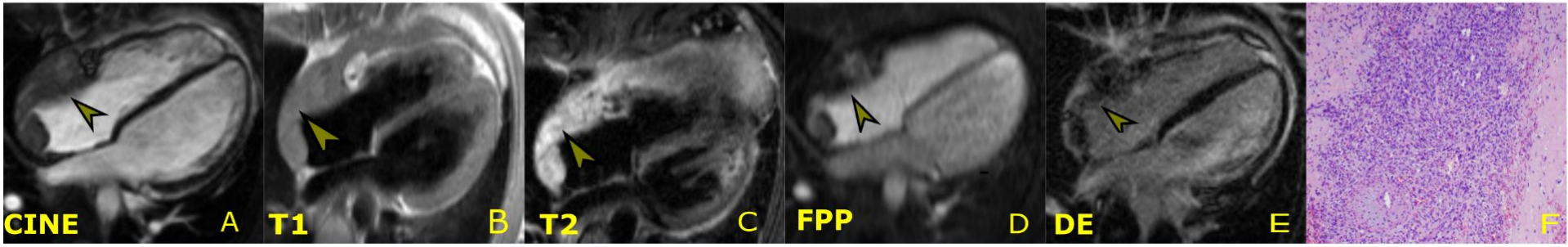


Panel 1: Myxoma



Panel 2: Sarcoma



Kassi M. J Thorac Cardiovasc Surg. 2018 Oct 6

LGE Showed Moderate Ability to Differentiate Benign from Malignant

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

116 patients: 84 thrombi, 17 benign tumors, & 25 malignant tumors

TABLE 4 Accuracy of CMR Features for the Diagnosis of Malignant (Versus Benign) Tumor

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Diameter ≥4.2 cm	52	100	100	61	73
Area ≥13.4 cm^2	48	100	100	57	69
FPP (+)	84	53	75	67	73
LGE (+)	92	59	78	83	79

Overlap in CMR tissue characteristics may require tissue diagnosis to aid in final determination

Pazos-Lopez. J Am Coll Cardiol Img 2014;7:896–905

Non-invasive Etiology of a Mass Requires Integrated Approach

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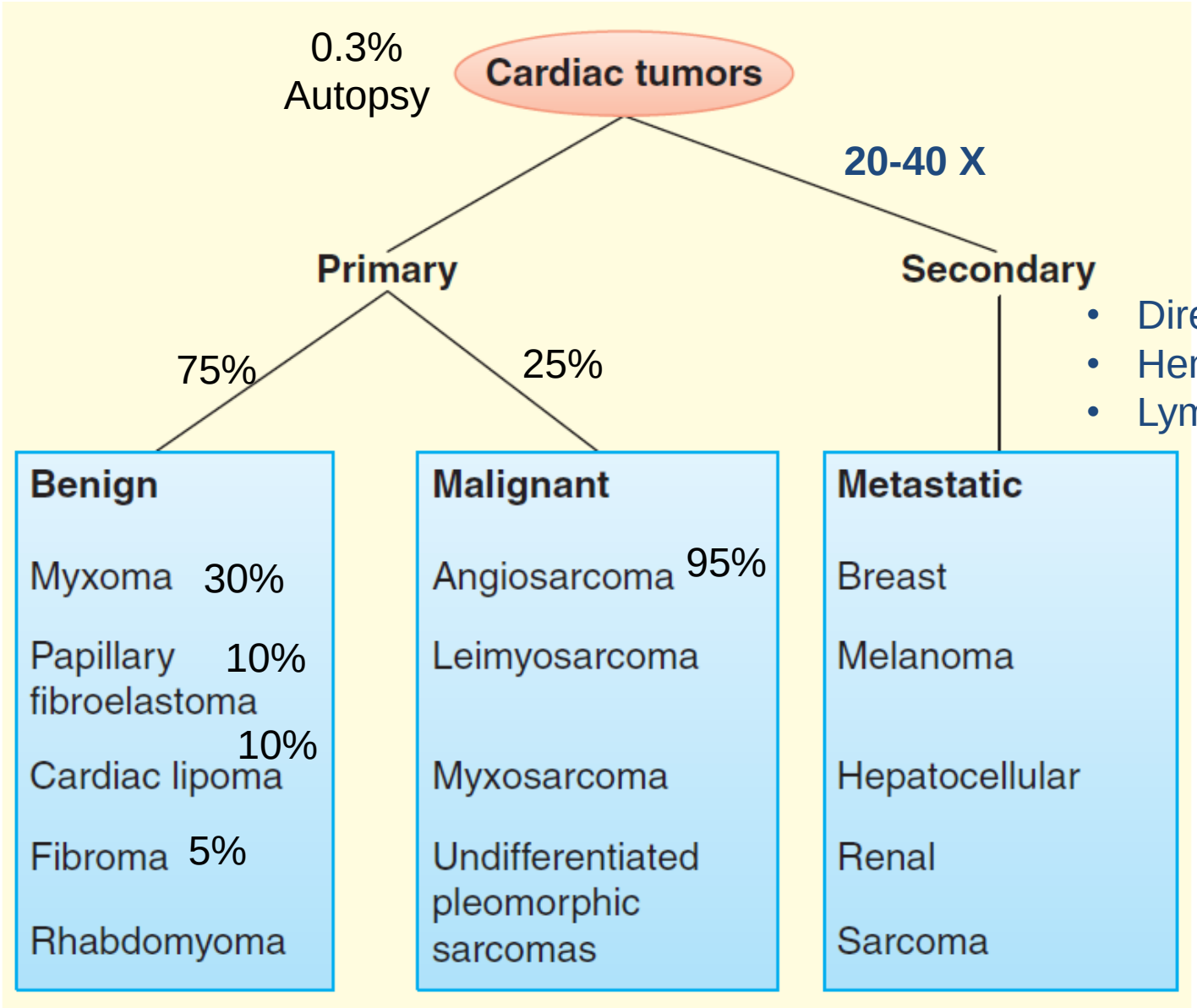
Clinical history

Signs and symptoms

Biochemical/tumor markers

Results of all cardiovascular imaging
(including location and tissue characterization)

Range of Cardiac Tumors: Primary and Secondary



- Direct extention
- Hematogenous
- Lymphatic

Bhattacharyya. Expert Rev. Cardiovasc. Ther. 12(1), 37–43 (2014)

Benign vs. Malignant: Characteristics

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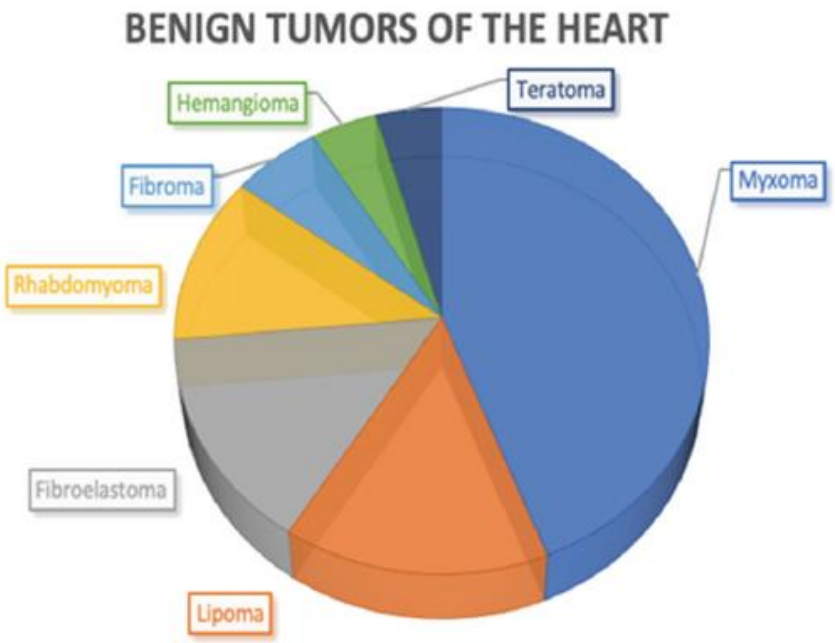
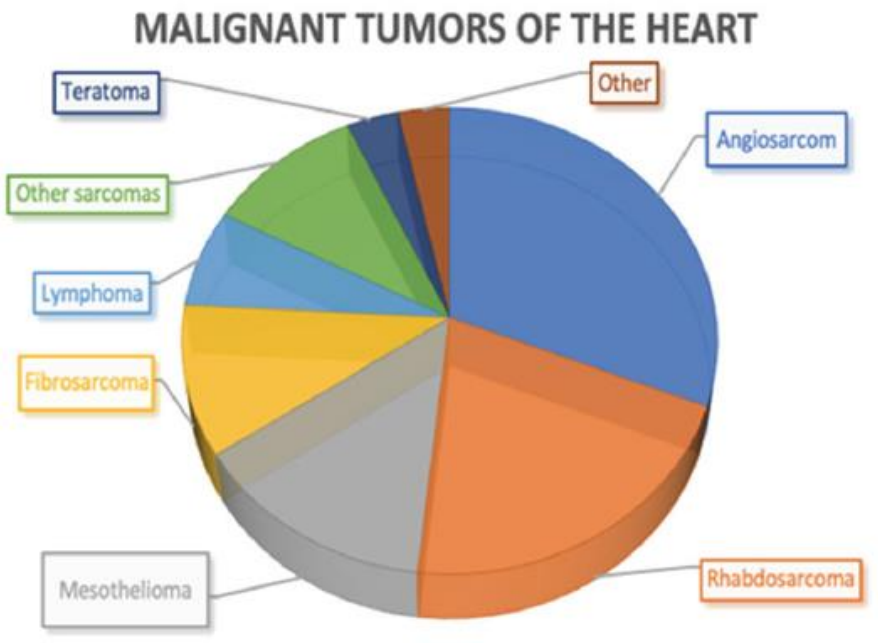
Benign Tumor
Small size
Involvement of the left side of the heart
Solitary tumor
Smooth margins
Intracameral
Narrow stalk

Malignant tumor
>5cm in size
Involvement of the right heart
Multiple tumors
Irregular margins
Broad base
Intramural
Invasion of the surrounding tissue
Pleural or pericardial effusion





Parwani. Curr Cardiovasc Imaging Rep (2020) 13:1

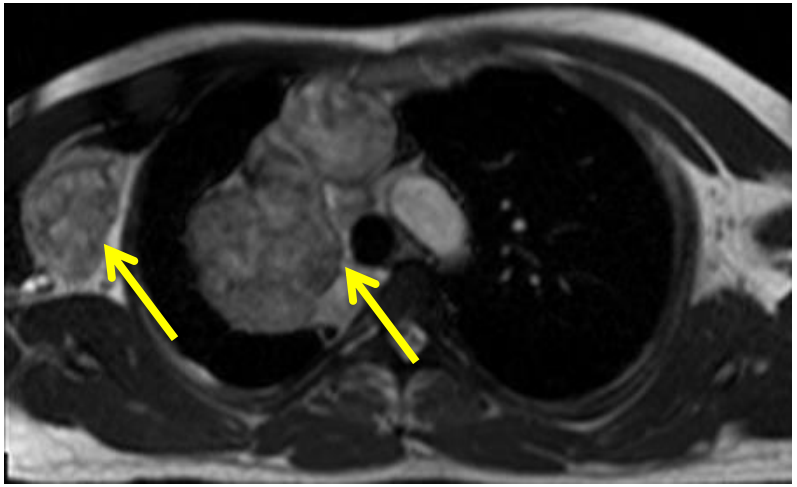
Characteristics of Malignant Cardiac Masses

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

Tumor Characteristics

- Large size—especially if >5 cm
- Irregular, ill-defined borders
- Direct invasion through tissue planes
- Most cardiac tumors involving the right heart are suspicious for malignancy
- Pericardial or pleural involvement—effusions and nodular masses
- Multiple lesions

Motwani. Radiology 2013; 268:26–43



Location Helps with Etiology

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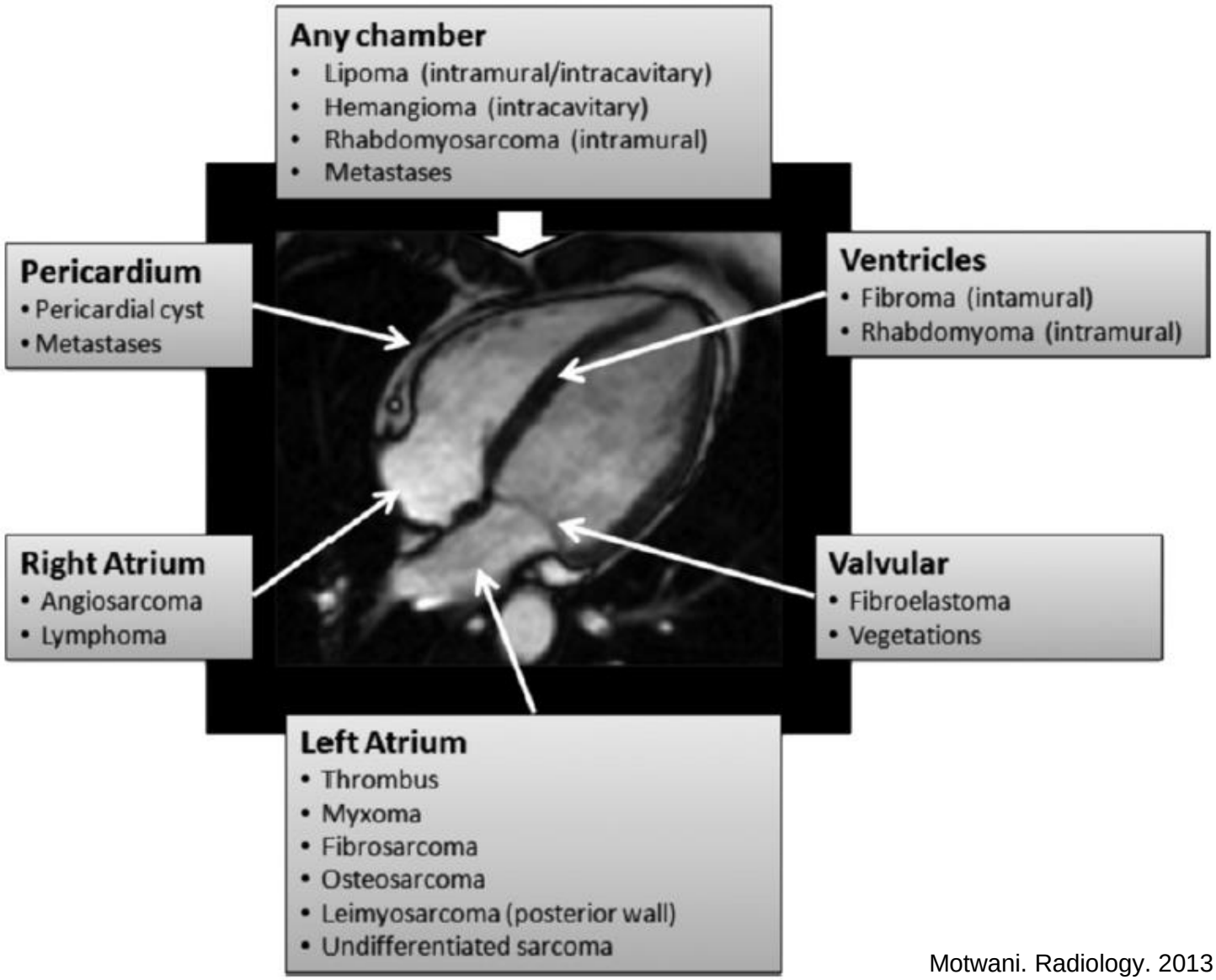

Motwani. Radiology. 2013 Jul;268(1):26-43

Non-invasive Tissue Characterication Helps with Etiology

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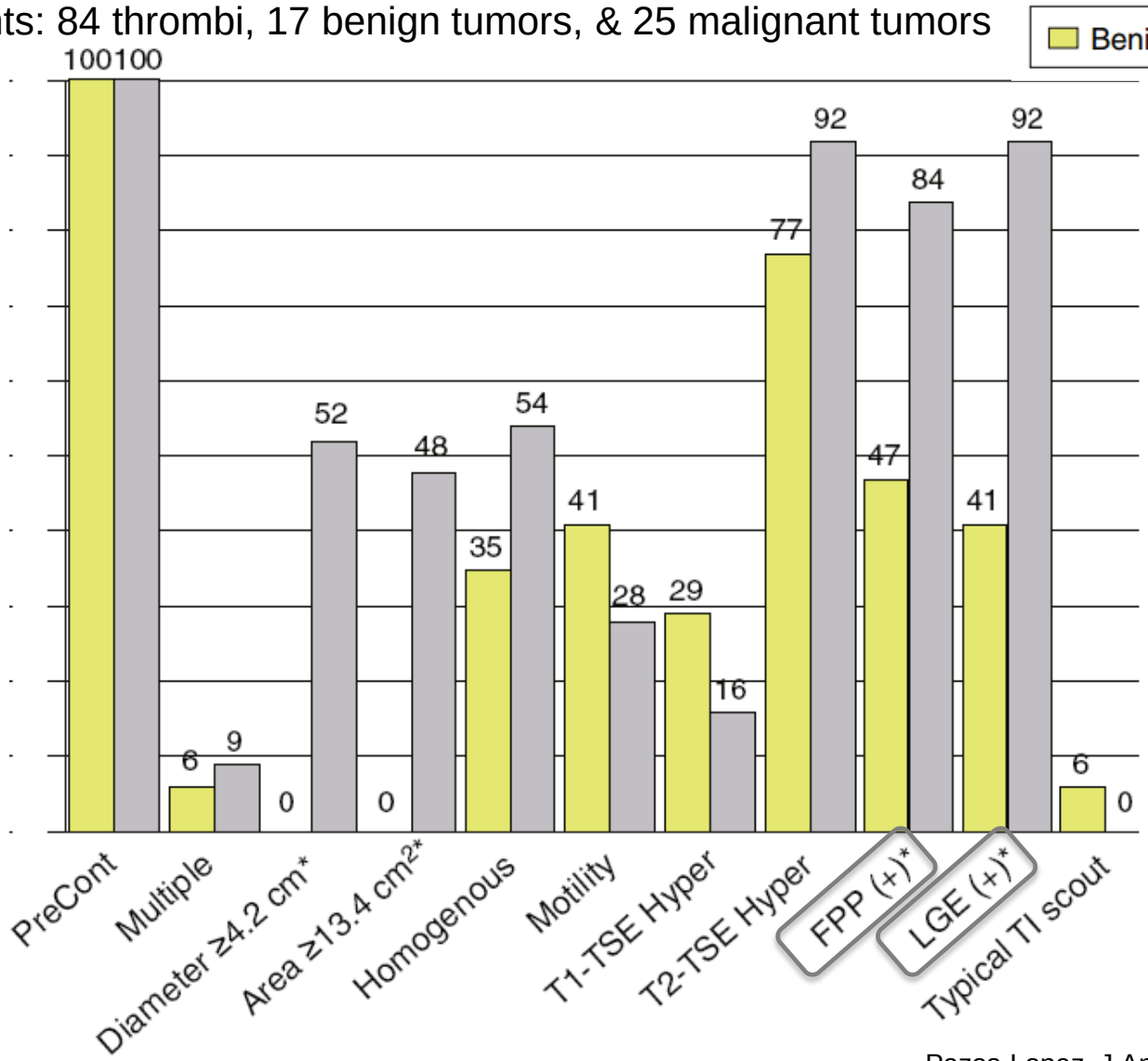
Cardic Mass	T1 Weighted	T2 Weighted	Post Contrast
Myxoma	Isointense, heterogeneous	Hyperintense, heterogeneous	Heterogeneous enhancement
Papillary fibroelastoma	Isointense	Hyperintense	Hyperintense
Rhabdomyoma	Iso- or hyperintense	Slightly hyperintense	Hyperintense
Fibroma	Iso- or hyperintense	Hypointense	Hyperintense
Hemangioma	Isointense	Hyperintense, heterogeneous	Hyperintense or heterogeneous
Paraganglioma	Iso- or hypointense	Hyperintense	Hyperintense
Intravenous leiomyomatosis	Isointense	Isointense	Heterogeneous
Bronchogenic cyst	Hypointense	Hyperintense	None
Angiosarcoma	Isointense, with hyperintense areas	Iso- or hyperintense	Hyperintense
Undifferentiated sarcoma	Isointense	Isointense	Nonspecific
Rhabdomyosarcoma	Isointense	Isointense, heterogeneous	Central nonenhancing areas
Osteosarcoma	Hyperintense	Hyperintense	Nonspecific
Malignant fibrous histiocytoma	Isointense	Hyperintense, heterogeneous	Nonspecific
Leiomyosarcoma	Isointense	Hyperintense	Nonspecific
Fibrosarcoma	Isointense, heterogeneous	Hyperintense	Central nonenhancing areas
Lymphoma	Hypo- or isointense	Hyperintense	Variable

Shah. Debakey Cardiovasc J. Jul-Sep 2010;6(3):4-11

Malignant Tumors Demonstrate More Contrast Uptake

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

116 patients: 84 thrombi, 17 benign tumors, & 25 malignant tumors



Malignant tumors were larger and more frequently exhibited FPP and LGE

Pazos-Lopez. J Am Coll Cardiol Img 2014;7:896–905

CMR Valuable Method for Differentiating Malignant from Benign Cardiac Tumors

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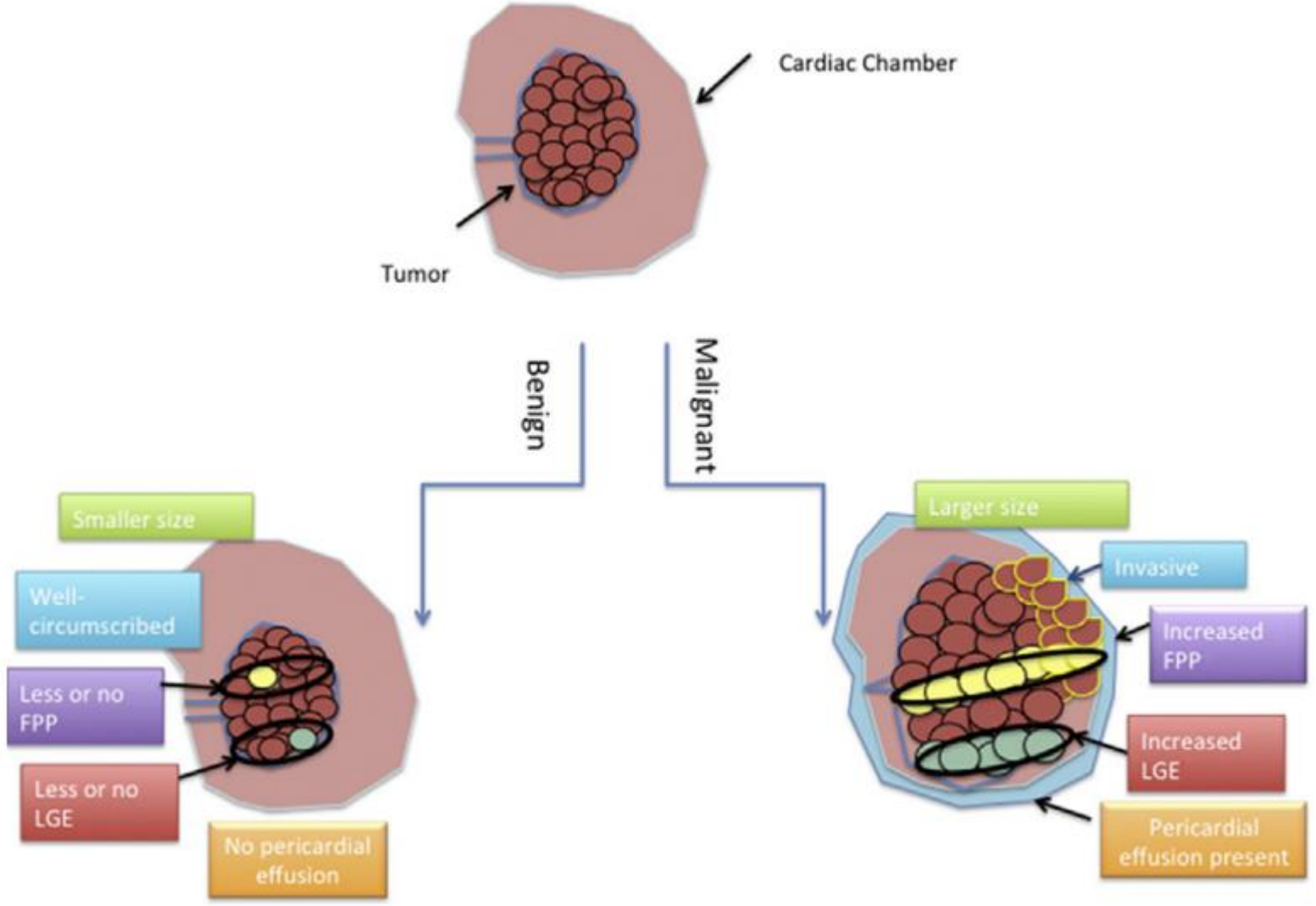

Kassi M. J Thorac Cardiovasc Surg. 2018 Oct 6

Secondary: Metastatic

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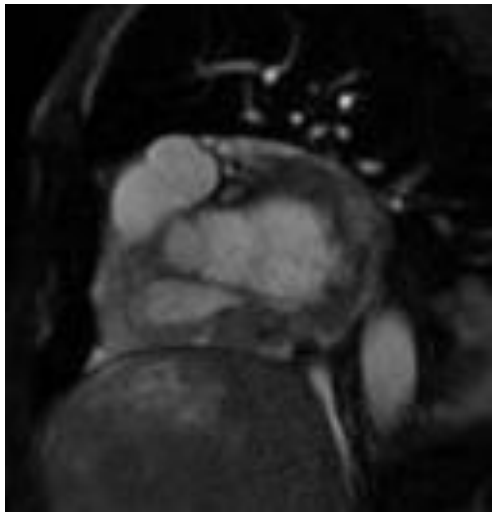
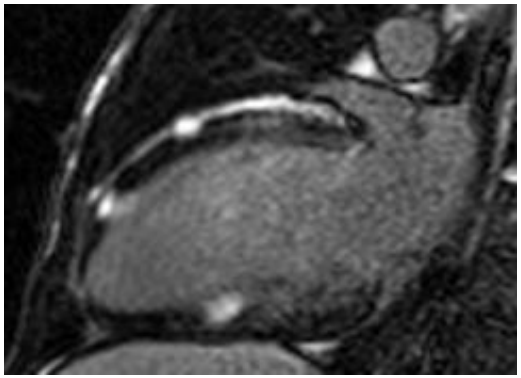
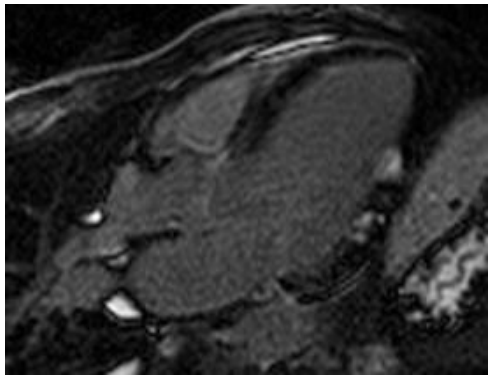
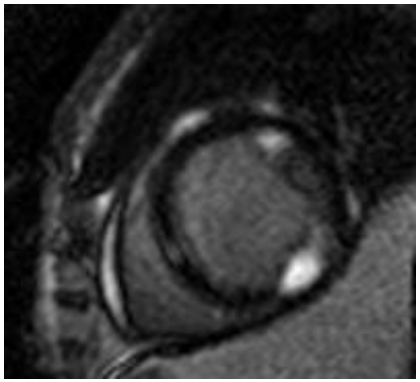
69M known melanoma with RA mass by TTE



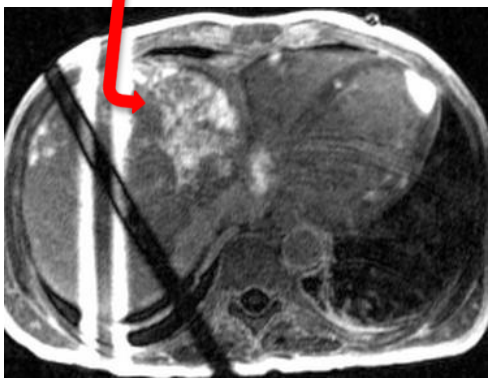
Multiple areas of delayed hyperenhancement







Liver mets



Metastatic Melanoma

Primary Benign: Myxoma

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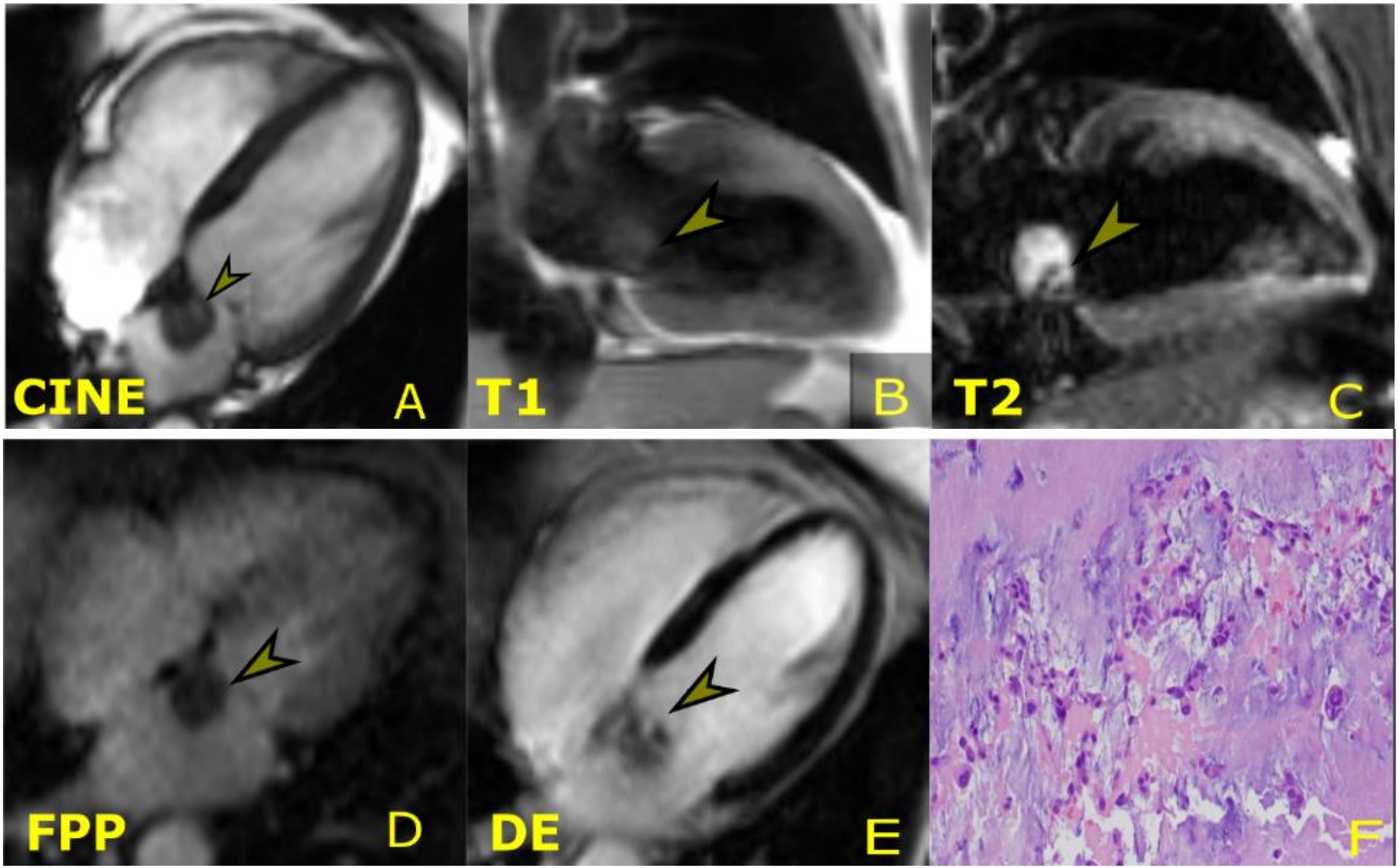

Myxoma

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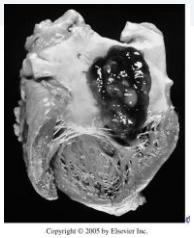

- Most common type of primary benign cardiac tumors
- Occur predominantly in adulthood; avg ~50yrs
- Always intracavitary, most commonly located in the LA (75%)
  - 20% RA, 5% ventricular origin
- Usually attached to IAS near the fossa ovalis
- Well defined, lobular or oval, and often pedunculated; may be mobile
- May contain cysts, regions of necrosis, fibrosis, hemorrhage and calcification
- Asymptomatic if small; otherwise present with mass effect, embolization or constitutional symptoms (IL-6)
- CMR findings: Heterogeneous mass with heterogeneous enhancement

Primary Benign

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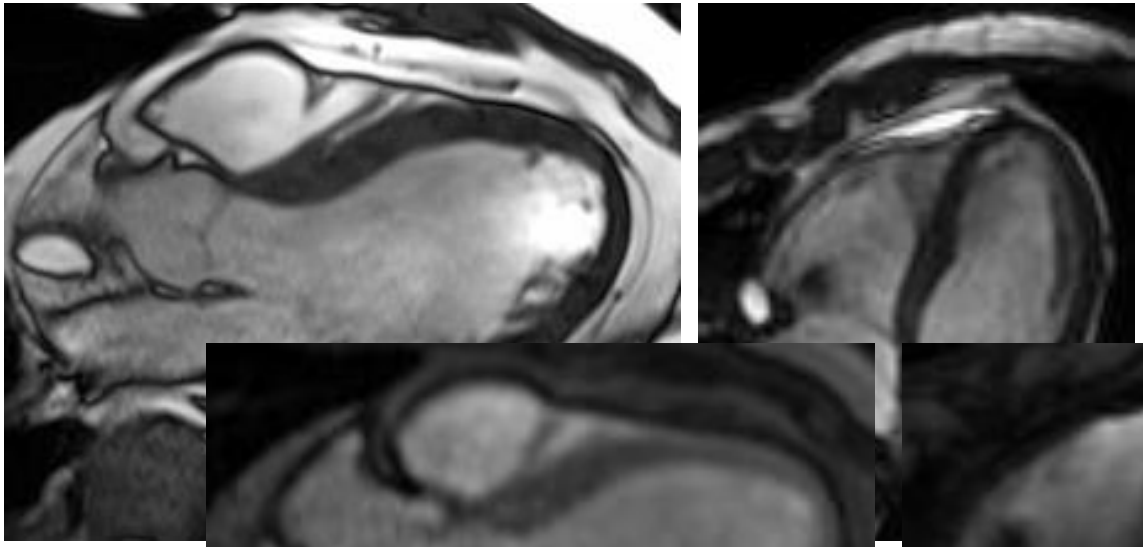
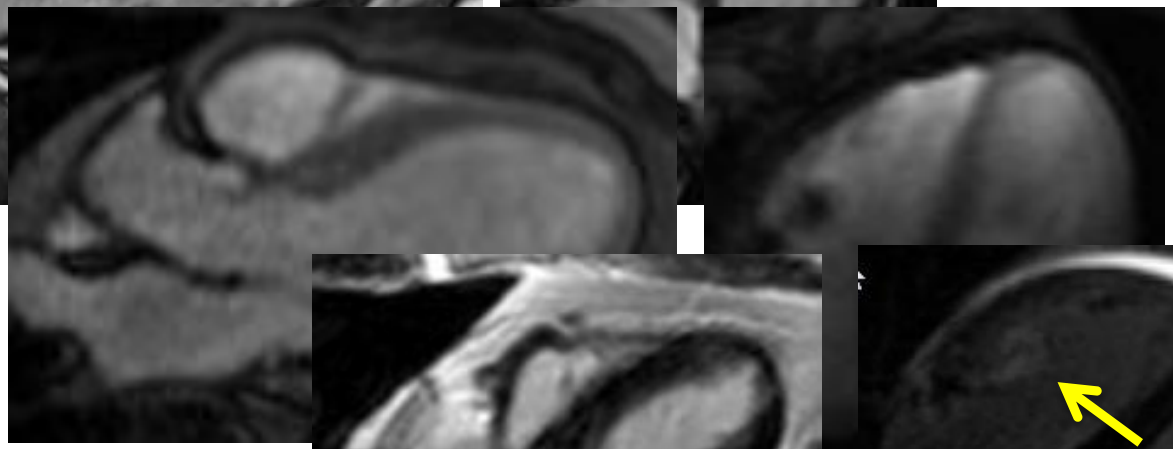
Mitral valve

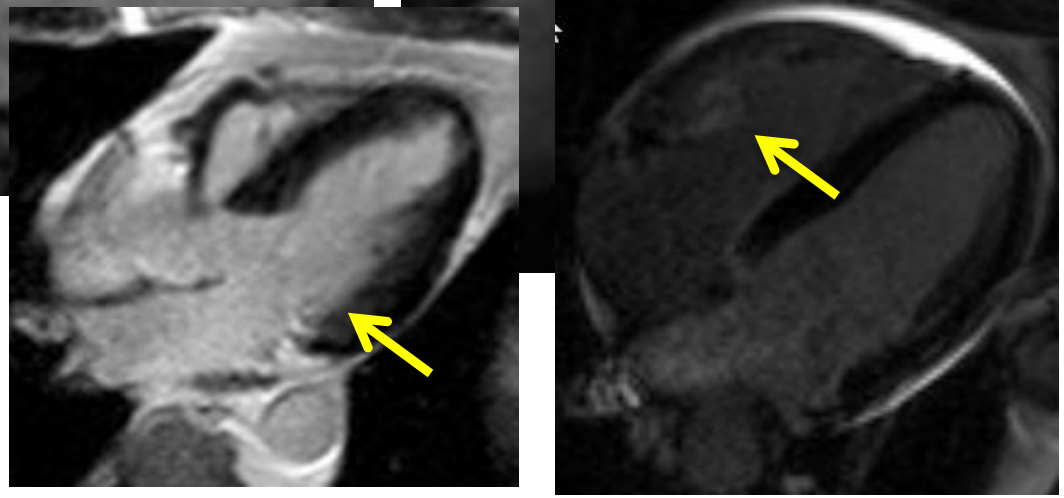
Tricuspid valve



Papillary fibroelastoma



Perfusion



DE

Intense contrast uptake

Papillary Fibroelastoma

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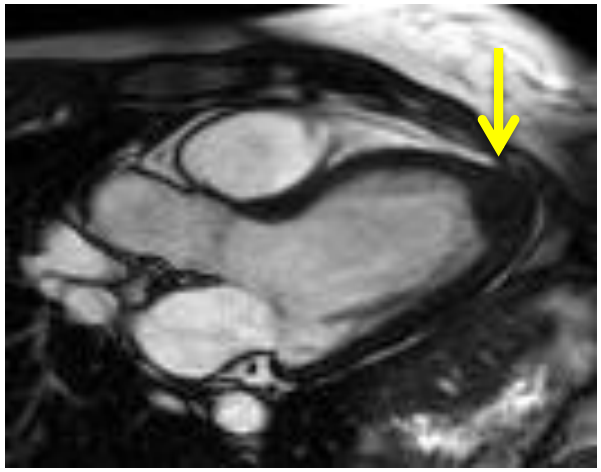
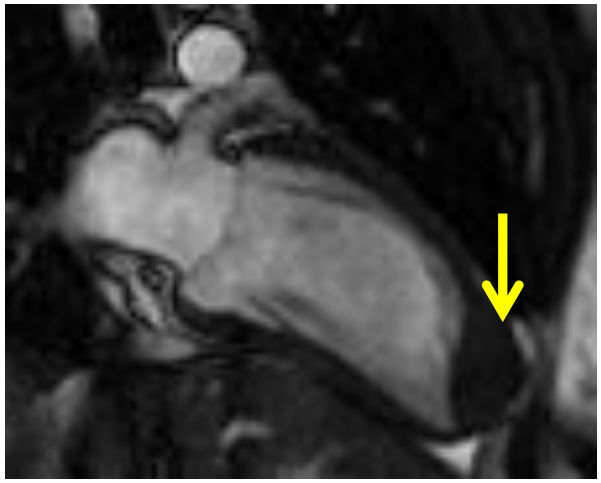
- Account for 75% of valvular neoplasms
- Benign, small (<1.5cm), high mobile, valvular mass
  - Rarely associated with valvular dysfunction
- *Avascular*, endocardial papillomas
  - Similar to Lambl's excrescences (histologically, cardiac valve predilection). Differ in that they tend to be larger in size and away from the site of valve closure
- Usually detected incidentally
- Rarely require excision except embolic symptoms
  - Larger, highly mobile, left sided tumors
- CMR findings: Valvular mass with contrast uptake

A

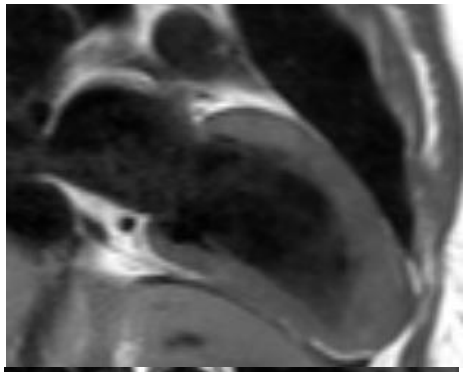
Primary Benign



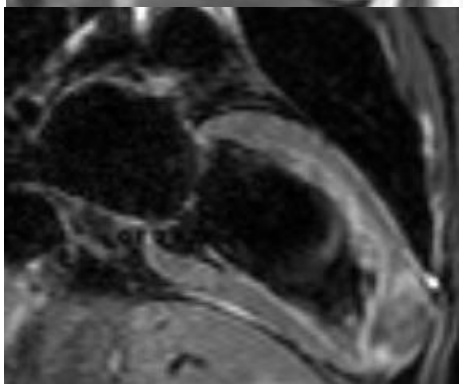


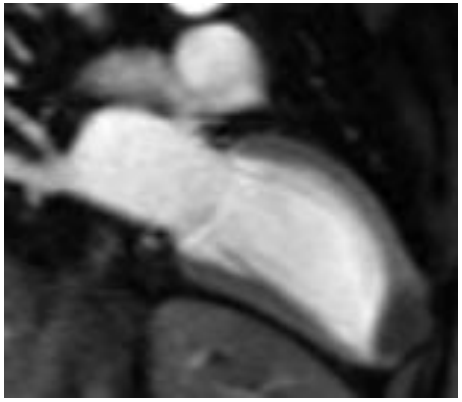
Cine FISP

T1

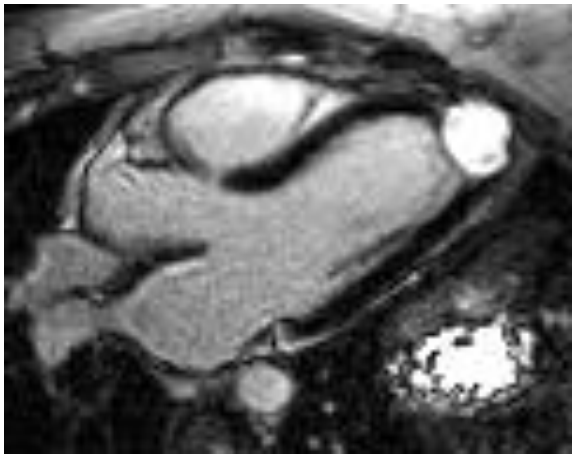


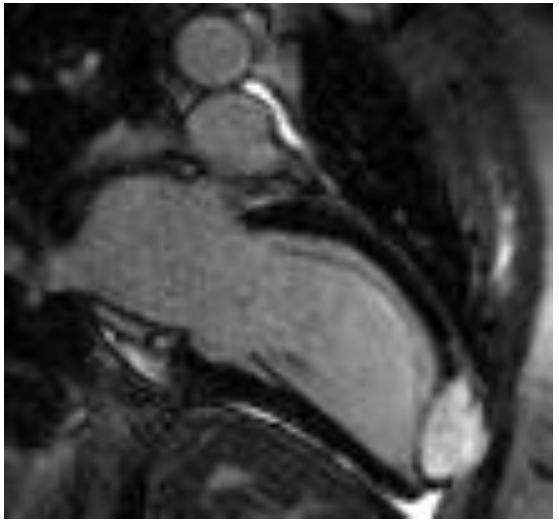
T2





Perfusion





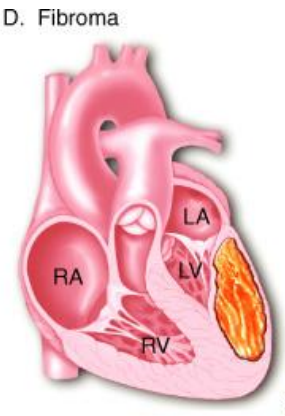
Delayed HE

Fibroma

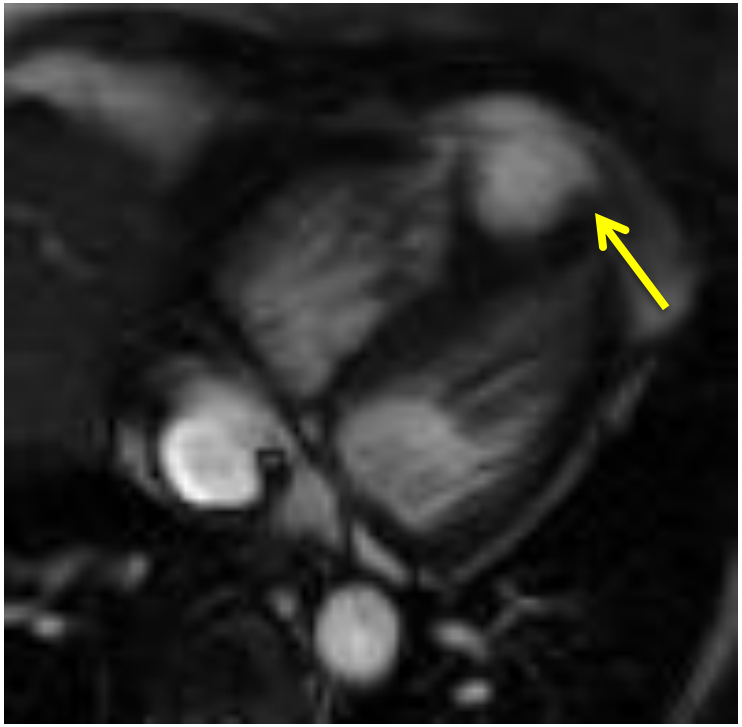
Fibromas

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

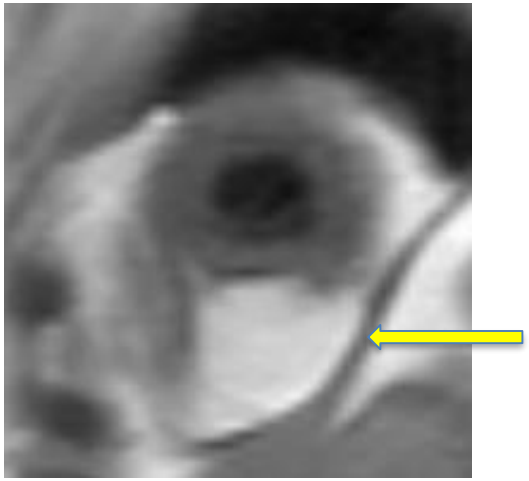
- Congenital in origin; occur in children; young adults
- Solitary, *avascular* intramural masses within ventricular myocardium
  - Discrete focal mass of collagen and fibroblasts
- Presentation: Arrhythmias, syncope, CP, HF
- CMR features:
  - Reduced signal on T2-weighted imaging (due to their limited water content)
  - Very high signal intensity on delayed enhancement imaging (due to their high collagen content)



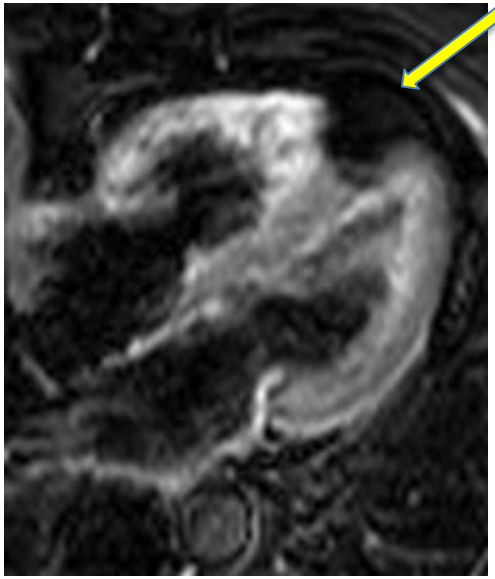
62F with frequent palpitations and frequent syncope



T1



T2 with fat sat



Lipoma

Lipomas

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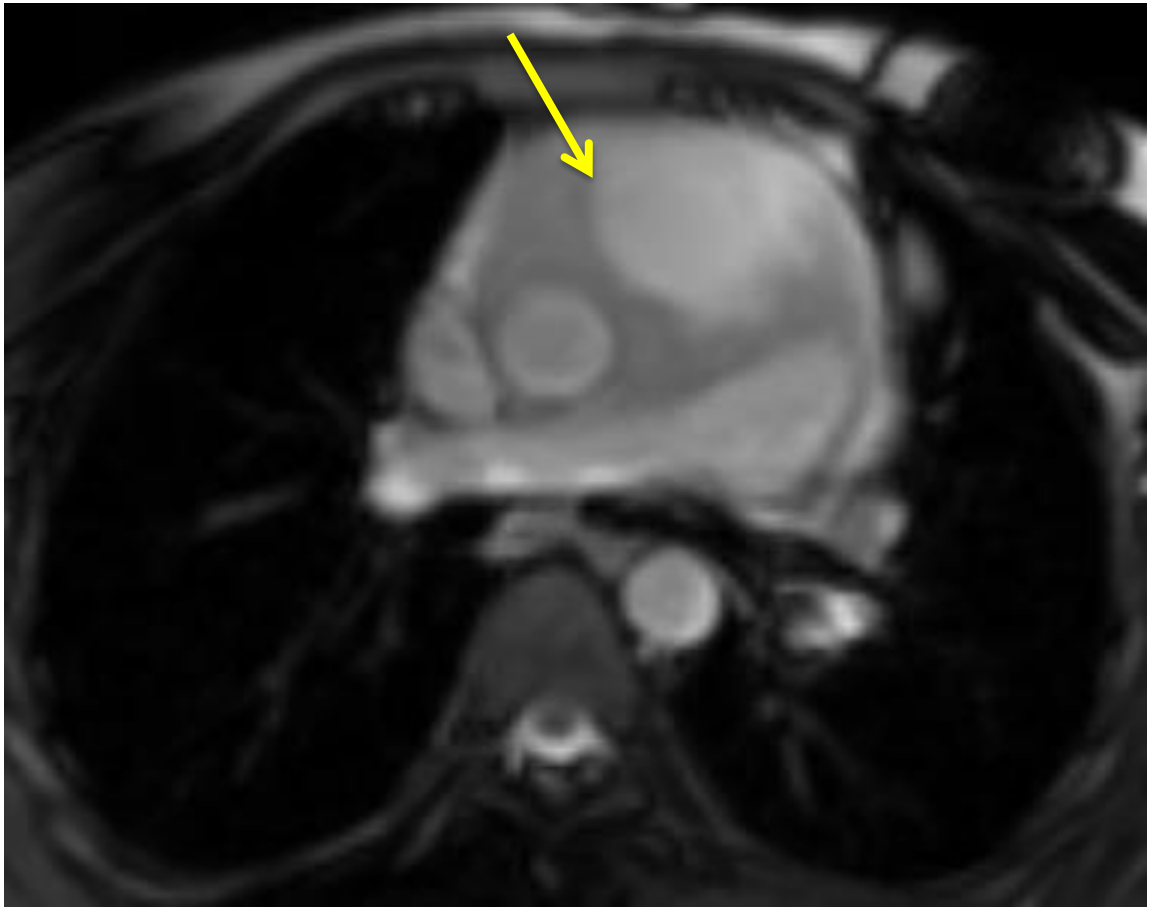
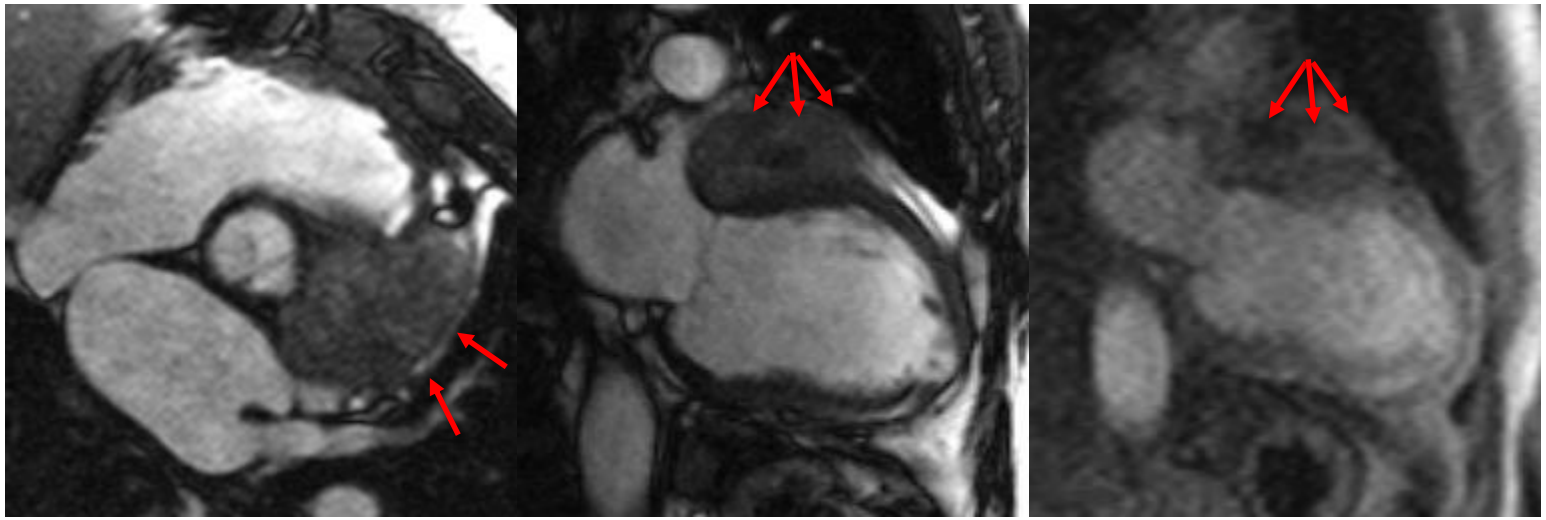
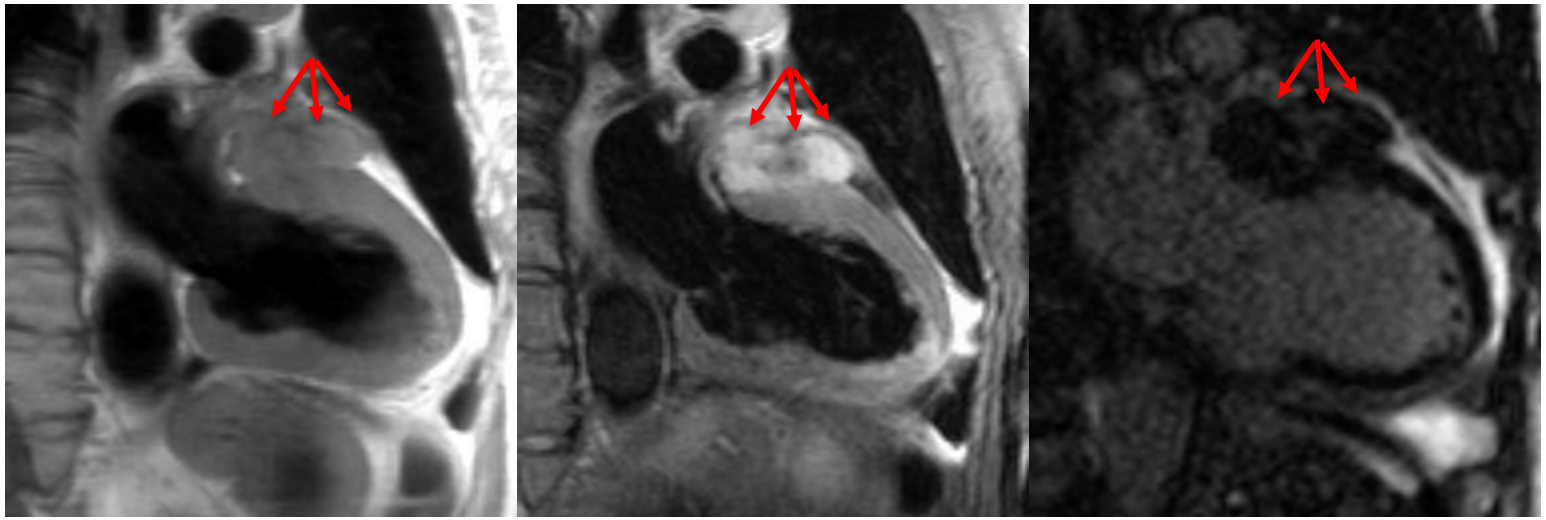
- Benign, avascular
- Well defined, homogenous, encapsulated tumors containing neoplastic adipose cells
- Majority arise from the epicardial surface
  - Subendocardial lipomas less common
- Rare, more often present as lipomatous hypertrophy of the interatrial septum
- Presentation: Asymptomatic, arrhythmias, obstruction



Cine *Cine* *Perfusion*





T1 weighted *T2 weighted* *Post contrast*

Paragangliomas

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- Originate from neuroendocrine cells
- Typically present with symptoms of catecholamine excess (e.g., hypertension, tachyarrhythmias or heart failure)
- Usually originate in the atria, along the atrioventricular sulcus or at the root of the great vessels.
- CMR Imaging features:
  - high signal on T2-weighted imaging
  - heterogeneous delayed hyperenhancement
  - high vascularity on perfusion imaging

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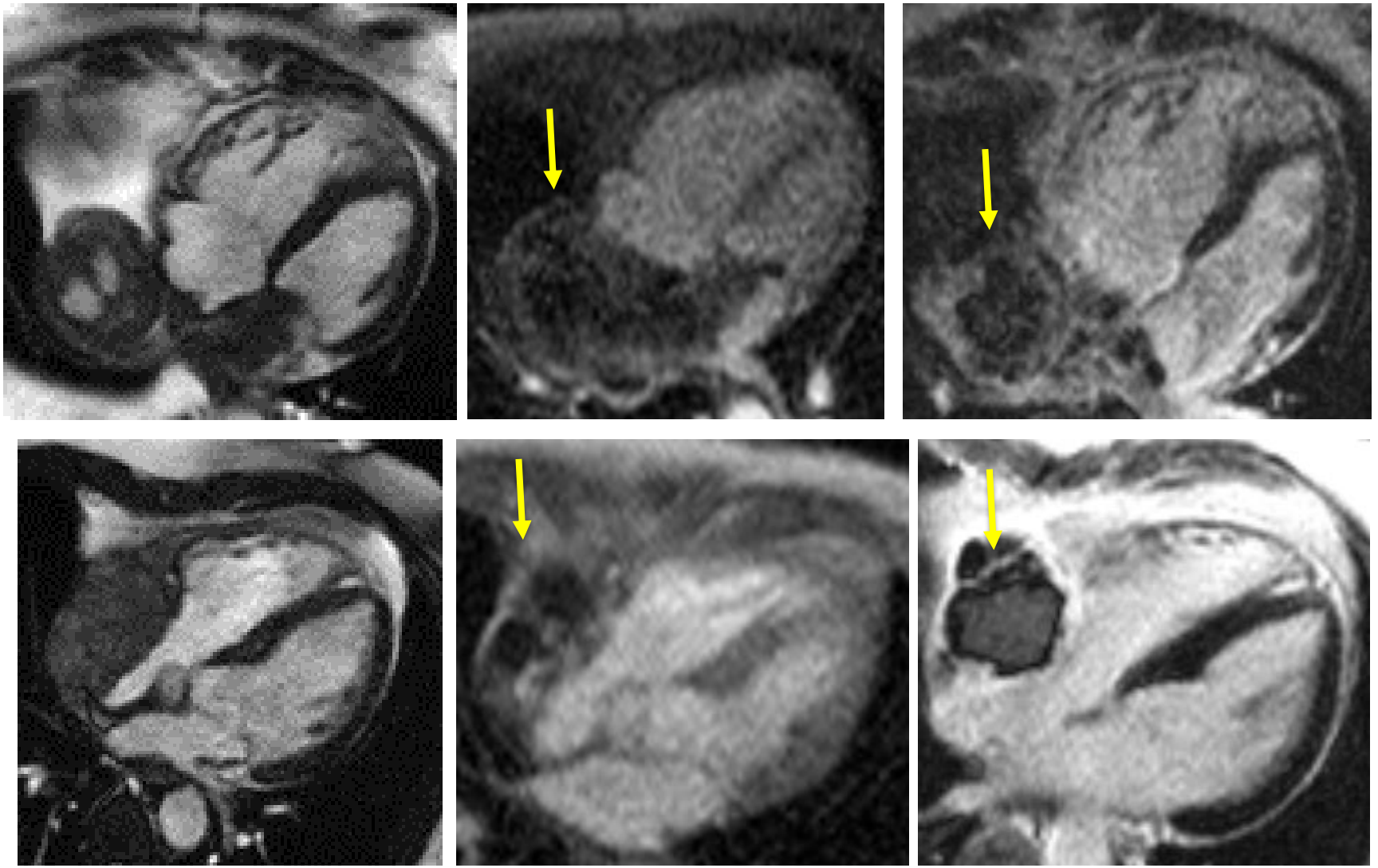
2 patients presenting with SOB

Cine FPP DE



Primary Malinant: Sarcoma

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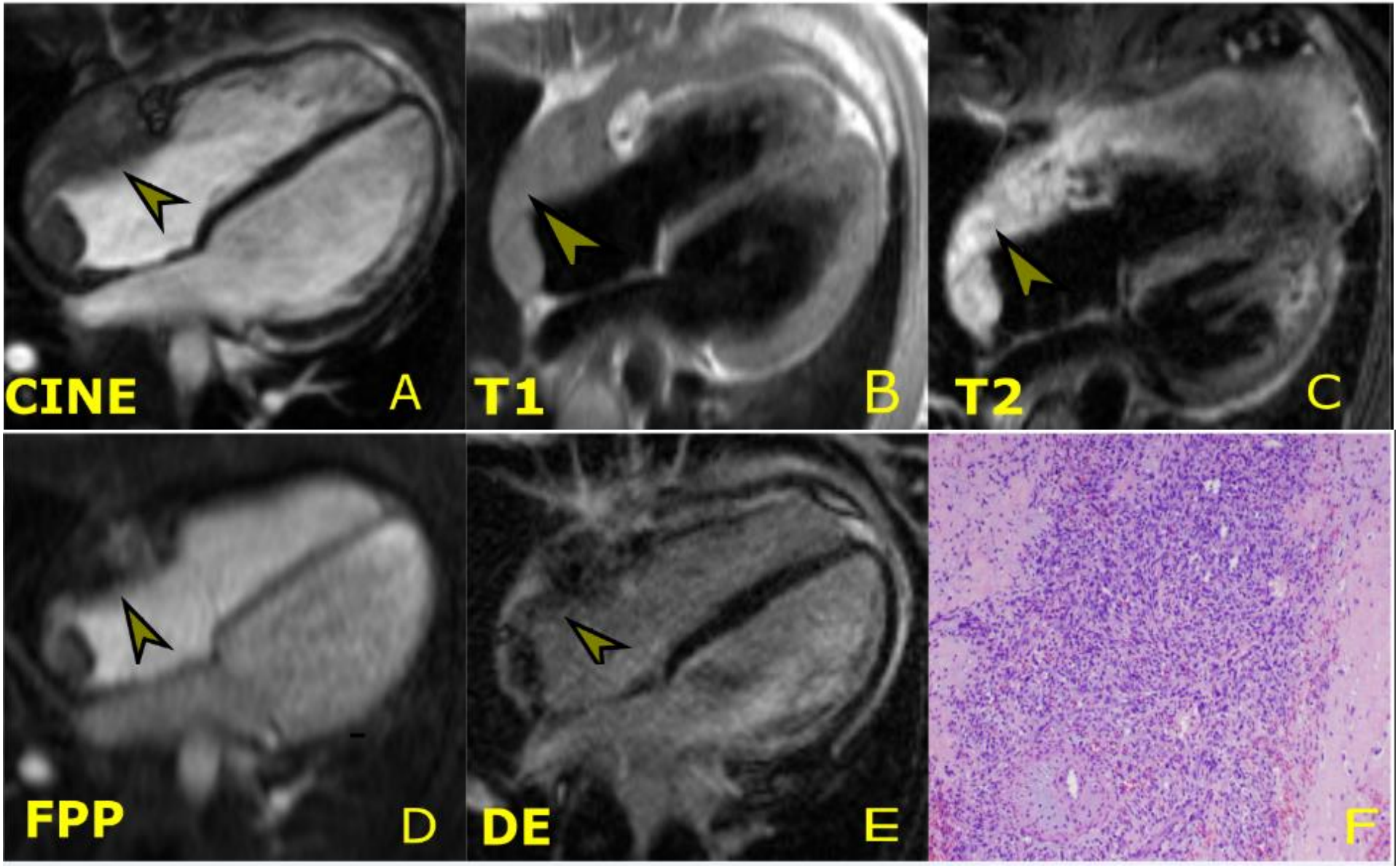

Sarcomas

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- Comprise 95% of primary malignant cardiac tumors
  - Angiosarcoma is the most common form (~40%)
- Poor prognosis
  - Rapid progression, widespread infiltration, obstruction, metastasis
- Angiosarcomas have predilection for the RA (>90%)
  - Unlike other sarcomas
- As the imaging features of different forms of sarcomas are similar, specific differentiation can only be made by histology

More than One Test May be Required

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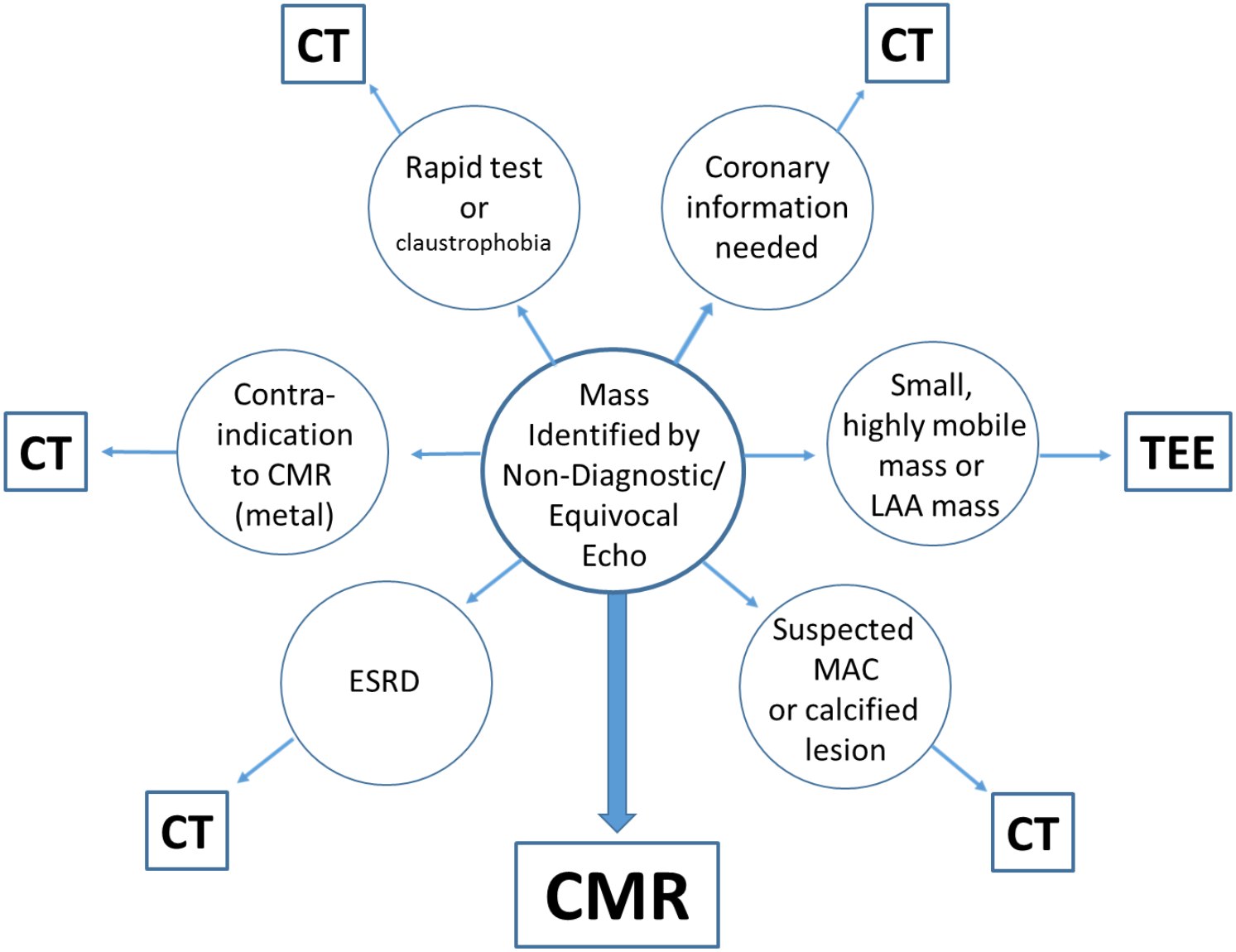

Take Home Points

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- CMR can identify with high specificity cardiac masses which do ***not*** require excision:
  - Pseudo-masses
  - Thrombus
  - Lipoma / lipomatous hypertrophy
  - Water based Cysts
- Can generate a differential diagnosis with an integration of history, symptoms, biomarkers and imaging findings
- Most cardiac tumors will require tissue diagnosis to aid in determination of treatment plan