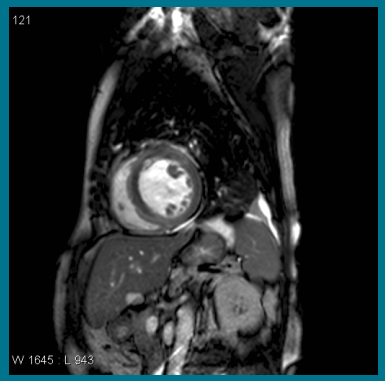
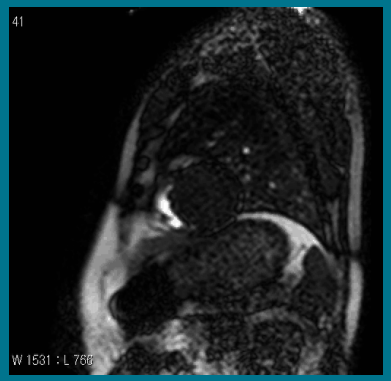
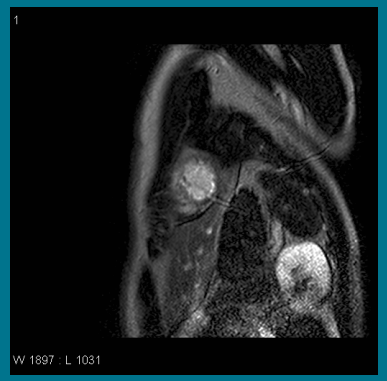
Journées Francophones d'Imagerie Médicale

Cardiac MRI for evaluation of Ischemic Heart Disease







Nguyen Khoi Viet, MD

Department of Radiology

Bach Mai Hospital

Cardiac MR for Ischemic Heart Disease

- Introduction
- CMR Techniques for IHD
- Evaluation of cardiac function
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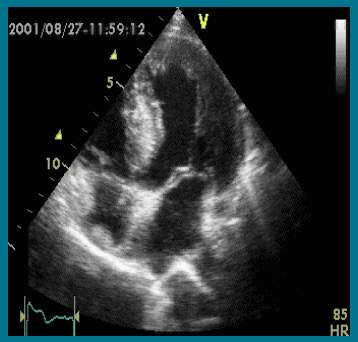
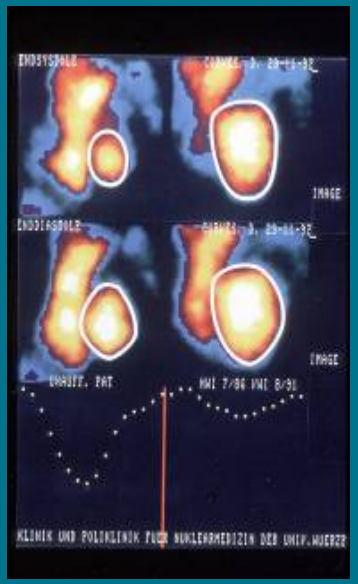
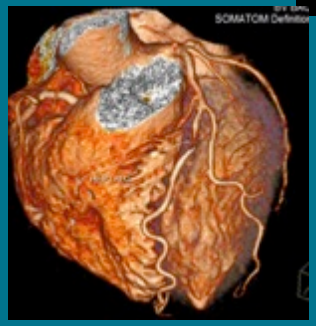
- Challenges and Future Aspects
- Conclusion

Imaging in Ischemic Heart Disease





- Chest X-ray
- Echocardiography
- Nuclear scintigraphy
- Catheterisation



- MDCT

- Cardiac MRI

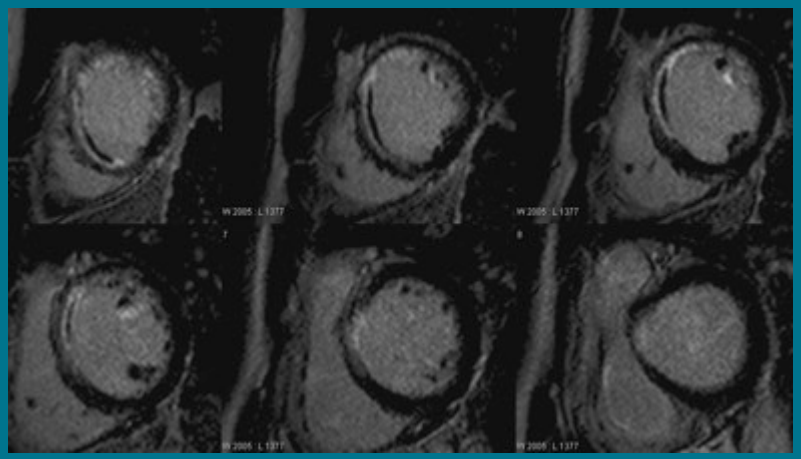
Resolution

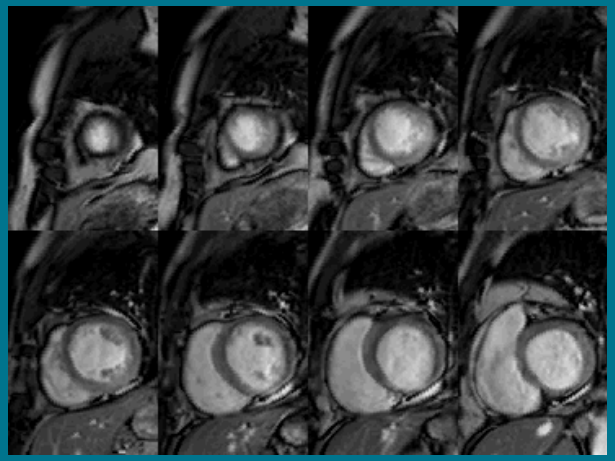
Information Radiation

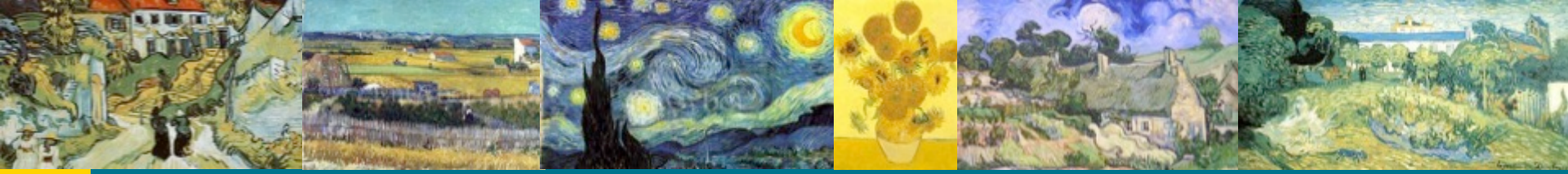
Invasiveness

Potential Merit of Cardiac MR for IHD

- **"One-stop exam" for IHD:**
  - morphology, function, perfusion, viability, coronary artery…
- Detection of myocardial infarction
  - for the evaluation of myocardial viability
- Accurate evaluation of cardiac morphology and function
  - reference of standard
- No radiation, high spatial resolution and temporal resolution, no invasive







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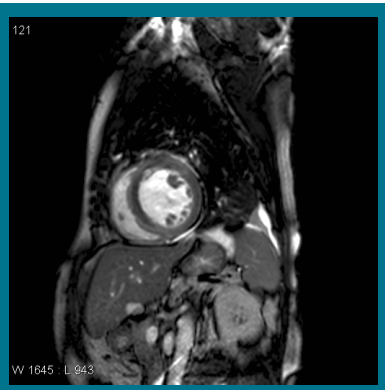
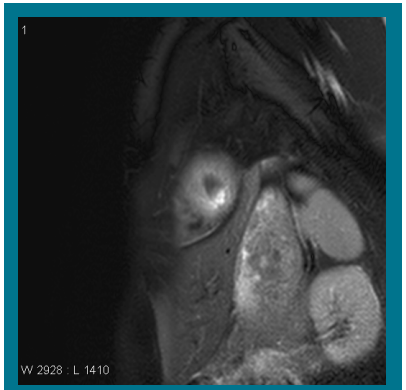
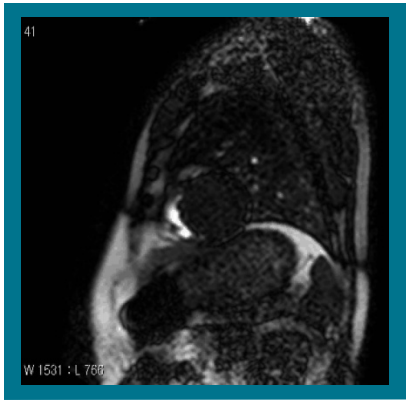
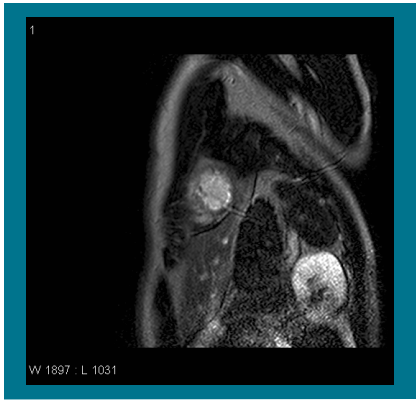
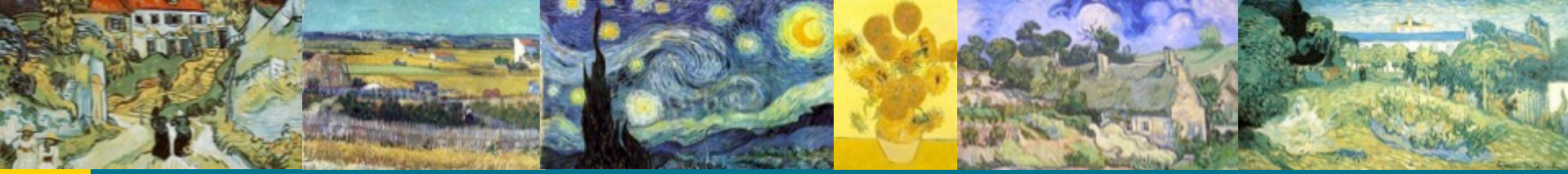
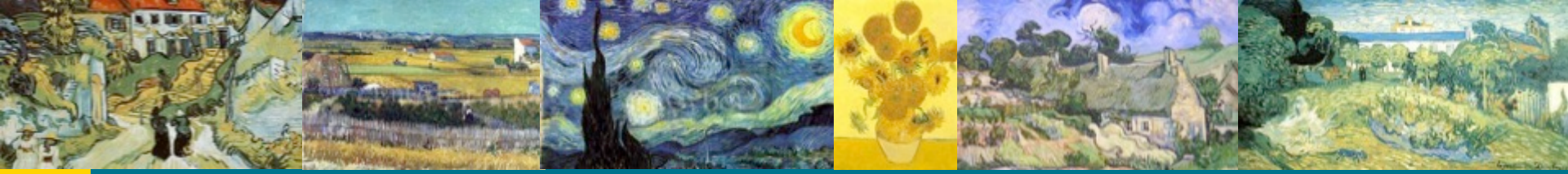
CMR Techniques for IHD

			
Cine MRI (Rest/Stress)	T2-MRI	Perfusion MRI (Rest/Stress)	DE-MRI
Contractile function	Myocardial edema	Myocardial blood flow	Myocardial necrosis
Systolic function/ Ischemia/Viability	Infarct age/ Area at risk	Myocardial ischemia	Infarct size/ Viability



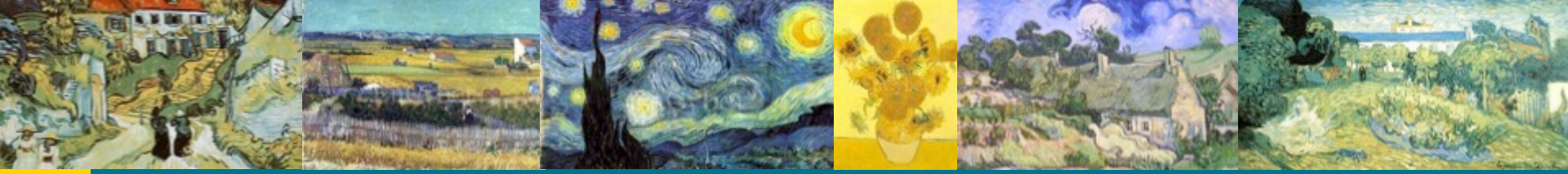
Stress CMR: Types of Stress

- Exercise
- Dobutamine
- Atropine
- Adenosine
- Dipyridamole

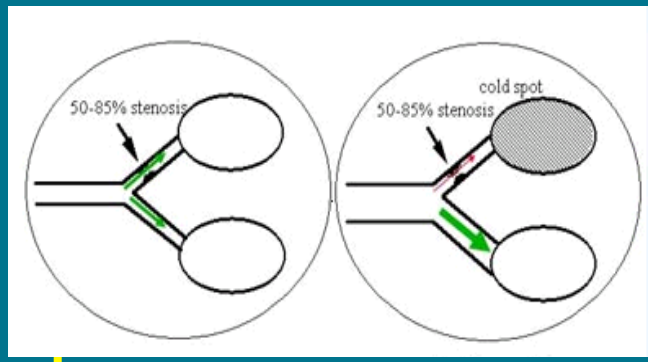


Stress CMR: Types of Stress

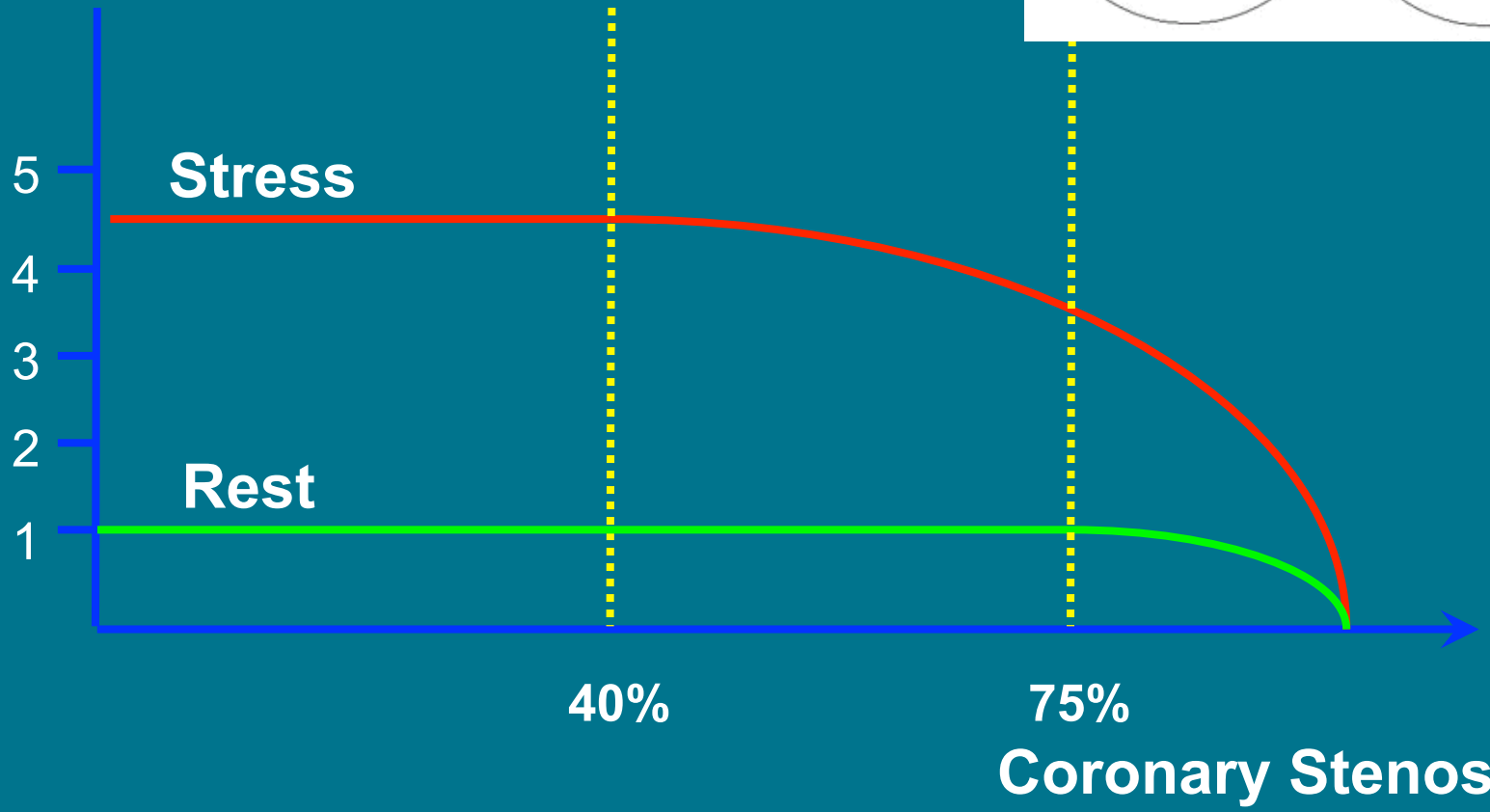
Stress test	Protocol
Low dose Dobutamine (for viability)	5,10,20 µg/kg/min for 3 minutes (half-life: 2 min) ♪
High dose Dobutamine (for ischemia)	30,40 µg/kg/min for 3 minutes ♪
Atropine	up to 1 mg
Adenosine	140 µg/kg/min for 3 minutes (half-life: 10 sec)
Dipyridamole	0.56 mg/kg/min for 4 minutes (half-life: 30 min) ♪

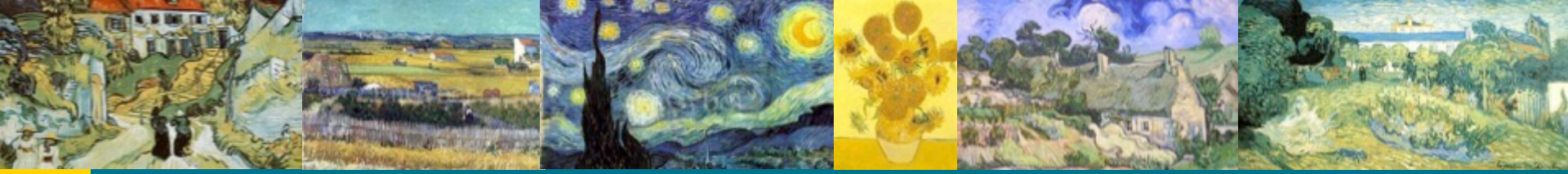


CMR Techniques: Stress MR

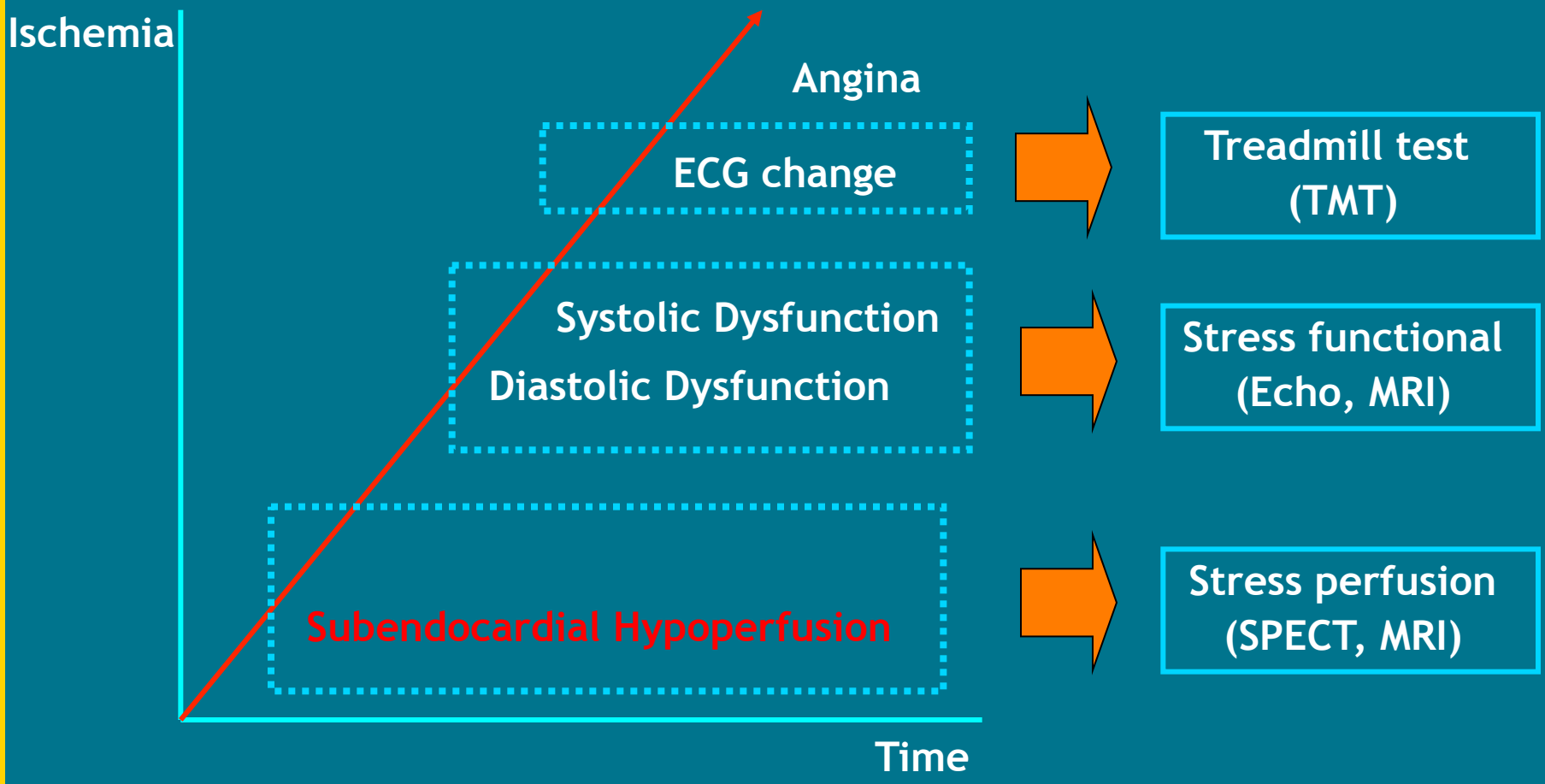


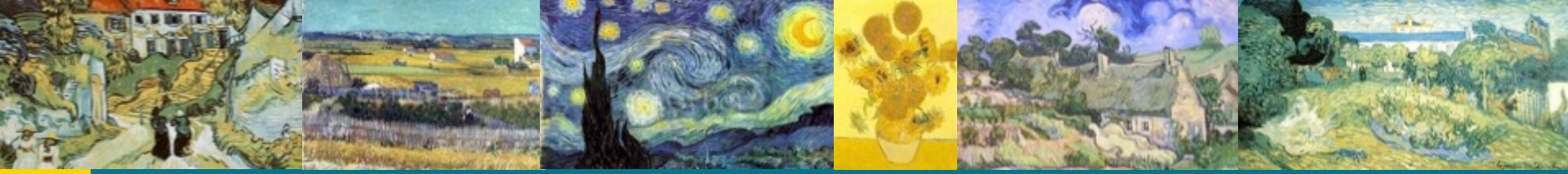
Relative Perfusion



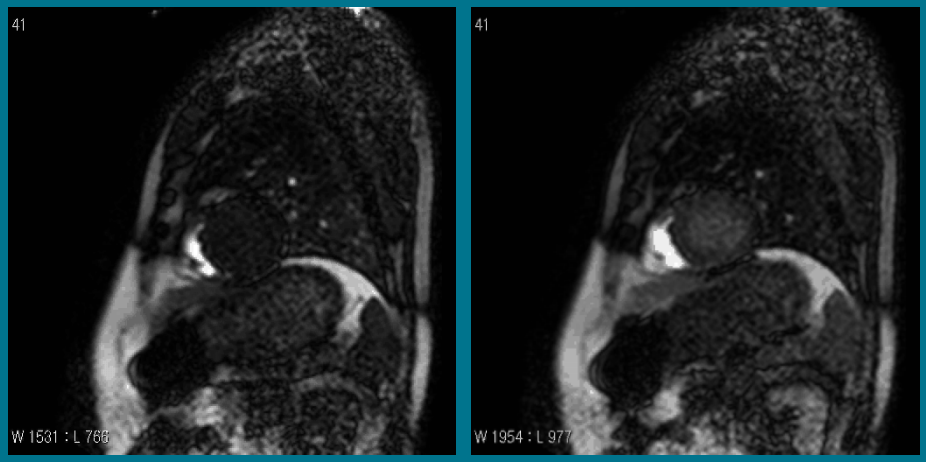


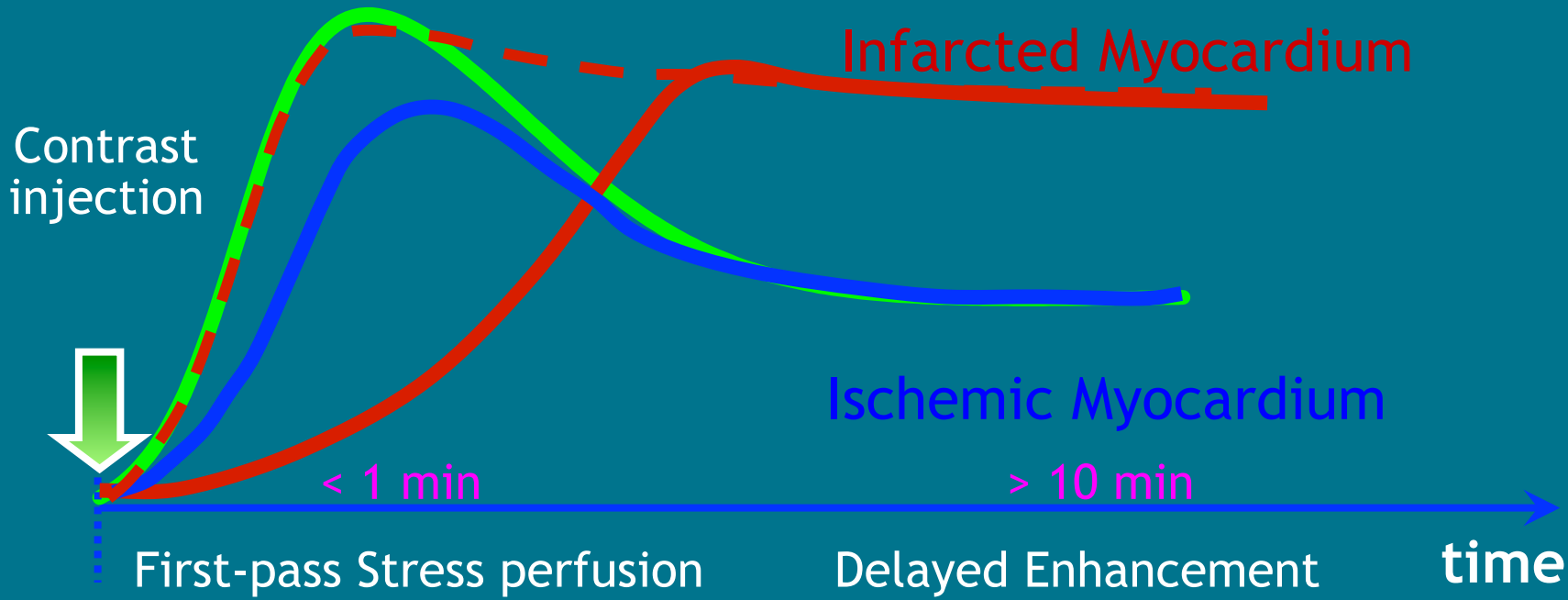
CMR Techniques: Stress MR



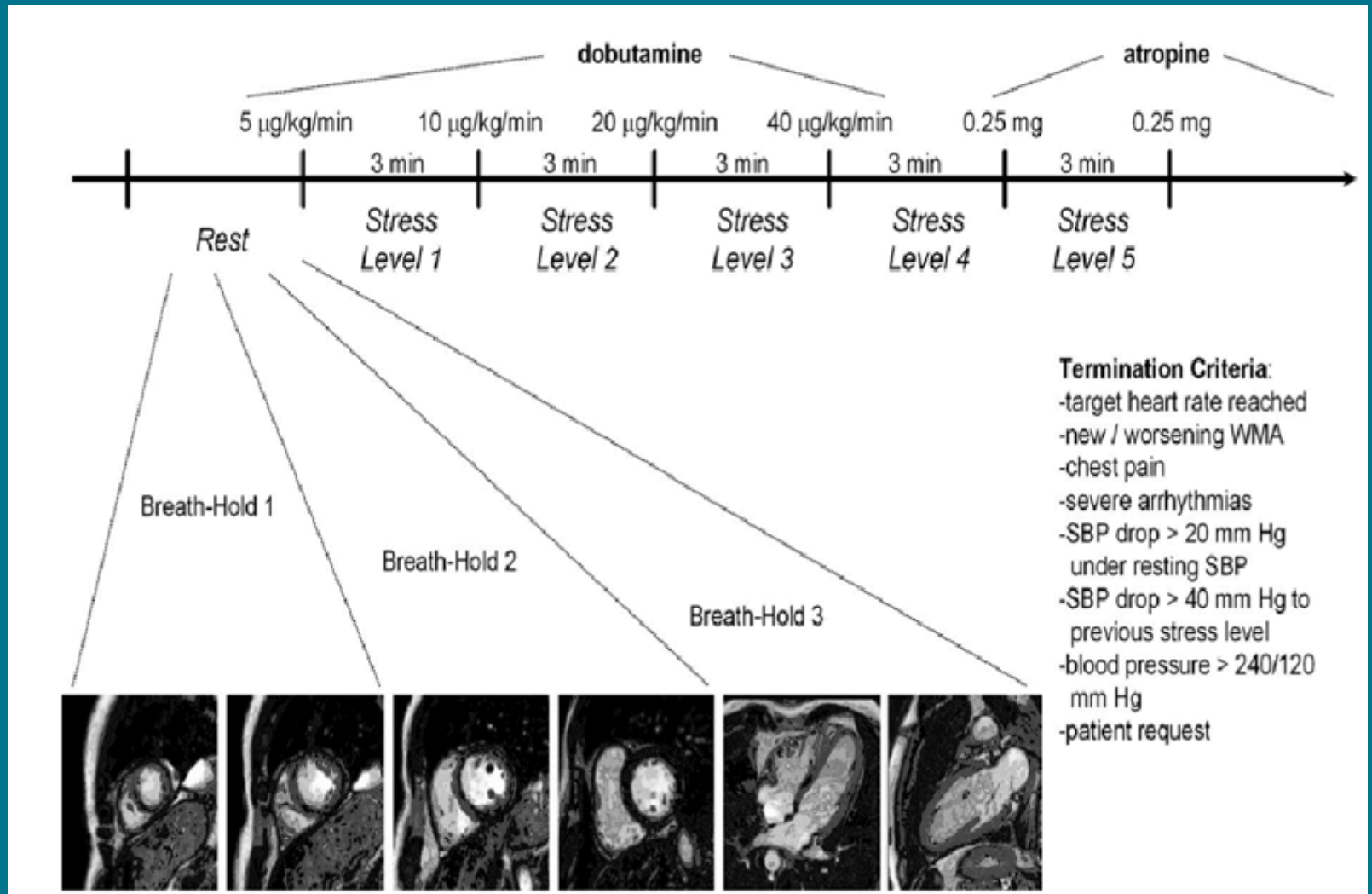


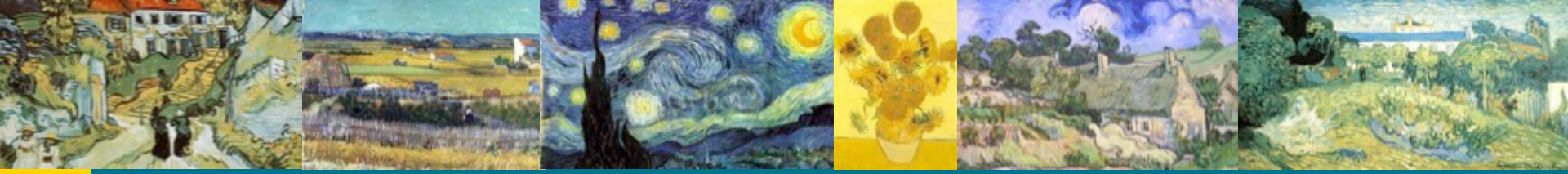
CMR Techniques: Stress Perfusion MR



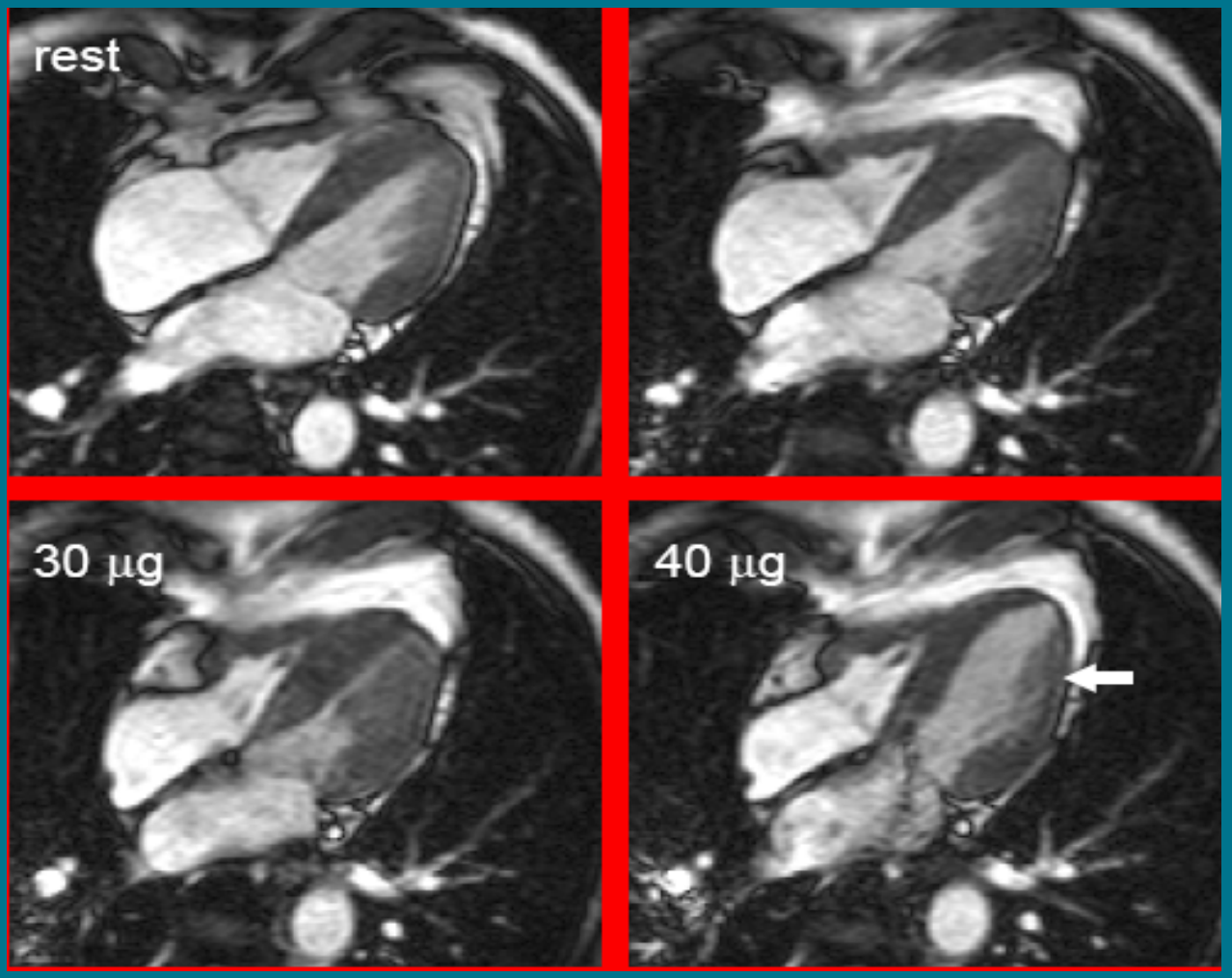


CMR Techniques: Dobutamine MR

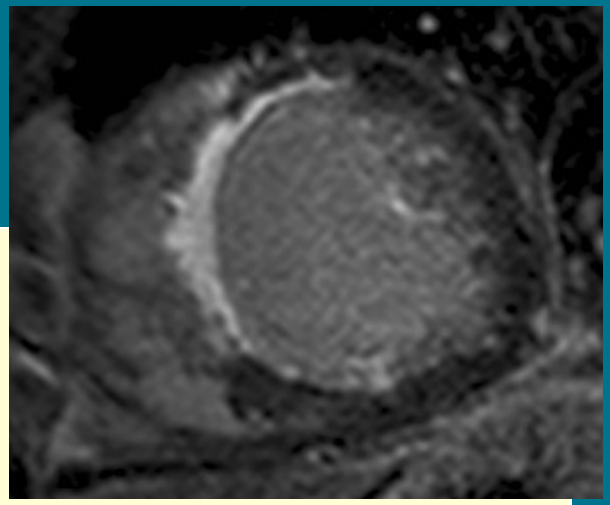




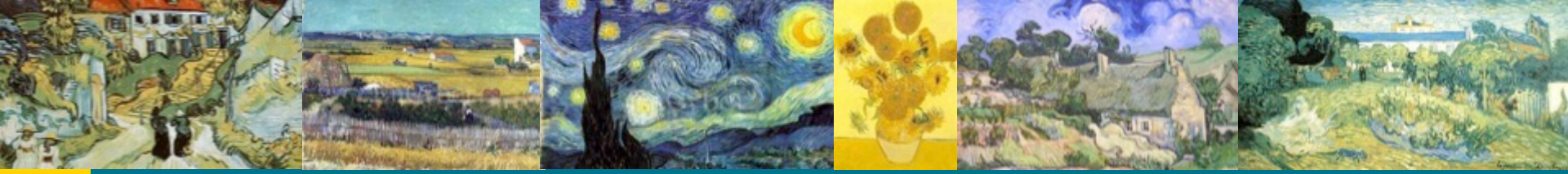
CMR Techniques: Dobutamine MR



Delayed Enhancement: kinetics of contrast agent

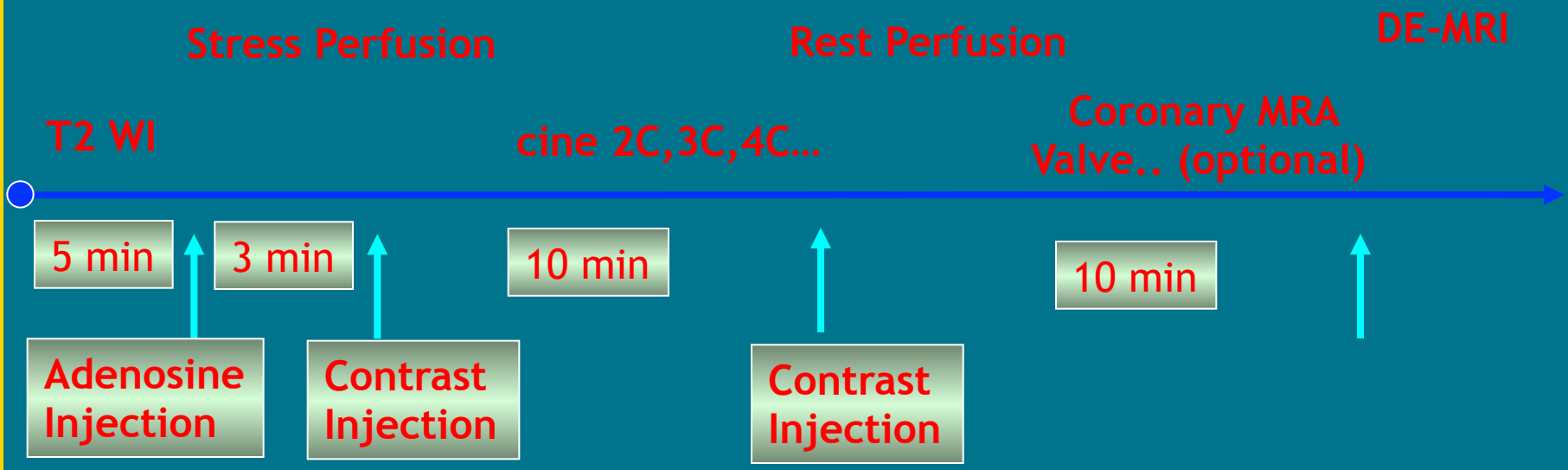


The contrast washout for damaged cells evolves much slower than the washout of the non-damaged (viable) myocardium.



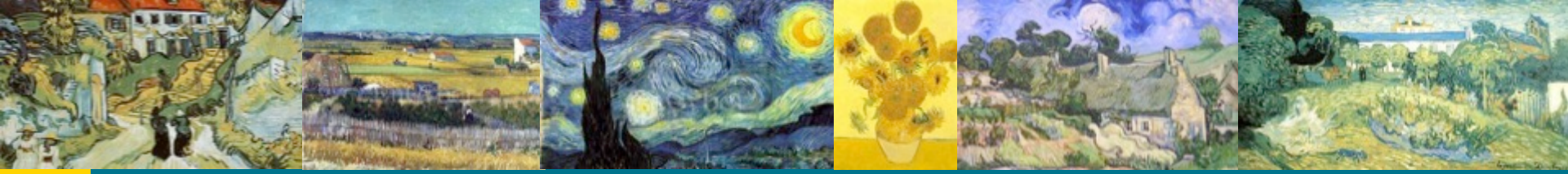
CMR Techniques for IHD

Combined MR Protocol of Bach Mai hospital for Ischemic Heart Disease



Adenosine: 140 μg/kg/min in 3 min

Gadolinium 0.05 mmol/kg-5ml/s



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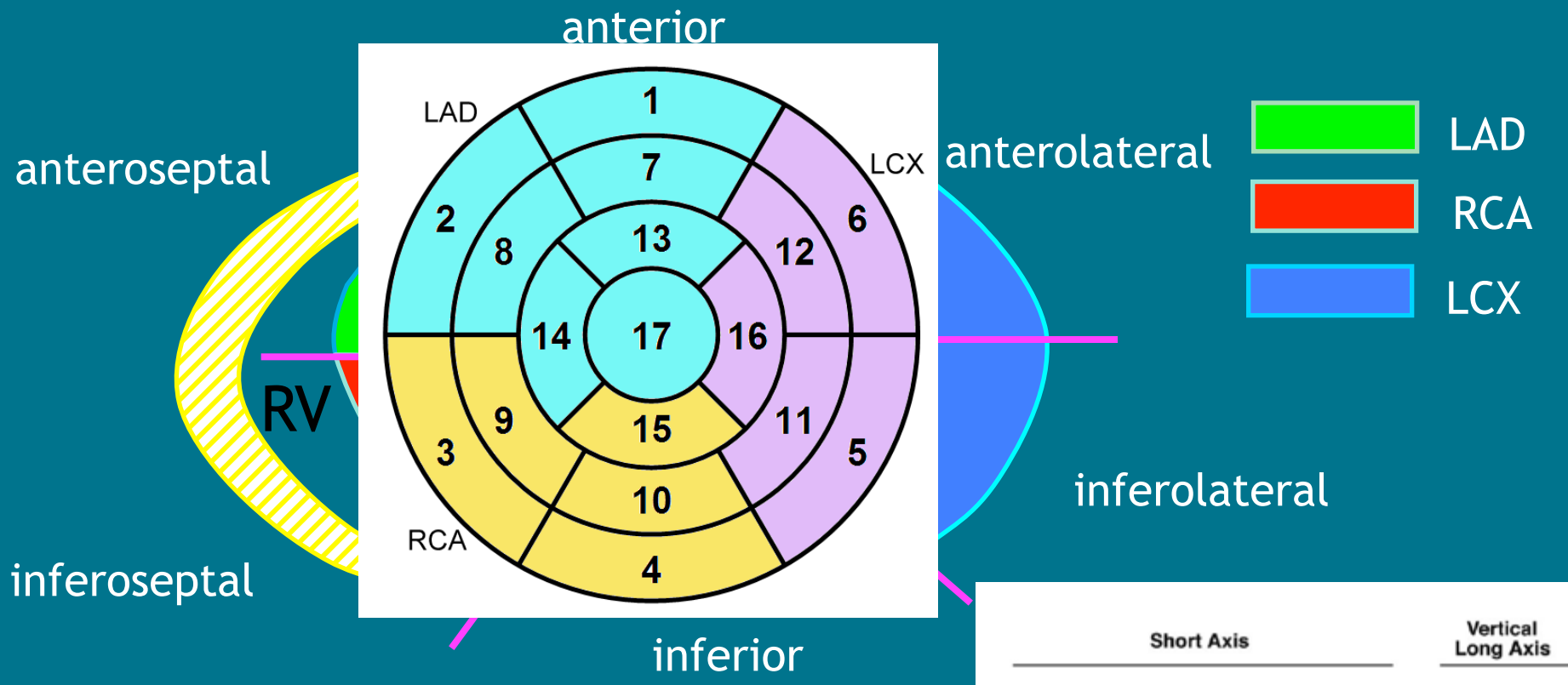
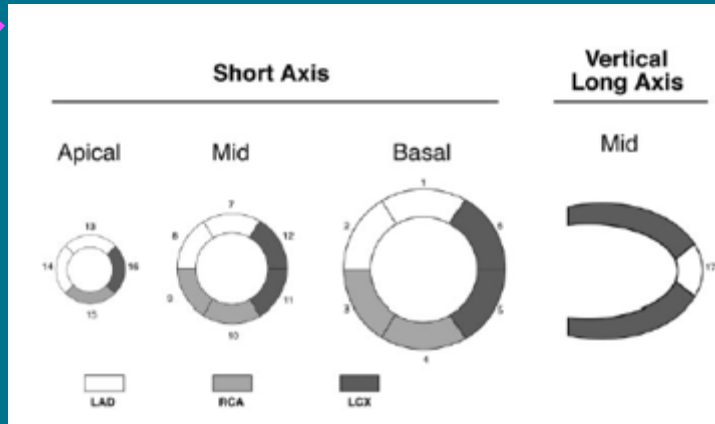
Myocardial Segmentation

Vascular Territory



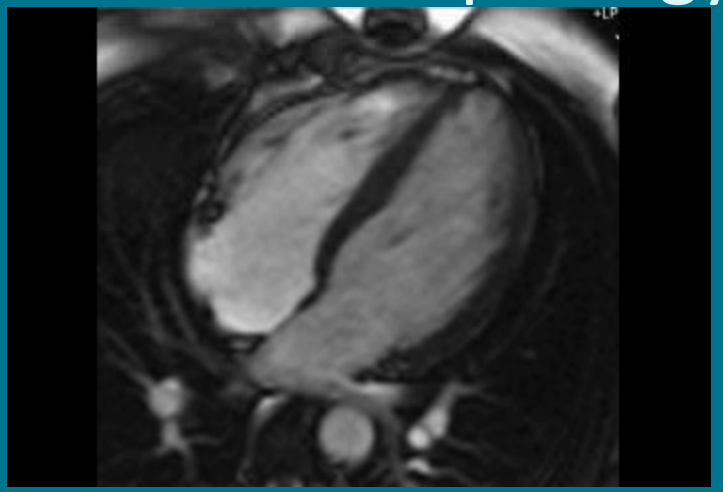
Mid and Basal section



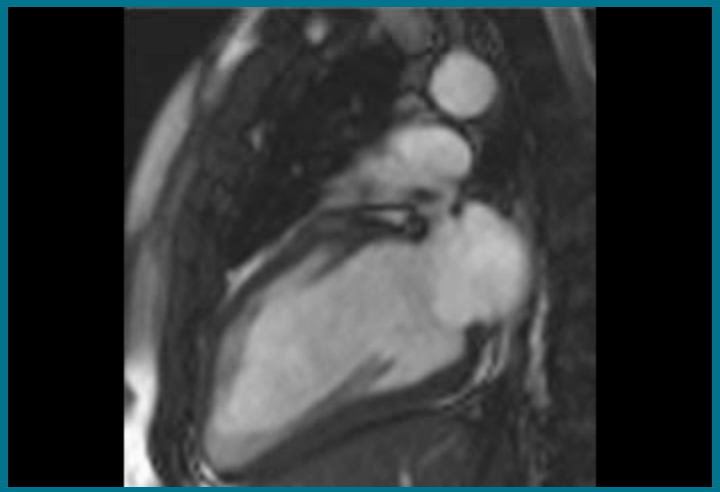
Cerqueira et al, Circulation. 2002; 105: 539-542

Evaluation of cardiac function and morphology

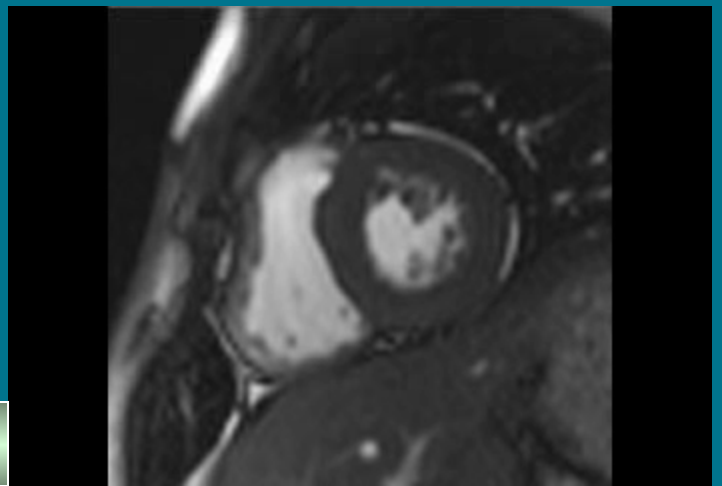
- Reference of standard
- Global systolic function
- Regional systolic motion



4C cine

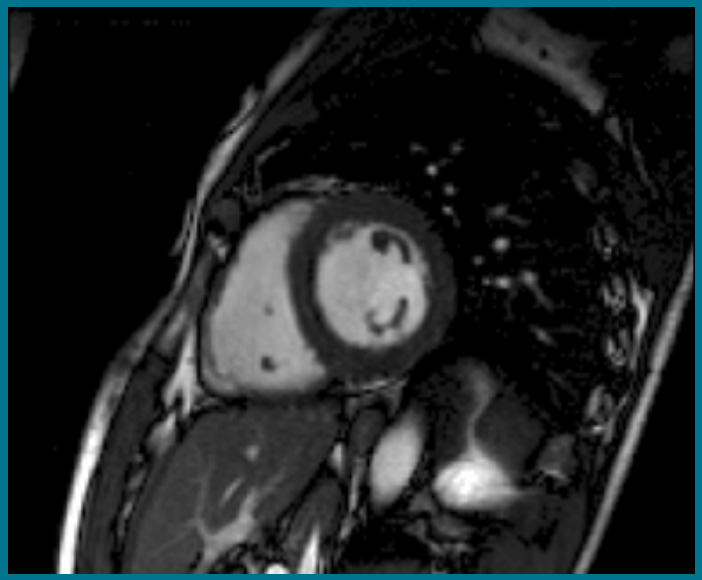


2C cine SSFP

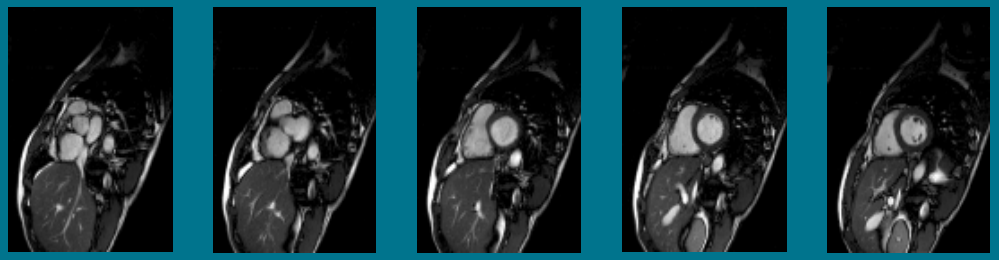


Short axis

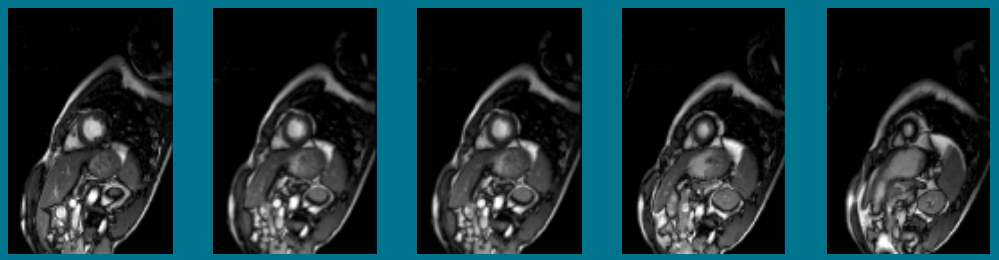
Short axis



Stack of short axes

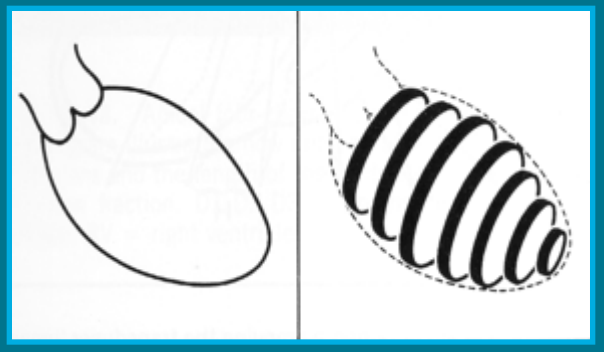


Base +10mm +20mm +30mm +40mm

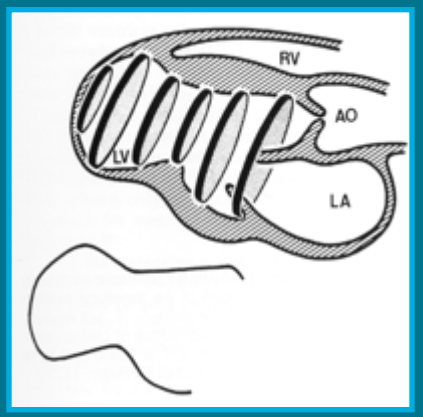


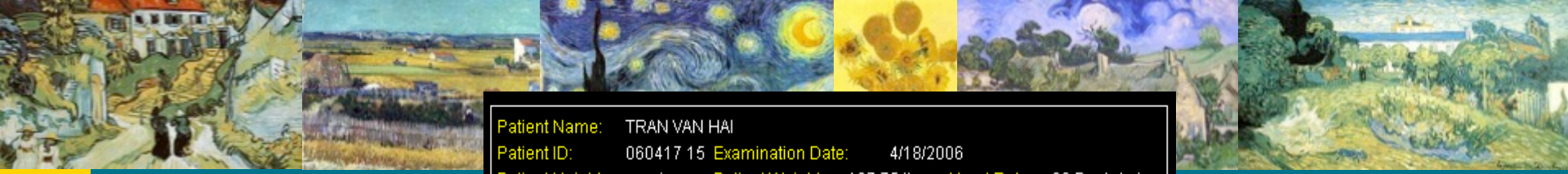
Apex

+50mm +60mm +70mm +80mm
+90mm



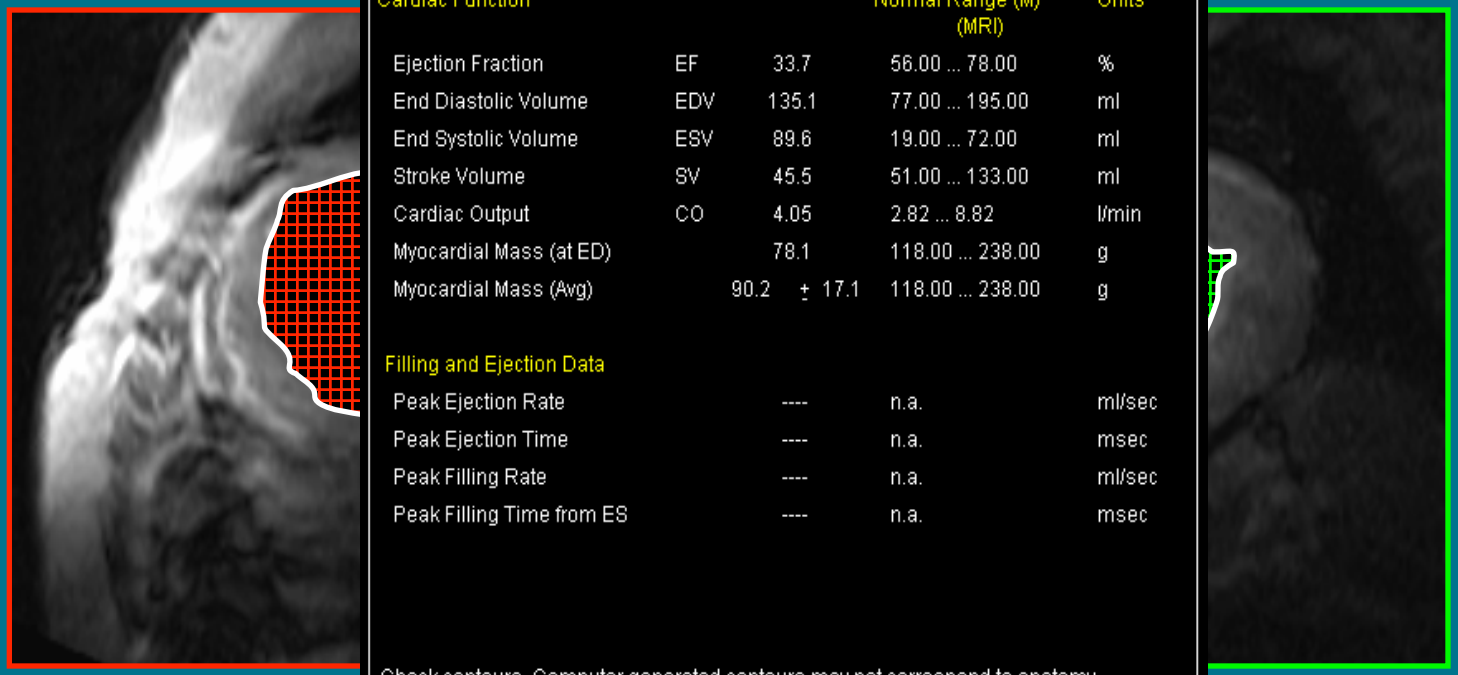
Simpson's Rule





Global sys ... action

end diastole



end systole

Patient Name: TRAN VAN HAI
Patient ID: 060417 15 Examination Date: 4/18/2006
Patient Height: ---- in. Patient Weight: 127.75 lbs. Heart Rate: 89 Beats/min

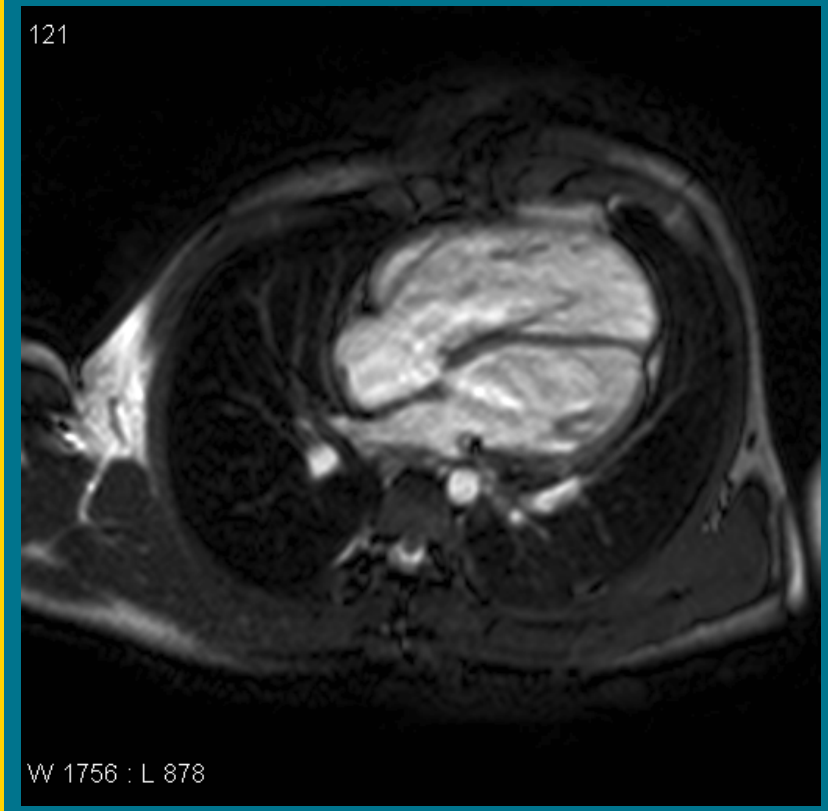
Left Ventricle - Absolute

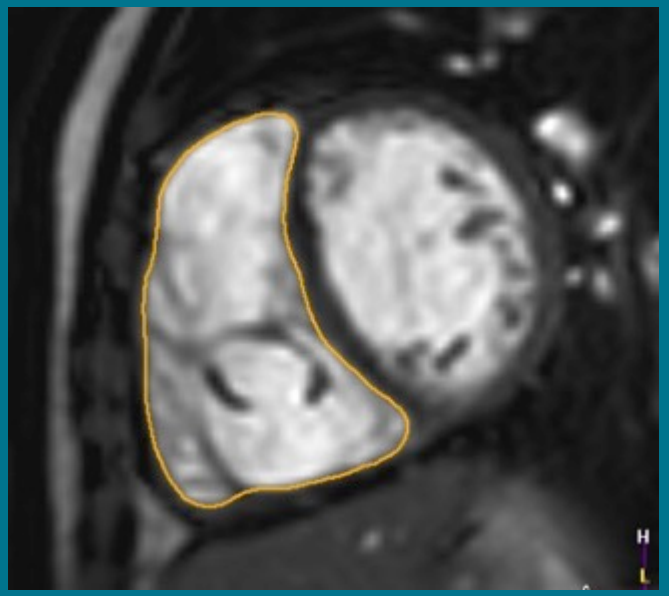
Cardiac Function			Normal Range (M) (MRI)	Units
Ejection Fraction	EF	33.7	56.00 ... 78.00	%
End Diastolic Volume	EDV	135.1	77.00 ... 195.00	ml
End Systolic Volume	ESV	89.6	19.00 ... 72.00	ml
Stroke Volume	SV	45.5	51.00 ... 133.00	ml
Cardiac Output	CO	4.05	2.82 ... 8.82	l/min
Myocardial Mass (at ED)		78.1	118.00 ... 238.00	g
Myocardial Mass (Avg)		90.2 ± 17.1	118.00 ... 238.00	g
Filling and Ejection Data				
Peak Ejection Rate		----	n.a.	ml/sec
Peak Ejection Time		----	n.a.	msec
Peak Filling Rate		----	n.a.	ml/sec
Peak Filling Time from ES		----	n.a.	msec

Check contours. Computer generated contours may not correspond to anatomy.

$$\text{Ejection fraction} = \frac{EDV - ESV}{EDV} = \frac{SV}{EDV} \; [\times 100\%]$$

Global systolic function- RV



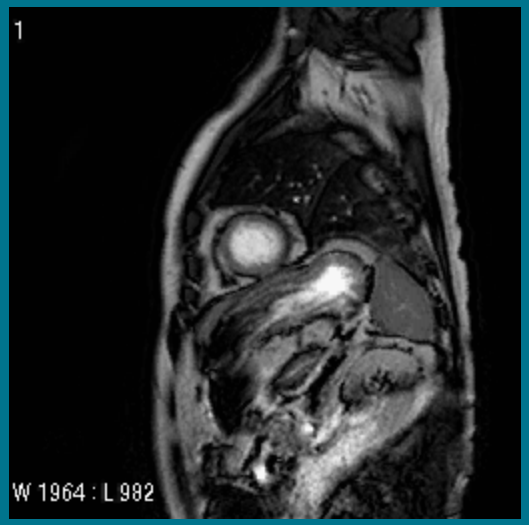


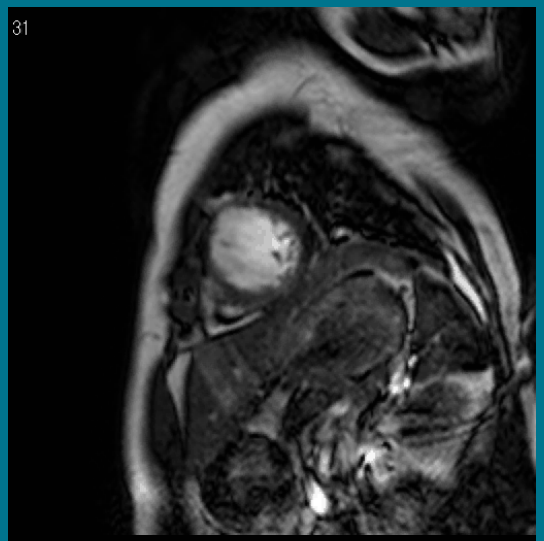
RV analysis: RV Rest analysis (not validated)

Ejection fraction	:	48.6 %	
Stroke volume	:	88.9 ml	
Cardiac output	:	8.2 l/min	
ED phase	:	0.0 ms	(phase 1)
ED volume	:	182.9 ml	
ES phase	:	284.0 ms	(phase 14)
ES volume	:	94.0 ml	
ED wall mass	:	n/a	
ED wall + papillary mass	:	n/a	
ED wall - correct. mass	:	n/a	
ED wall + papillary - correct. mass	:	n/a	
Heart rate	:	92.0 bpm	

Regional systolic function: Wall thickening

Hypokinesia at inferior wall



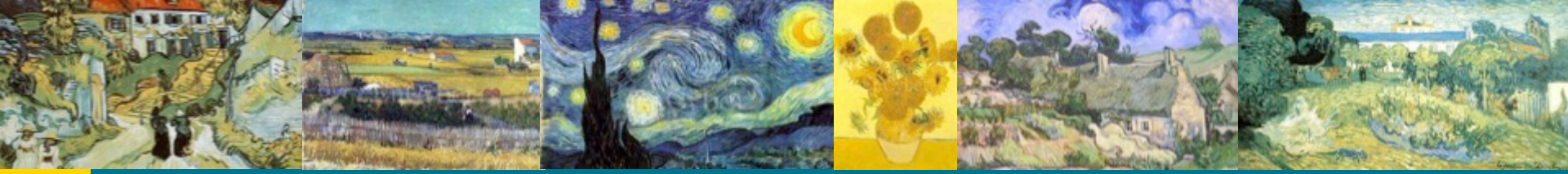


Akinesia at anterior and AS

Dyskinesia

Aneurysm

Various findings of abnormal wall motion on cine MRI.



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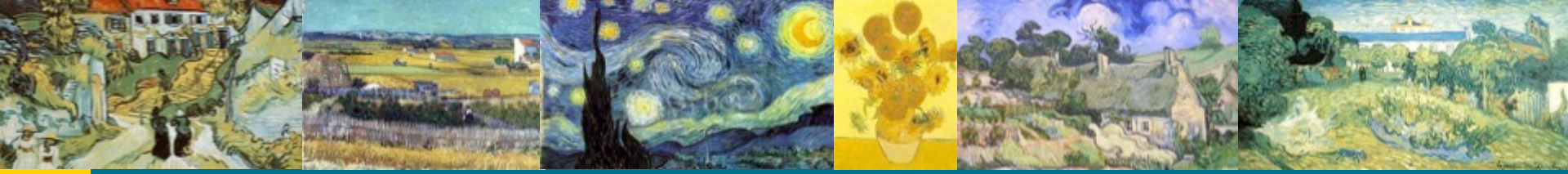
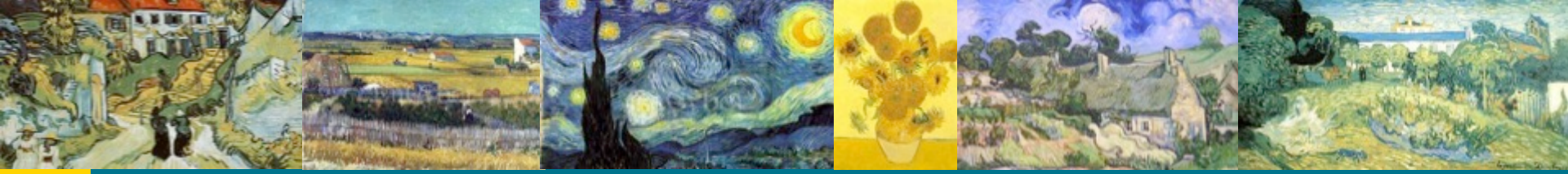


Accuracy of CMR for Detection of IHD

- Stress/rest Perfusion MRI
- Stress/rest Cine MRI
- Coronary MRA
- DE – MRI and viability
- Combined Method



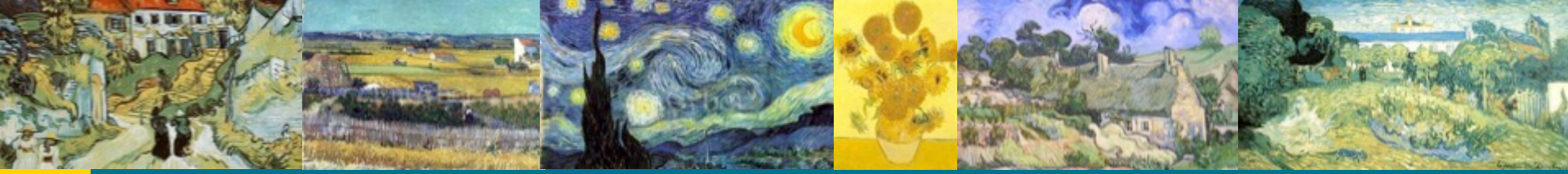
Accuracy of CMR for Detection of IHD

- Stress/rest Perfusion MRI for CAD

Author	Journal	Sensitivity	Specificity	n
Hartnell, G.	Am J Roent1994	92%	100%	18
Klein, M.A.	Am J Roent 1993	81%	100%	5
Al-Saadi, N.	Circulation 2000	92%	87%	40
Nagel, E	J CVMR 2000	90%	84%	139
Hamon, M (meta analysis)	J CMR 2010	90 (88-92%)	81 (78-84%)	1658

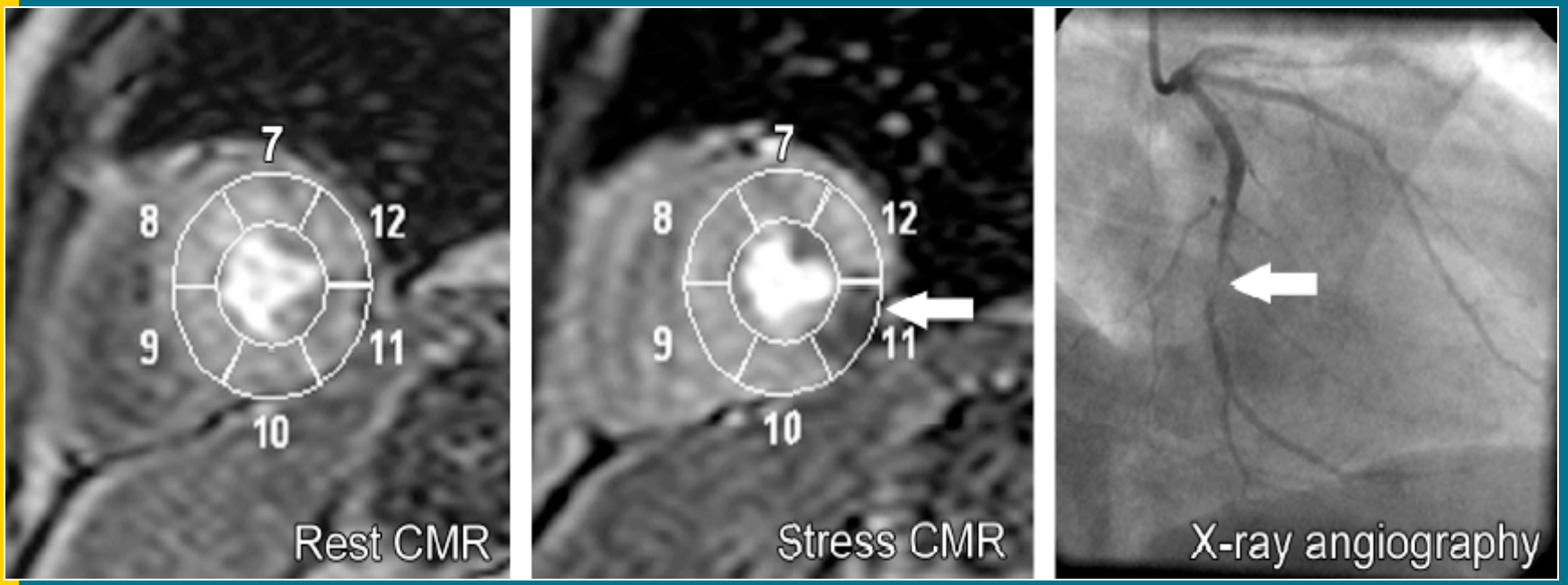
- Stress/rest Perfusion MRI for CAD
  - superior to SPECT (MR-IMPACT study)

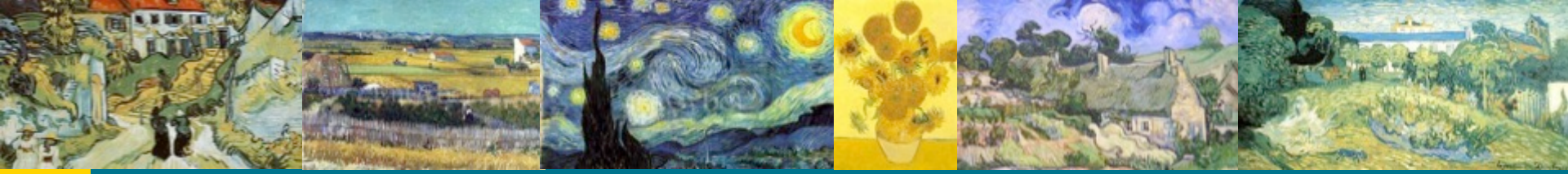
Schwitter J et al. Eur Heart J 2008; 29:480-489.



Accuracy of CMR for Detection of IHD

- Stress/rest Perfusion MRI for CAD

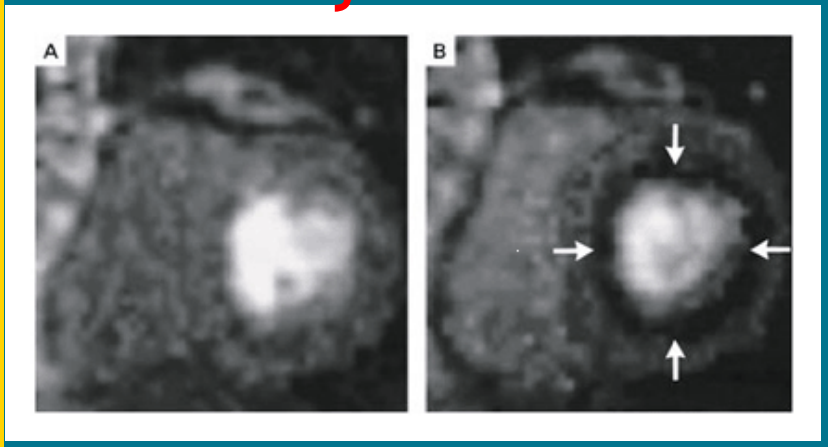




Accuracy of CMR for Detection of IHD- Differentiation

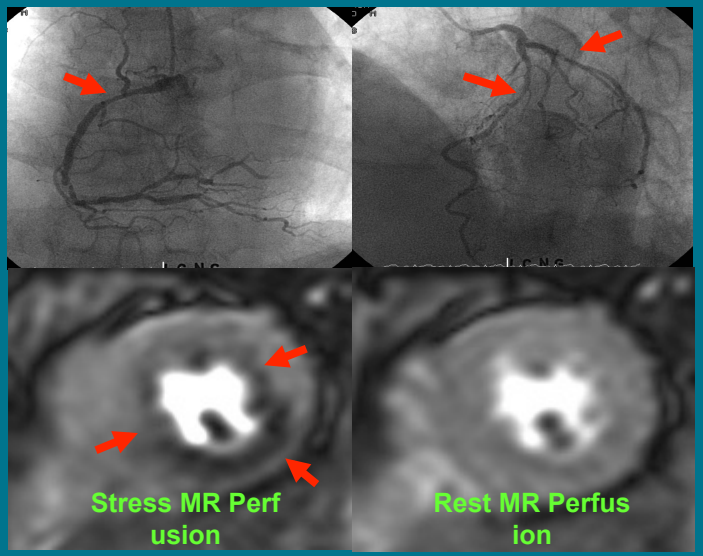
- Stress/rest Perfusion MRI for CAD
  - subendocardial perfusion defect !!

Syndrome-X

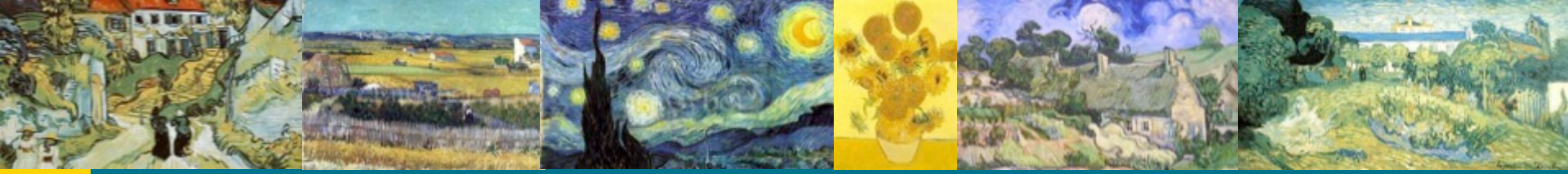


Panting et al. NEJM 2002

Balanced 3VD



Chung SY et al. Am J Roentgenol (Accepted)



Accuracy of CMR for Detection of IHD

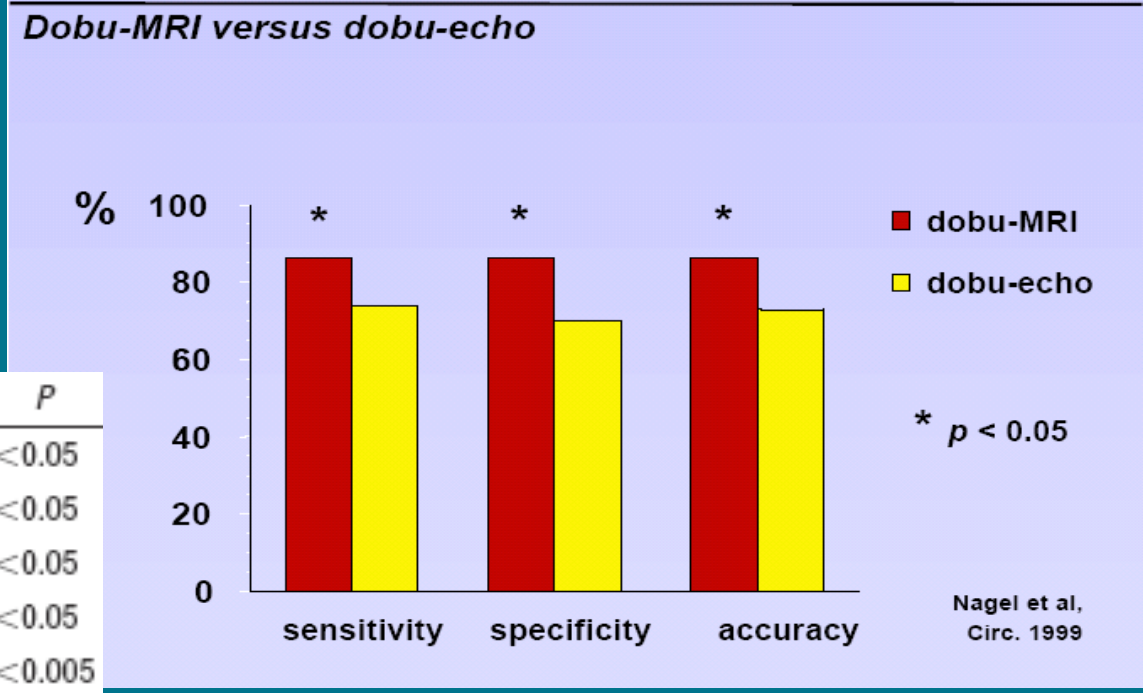
- High dose Dobutamine Cine MRI for CAD

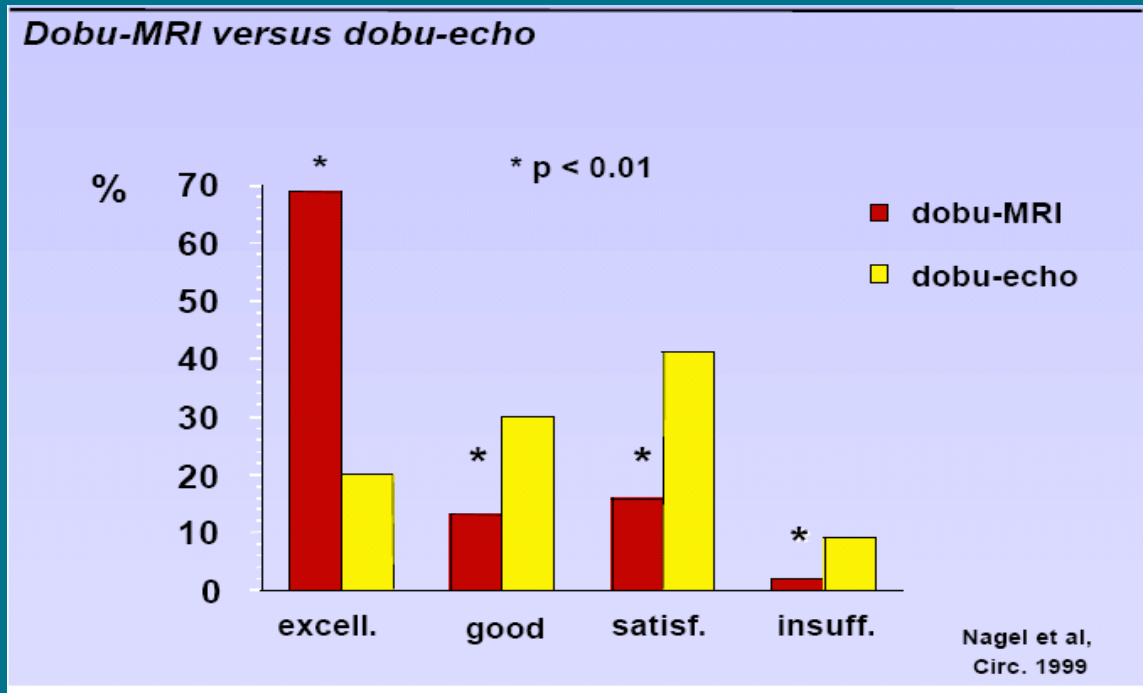
Author	Journal	Sensitivity	Specificity	n	dose
Pennell	Am J Cardiol 1992	91%	-	25	20
Baer	Eur Heart J 1994	85%	-	26	20
van Rugge	Circulation 1994	91%	80%	39	20
Nagel	Circulation 1999	86%	86%	208	40
Hundley	Circulation 1999	83%	83%	41	40

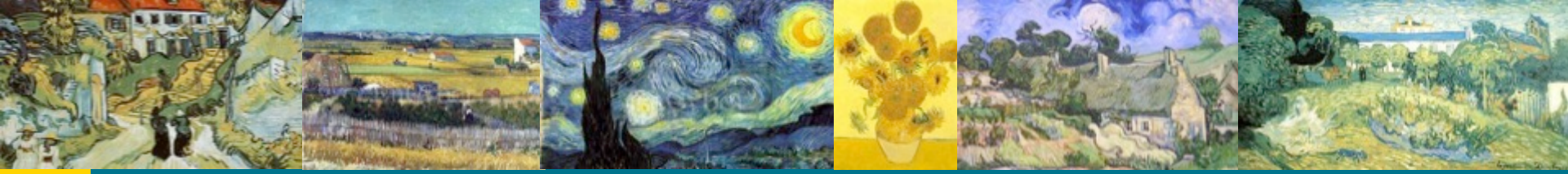
DOBU-ECHO vs DOBU-MRI

	DSE	DSMR	*P*
Sensitivity	74.3%	86.2%	<0.05
Specificity	69.8%	85.7%	<0.05
Positive predicting value	81.0%	91.3%	<0.05
Negative predicting value	61.1%	78.3%	<0.05
Accuracy	72.7%	86.0%	<0.005

Circulation 1999;99:763-770







Dobutamine Stress MR

Rest

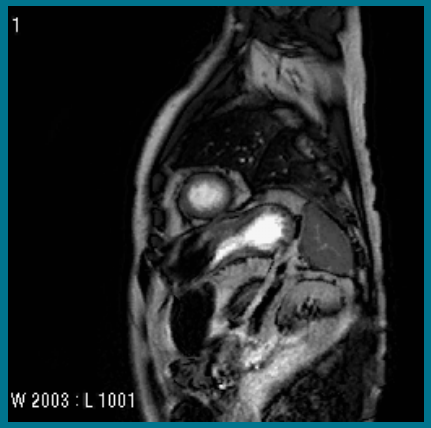
Low dose (10-20)

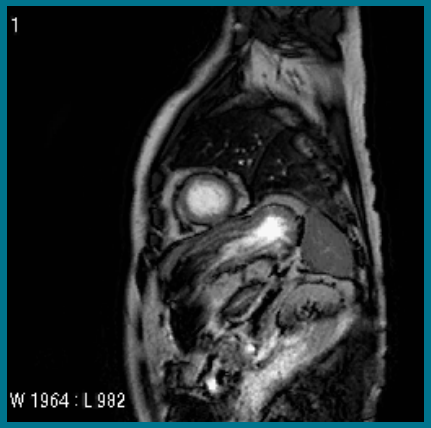
Contractile reserve

High dose (30-40 micro)

Inducible wall motion abnormality

Stress-induced Hypokinesia



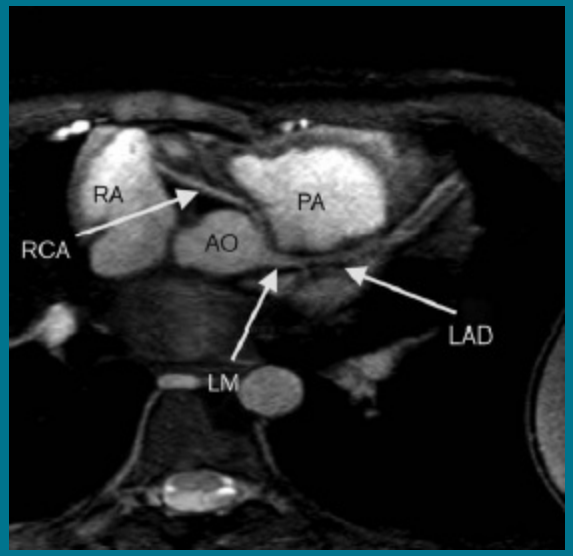


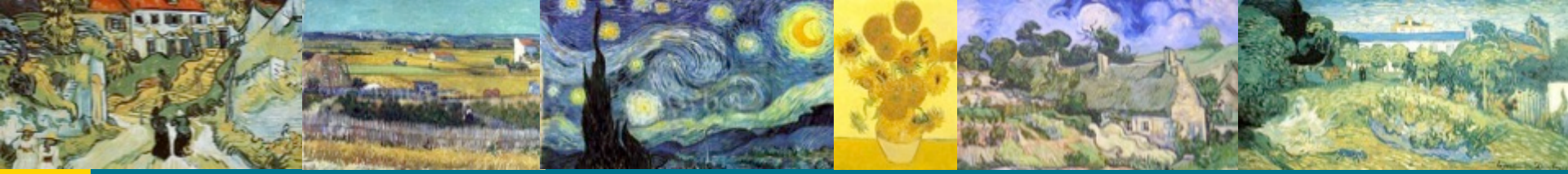
Accuracy of CMR for Detection of IHD

- Coronary MRA:
  - still developing technique, technical challenges
  - Evaluating congenital CA anomalies, aneurysm
  - for identification of native vessel coronary stenosis:

    currenly not sufficient to support coronary stenosis for routine screening except LM or multivessel disease

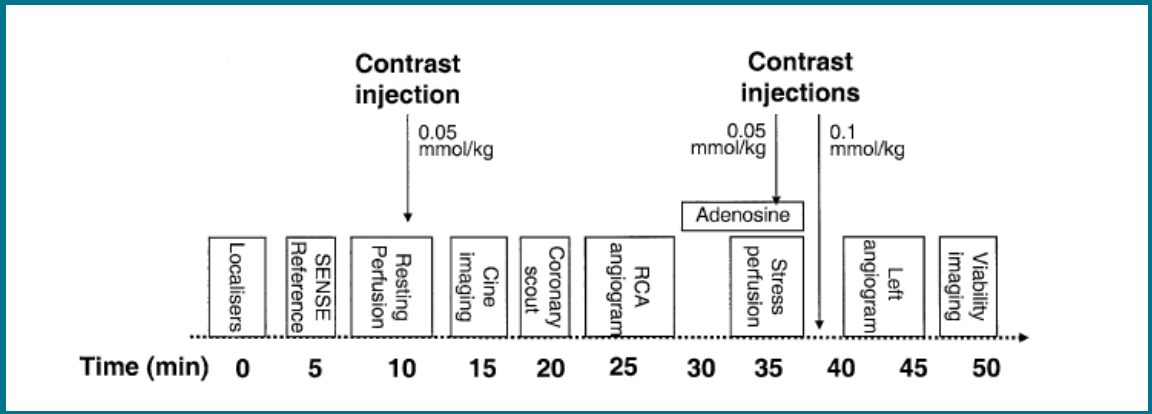
Evan Appelbaum et al, Lippincott Willam and Wilkins, 16:345-353





Accuracy of CMR for Detection of IHD

- Stress/rest perfusion
- Cine MRI
- Coronary MRA
- DE-MRI



Plein S et al. JACC 2004;44:2173-2181

Table 2. Comprehensive CMR Analysis and Analysis of Individual CMR Components for the Detection of the Presence of Significant CAD*

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Overall Accuracy (%)
Comprehensive analysis	96 (92–100)	83 (62–100)	96 (91–100)	83 (62–100)	94 (88–100)
Individual component analysis					
Perfusion	88 (79–96)	83 (62–100)	96 (91–100)	59 (35–82)	87 (79–95)
Coronaries	84 (74–94)	75 (51–100)	94 (87–100)	50 (27–73)	82 (73–92)
Wall motion	68 (56–80)	75 (51–100)	93 (85–100)	50 (27–73)	69 (58–80)
Late contrast enhancement	57 (44–70)	83 (62–100)	94 (86–100)	42 (25–58)	62 (50–73)

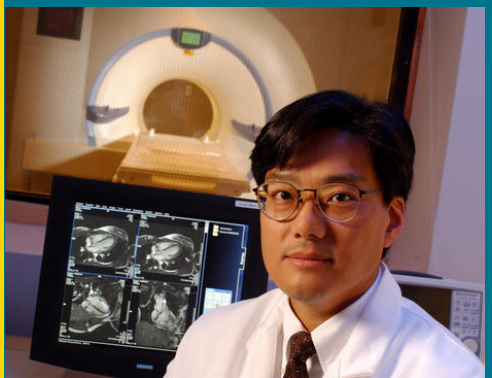
Delayed Enhancement MRI

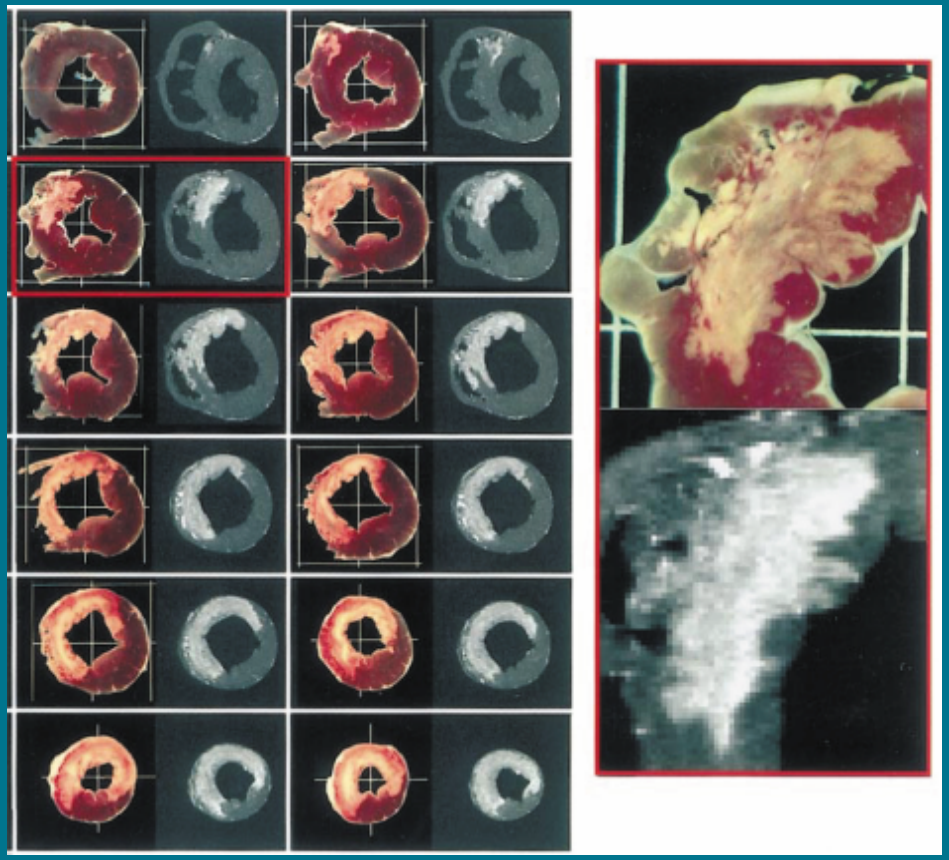
10-15 min after Gd

Area of delayed enhance ment

= nonviable myocardium

"Bright is dead"

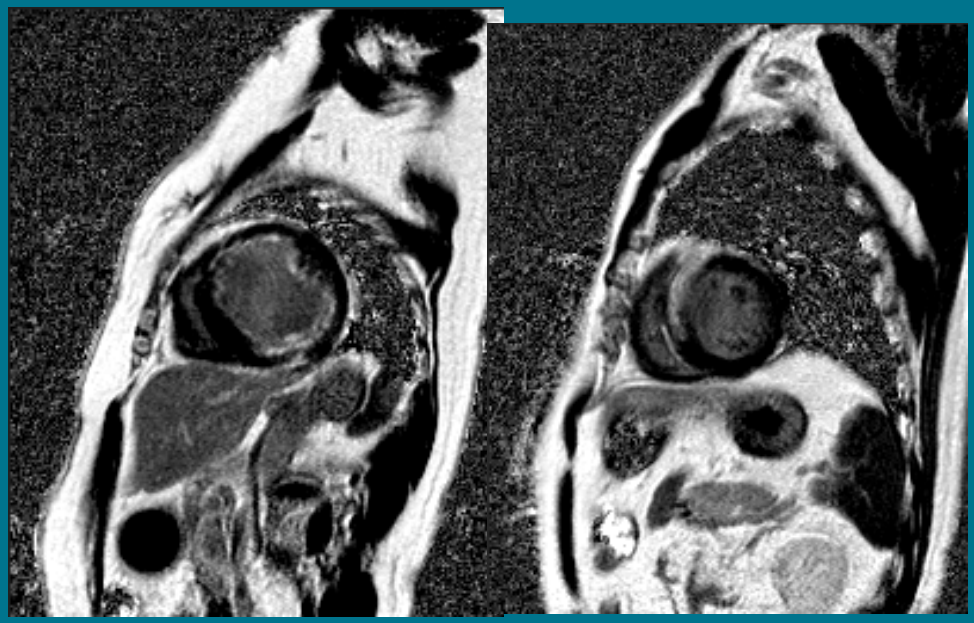


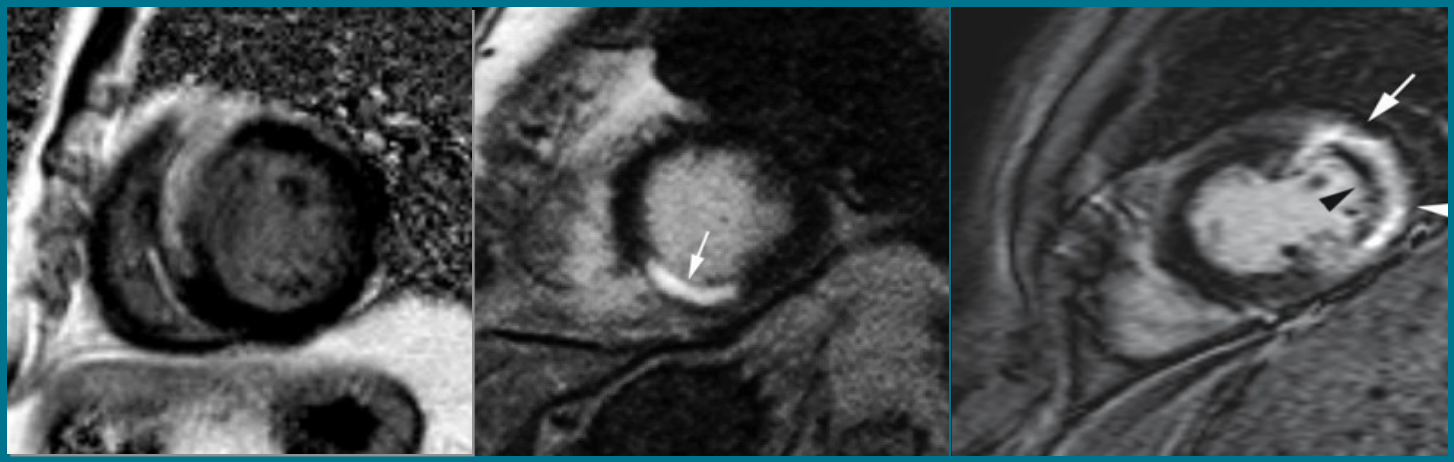


Kim R et al, Circulation 1999

Clinical Impact: Myocardial Infarction

- Subendocardial and transmural enhancement
- Limited to a vascular territory





Kim RJ et al, Circulation 1999

Patterns of Delayed enhancement

Mesocardial
- Hypertrophic cardiomyopathy
- Dilated cardiomyopathy
- Pulmonary hypertension

Subendocardial

Vascular
- Infarction

Non-vascular
- Amyloid
- Hypereosinophilic syndrome
- Histiocytoid cardiomyopathy
- Cardiac transplant

Patchy
- Sarcoid
- Amyloid
- Myocarditis

Subepicardial
- Myocarditis *(most common)*
- Sarcoid

Transmural
- Infarction *(most common)*
- Myocarditis, severe
- Sarcoid, chronic

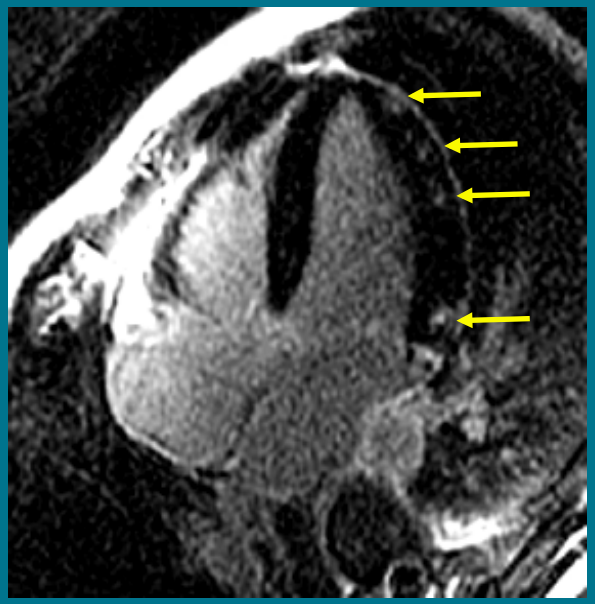
Figure 17. Chart illustrates the differential diagnosis of delayed contrast enhancement at cardiac MR imaging by location.

Kristopher W. Cummings et al, Radiographics, 2009

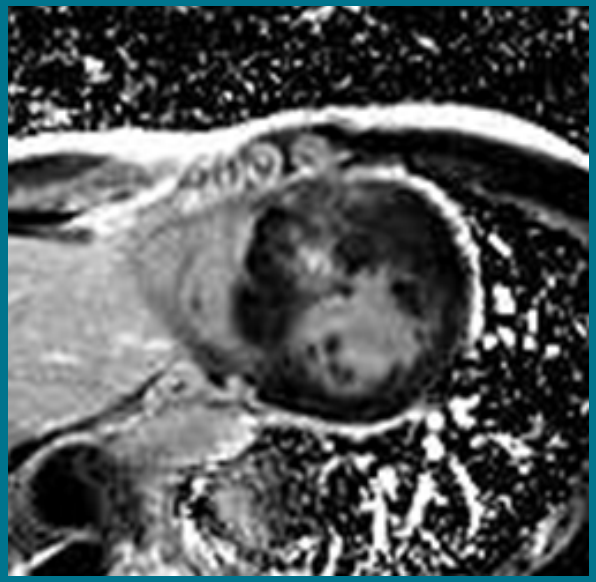
Patterns of Delayed enhancement

Not specific for ischemic injury

Acute Myocarditis

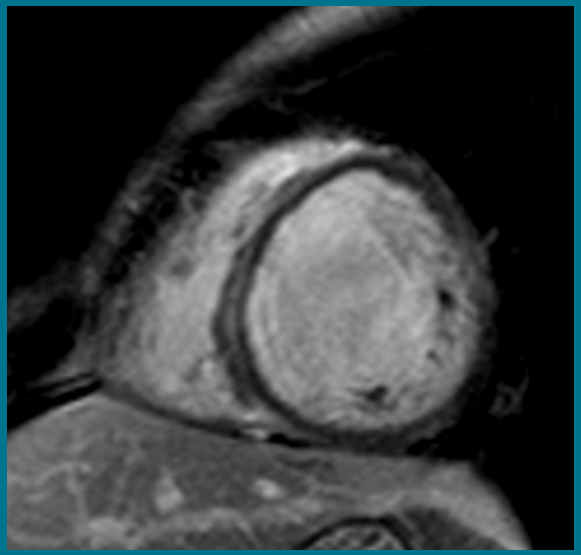


HCM: Fibrosis

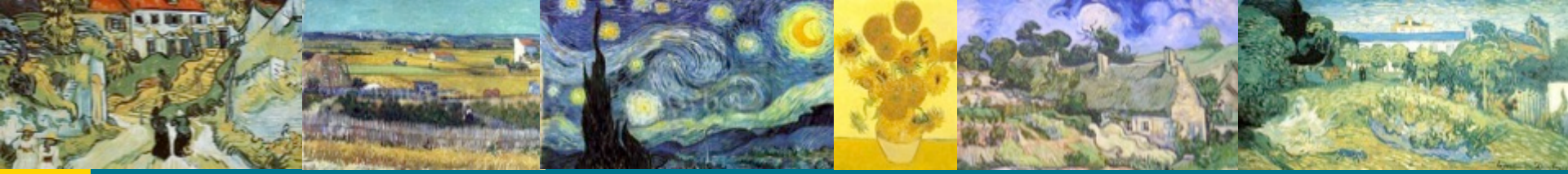


M25, chest pain 4 months

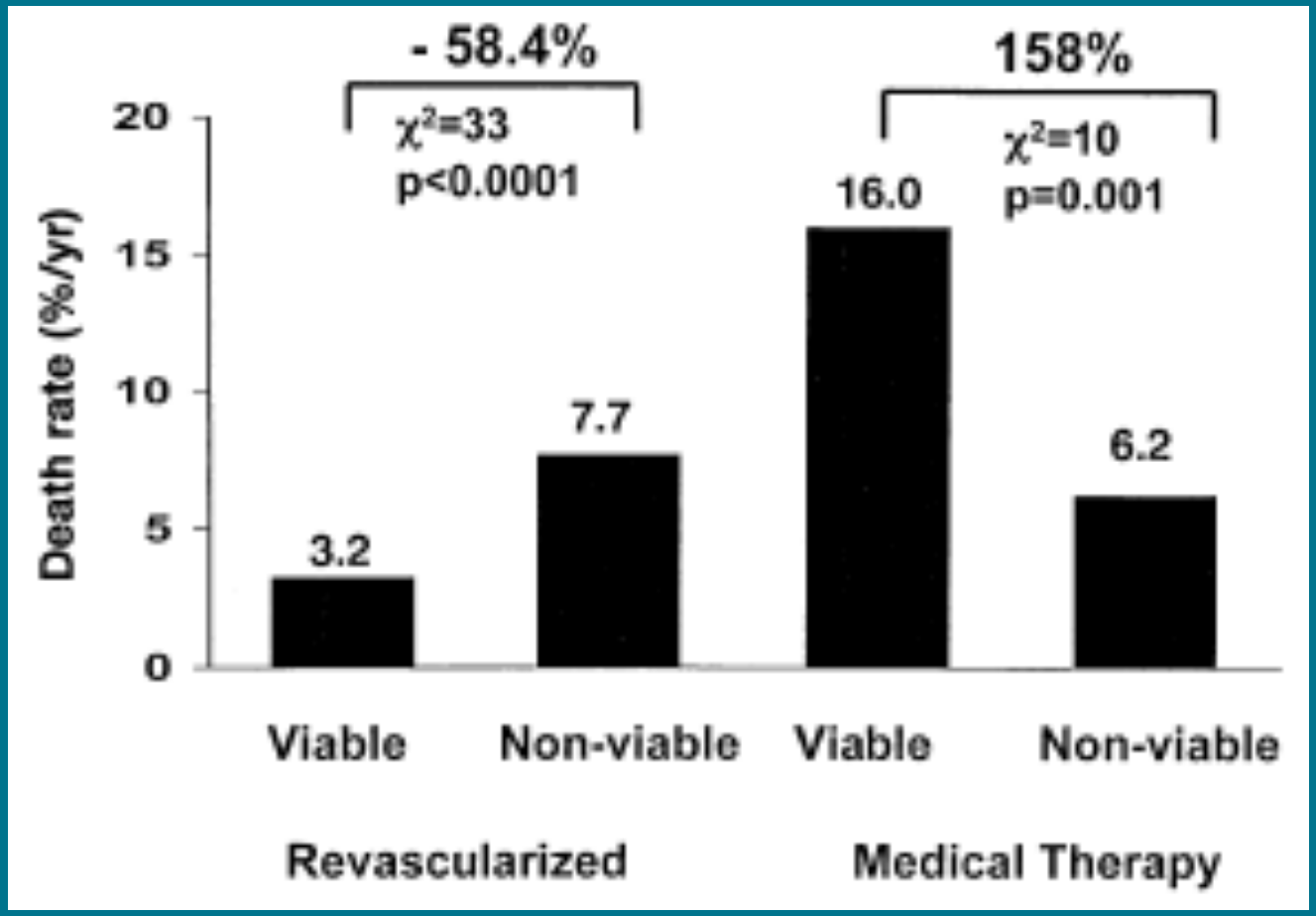
DCM: Fibrosis



M 30, alcoholism



Myocardial Viability



J Am Coll Cardiol 2002;39:1151-8

Myocardial Viability
The Clinical Problem:

Akinetic myocardium,
supplied by stenosed coronary artery

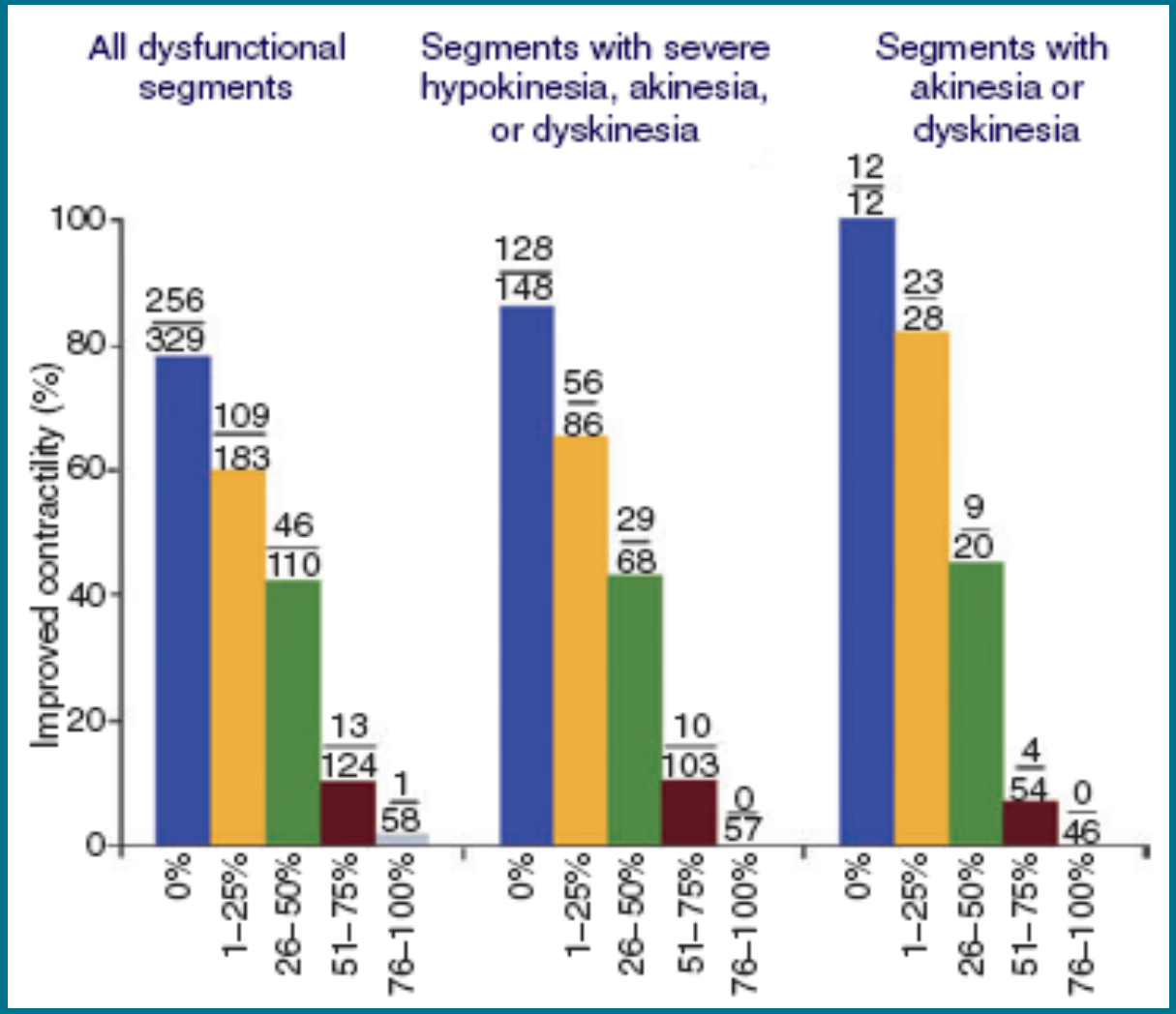
Viable
= Stunning, Hibernation

Non-viable
= Scar

Revascularisation
(PTCA, CABG)

No Revascularisation

DE-MRI: viability and predict functional recovery



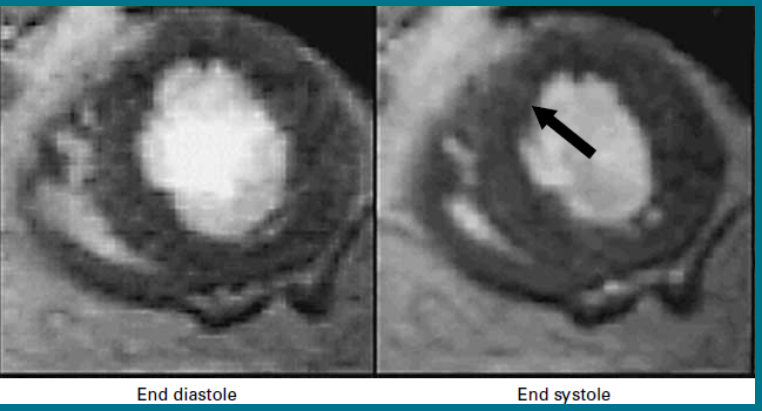
New Engl J Med 2000;343:1445-5

DE-MRI: viability and predict functional recovery

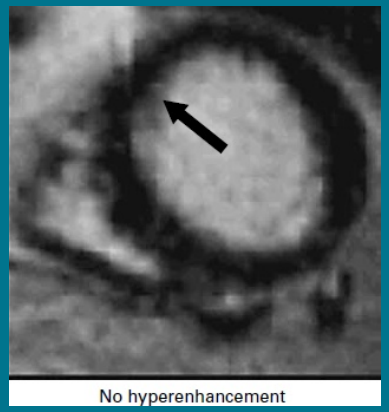
Before stent

No enhancement

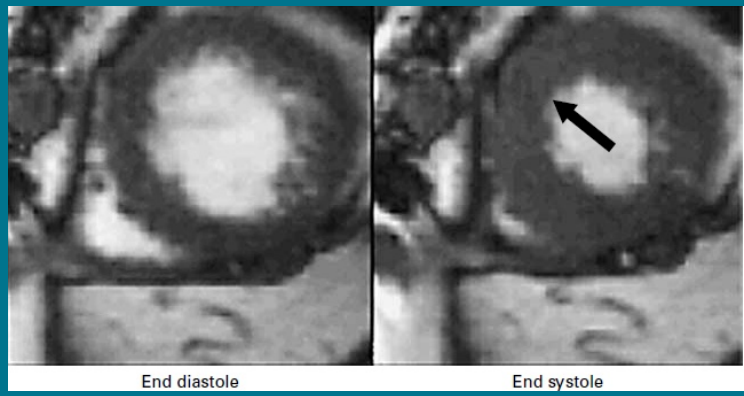
After stent



End diastole End systole

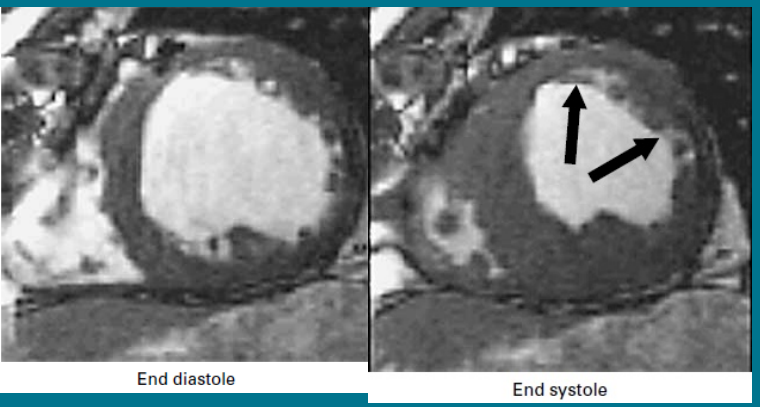


No hyperenhancement

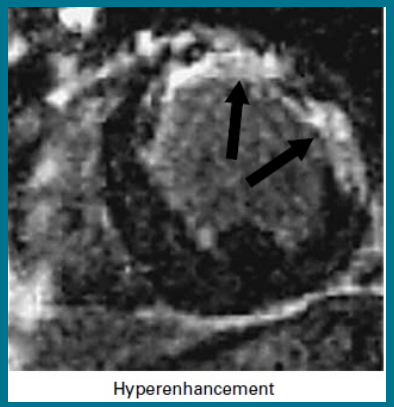


End diastole End systole

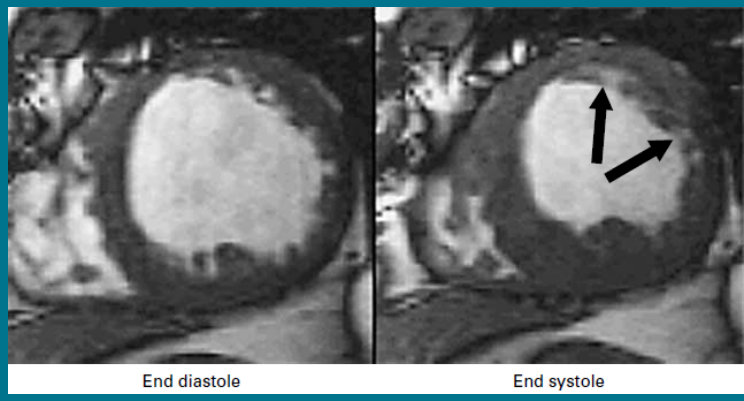
Transmural enhancement>75%



End diastole End systole



Hyperenhancement

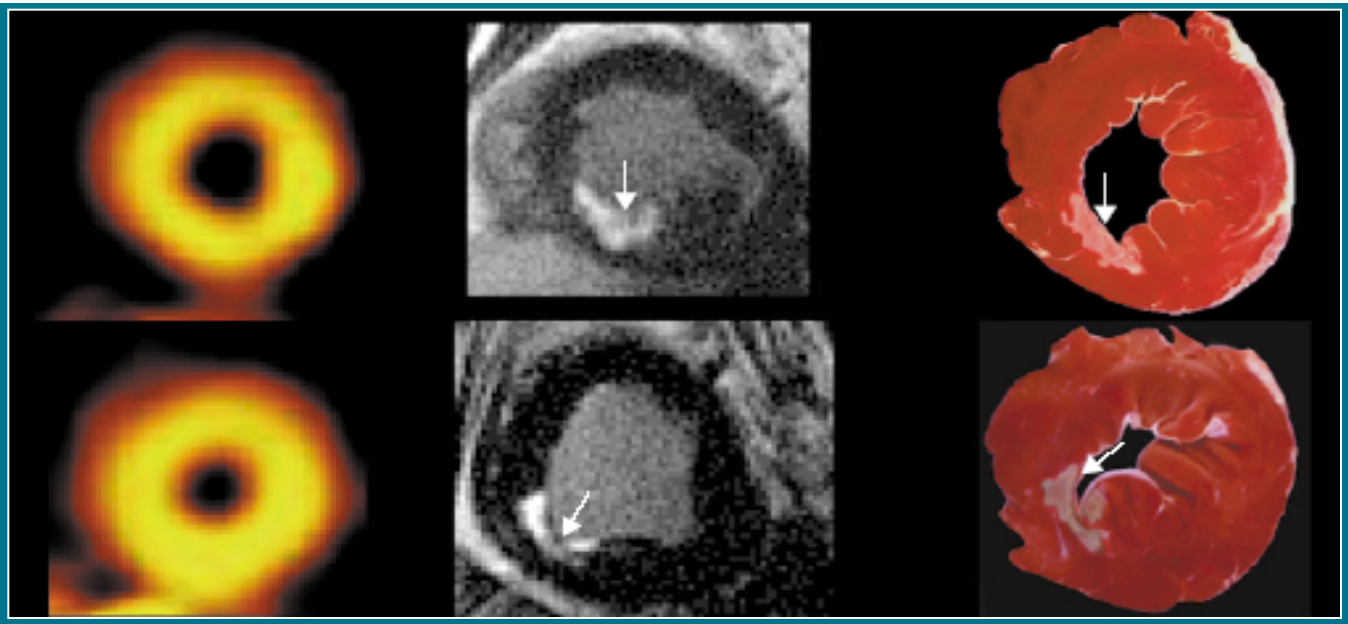


End diastole End systole

Kim, R. J.2000. N Engl J Med

Contrast-enhanced MRI and routine single photon emission computed tomography (SPECT) perfusion imaging for detection of subendocardial myocardial infarcts: an imaging study

Anja Wagner, Heiko Mahrholdt, Thomas A Holly, Michael D Elliott, Matthias Regenfus, Michele Parker, Francis J Klocke, Robert O Bonow, Raymond J Kim, Robert M Judd



Dog model:

SPECT and MRI detect 100% of transmural infarction

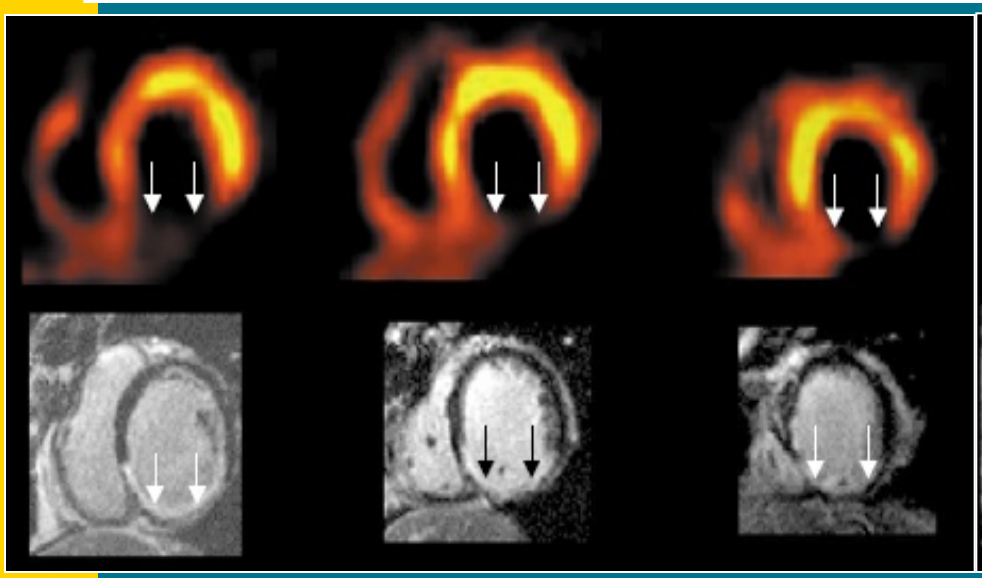
MRI detect 92% of subendocardial MI

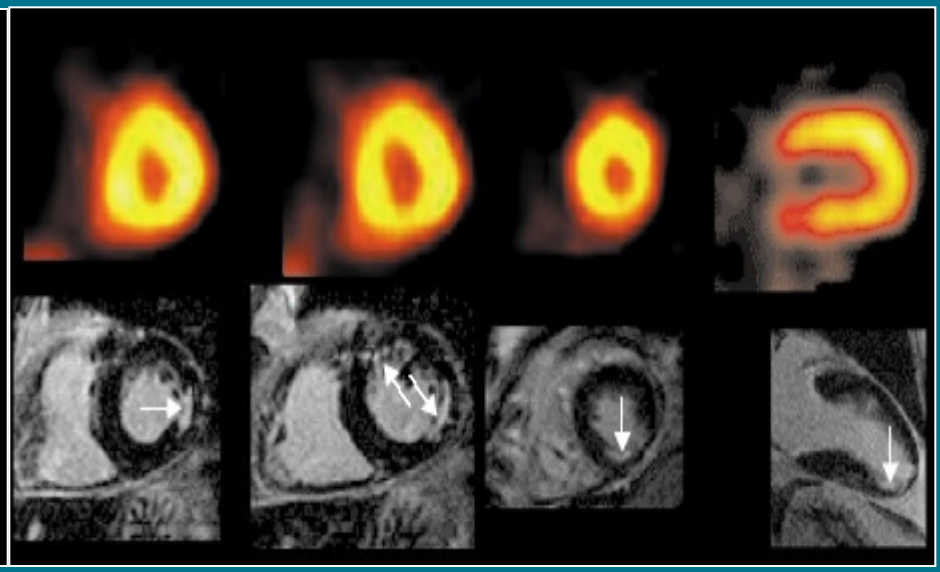
SPECT lost 72% of subendocardial MI

Lancet 2003;361:374-9

Contrast-enhanced MRI and routine single photon emission computed tomography (SPECT) perfusion imaging for detection of subendocardial myocardial infarcts: an imaging study

Anja Wagner, Heiko Mahrholdt, Thomas A Holly, Michael D Elliott, Matthias Regenfus, Michele Parker, Francis J Klocke, Robert O Bonow, Raymond J Kim, Robert M Judd



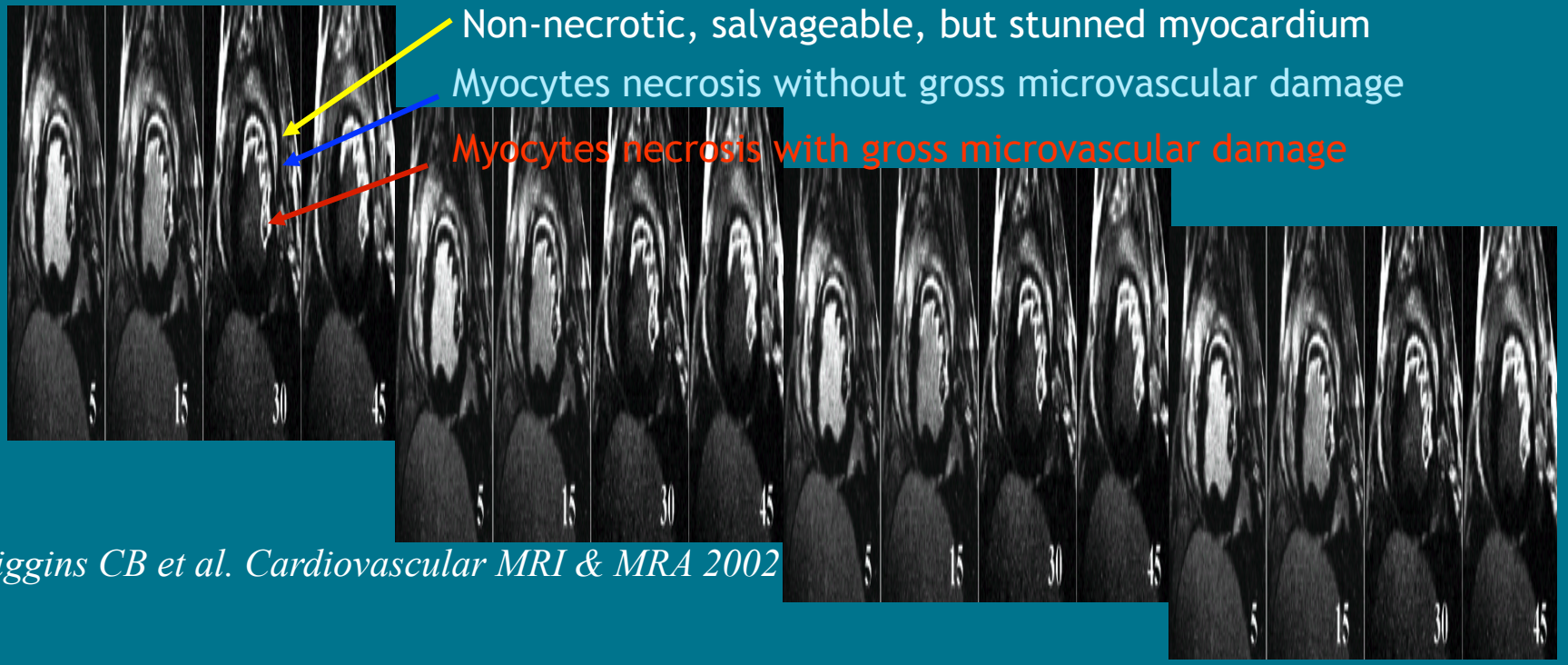


Human model: compare with MRI
SPECT detect 100% of transmural MI
SPECT lost 47% sub-endocardial infarction

Superior to SPECT for the detection of sub-endocardial infarction

Lancet 2003;361:374-9

Microvascular Obstruction on CMR

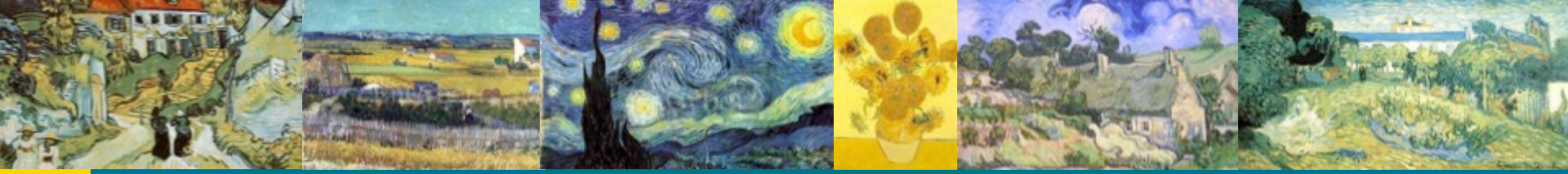


Higgins CB et al. Cardiovascular MRI & MRA 2002

Late (or Persistent) MVO:

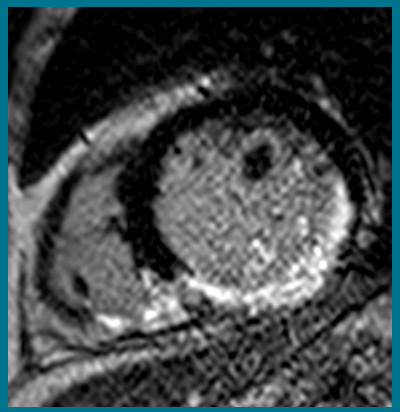
- more powerful predictor of global and regional functional recovery than all of the other characteristics, including transmural extent of infarction.

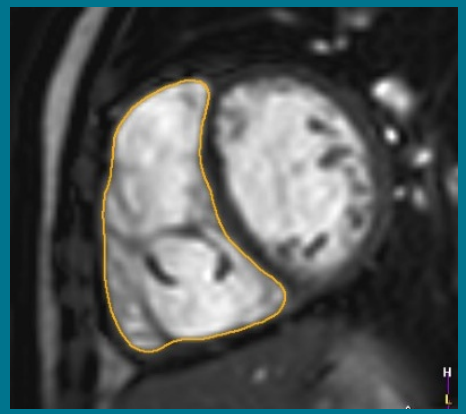
Nijveldt R et al. JACC 2008;52:181-189

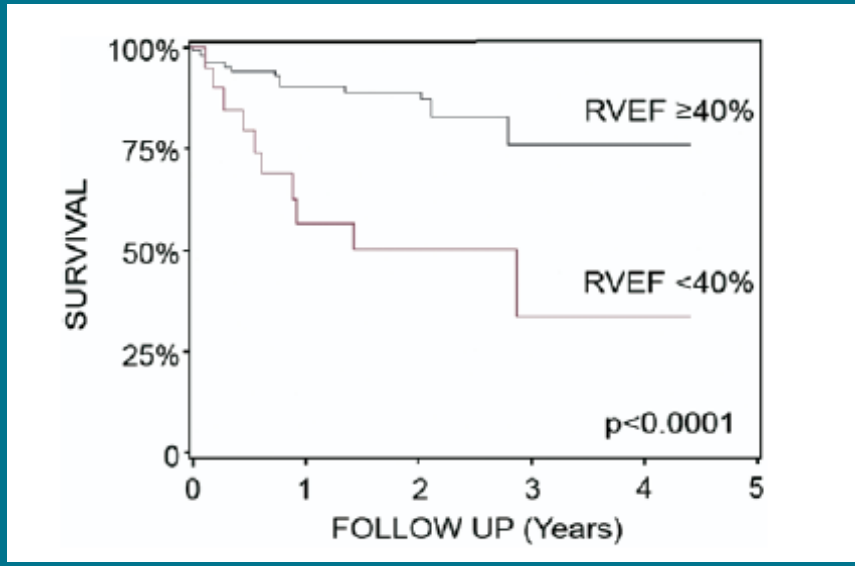


RV function and infarction

- Evaluation of RVEF using CMR imaging can improve risk-stratification and potentially refine patient management after MI.



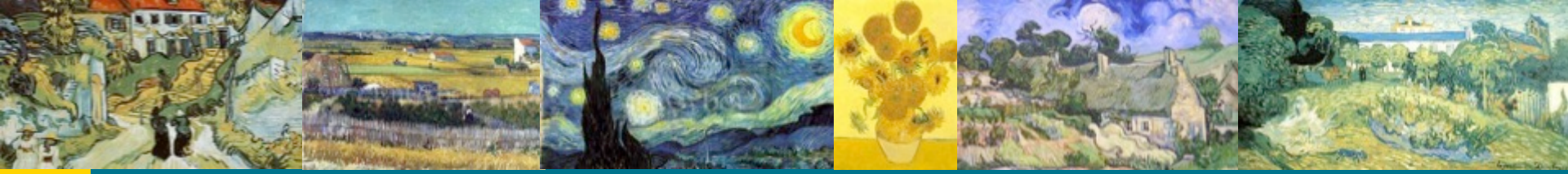




Larose E et al. JACC 2007;49:855-862

Comprehensive MR Approach for dysfunctional myocardium

Myocardial status	Perfusion	Wall motion			DE-MRI
		Rest	Low dose	High dose	
Normal	Normal	Normal	↑	↑↑	Normal
Stunned	Normal	↓	↑	↑↑	Normal
Hibernating	↓	↓	↑	↓↓	Normal
Infarction	↓	↓	↓	↓	Hyperenhance

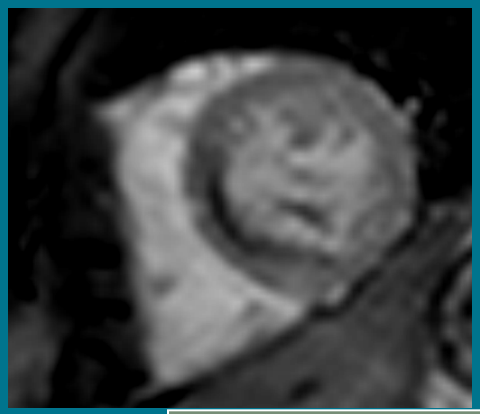


Value of the cardiac MRI in diagnose chronic IHD (Stenosis ≥ 50% in invasive coronary angiography was significant) Bach Mai hospital, 2012-2014

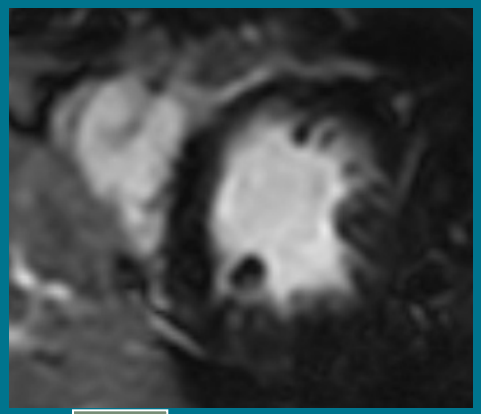
87 patients with suspected chronic IHD underwent CMR 1.5 Tesla
36 patients with adenosine followed by LGE using Gadolinium

CMR	Se (%)	Sp (%)	PPV (%)	NPV (%)
PERF	93.3	83.3	96.6	71.4
DE	91	77.8	97.3	50
PERF/ DE	93.3	83.3	96.6	71.4

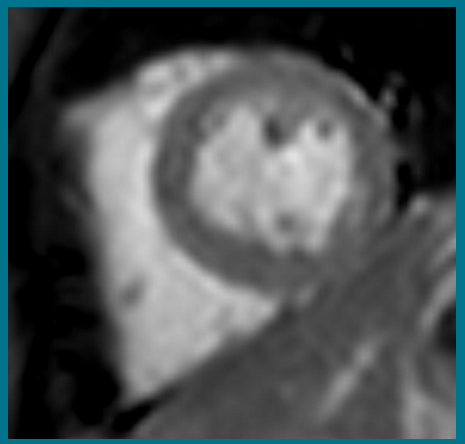
Case 1: 74 year-old female, chest pain



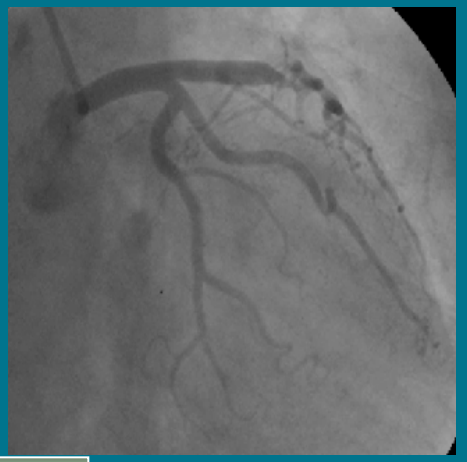
Stress perfusion



DE



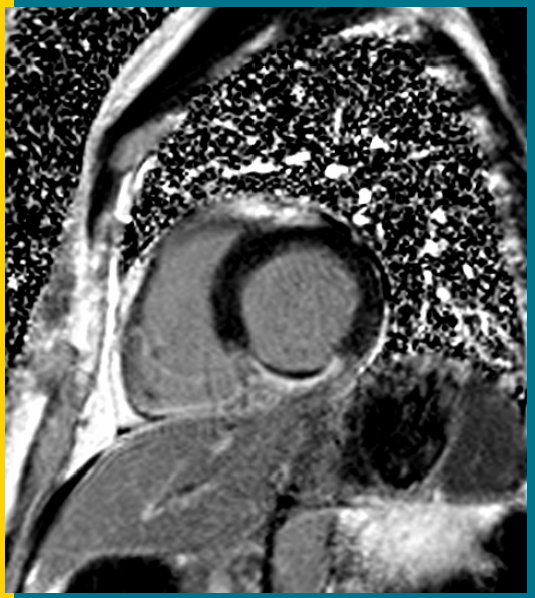
Rest perfusion



CA

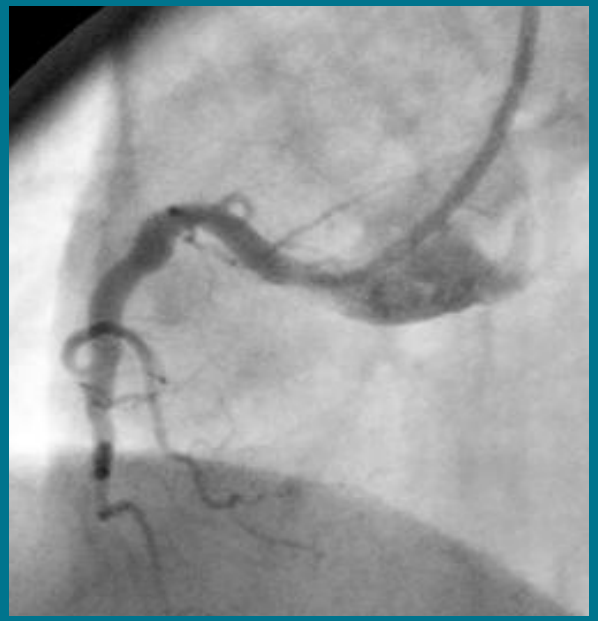
Case 2

M/62

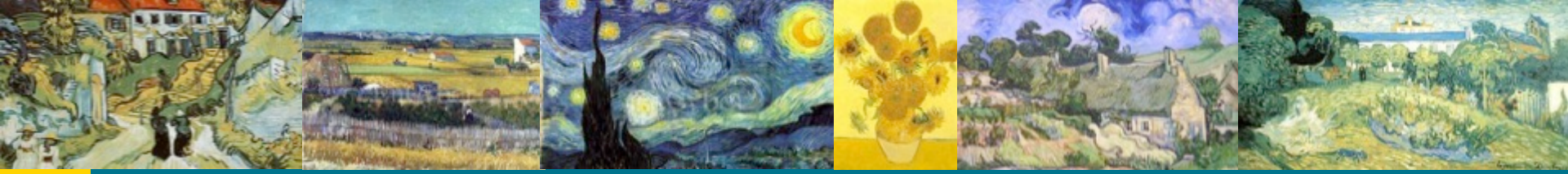


Short axis - DE

2C- DE

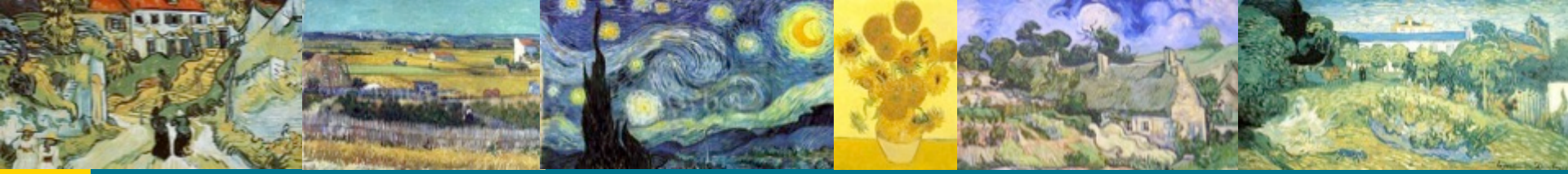


CA



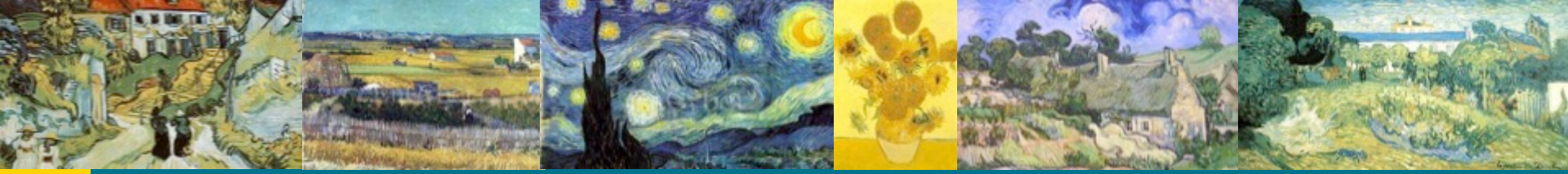
Cardiac MR for Ischemic Heart Disease

- Introduction
- CMR Techniques for IHD
- Evaluation of cardiac function
- Detection and Differentiation of IHD
- Challenges and Future Aspects
- Conclusion



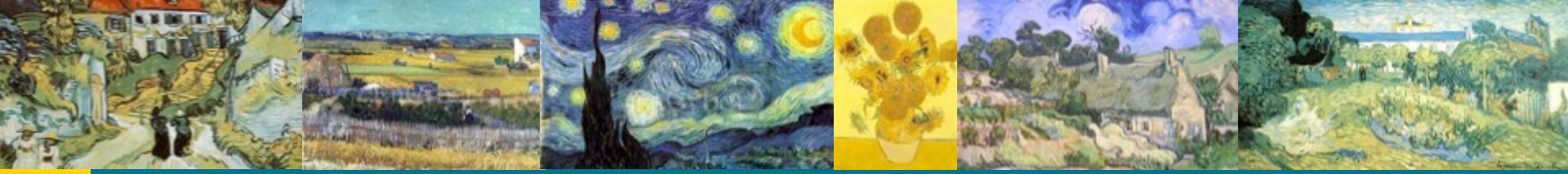
Challenges and Limitations of CMR

- Long scan time (at least 30 min ~ 1 hour)
- Limited experienced clinicians and radiologists
- Limited facility
- High cost
- Contrast media related complication:
  - Nephrogenic systemic fibrosis in patients with impaired renal function



Future Aspects of CMR

- Faster scan time: 32-channel coil etc
- High spatial resolution: 3T, 7T etc
- Real time imaging: k-t blast sequence etc
- Myocardial fiber tracking: DTI etc
- Molecular MR imaging

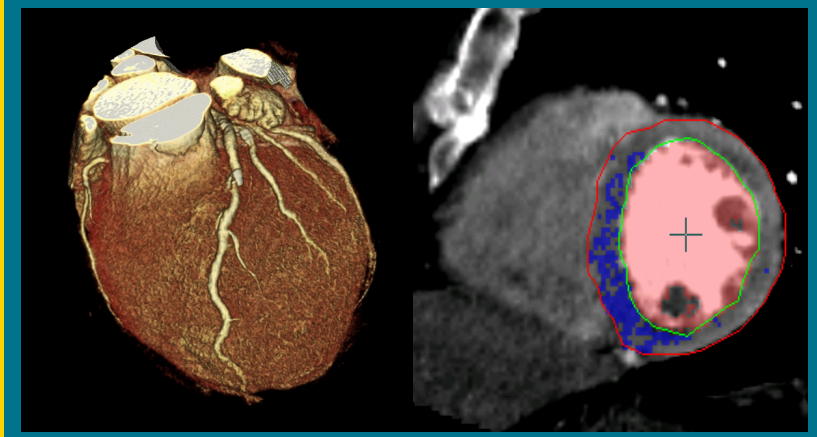


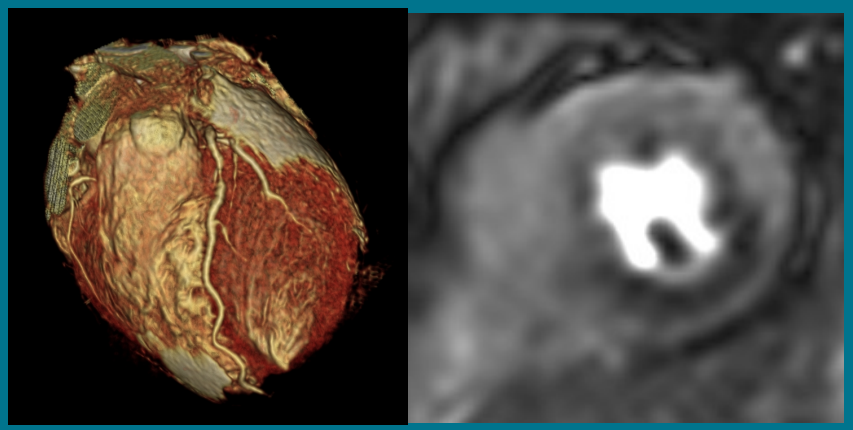
Coronary artery + Function + Perfusion + Viability

Cardiac MDCT

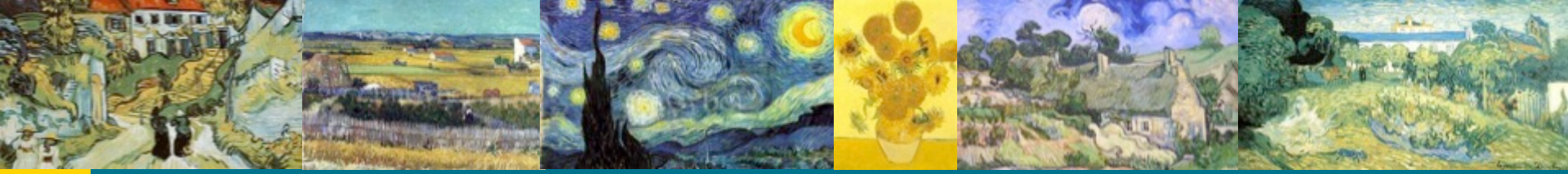
?

Cardiac MRI





Choi SI et al, Int J Cardiovascular Imaging 2009; 25;23-29



Conclusion

- CMR imaging is emerging as a “one-stop exam” tool for the management in patients with suspected or established IHD.
- CMR can provides additional information over other clinical tests for the detection, differential diagnosis, and prognostication in patients with IHD.
- With advances of MR technology, CMR will play an increasing role in patients with suspected or established IHD.