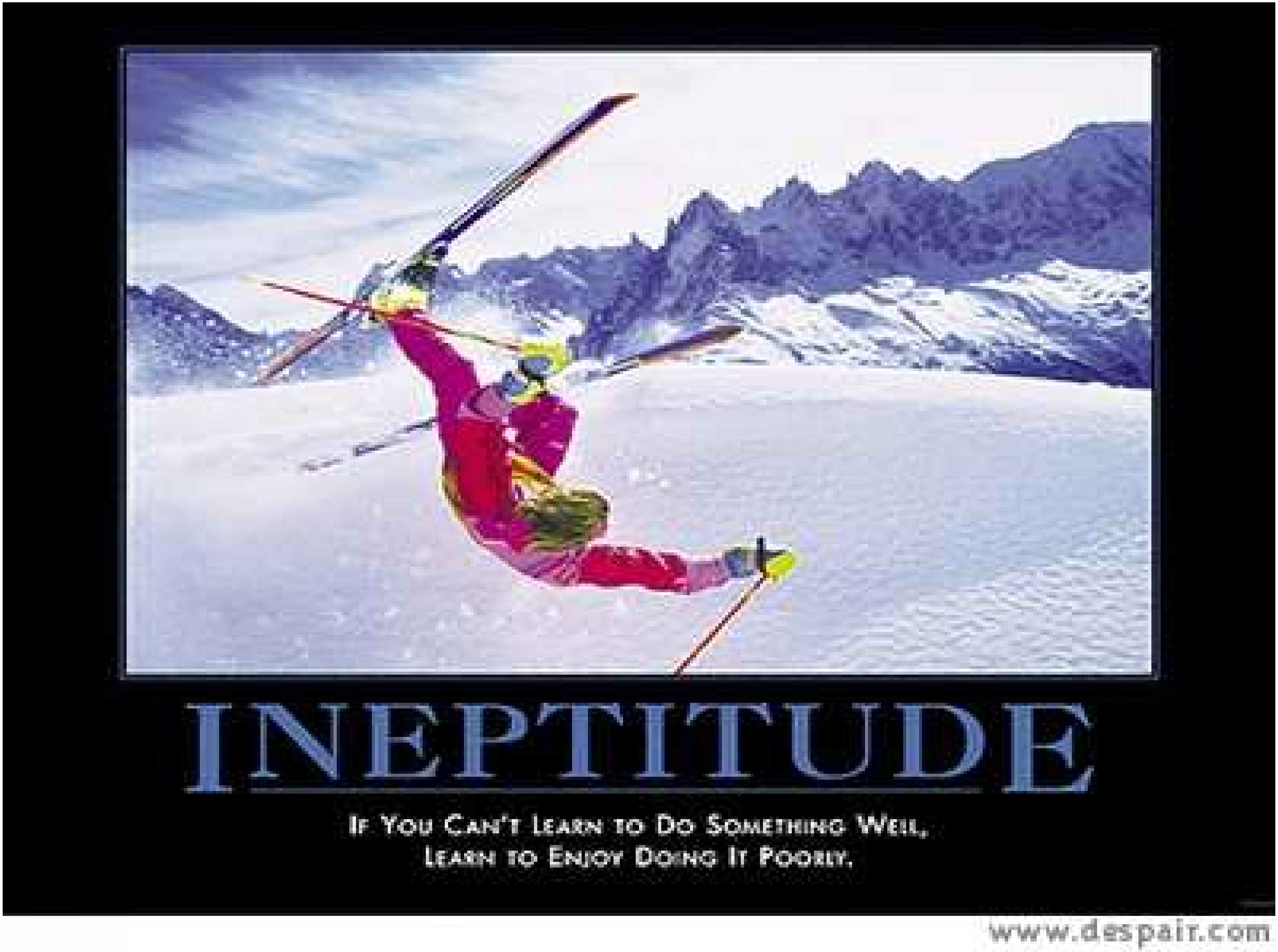
COCATS 2 and MRI

David Stultz, MD
Cardiology Fellow PGY-6

July 11, 2005


INEPTITUDE
IF YOU CAN'T LEARN TO DO SOMETHING WELL,
LEARN TO ENJOY DOING IT POORLY.
www.despair.com

Goals of Conference

- Quickly review COCATS-2
- Review Applications of MRI
- Understand how to achieve COCATS level 1 MRI without ever leaving Dayton

COCATS 2

ACC Revised Recoomendations for Training in Adult Cardiovascular Medicine Core Cardiology 2

- Revised 2002
- Guidelines for Level 1, 2, 3 training
  - **Level 1**—Basic training required of all trainees to be competent consultant cardiologists.
  - **Level 2**—Additional training in one or more specialized areas that enables the cardiologist to perform or interpret (or both) specific procedures at an intermediate skill level or engage in rendering cardiovascular care in specialized areas.
  - **Level 3**—Advanced training in a specialized area that enables a cardiologist to perform, interpret, and train others to perform and interpret specific procedures at a high skill level.

http://www.acc.org/clinical/training/COCATS2.pdf

Task Force 1-2

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
1	Clinical cardiology	1		36	
2	Electrocardiography	1	500 to 3,500 *,#		3,500
		2			greater than 3,500
	Ambulatory monitoring	1	150 *		150
		2	75		225
	Exercise testing	1	200 *		200
		2	100		300

[*] Can be taken throughout the training program.

[#] The committee strongly recommends that cardiologists achieve Level 2 training in ECG interpretation.

Task Force 3-4

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
3	Diagnostic catheterization	1	100	4	100
		2	200	8	300
	Interventional catheterization	3	250	20	550
4	Echocardiography	1	150	3	150
		2	150	6	300
		3	450	12	750

Task Force 5-6

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
5	Nuclear cardiology	1	80 hours	2	80 hours
		2	300 cases	4 to 6	300+ cases
		3	600 cases	12	600+ cases
6	Electrophysiology, pacing, and arrhythmias	1		2	
		2		6	
		3	150	24	150+ cases

Task Force 7-8

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
7	Research	1		6 to 12 †	
		2		24	
		3		24 to 36	
8	Heart failure and transplantation	1		1 †,§	
		2		6	
		3		12	

[†] Can be taken as part of 9 months of required nonlaboratory clinical practice rotation.
[§] It is assumed that trainees will obtain additional training in heart failure and preventive cardiology beyond the 1-month core training as part of the experience during other clinical months, such as consult services and CCU.

Task Force 9

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
9	Congenital heart disease	1		Core lectures †	
		2		12	
		3		24	40 Cath
					300 TTE
					50 TEE
	Preventive cardiology	1		1 †,§	
		2		6 to 12	
		3		12	

[†] Can be taken as part of 9 months of required nonlaboratory clinical practice rotation.
[§] It is assumed that trainees will obtain additional training in heart failure and preventive cardiology beyond the 1-month core training as part of the experience during other clinical months, such as consult services and CCU.

Task Force 11

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
11	Vascular medicine and peripheral catheter-based intervention	1		2 *	
	Vascular Medicine Specialist	2		14 ¶	400+ noninvasive cases **
	Peripheral Vascular Intervention	3		20 ††	160+ §§
	Vascular Medicine Specialist plus Vascular Intervention	3		34 ‡‡	

[¶] 2 months of vascular medicine as defined by Level 1, plus 12 months of Level 2 training. Level 2 training is not a prerequisite for Level 3 training but is intended for individuals who want to become a vascular medicine specialist.

[**] In addition, observing 25 peripheral angiograms and 25 peripheral interventions

[††] Including 2 months of vascular medicine training as defined by Level 1, 8 months of diagnostic catheterization training, and 12 months of interventional lab training. Interventional training for Level 3 requires a 4th year. The 12 months of Level 2 training are not required for this interventional training year.

[‡‡] Including 2 months of Level 1 and 12 months of Level 2 vascular medicine training, 8 months of diagnostic catheterization training, and 12 months of interventional lab training.

[§§] Including 100 diagnostic peripheral angiograms, 50 peripheral interventions, and 10 thrombolysis/thrombectomies.

Task Force 12

Task Force	Area	Level	Minimal Number of Procedures	Cumulative Duration of Training (mo)	Cumulative Number of Procedures
12	Cardiovascular magnetic resonance imaging	1		1 ‡	50
		2		3 to 6	150
		3		12	350

[‡] Can be taken as part of 6 months of noninvasive imaging rotation.

Reasons for Cardiac MRI

- Pre- and Post- operative congenital heart disease assessment
- Clinical suspicion of RV dysplasia
- Pericardial disease (constrictive pericarditis versus restrictive cardiomyopathy)
- Cardiac tumors
- Anomalous coronary arteries
- Valvular disease

Poustchi-Amin, 6-7

Other uses of Cardiac MRI

- Myocardial function and viability
- Assessment of proximal coronary artery stenoses (Investigational)

Poustchi-Amin, 7

MRI Imaging Contraindications

- Pacemakers?[1]
  - 1.5 T MRI, 52 patients / 62 MRI exams
  - 107 leads / 61 pulse generators
    - 37% of leads underwent changes
    - 9.4% of leads had significant changes
    - 2% of leads required change in output
- Ferromagnetic implants
- Aneurysm clips
  - Titanium clips are safe in up to 3.0T systems[2]

[1] www.cardiosource.com/webfiles/editorial/cardio/shared/zja007049804p.pdf
[2] Shellock FG, Tkach JA, Ruggieri PM, Masaryk TJ, Rasmussen PA. Aneurysm clips: evaluation of magnetic field interactions and translational attraction by use of "long-bore" and "short-bore" 3.0-T MR imaging systems. AJNR Am J Neuroradiol. 2003 Mar;24(3):463-71.
Poustchi-Amin, 3

MRI Imaging Basics

- Gated acquisition
  - Image acquisition limited to frame within normal cardiac cycle
    - QRS complex
    - Peripheral pulse
- Continuous patient monitoring

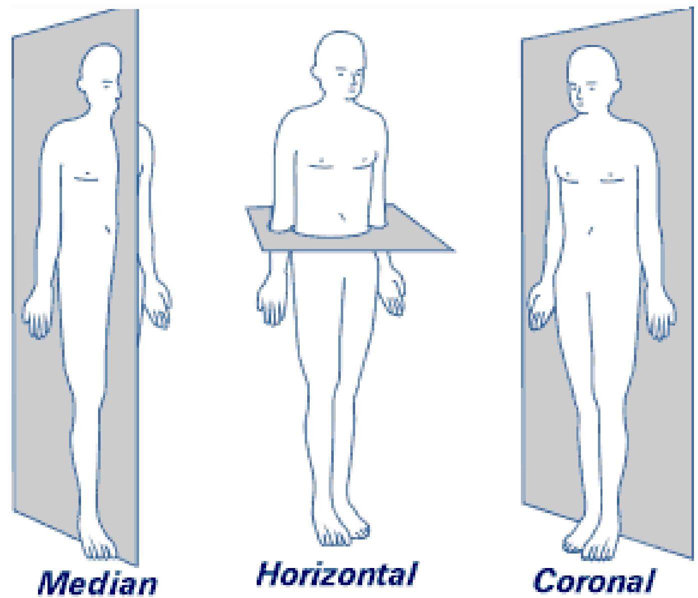
Cardiac MRI Pulse Sequences

- Dark Blood
  - Fast flowing blood is black
  - Imaging for blood vessel lumens
  - Provides anatomic definition
- Bright Blood
  - Flowing blood is white
  - Gradient Recalled Echo sequences produce cine
  - Functional status

Poustchi-Amin, 3

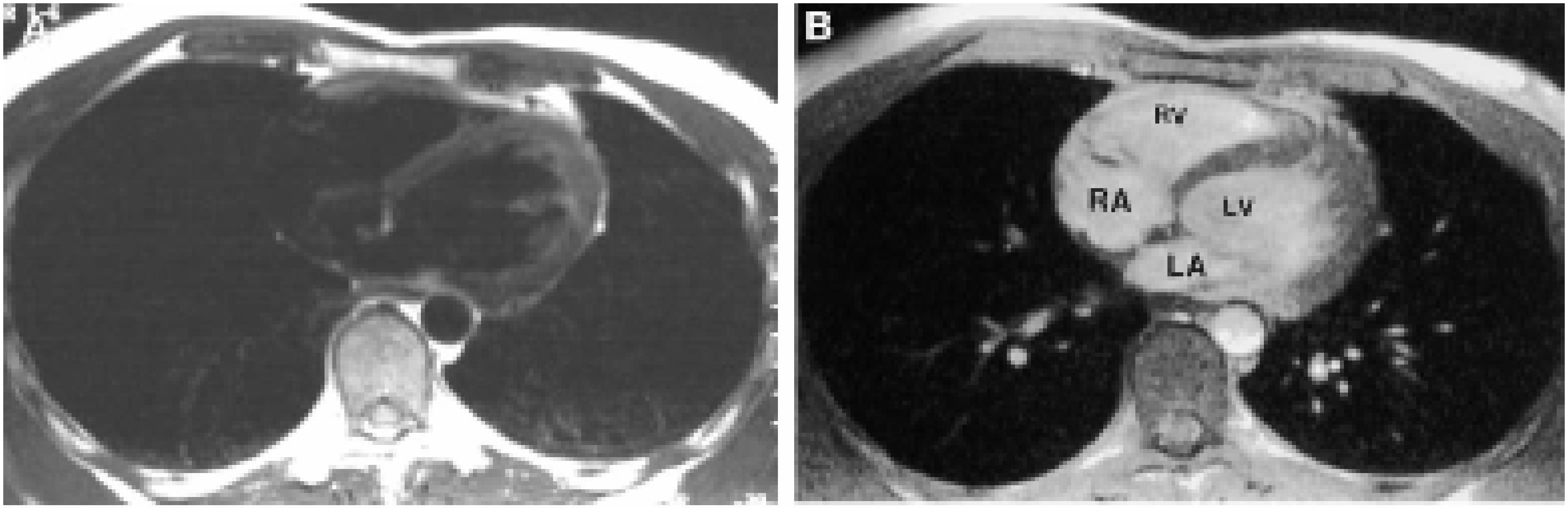
Imaging Planes - Body

- Transverse / Transaxial
  - Scout films
  - Same as CT orientation
- Coronal Plane
  - Useful for aortic valve
- Double Oblique / Oblique Saggital
  - Pulmonic and aortic outflow



Poustchi-Amin, 3-4
http://www.physio-net.com/reference/glossary/misc/anatomicalplanes.htm

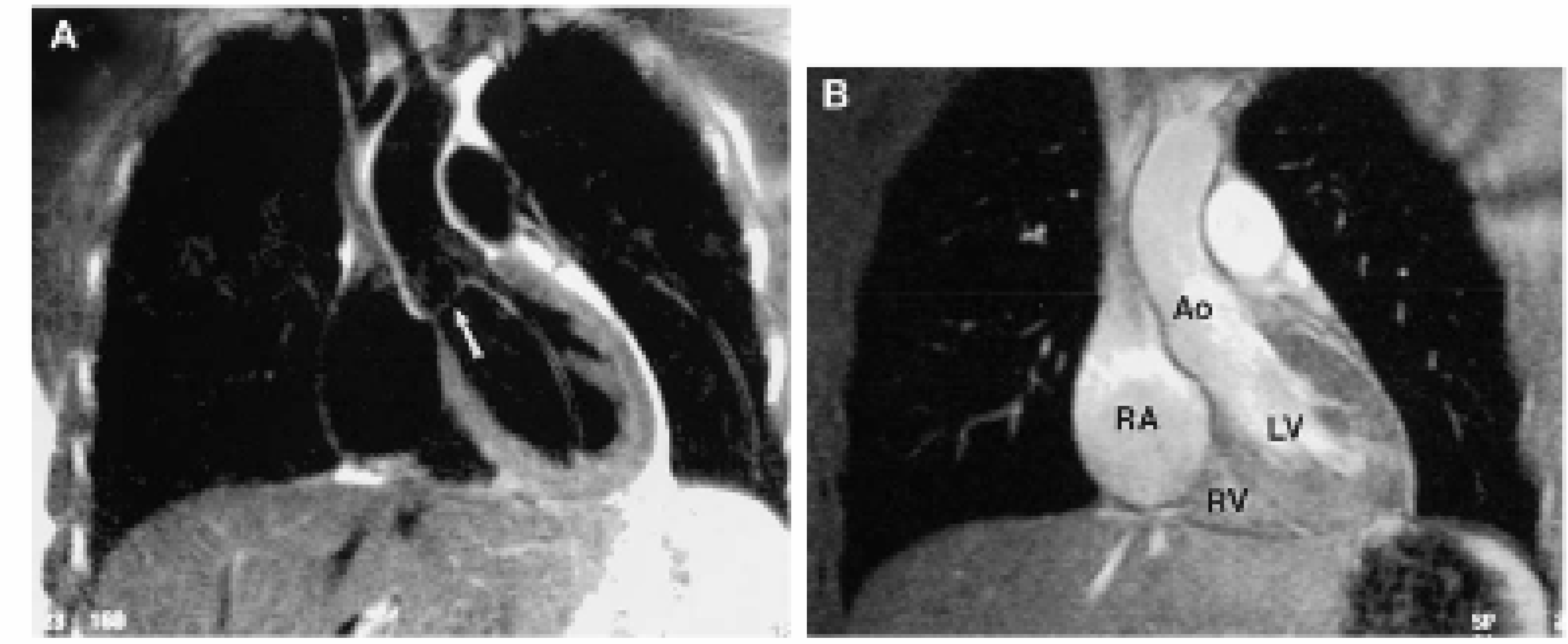
Transverse Axis



Transverse or transaxial images. (A) Dark-blood technique: single slice breath-hold turbo spin echo T1 is often used to assess cardiac morphology. (B) Bright-blood technique: breath-hold cine gradient recalled echo sequence is useful in assessing cardiac function. LA, left atrium; RA, right atrium; LV, left ventricle; RV, right ventricle.

Poustchi-Amin, 4

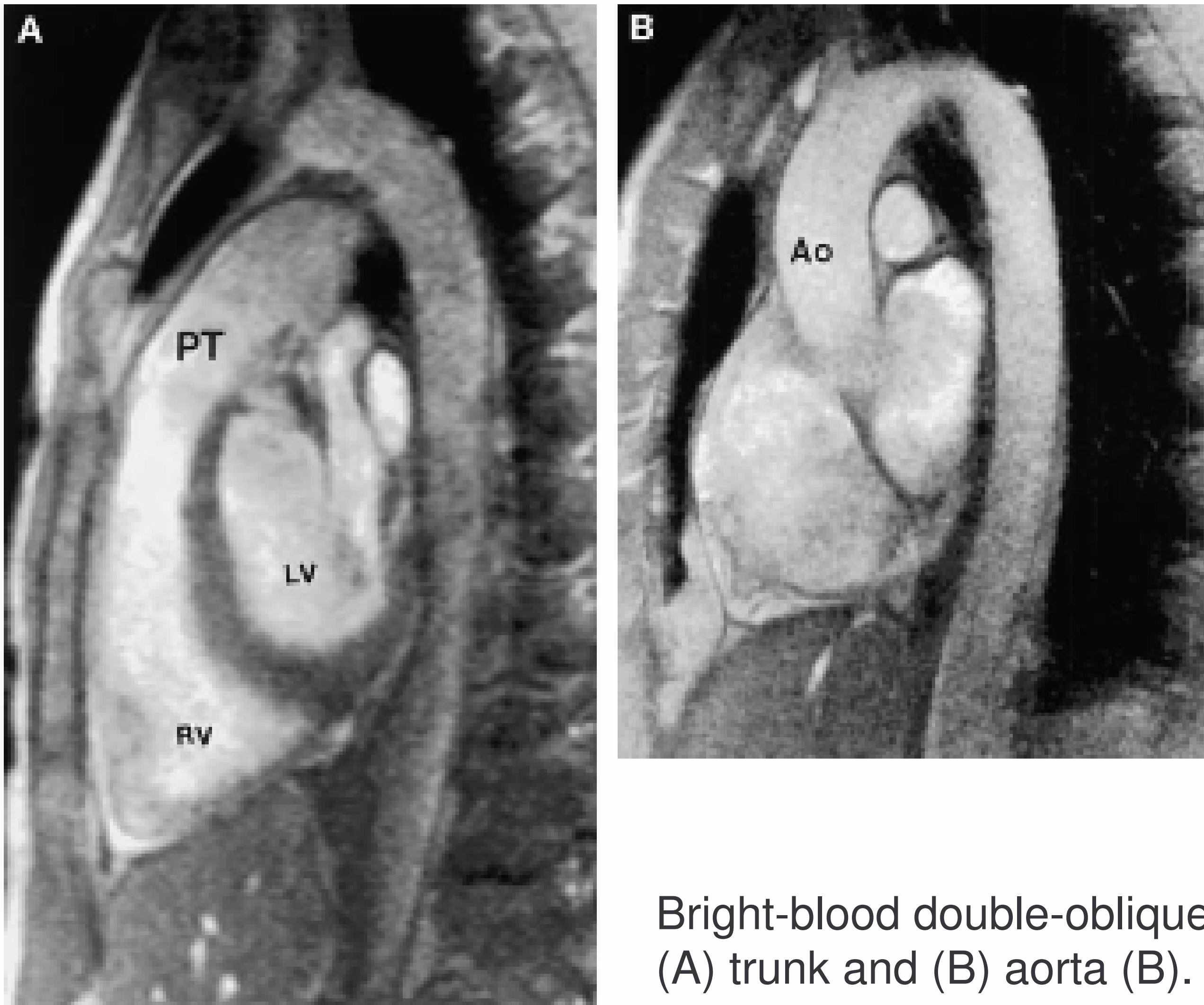
Coronal Axis



Coronal images. (A) Dark-blood technique: turbo spin echo T1. This plane nicely demonstrates the aortic valve (arrow). A plane set through the midaortic valve and LV apex provides a 5-chambered view. (B) Bright-blood technique: cine gradient recalled echo. This plane can be used to assess the jet of aortic stenosis or insufficiency. Ao, aorta; LV, left ventricle; RV, right ventricle; RA, right atrium.

Poustchi-Amin, 4

Double-Oblique Axis



Bright-blood double-oblique images through pulmonary (A) trunk and (B) aorta (B). Ao, aorta; PT, pulmonary trunk.

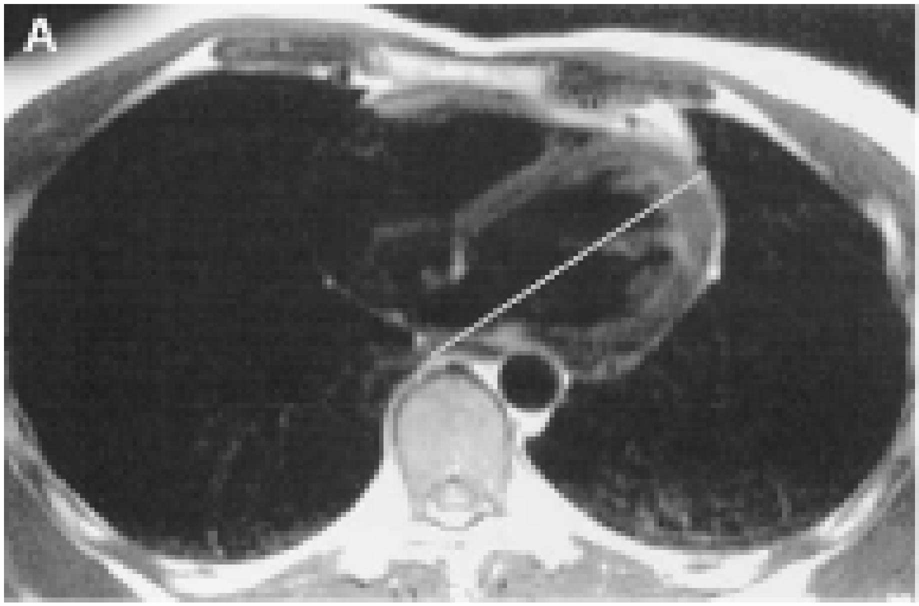
Poustchi-Amin, 5

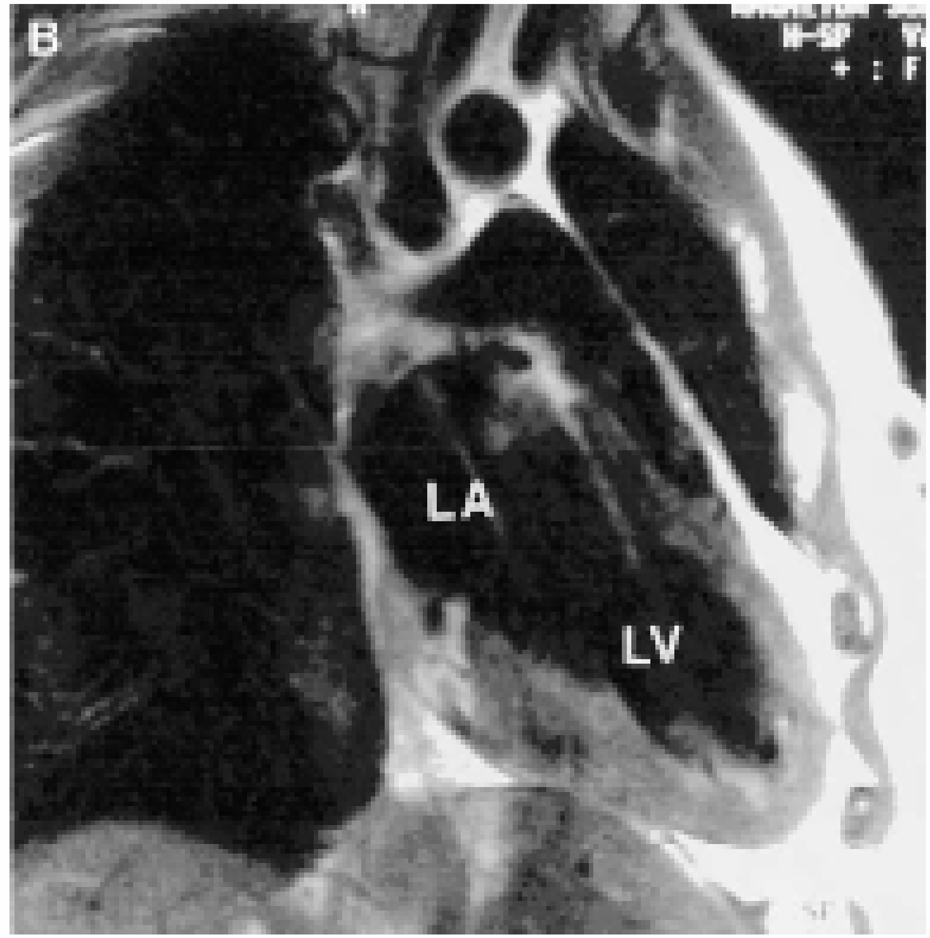
Imaging Planes - Cardiac

- Derived from standard body imaging planes
- Vertical Long Axis (2 chamber)
  - Left heart structures
  - Mitral valve
- Horizontal Long Axis (4 chamber)
  - Cine GRE show RV, LV function; Mitral tricuspid valve function
- Short Axis
  - Cross sectional dimensions of all chambers
  - Quantify Systolic and Diastolic dimensions and wall shortening
  - LV/RV mass
  - Stroke volume differences can estimate regurgitant volumes
- Long Axis through aortic and mitral valves (5

Doustchi-Amin, 5

Vertical Long Axis

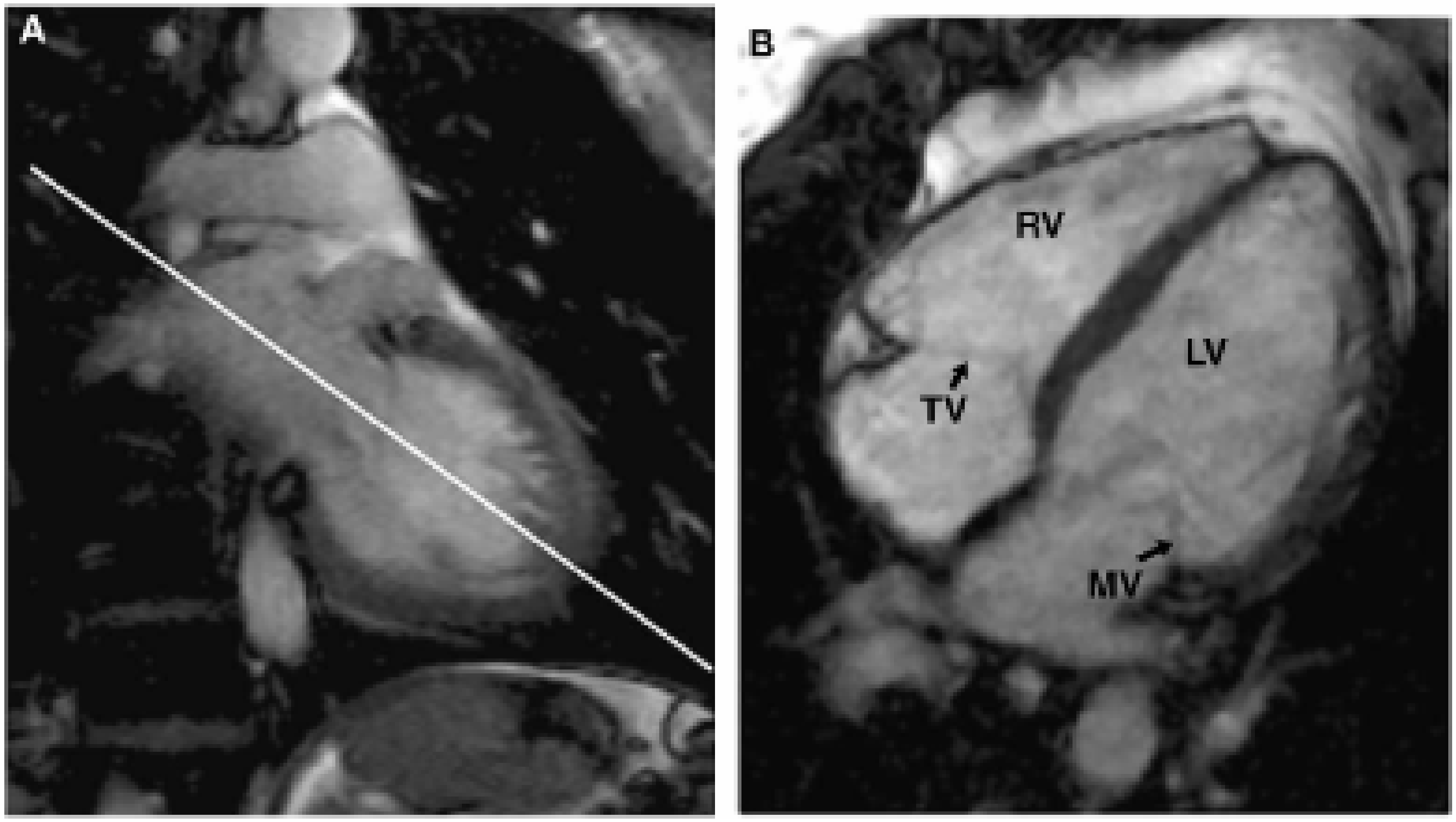




Two-chambered long axis view. An image obtained parallel to the line shown on (A) the transaxial image provides (B) the vertical long axis plane or two-chamber view. This image plane is ideal for assessing the mitral valve. LA, left atrium; LV, left ventricle.

Poustchi-Amin, 6

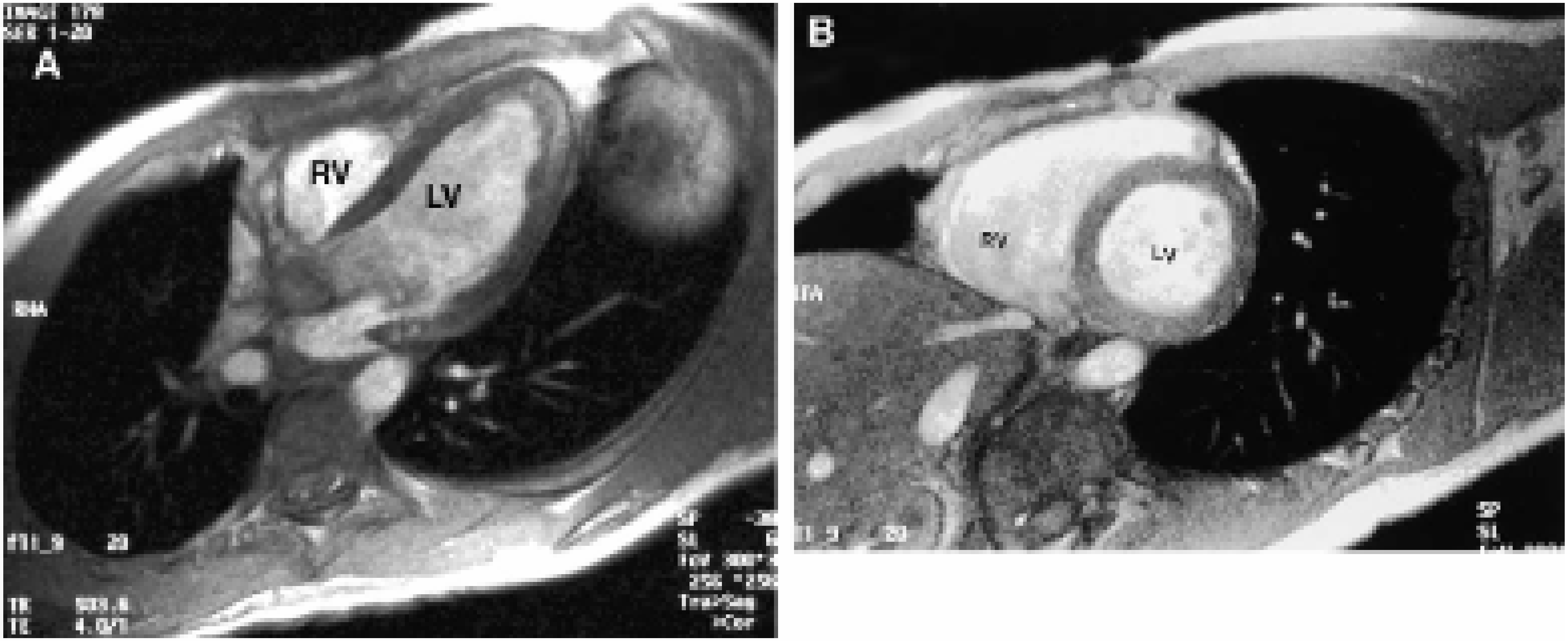
Horizontal Long Axis



Horizontal long axis plane or 4-chamber view. An image obtained parallel to the line shown on (A) the vertical long-axis image provides (B) the horizontal long axis or four-chamber view. In this image, both the mitral and tricuspid valves can be assessed. RV, right ventricle; LV, left ventricle; MV, mitral valve; TV, tricuspid valve.

Poustchi-Amin, 6

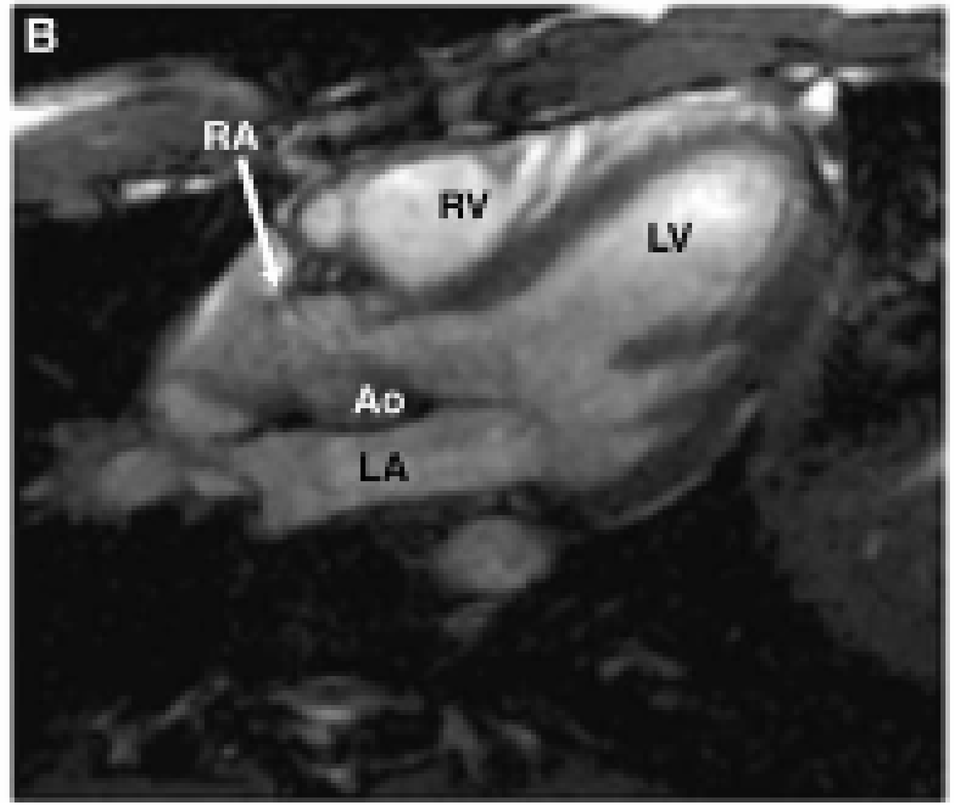
Short Axis



Short axis plane. Bright-blood technique cine GRE. This image plane is favored in the assessment of LV function. Multiple contiguous short axis images are obtained from the base of the heart to (A) the apex to provide images in (B) the short axis orientation. Functional analysis software then can be used to calculate stroke volume, ejection fraction, and myocardial mass. A horizontal 4-chamber view can be prescribed from a short axis image by drawing a line perpendicular to the LV septum. RV, right ventricle; LV, left ventricle.

Poustchi-Amin, 7

5 Chamber View



A line drawn through the LV apex and aortic outflow as prescribed from (A) a coronal image provides a long axis view sometimes known as (B) the 5-chamber view. This view demonstrates both aortic valve and mitral valve function and displays portions of the right and left ventricles and atria and the aorta (5 chambers). RV, right ventricle; LV, left ventricle; LA, left atrium; RA, right atrium; Ao, aorta.

Poustchi-Amin, 7

Congenital Anomolies

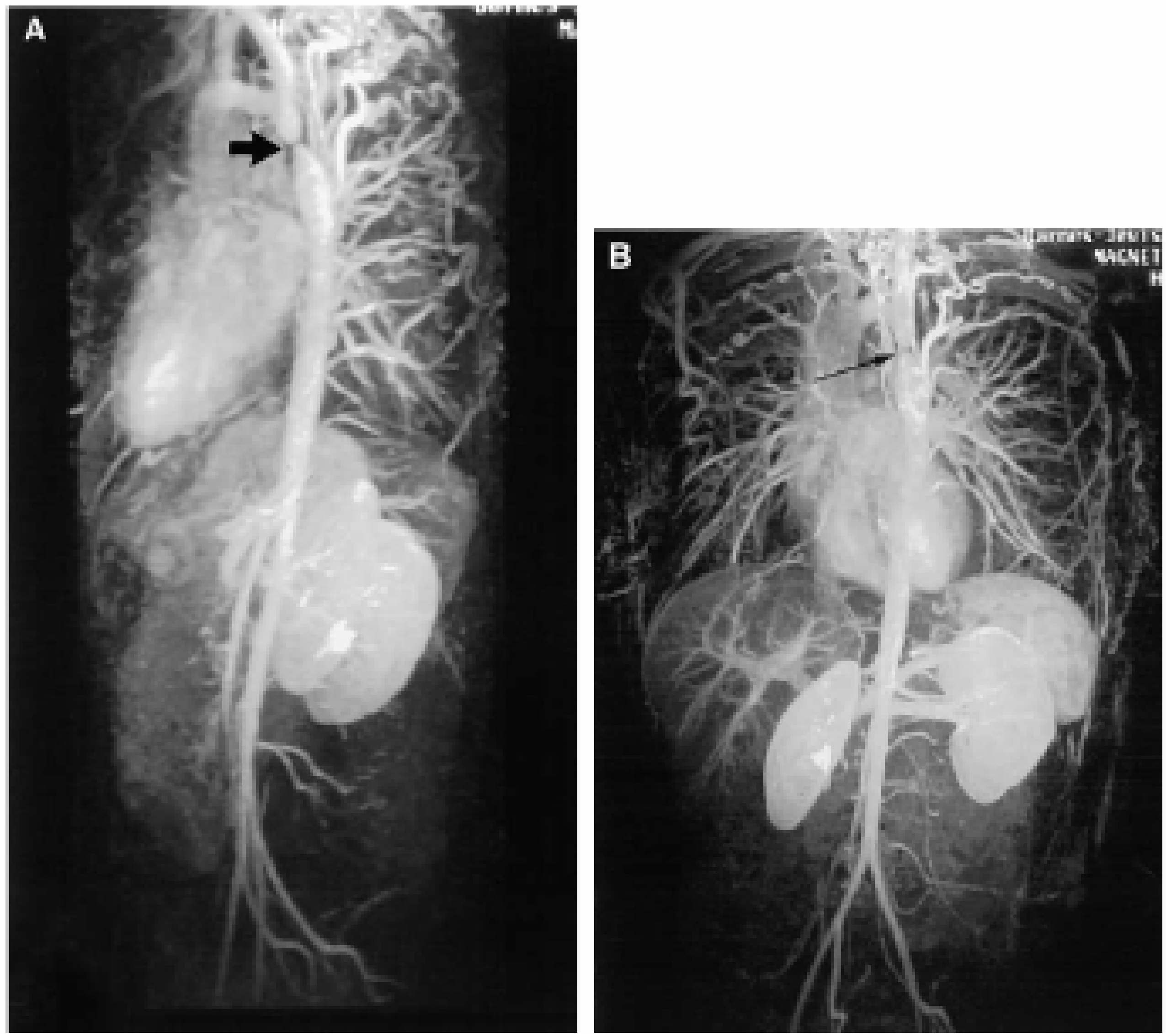
- Aortic Coarctation
- Transposition of the Great Vessels
- Tetralogy of Fallot
- Patent Ductus Arteriosus
- Ventricular Septal Defect
- Anomalous pulmonary veins

Contrast Enhanced MRI

- Useful for evaluation of aorta, pulmonary stenosis, collaterals, shunts
- Short breath hold acquisition, no gating
- Pre and post contrast images acquired
  - Digital subtraction
- Contrast agents
  - 2 mL/sec of 0.2 mmol/Kg Gd-DTPA
  - Gadolinium

Poustchi-Amin, 8-9

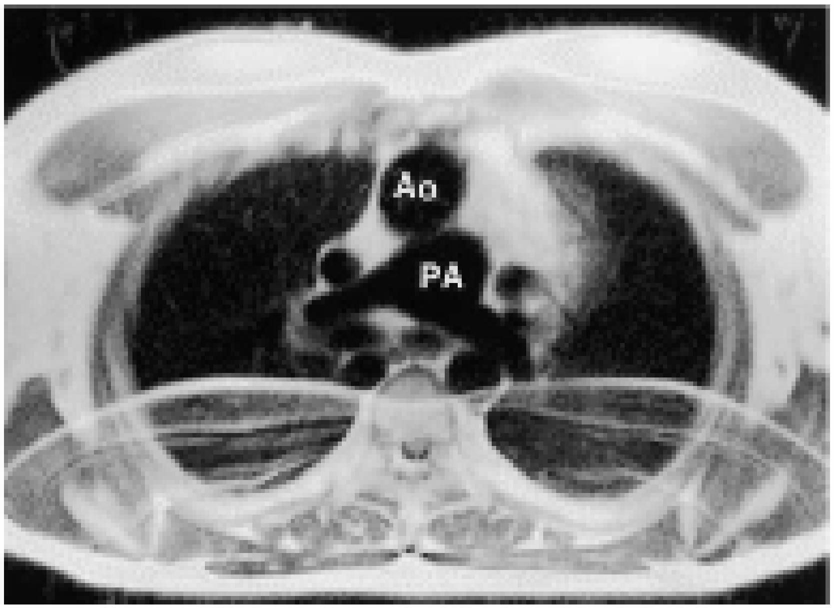
Coarctation of the Aorta



A 20-year-old female patient with hypertension, unresponsive to medication. (A) lateral and (B) coronal views of contrast-enhanced 3-D MRA clearly show coarctation of descending aorta (arrow) and extensive collateral vessels.

Poustchi-Amin, 8

Transposition of the Great Vessels



D-loop transposition of the great arteries. Axial dark-blood HASTE. Note the aorta arising anterior and to the left of the main pulmonary artery. PA, pulmonary artery; Ao, aorta.

- D-Loop (Complete transposition)
  - Aortic valve and aorta arise from RV
  - Pulmonic valve and pulmonary artery arise from LV
  - RV hypertrophied
  - Aortic valve anterior to pulmonic valve

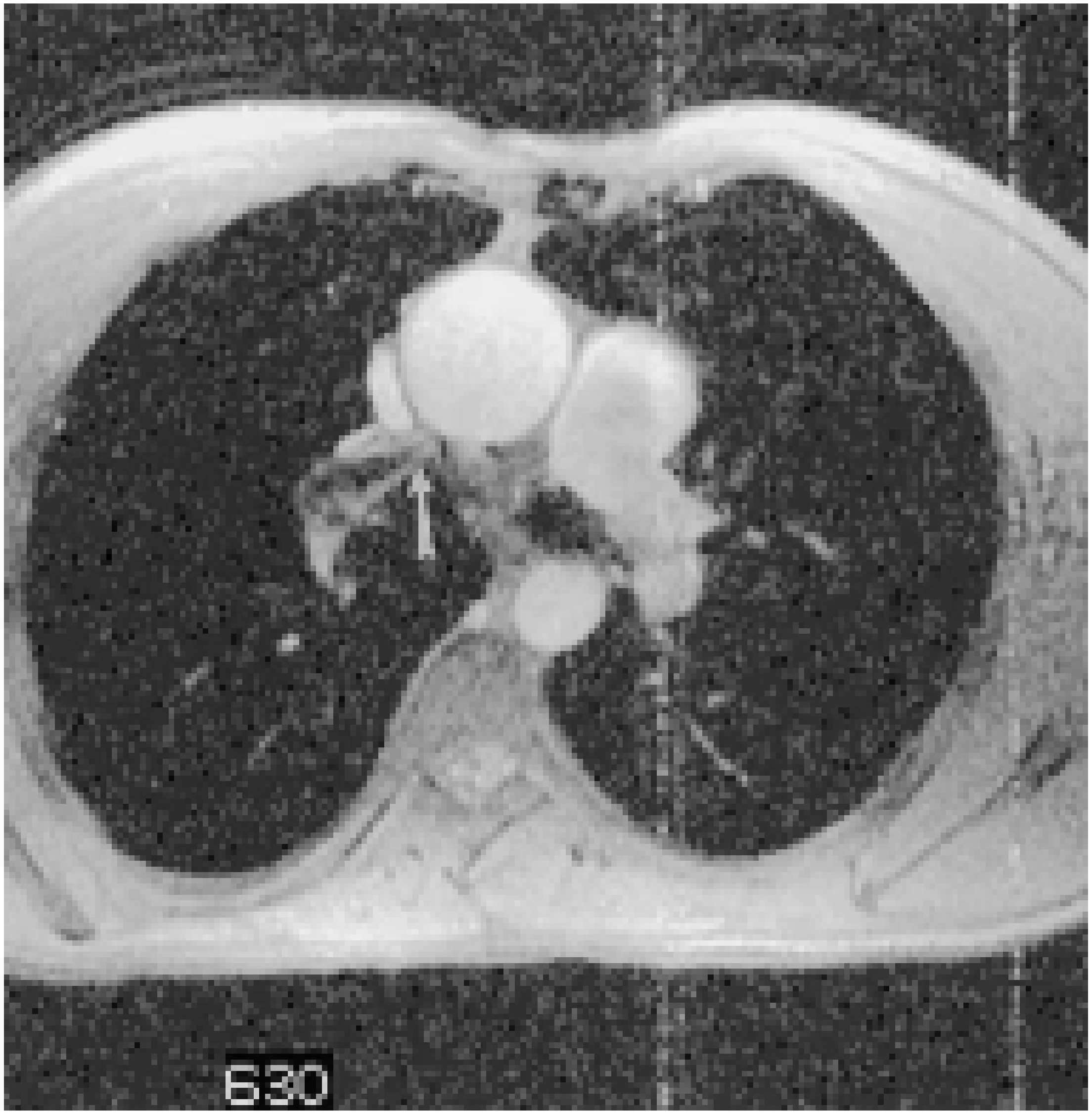
Poustchi-Amin, 9

Tetralogy of Fallot

- Anatomical features
  – Large ventricular septal defect (VSD)
  – RV outflow tract obstruction
  – RV hypertrophy
  – Over-riding aorta
- Complete repair = VSD closure + infundibulectomy
- Paliative shunt procedures
  – Blalock-Taussig shunt – connects the subclavian artery to the pulmonary artery
  – Waterston shunt – connects the ascending aorta to the right pulmonary artery
  – Potts shunt – connects the descending aorta and left pulmonary artery
  – Glenn shunt – connects the SVC to the right pulmonary artery.

Poustchi-Amin, 9-10

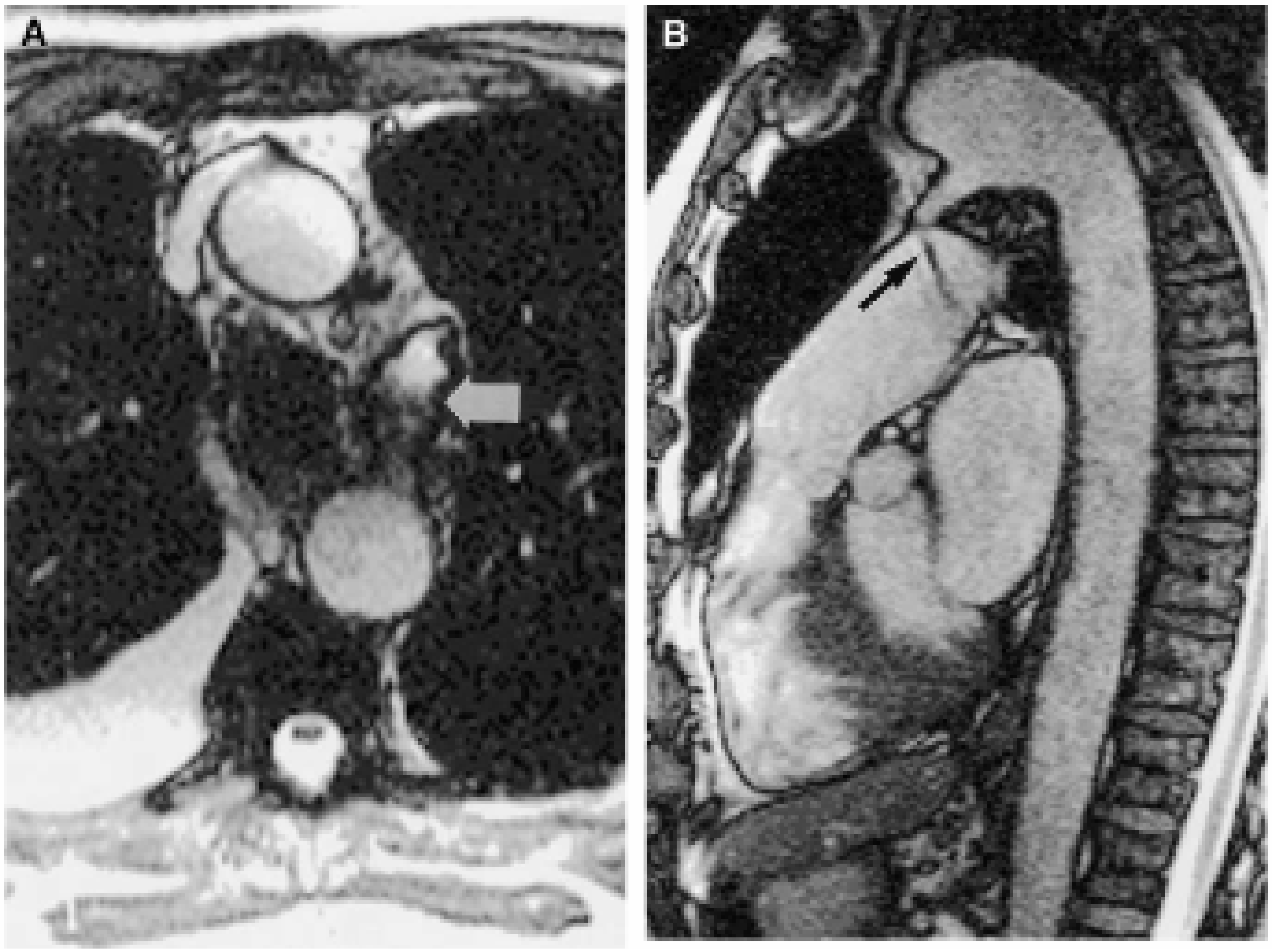
Evaluation of shunt stenosis



Axial cine GRE image shows a stenotic Waterston shunt in a patient with pulmonic atresia and hypoplastic right ventricle. The Waterson shunt connects the ascending aorta to the right pulmonary artery. Arrows point to a jet in right pulmonary artery.

Poustchi-Amin, 10

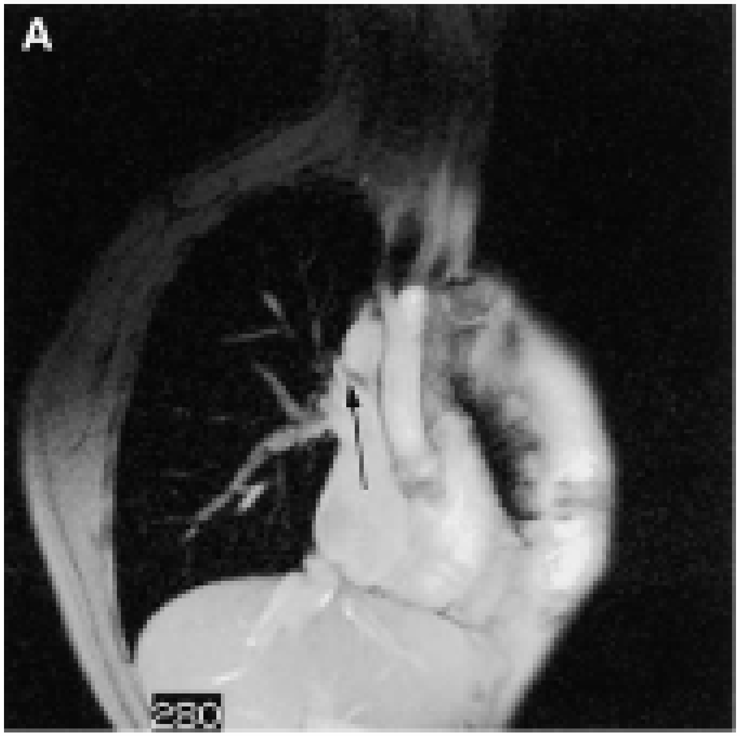
Patent Ductus Arteriosus



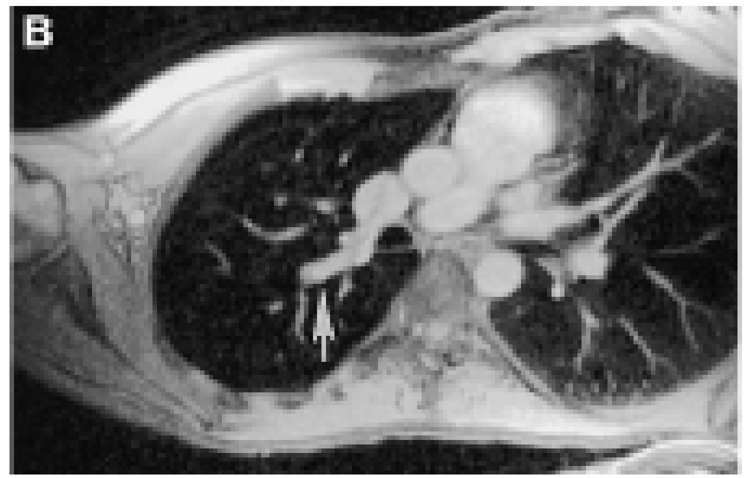
(A) Transaxial true FISP image shows an abnormal structure (white arrow) adjacent to the aorta and superior pulmonary trunk. (B) True FISP sagittal image obtained in plane through the long axis of the structure seen on image A provides greater characterization and demonstrates that the structure is a patent ductus. Turbulent flow through the ductus produces a jet into the pulmonary trunk (black arrow).

Poustchi-Amin, 11

Anomalous pulmonary vein



- RUL anomalous pulmonary vein usually drains to SVC
- LUL anomalous pulmonary vein looks like a duplicated SVC



Anomalous right upper-lobe pulmonary vein. Young woman with Turner's syndrome who had an enlarged RA seen on an echocardiogram. The etiology of the enlarged RA could not be determined. (A) An oblique cine image showed a dilated superior vena cava with a small jet (black arrow). (B) Additional imaging in (B) the plane of the jet showed an anomalous right upper-lobe pulmonary vein (white arrow).

Poustchi-Amin, 11

Trivia/Boards Question

- Which type of Atrial Septal Defect is associated with anomalous pulmonary venous return?
  - Sinus venosus ASD
- What valve malformation is associated with a primum defect?
  - Cleft mitral valve

Arrythmogenic RV dysplasia

- Replacement of RV muscle fibers with fat
- Right sided chamber enlargement
- Ventricular arrythmias
- LBBB
- Familial in 30% of cases
- Endomyocardial biopsy not reliable (no septal involvement)

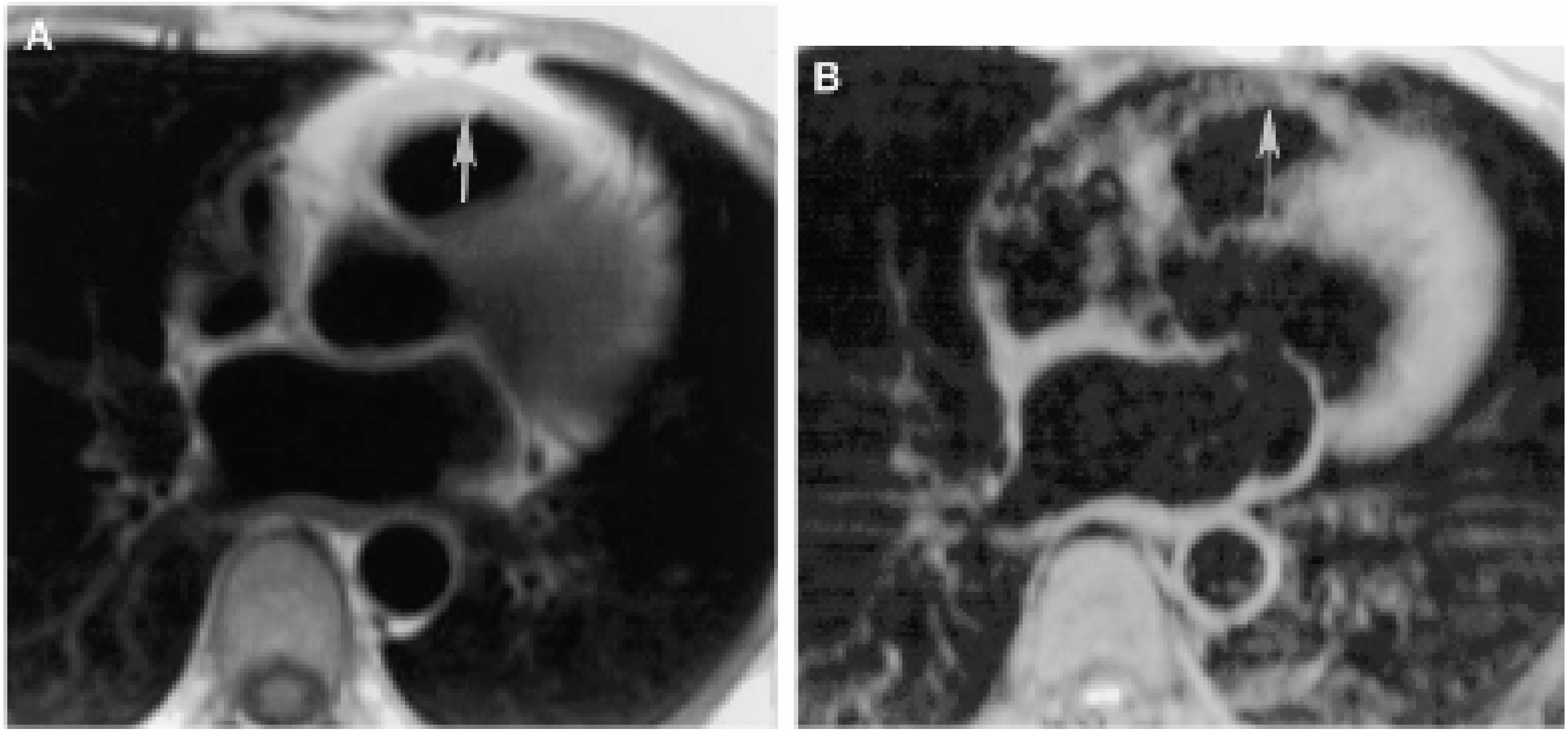
Poustchi-Amin, 11-12

MRI features of RV dysplasia

- Thinning of the RV free wall
- Increased myocardial signal intensity from fatty replacement
- Decreased systolic wall thickening or motion (RV akinesis or dyskinesis) causing focal bulging at the site of myocardial fibrosis
- Diminished ejection fraction
- Impaired ventricular filling in diastole
- Right ventricle and atrium can be normal in size or dilated.

Poustchi-Amin, 12

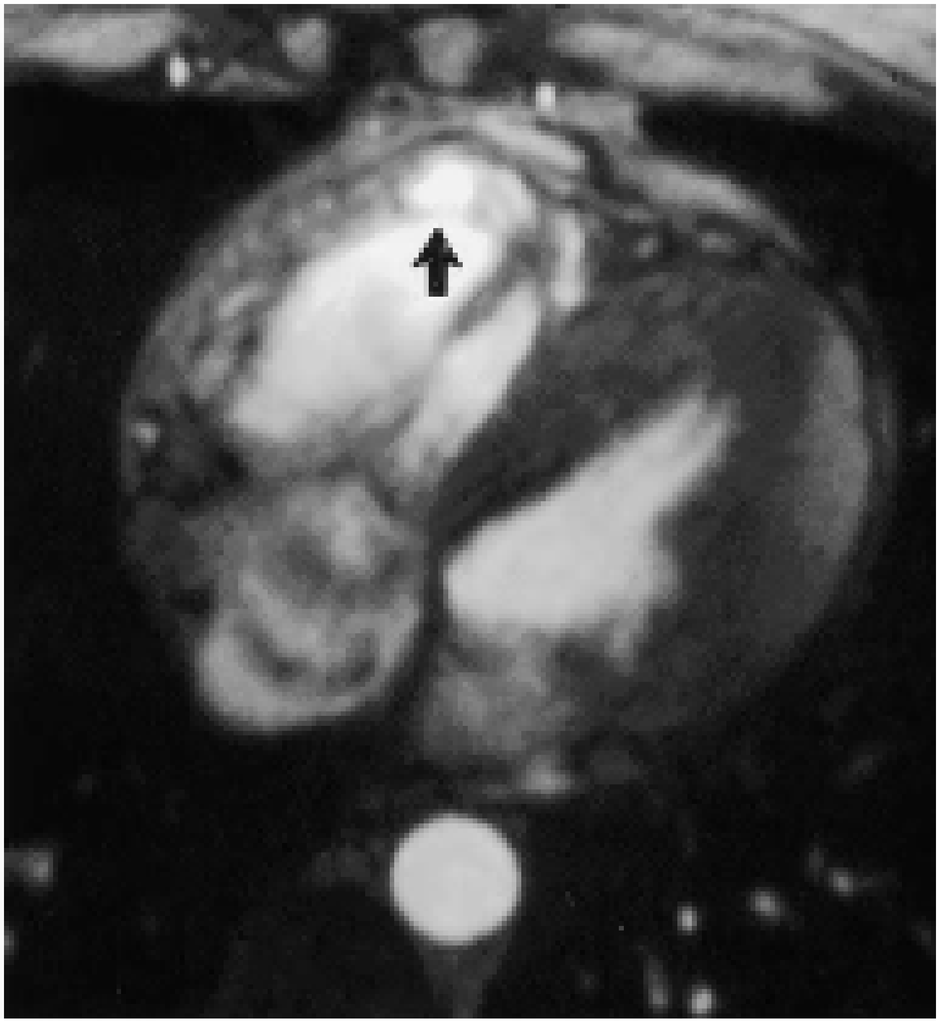
RV dysplasia



Biopsy proven case of arrythmogenic RV dysplasia. (A) Axial turbo spin echo T1-weighted image shows fatty infiltration of the myocardium involving the pulmonary outflow tract (arrow). (B) Fat saturated axial TSE T1-weighted image shows signal dropout of this region (arrow) because of fatty infiltration.

Poustchi-Amin, 12

RV dysplasia



Axial bright-blood cine GRE image in a patient with RV dysplasia shows focal bulge (arrow) of the right ventricular wall.

Poustchi-Amin, 13

Constrictive Pericarditis vs Restrictive Cardiomyopathy

- Restrictive cardiomyopathy
  - Myocardial stiffness and restriction
    - Infiltrative (amyloid, sarcoid)
    - Noninfiltrative (idiopathic, scleroderma)
    - Storage diseases
    - Carcinoid
    - Endomyocardial fibrosis
  - Normal pericardial thickness, thickened myocardium
- Constrictive pericarditis
  - Pericardial injury followed by inflammation
    - Infectious pericarditis
    - Connective tissue disease
    - Neoplasm
    - Renal failure
    - Cardiac surgery
    - Radiation therapy
  - Pericardial thickness of 4mm or more

Poustchi-Amin, 13

Constrictive Pericarditis

Constrictive pericarditis. Axial dark-blood HASTE image shows a thickened pericardium (>4 mm), normal myocardial thickness, large right and left atria, and relatively small ventricular size. MR imaging also may show a dilated IVC or paradoxical septal motion because of increased right-sided pressure.

Poustchi-Amin, 13

Restrictive Cardiomyopathy

Patient with sarcoid. Axial dark-blood HASTE image shows normal thickness of pericardium, markedly thickened myocardium, small ventricular volume, and, as with restrictive pericarditis, large right and left atria.

Poustchi-Amin, 13

Cardiac Tumors

- Primary
  - 80% benign
  - Rare
  - Intraluminal, attached by stalk
- Secondary
  - 40-50x more common than primary
  - Broad based, invade myocardium
- Tumors enhance with gadolinium
- T2-weighted signal enhances tumors

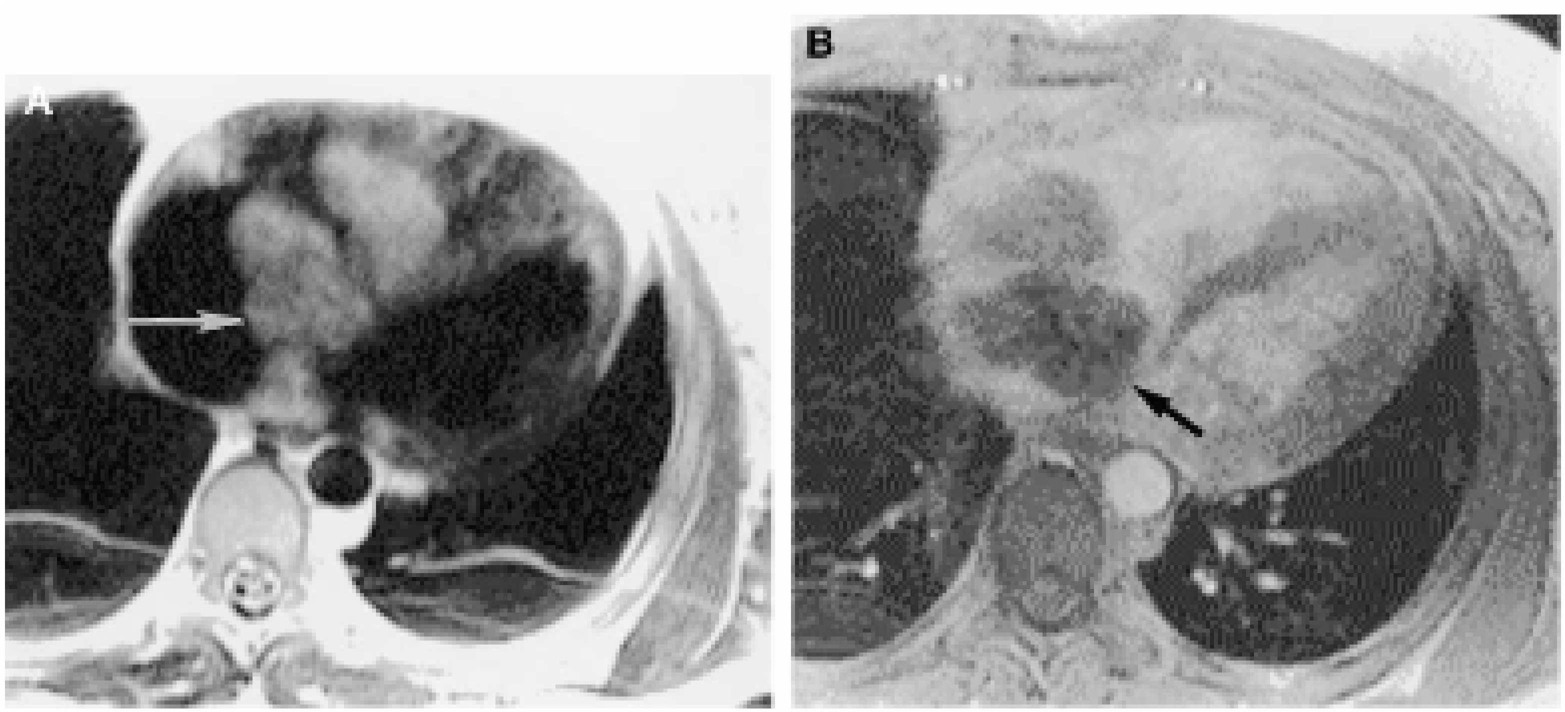
Poustchi-Amin, 14

Primary cardiac tumors

- **Myxoma**
  - most frequent benign cardiac tumor, usually within the left atrium
- **Lipoma**
  - Usually right atrium, fat saturation helpful
- **Angiosarcoma**
  - most common malignancy, arising from the right atrium
- **Rhabdomyoma**
  - frequent tumor in children
- **Fibroma**
  - low signal on T2
- **Hemangioma**
  - “light bulb” appearance on T2-weighted images

Poustchi-Amin, 14

Myxoma



Right atrial myxoma. (A) Axial dark-blood HASTE image shows a bilobed mass (arrow) straddling the tricuspid valve. Note the relatively bright signal of the mass on this T2-weighted sequence. Images are acquired in diastole and, thus, do not demonstrate the location of the mass throughout the cycle. (B) Axial bright-blood cine GRE image obtained in systole shows that the mass arises from the RA with the point of tumor attachment at the intra-atrial septum.

Poustchi-Amin, 14

Coronary Anatomy

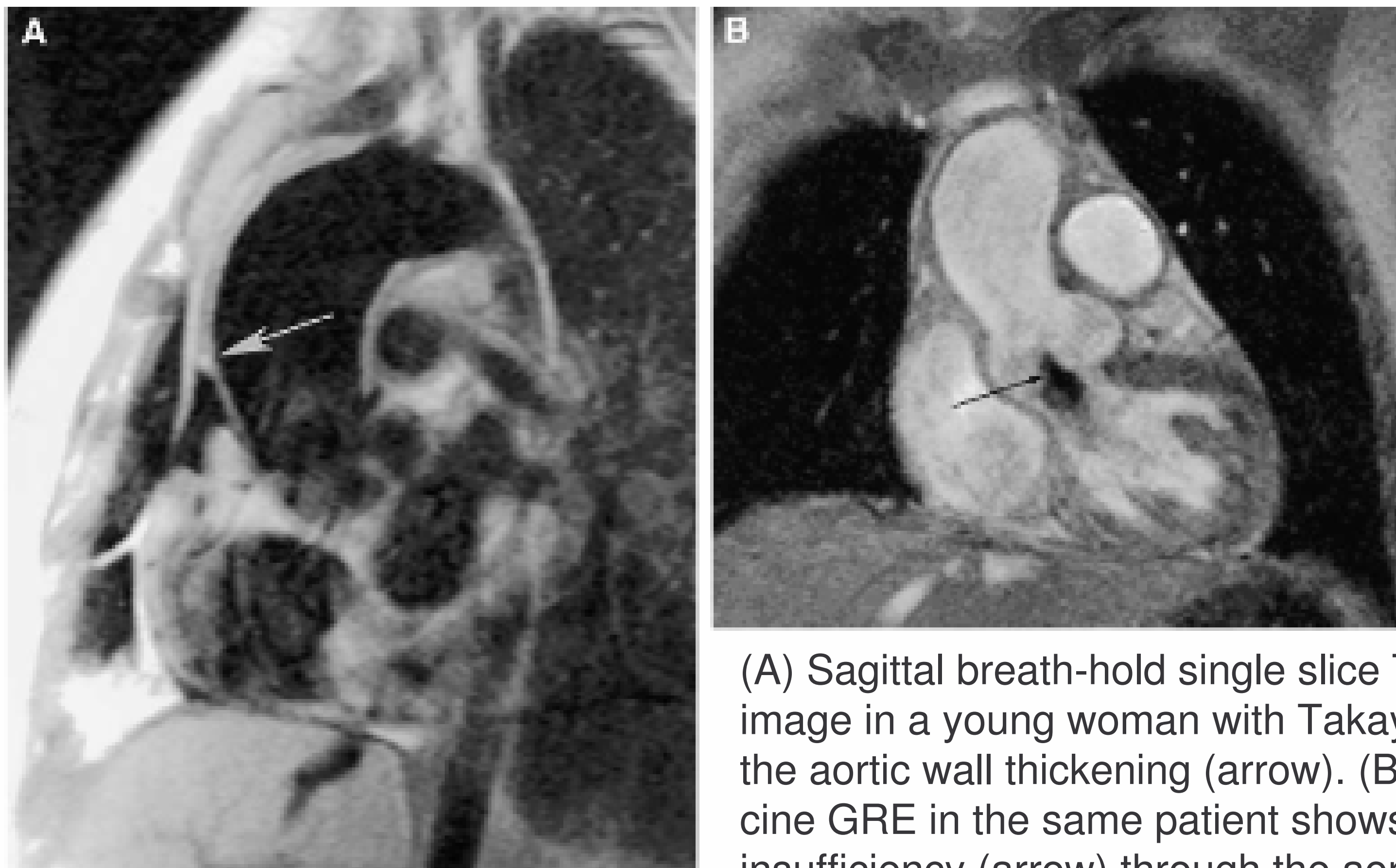
- Useful for
  - Assessment of anomalous coronary arteries
    - RCA or LAD coarsing between pulmonic outflow tract and aorta associated with sudden death
  - Coronary artery aneurysm
  - Assessment of bypass graft patency
- Still investigational for atherosclerosis
- Compared to angiography (>50% stenosis)
  - MRI 75% sensitivity, 77% specificity
  - CT (16 slice) 82% sensitivity, 79% specificic

Poustchi-Amin, 15
Kefer et al. Head to Head Comparison of Three-Dimensional Navigator Gated Resonance Imaging and 16-Slice Computed Tomography to Detect Coronary Artery Stenosis in Patients. J Am Coll Cardiol. 2005 Jul 5; 46(1): 92-100.

Valvular disease

- Demonstrate regurgitant jet
- Demonstrate chamber enlargement
- Can calculate regurgitant fraction by showing difference of RV, LV stroke volumes

Takayasu's Arteritis with Aortic Regurgitation



(A) Sagittal breath-hold single slice TSE T1-weighted image in a young woman with Takayasu's arteritis. Note the aortic wall thickening (arrow). (B) Coronal breath-hold cine GRE in the same patient shows a jet of aortic insufficiency (arrow) through the aortic valve toward the left ventricle. The aortic insufficiency is caused by poor apposition of the aortic valve leaflets. Note the dilatation of the sinuses at the aortic root.

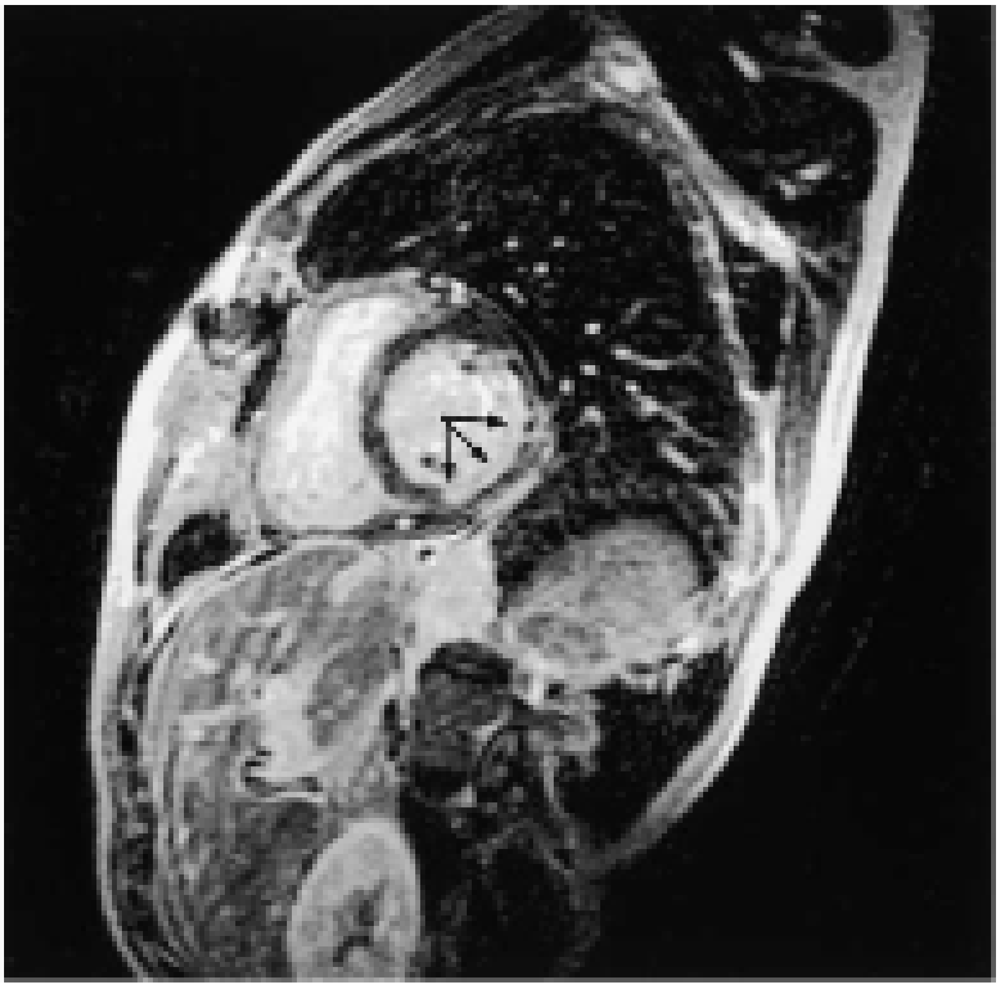
Poustchi-Amin, 16

Newer MRI Techniques

- LV function
  - Cine techniques
  - Stress testing
- LV wall motion
- Myocardial perfusion / viability
  - Gadolinium administration reveals low signal in ischemic myocardium
  - 10-15 minute delayed images demonstrate infarcted myocardium that enhances with T1 weighting

Poustchi-Amin, 16-17

Myocardial Viability



Subendocardial lateral wall myocardial infarction. Delayed imaging in the short axis is obtained using a contrast-enhanced T1-segmented TurboFLASH sequence. Arrows point to the nonviable myocardium.

Poustchi-Amin, 17

So Where Are We Now?

- Recent ACC survey of fellowship programs
- Limited availability of Cardiac MRI
  - 13% of programs own MRI
  - 30% have dedicated educational rotations for all fellows
  - 33% have no MRI educational curricula
  - Most programs have only Aortic MRI imaging

Taylor et al.

How to Achieve Level 1 MRI without leaving Dayton

- CMR SAP
- Provides around 40 CME hours
- Endorsed by ACC to provide Level 1 CMR training

Reicheck.

References

- Beller GA, Bonow RO, Fuster V; Core Cardiology Training Symposium (COCATS). ACC revised recommendations for training in adult cardiovascular medicine. Core Cardiology Training II (COCATS 2). (Revision of the 1995 COCATS training statement). J Am Coll Cardiol. 2002 Apr 3;39(7):1242-6.
- Poustchi-Amin M, Gutierrez FR, Brown JJ, Mirowitz SA, Narra VR, Takahashi N, Woodard PK. Performing cardiac MR imaging: an overview. Magn Reson Imaging Clin N Am. 2003 Feb;11(1):1-18.
- Reicheck N. Cardiac Magnetic Resonance Imaging and Core Cardiology Training II (COCATS-2) – Can we get there from here. J Am Coll Cardiol. 2004 Jun 2; 43(11):2112-15.
- Taylor AJ, Udelson JE, Fuster V. Training Cardiovascular Fellows in Cardiovascular Magnetic Resonance and Vascular Imaging. J Am Coll Cardiol. 2004 Jun 2; 43(11):2108-12.