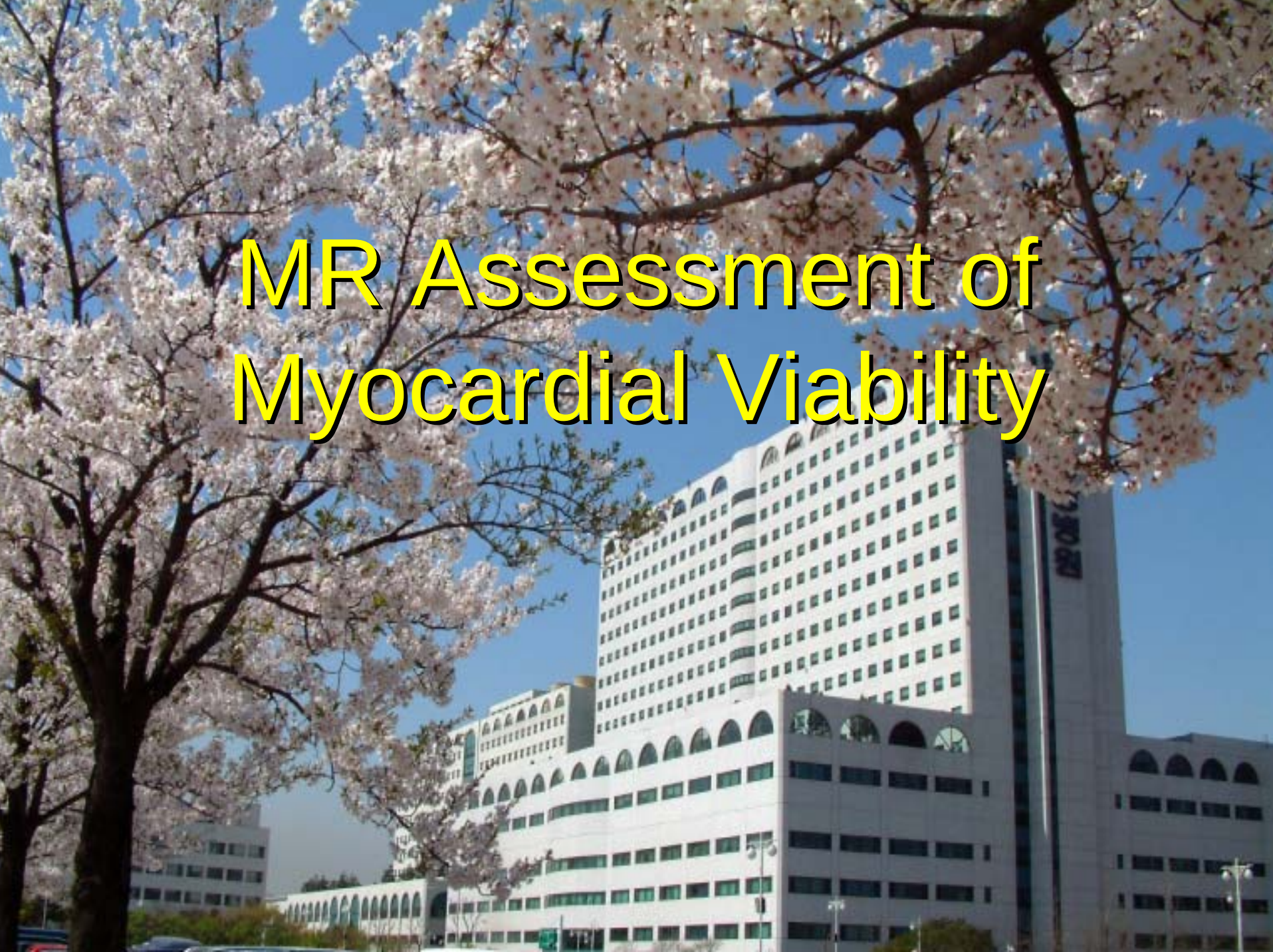
MR Assessment of
Myocardial Viability

Definition of Viability

- Clinical
  - Metabolism: Presence of glucose uptake
  - Perfusion / Perfusion reserve
  - Morphology: Wall thickness, wall thickening
  - Contractility:
    Recovery after treatment / Contractile reserve
- Histologic
  - Presence of living myocytes

Kim et al. Herz 2000

Merits of MRI as “one-stop exam”

- Morphology
- Function
- Perfusion
- Viability
- Coronary Artery
- Metabolism
- Flow Measurement

Merits of MRI as “one-stop exam”

- Morphology: T2 WI, T1 WI
- Function: Cine MR, Myocardial Tagging
- Perfusion: MR Perfusion (rest/stress)
- Viability: Delayed Enhancement, Low dose DSMR etc.
- Coronary Artery: Coronary MR angiography
- Metabolism: ^{31}P, ^{1}H MR Spectroscopy etc
- Flow Measurement: Coronary flow reserve

Merits of MRI as “one-stop exam”

- Morphology: T2 WI, T1 WI
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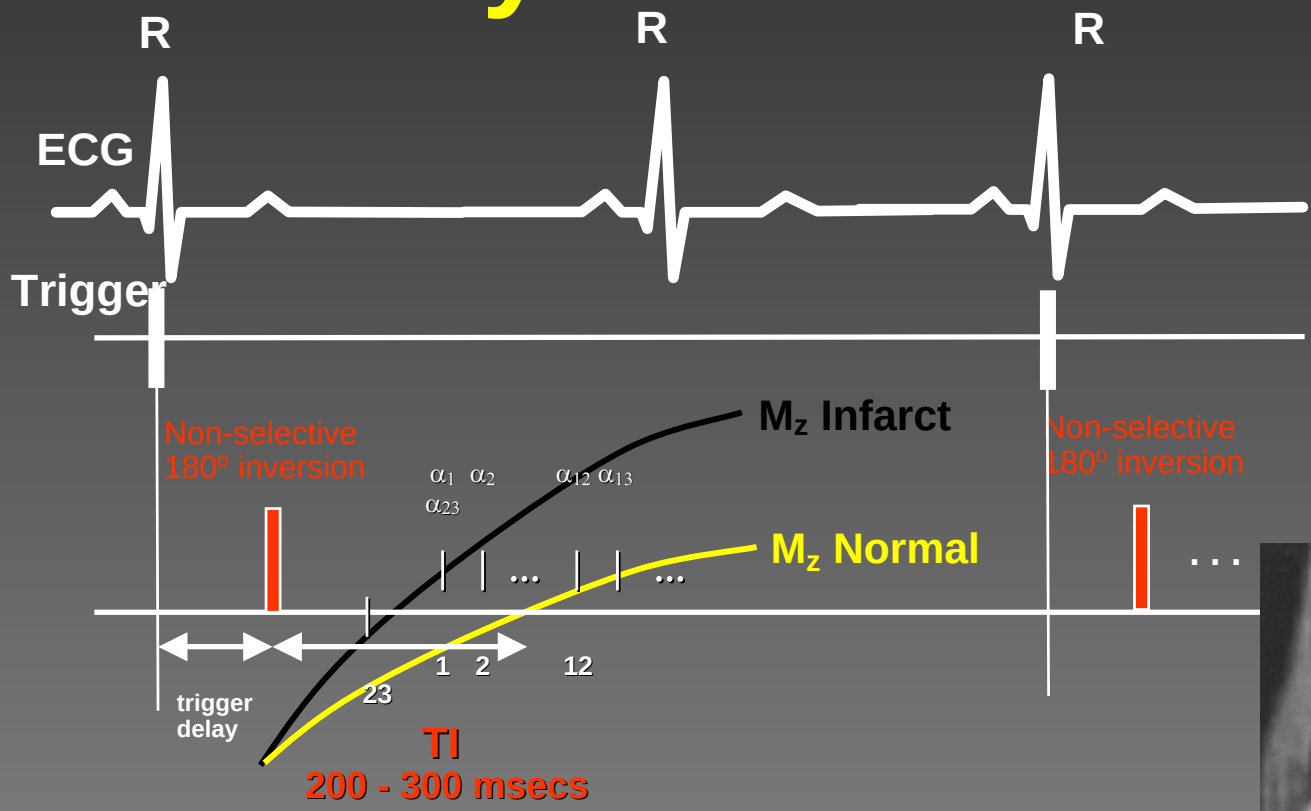
- Flow Measurement: Coronary flow reserve

MRI for Myocardial Viability

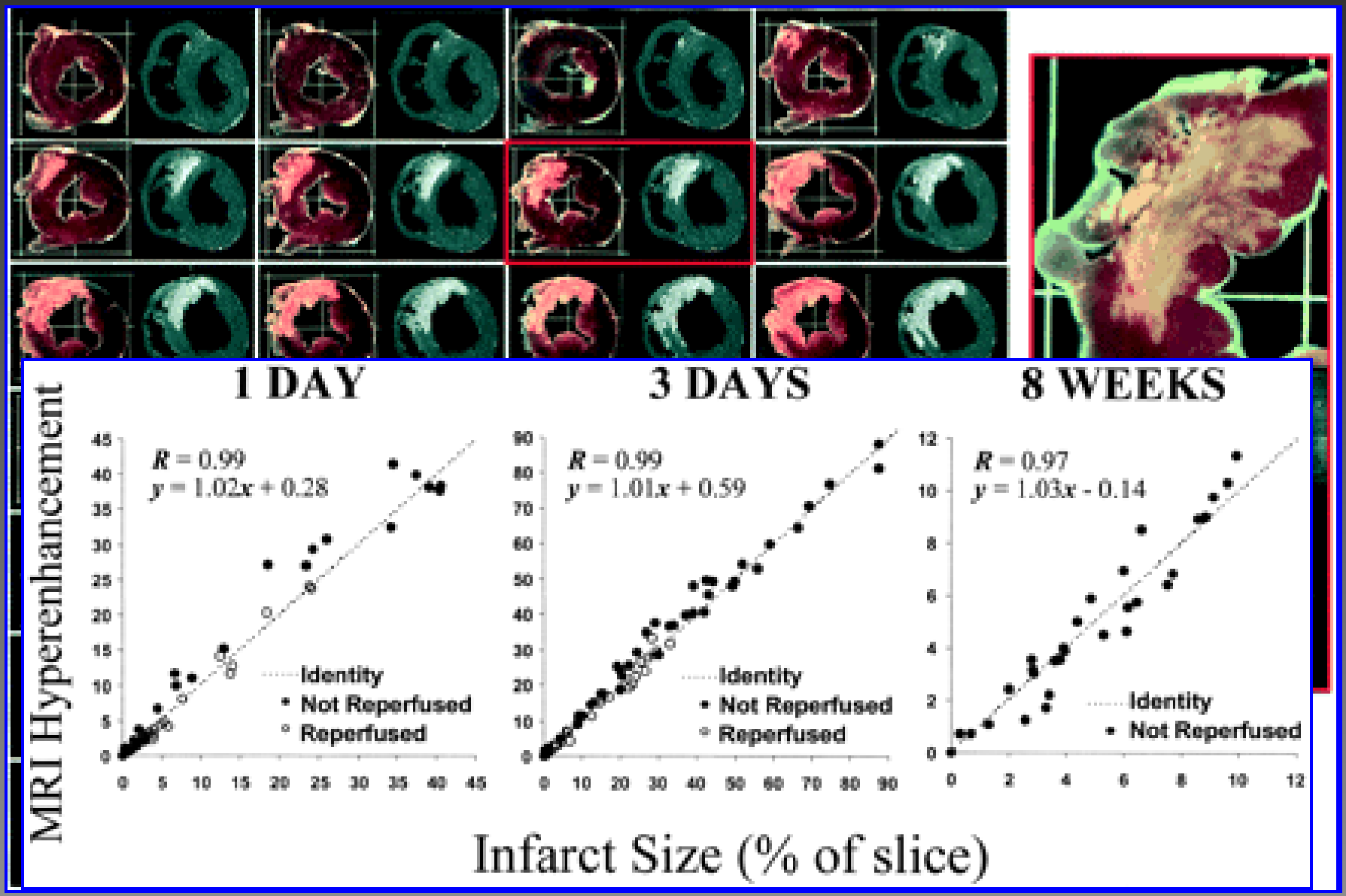
1. Detection of Myocyte necrosis or scar: Delayed Enhancement (DE) MRI
2. Assessment of LV function:
   - Myocardial mass: End-diastolic wall thickness
   - LV contractility: End-systolic wall thickening
   - Contractile (inotropic) reserve

I. Delayed Enhancement MRI



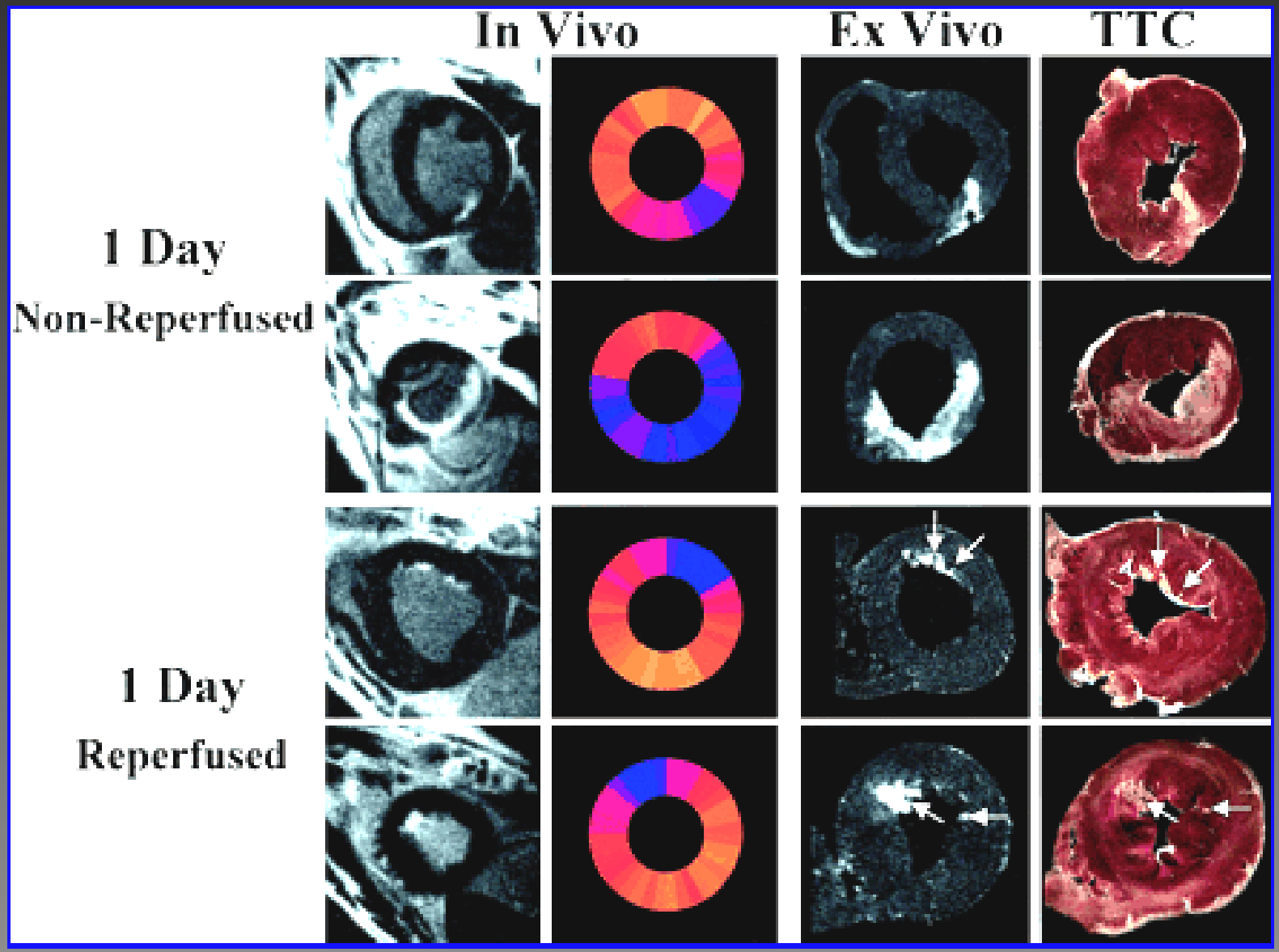
Segmented IR Turbo-FLASH

DE-MRI vs TTC



Kim et al. Circulation 1999

Reperfused vs Non-reperfused Infarction



Kim et al. Circulation 1999

Delayed Enhancement MRI

Area of delayed enhancement

= nonviable myocardium

(*Bright is dead !!!)*

Kim RJ et al, Circulation 1999

Fieno et al, JACC 2000

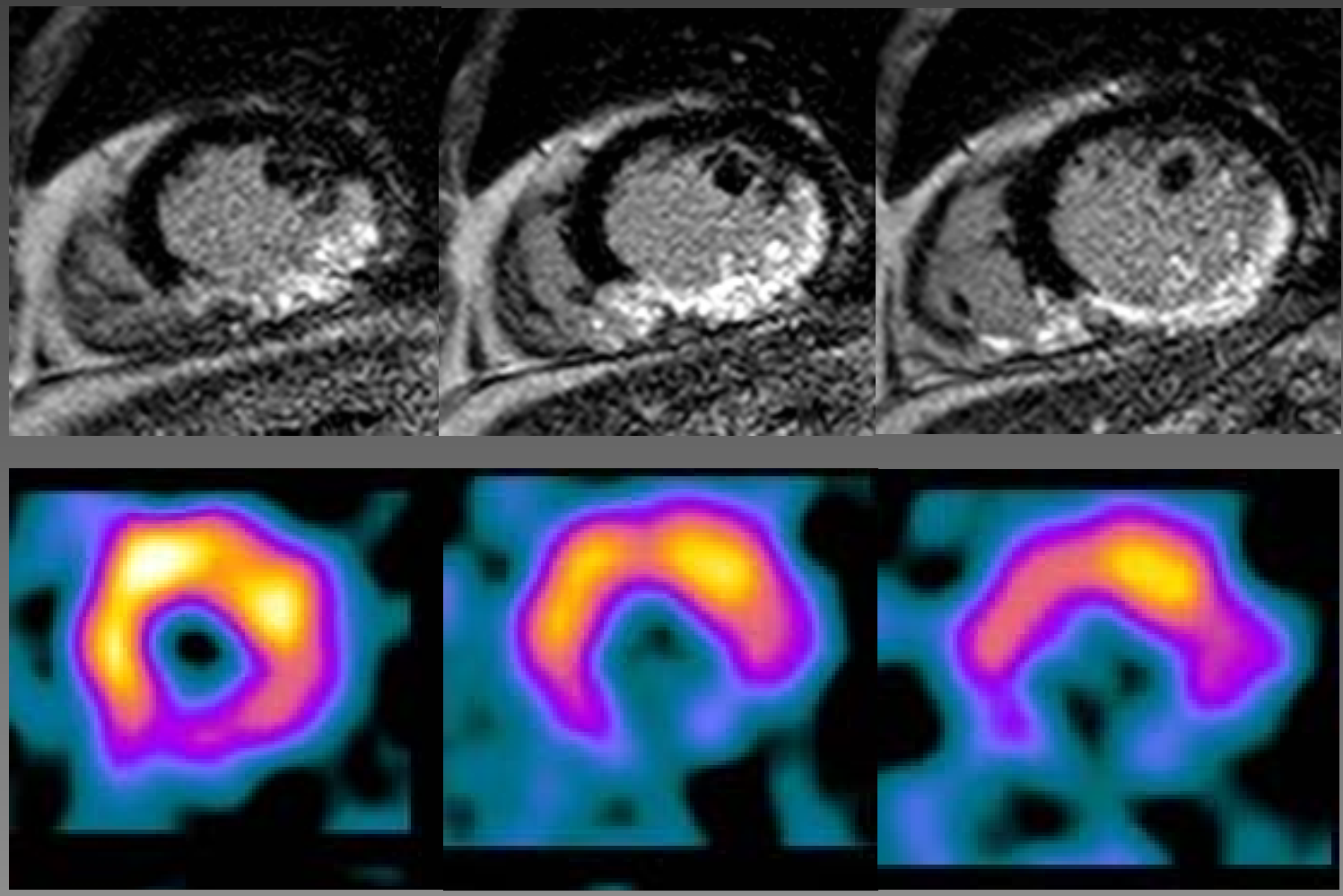
Delayed Enhancement MRI

CLINICAL IMPLICATIONS

- Detection of Myocardial Infarction
  - Acute Infarction
  - Chronic (healed) Infarction

- Prediction of Functional Recovery after Revascularization Treatment

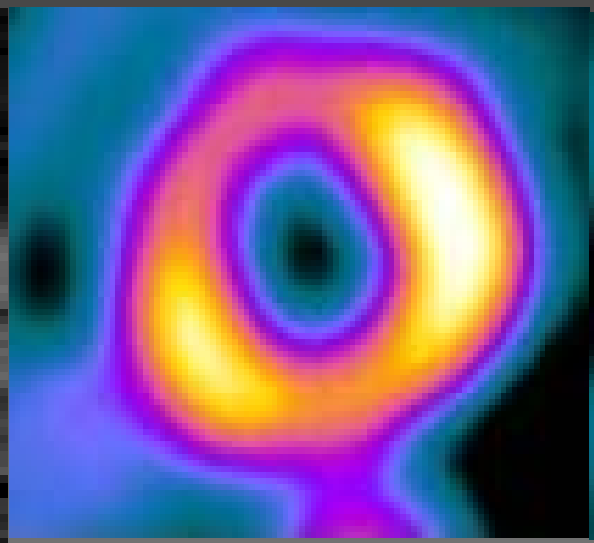
DE-MRI *vs* SPECT



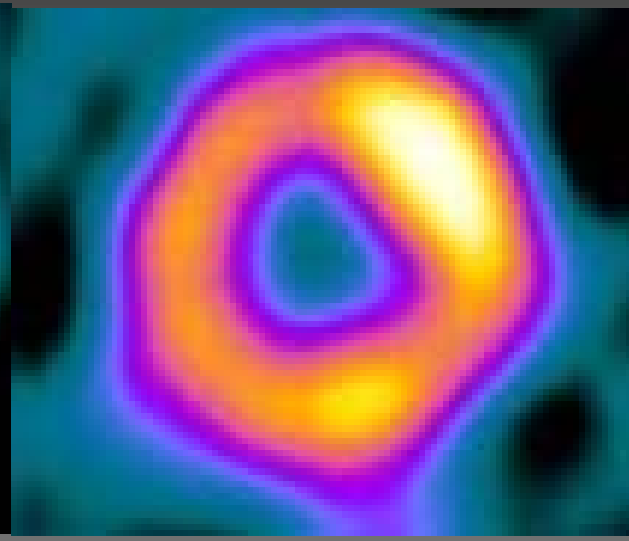
Transmural infarction

DE-MRI *vs* SPECT

DE-MRI



Stress SPECT

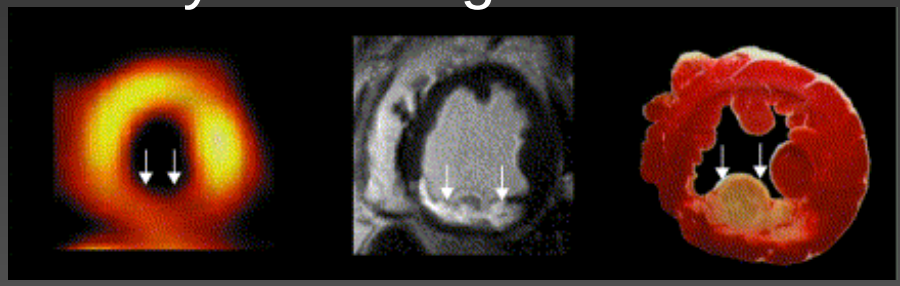


Rest SPECT

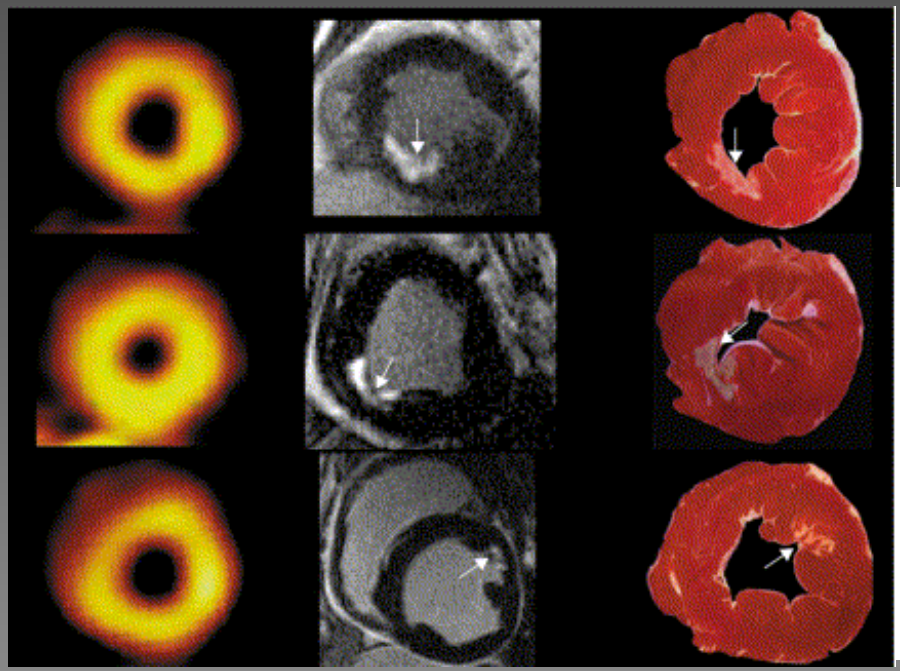
Subendocardial infarction

Detection of MI: DE-MRI vs SPECT

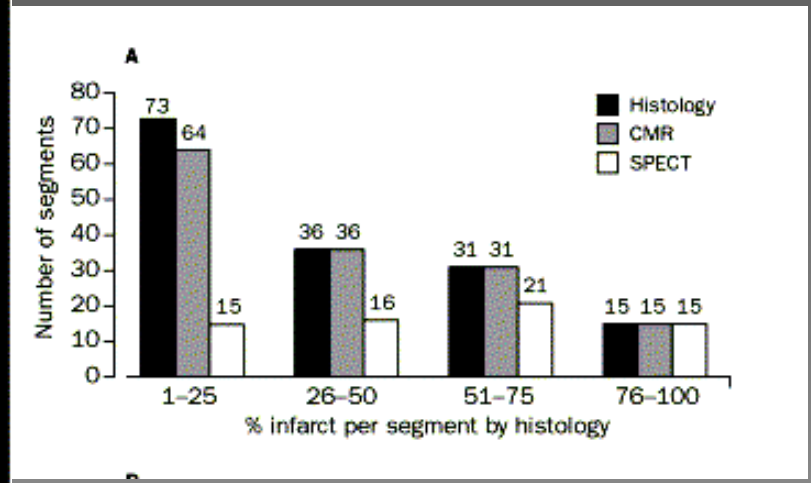
A study in 12 dogs



SPECT CE-MRI TTC



SPECT CE-MRI TTC



Wagner et al. Lancet 2003

Detection of MI: DE-MRI vs SPECT

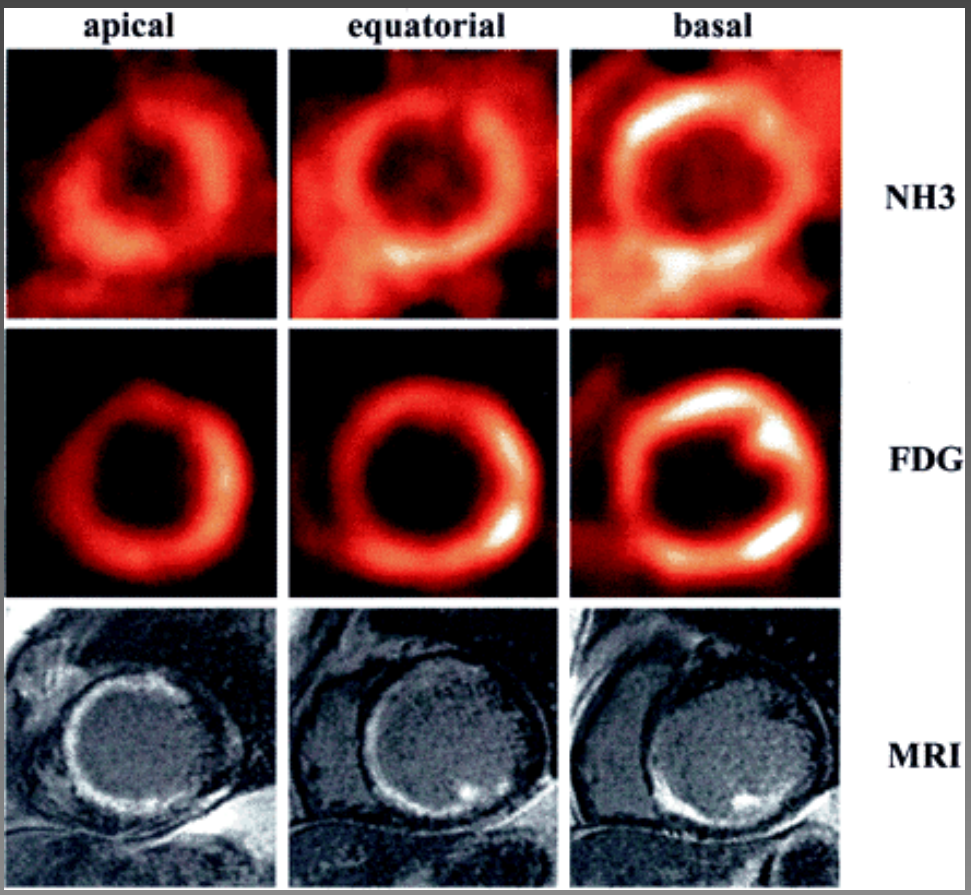
Detection of subendocardial infarcts

	*Animal Research	+Human Study
CE-MRI	100/109 (92%)	181/181 (100%)
SPECT	31/109 (28%)	96/181 (53%)

*Gold standard : TTC, +Gold standard : CE-MRI

Wagner et al. Lancet 2003

DE-MRI *vs* PET



- In severe ischemic heart failure, hyperenhancement on DE-MRI as a marker of myocardial scar closely agrees with PET data.

Klein et al Circulation 2002

Detection of MI: DE-MRI vs PET

Assessment of Myocardial Viability With Contrast-Enhanced Magnetic Resonance Imaging

Comparison With Positron Emission Tomography

A study in 31 patients with ischemic heart failure

	PET(t)	PET(nt)	PET(v)
MRI(t)	126	11	38
MRI(nt)	7	27	51
MRI(v)	13	21	695

t : transmural, nt : non-transmural, v : viable

Conclusions—In severe ischemic heart failure, MRI hyperenhancement as a marker of myocardial scar closely agrees with PET data. Although hyperenhancement correlated with areas of decreased flow and metabolism, it seems to identify scar tissue more frequently than PET, reflecting the higher spatial resolution.

Klein et al Circulation 2002

Lee SD 76/F

- C.C : Aggravated dyspnea for 1 week

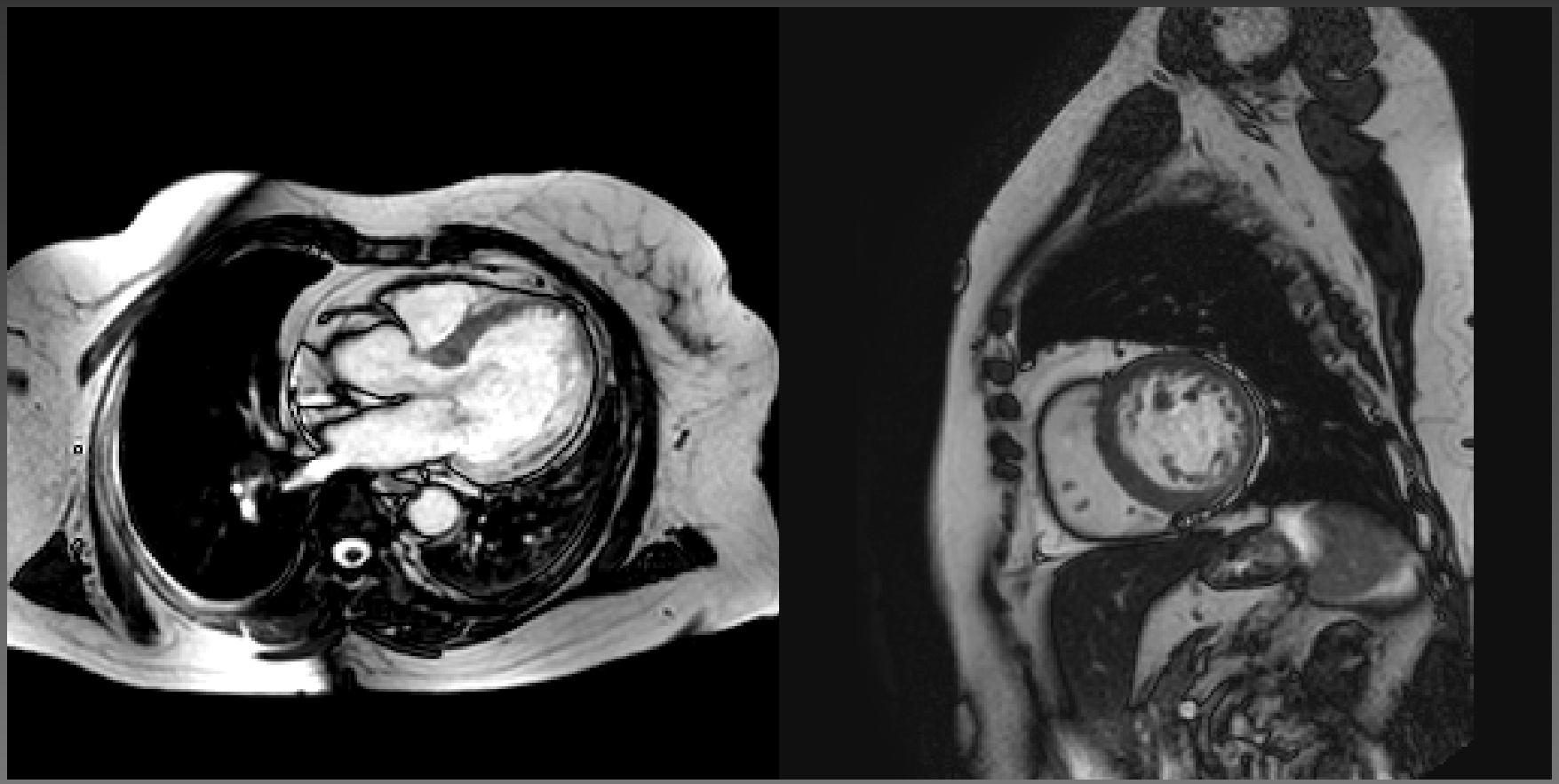
- PMH: Diabetes mellitus for 10 years
- Cardiac Echo: Hypokinesia on anterolateral wall, apical to basal
- Cardiac enzyme :

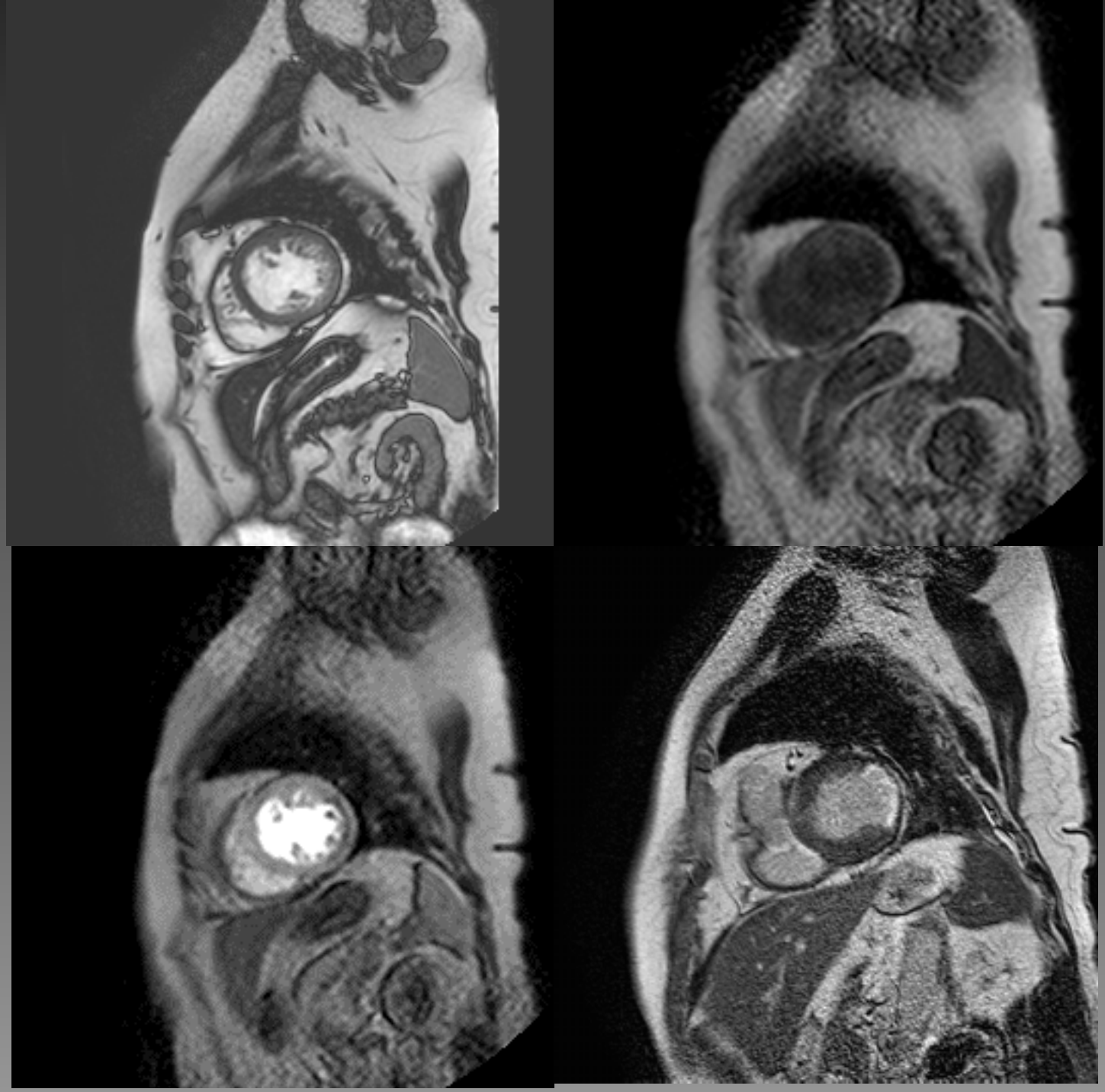
  CK(EM)(50-250 U/L) : 265

  CK-MB(0.0-5.0 ng/ml) : 3682

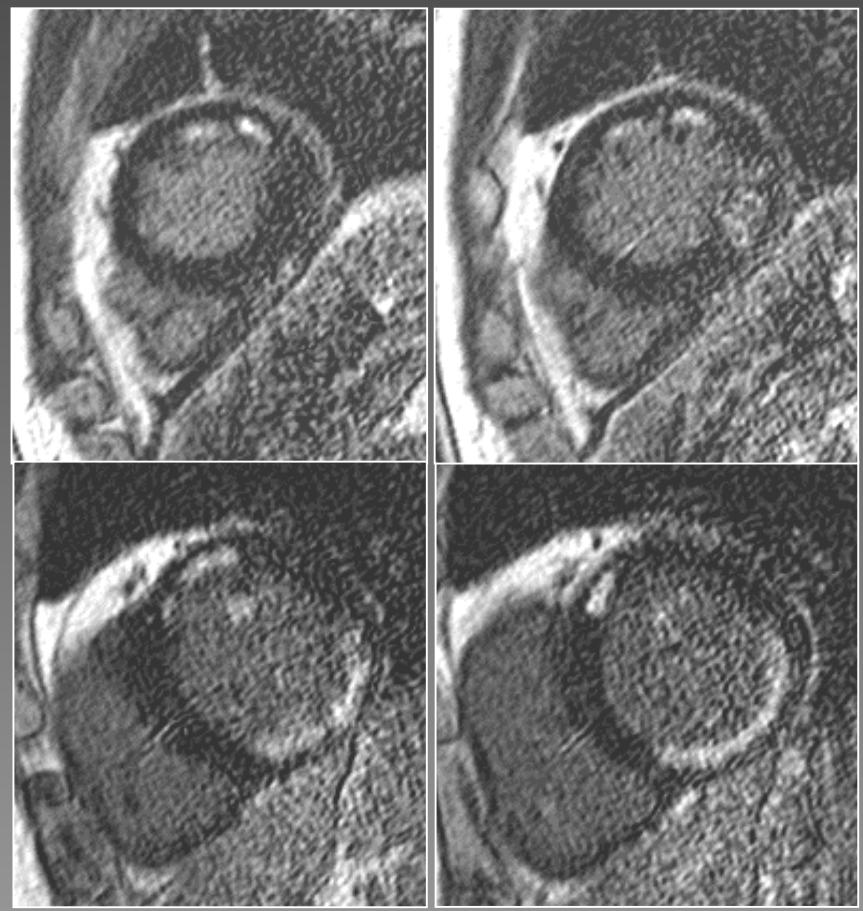
  Troponin -I (0-1.5) : 20.2
- EKG : Lateral AMI

Lee SD 76/F



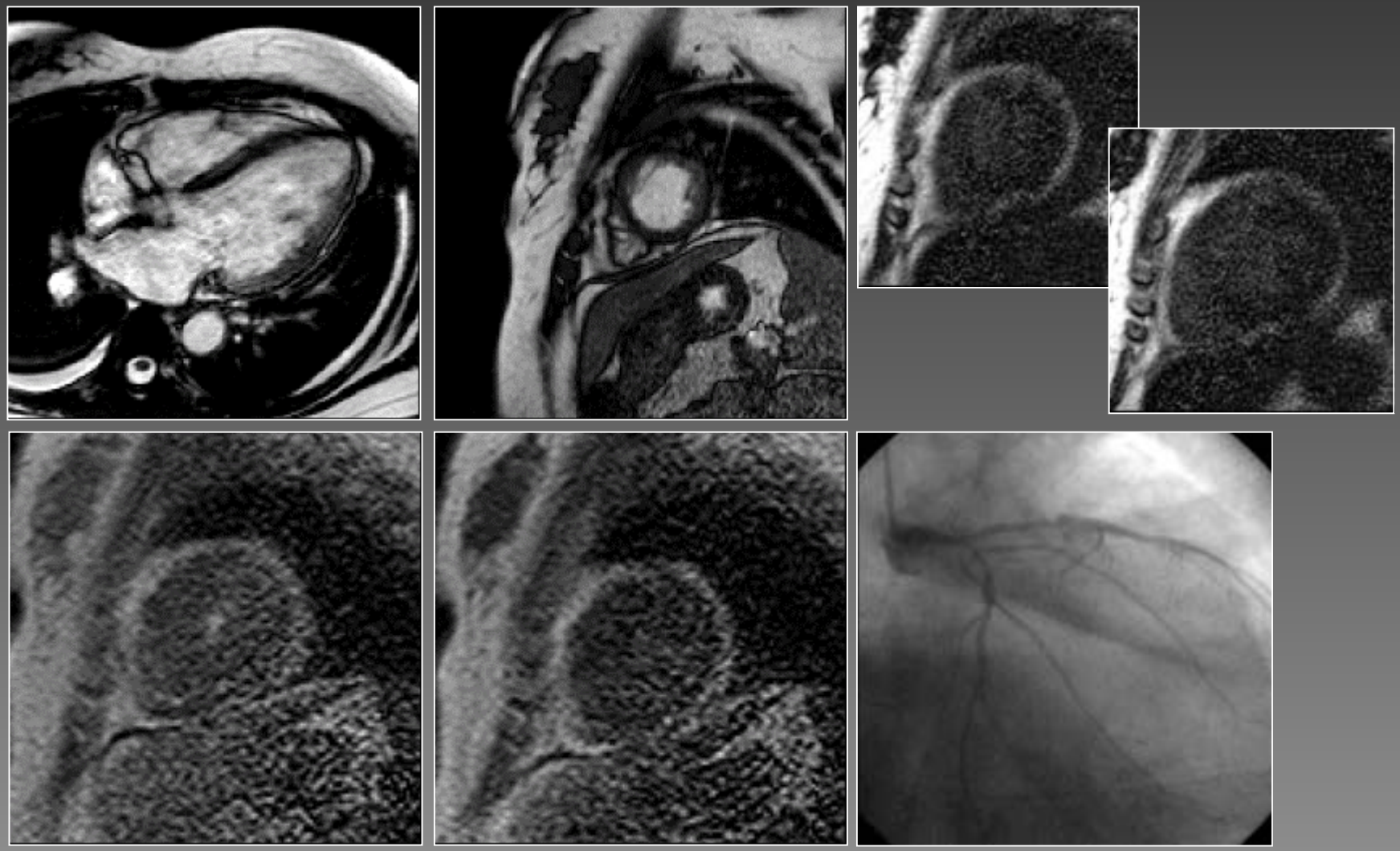


Detection of Multiple Foci of MI: In Addition to the Expected Lesion



- ✓ Induced ischemia: mid-anterolateral wall
- ✓ Normal motion / no enhancement: viable !!

47/F chest pain



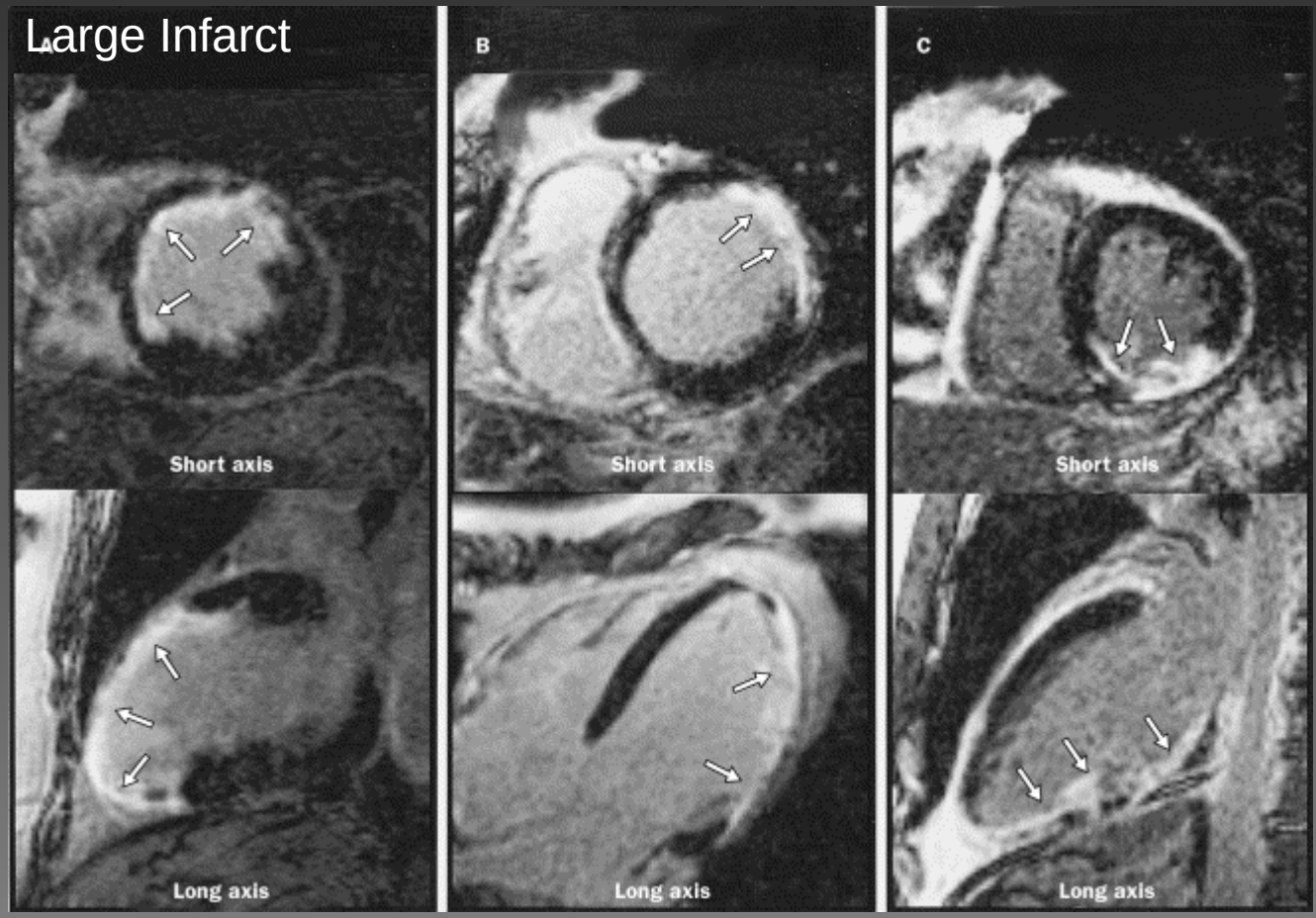
REST STRESS

DE-MRI: CLINICAL IMPLICATIONS

- Detection of Myocardial Infarction
  - Acute Infarction
  - Chronic (healed) Infarction

- Prediction of Functional Recovery after Revascularization Treatment

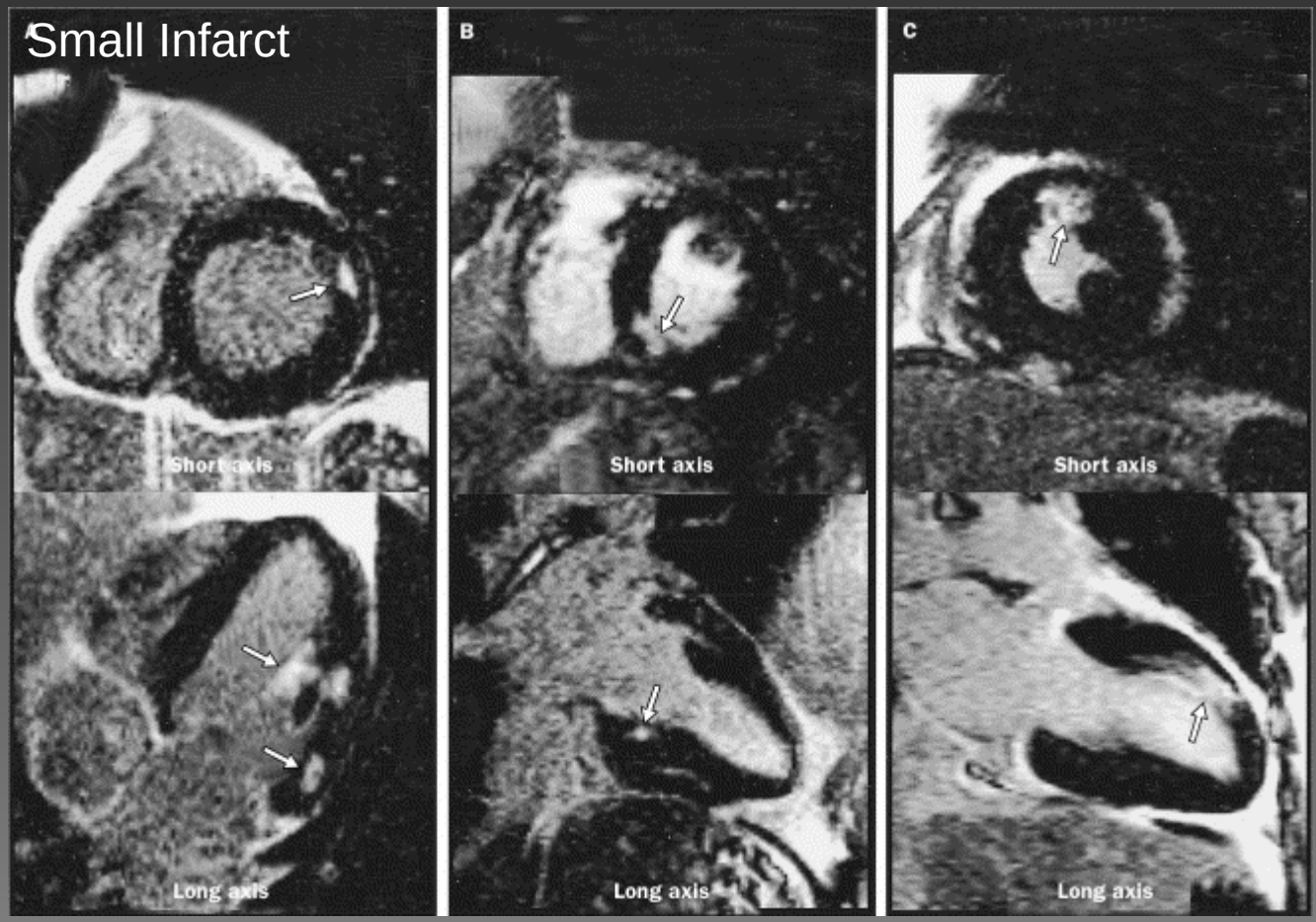
DE-MRI Detection of Healed MI



Hx:	10 months	5 months	4 months
CK:	3300 IU/L	5912 IU/L	3352 IU/L
MB:	294 µg/L	792 µg/L	389 µg/L

Wu et al. Lancet 2001

DE-MRI Detection of Healed MI

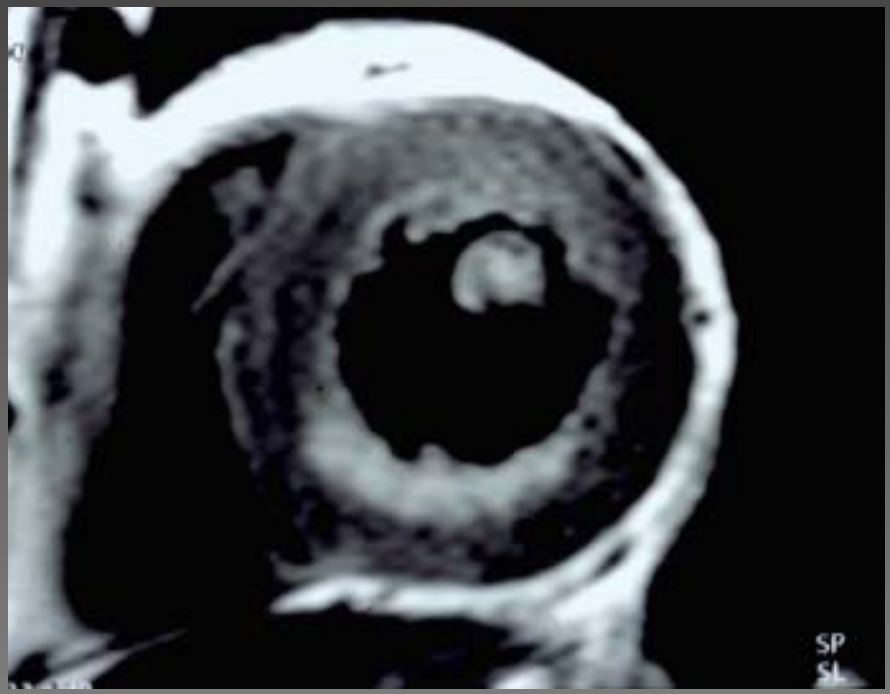


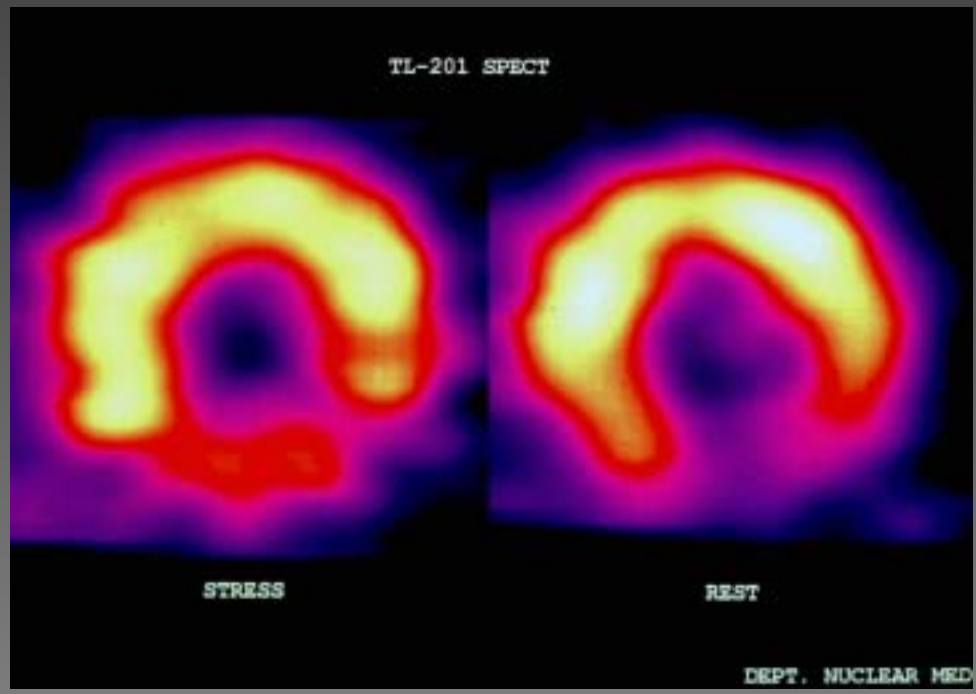
Hx:	13 months	2 months	3 months
CK:	513 IU/L	219 IU/L	508 IU/L
MB:	62 µg/L	12 µg/L	35 µg/L

Wu et al. Lancet 2001

Limitations of DE-MRI:

Differentiation between Acute and Chronic MI?

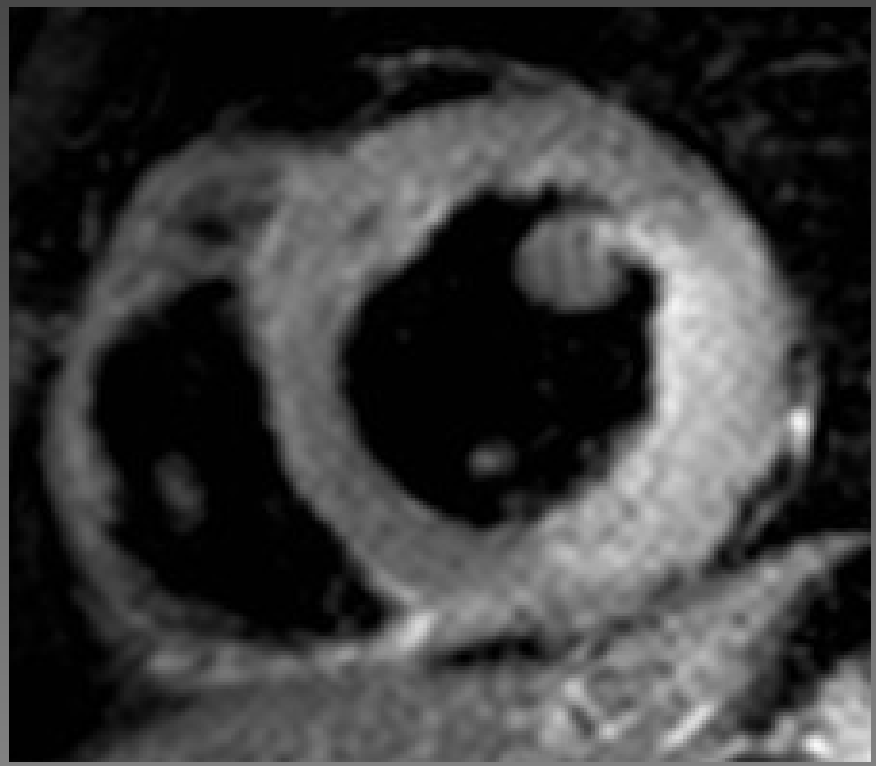


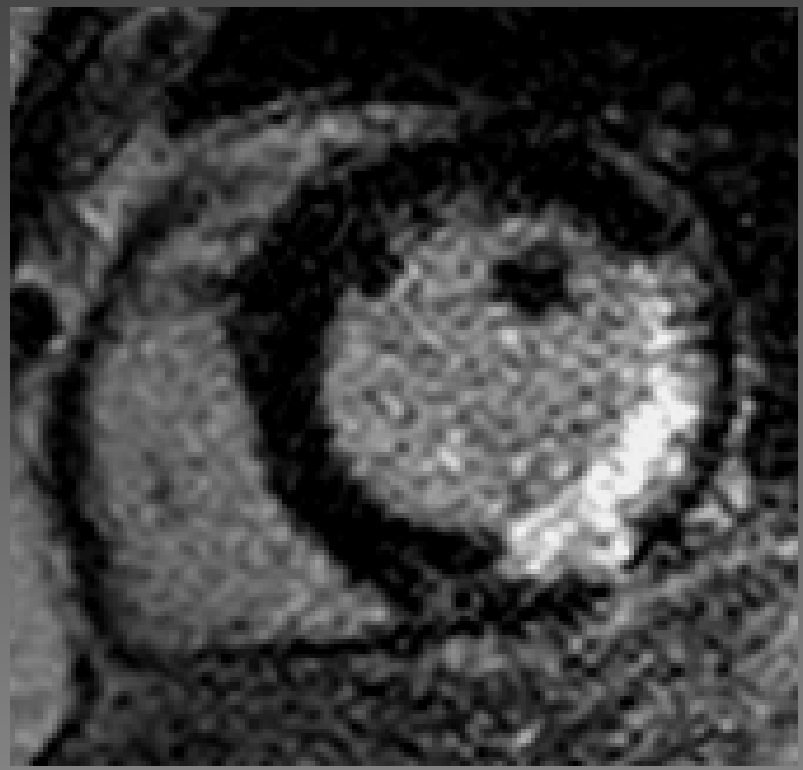


T2 WI **SPECT**

Lim TH et al, JMRI 1997

DE-MRI *vs* T2 MRI

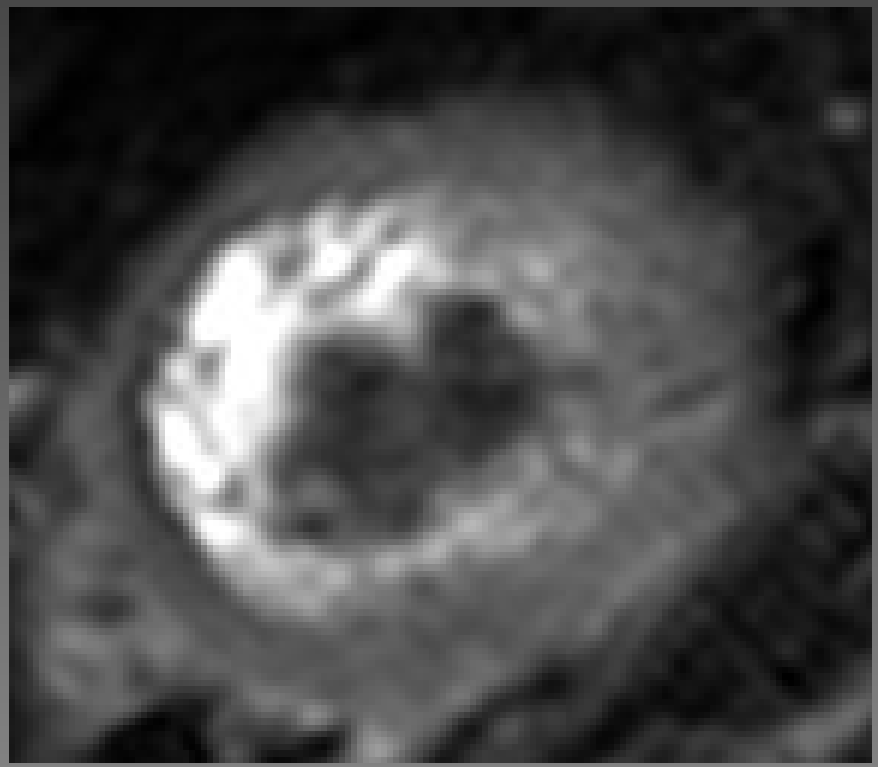


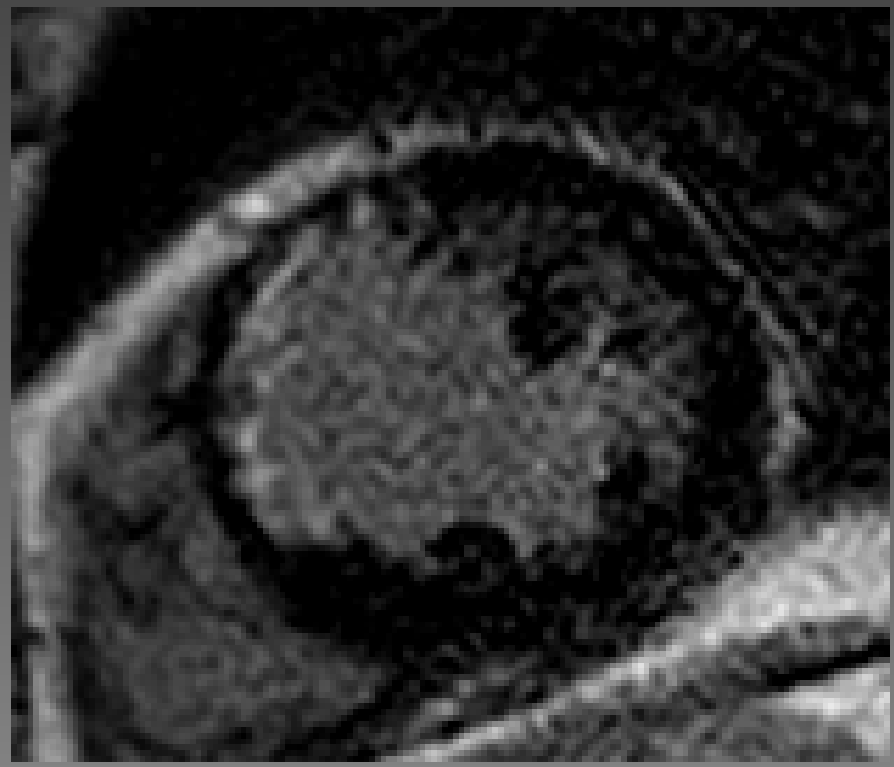


T2 WI **DE-MRI**

Acute MI (5 days ago)

DE-MRI *vs* T2 MRI





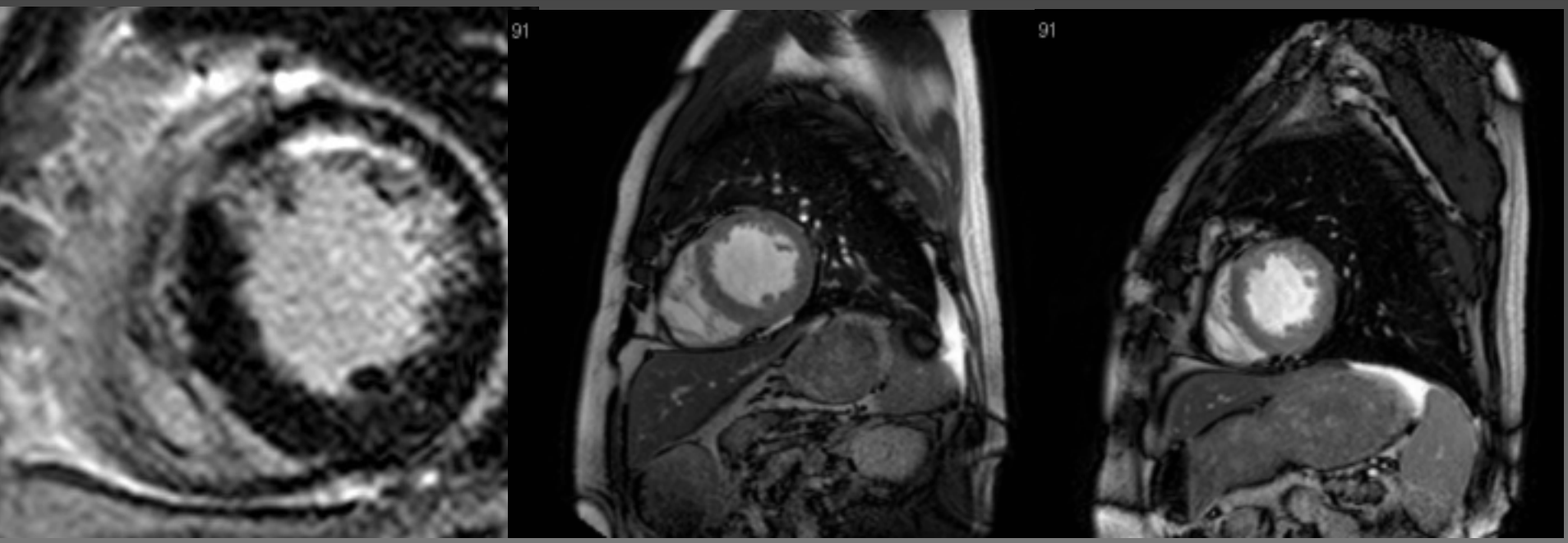
T2 WI **DE-MRI**

Chronic MI (9 years Hx)

DE-MRI: CLINICAL IMPLICATIONS

- Detection of Myocardial Infarction
  - Acute Infarction
  - Chronic (healed) Infarction
- Prediction of Functional Recovery after Revascularization Treatment

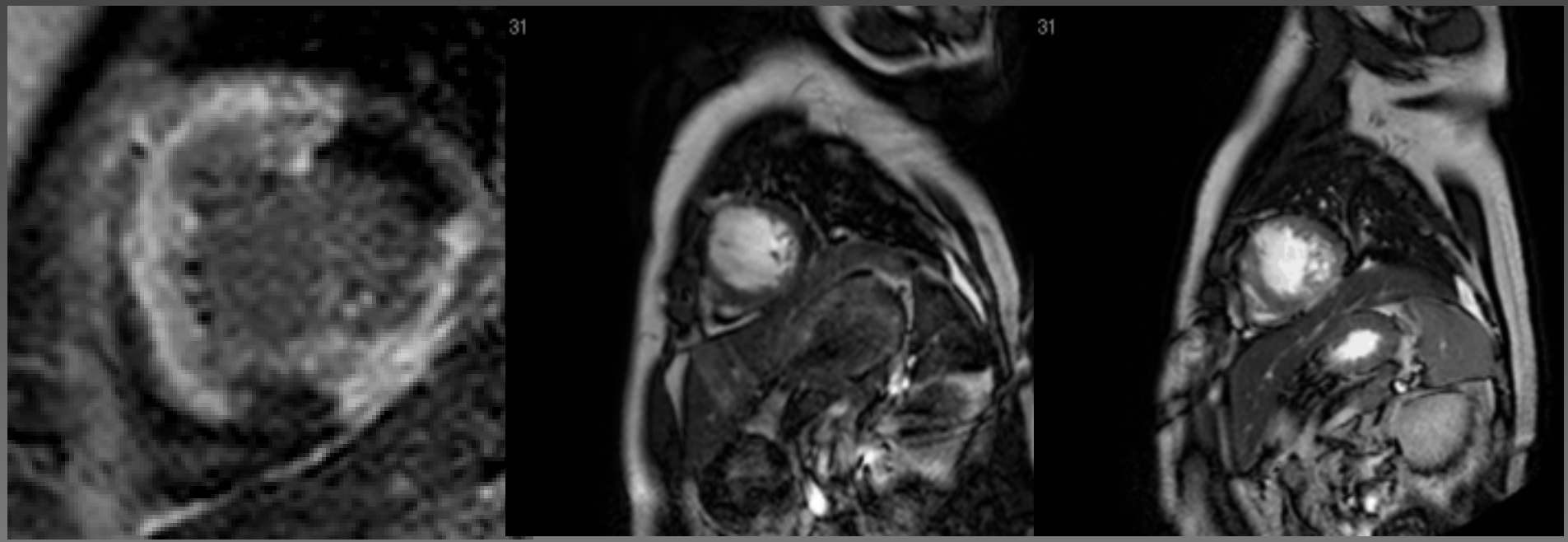
DE-MRI: Functional Recovery



DE-MRI **Pre-tx cine** **Post-tx cine**

3 VD, F/U 3 months after CABG
EF: 47.4% → 63.4%

DE-MRI: Functional Recovery



DE-MRI **Pre-tx cine** **Post-tx cine**

3 VD, F/U 3 months after CABG
EF: 17.8% → 19.4%

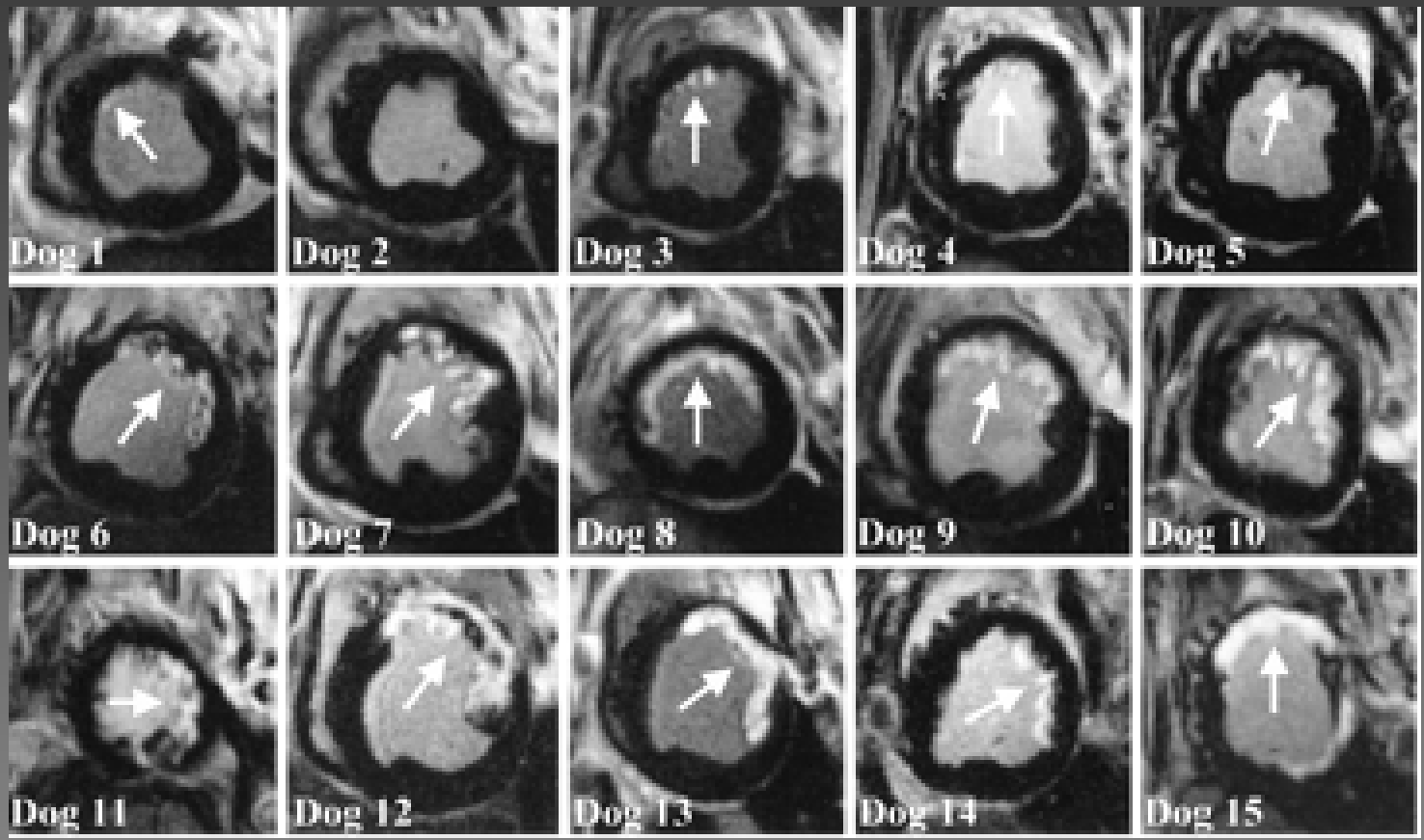
Assessment of Myocardial Salvage

An animal study in 15 dogs

45 min Occlusion

90 min Occlusion

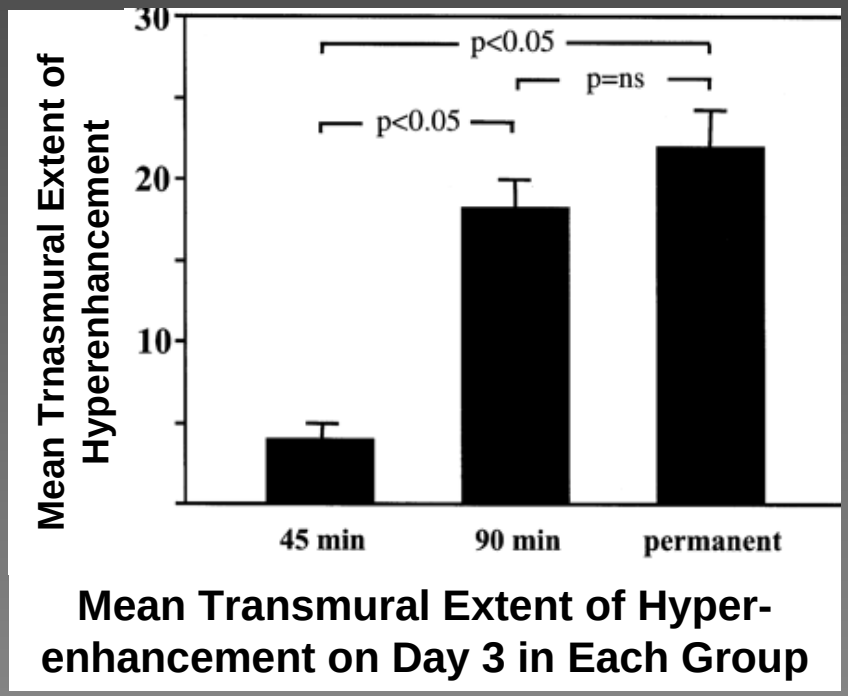
Permanent Occlusion



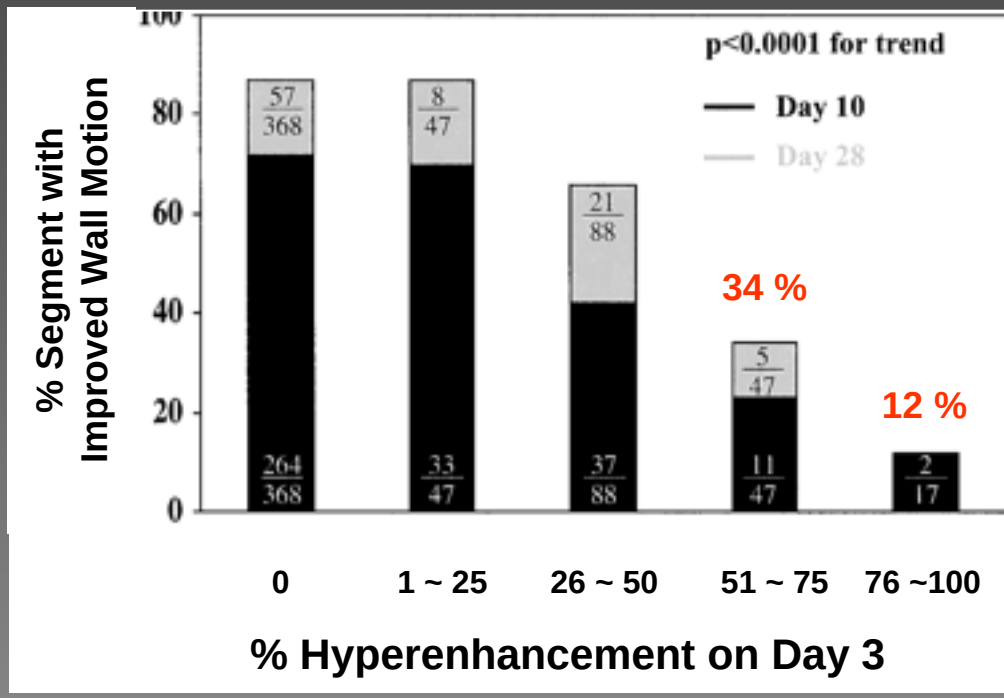
Hillenbrand et al. Circulation 2000

Assessment of Myocardial Salvage

An animal study in 15 dogs



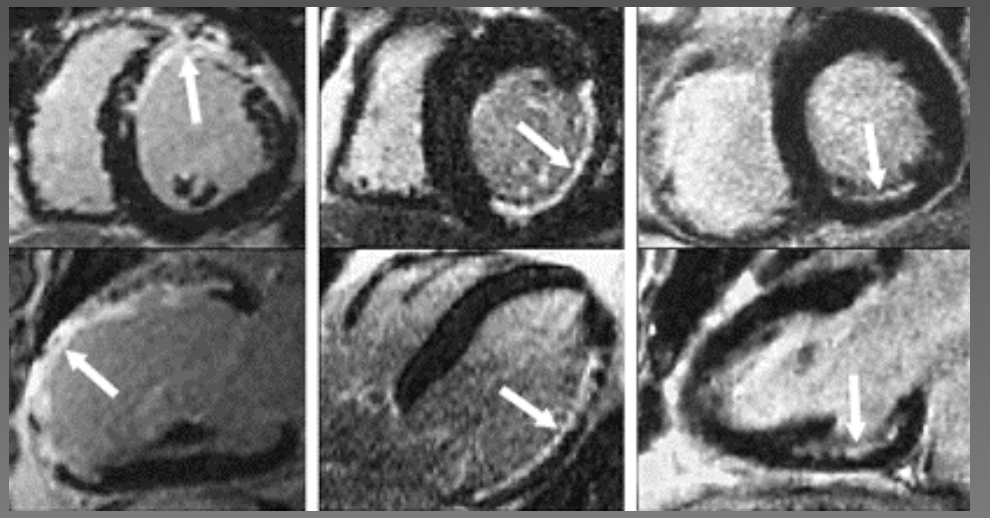
Mean Transmural Extent of Hyper-enhancement on Day 3 in Each Group



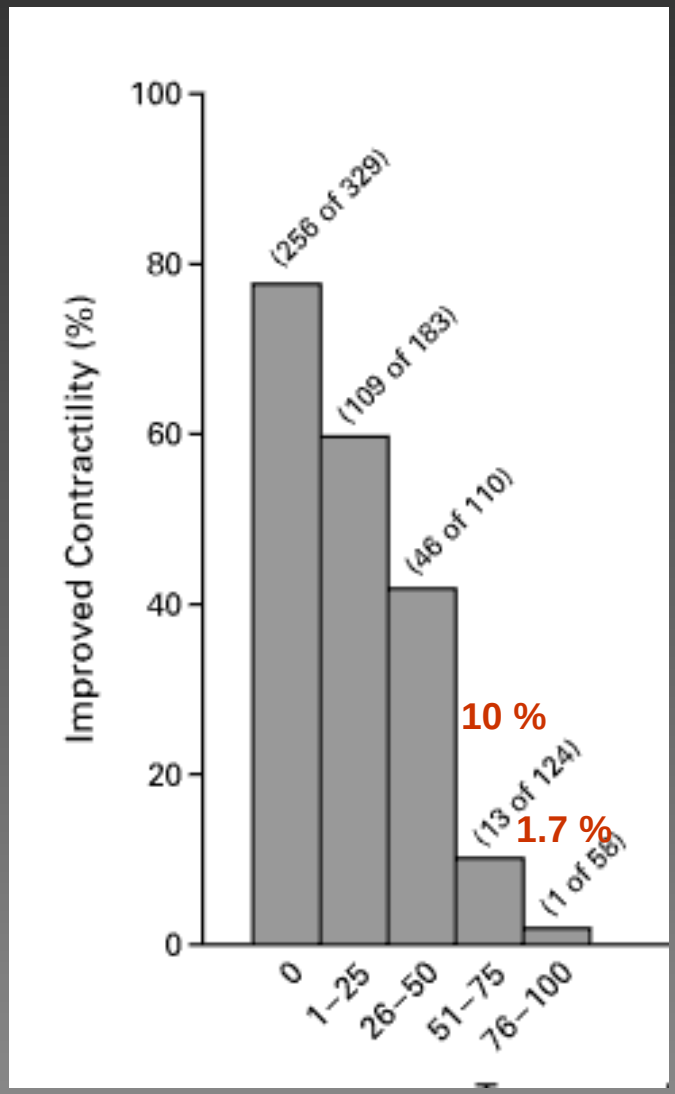
Hillenbrand et al. Circulation 2000

Assessment of Myocardial Salvage

A prospective study in 61 patients



LAD LCX RCA

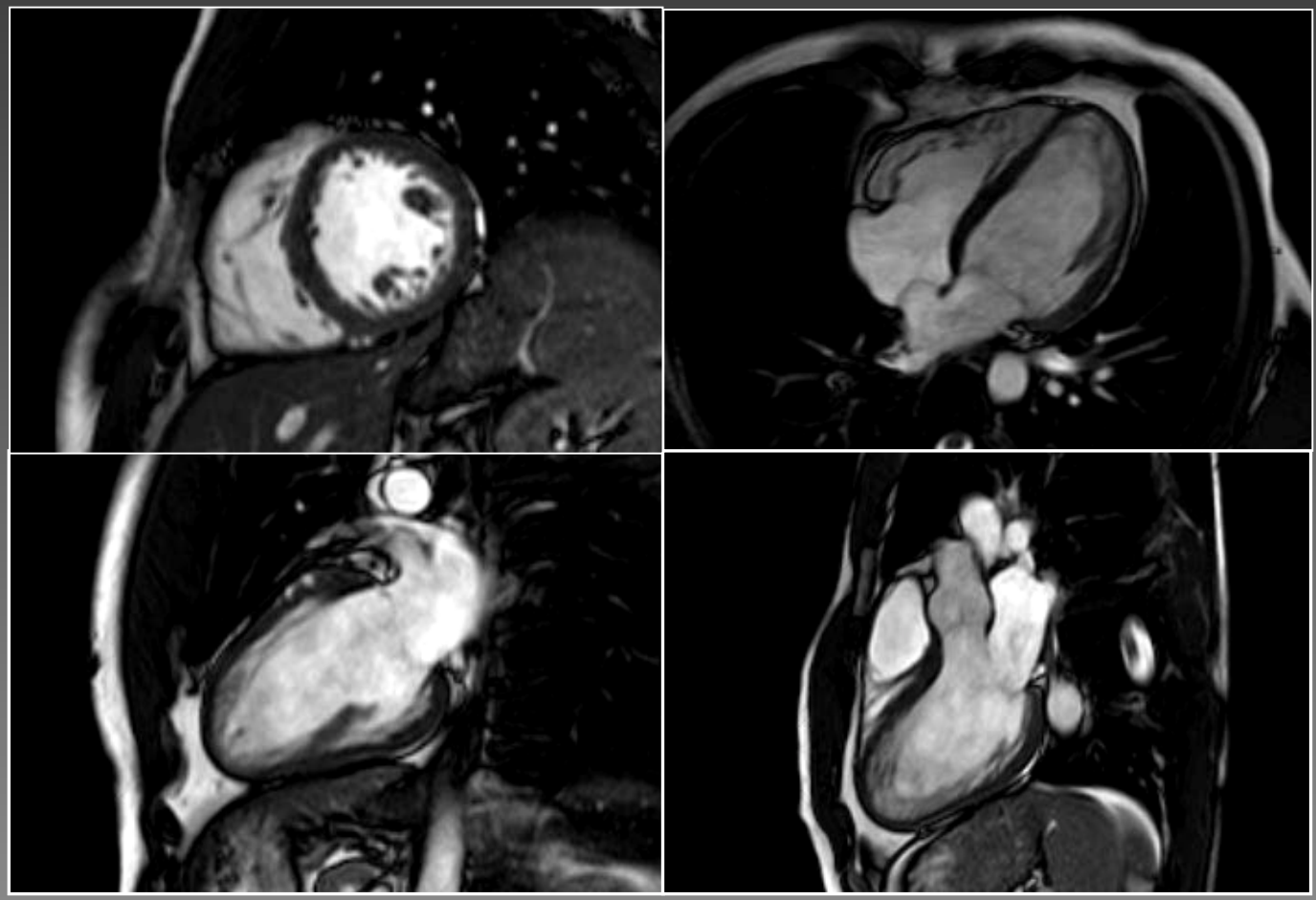


Kim et al. N Engl J Med 2000

MRI for Myocardial Viability

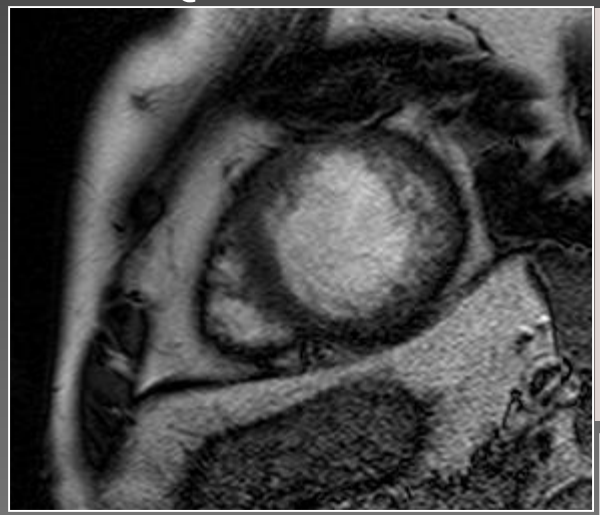
1. Detection of Myocyte necrosis or scar: DE-MRI
2. Assessment of LV function:
   - Myocardial mass:
     End-diastolic wall thickness
   - LV contractility:
     End-systolic wall thickening
   - Contractile (inotropic) reserve

2. LV Function: *Cine MRI*



Analysis of LV Function

- Visual qualitative assessment
- Quantitative assessment



Ejection fraction	: 15.0 %		
Stroke volume	: 55.2 ml		
Cardiac output	: 2.9 l/min		
ED phase	: 0.0 ms	(phase 1	)
ED volume	: 368.1 ml		
ES phase	: 461.0 ms	(phase 9	)
ES volume	: 312.8 ml		
ED wall mass	: 35.9 g		
ED wall + papillary mass	: n/a		
ED wall - correct. mass	: n/a		
ED wall + papillary - correct. mass	: n/a		
Heart rate	: 52.0 bpm		

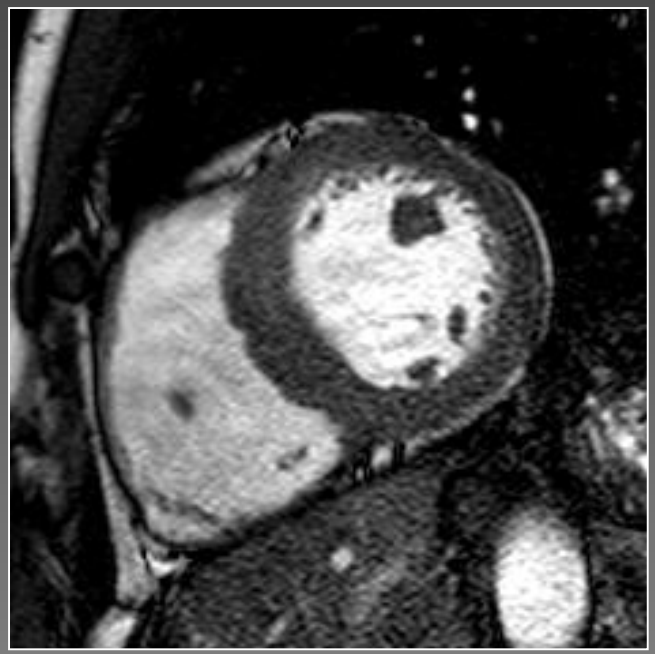
Thickness (ED)

Thickening

Motion

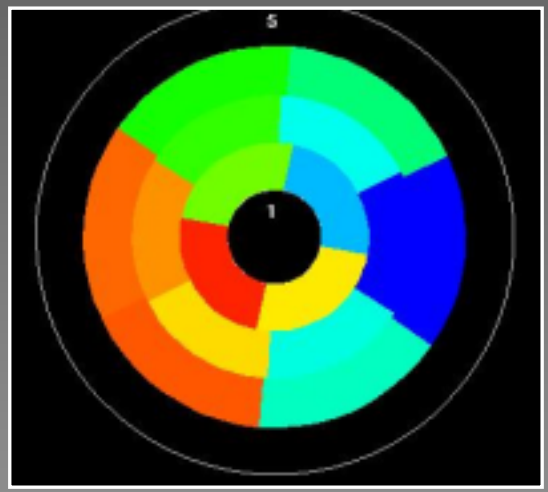
Quantitative Assessment

- More accurate than visual assessment



Wall thickening results

slice	Global thickening	segment	Regional thickening
4	0.8	1	0.9
4	0.8	2	1.0
4	0.8	3	1.5
4	0.8	4	1.1
4	0.8	5	0.4
4	0.8	6	0.4

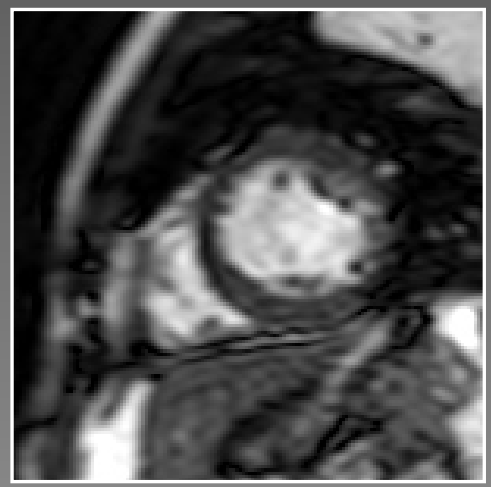


47/M
Acute myocardial infarction
Echo: normal wall motion

Real Time Cine MR

- Retrospective TFE Synchronized Real Time Multi Slice (M2D) B-TFE
- Free breathing, real time, no breathhold
  - Pediatric patients, sick patients

Breathhold retrospective bTFE



Free breathing real time cine

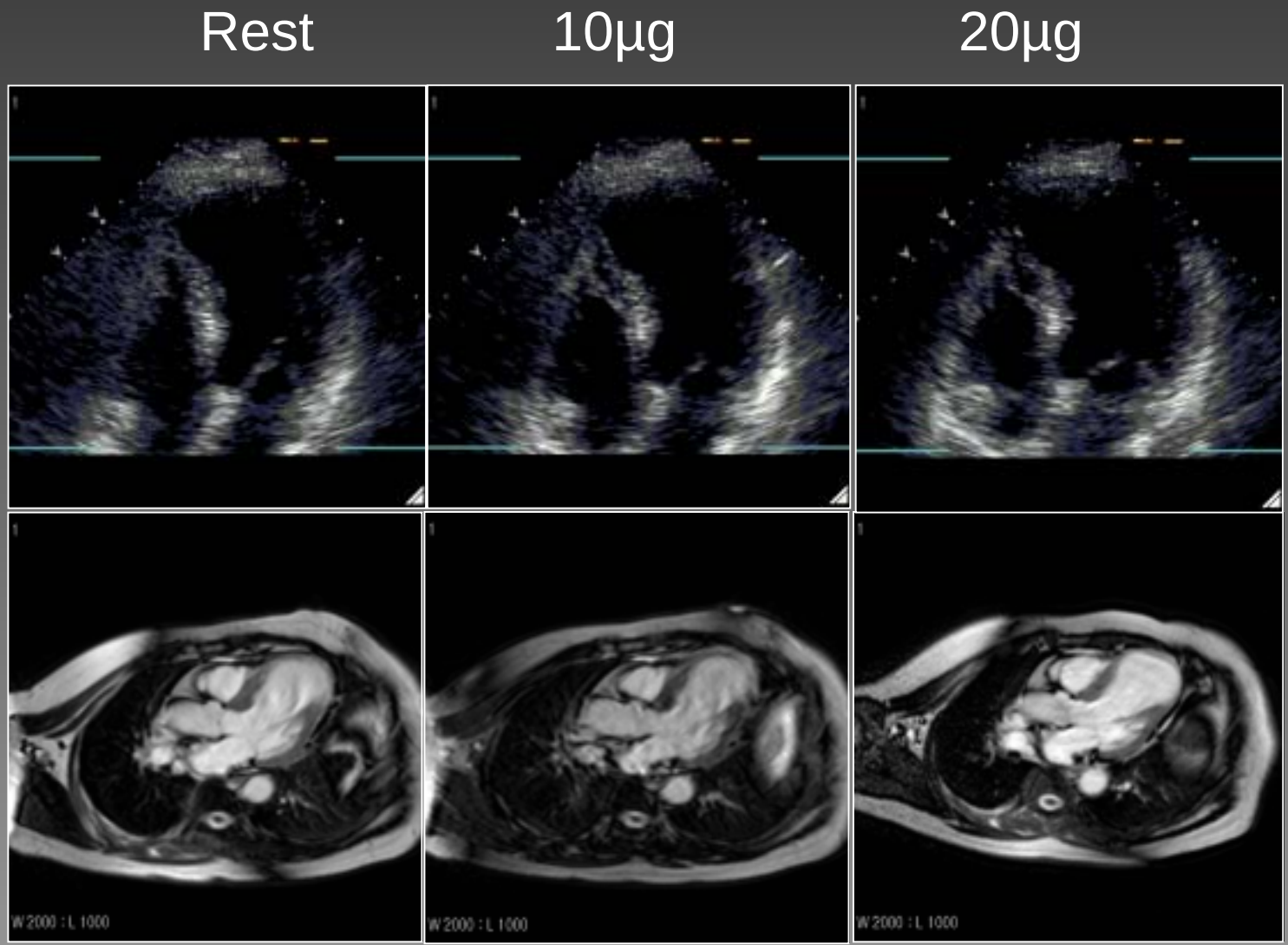
2. LV Function: *Low Dose DSMR*

"contractile (inotropic) reserve"

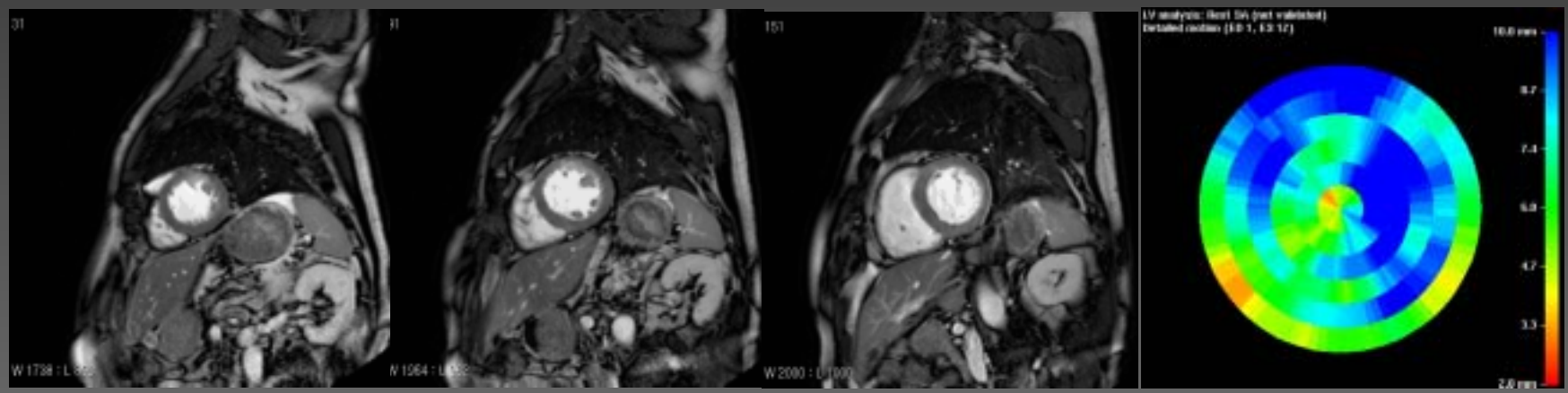
- DE-MRI: impaired specificity as a predictor of functional recovery in non-transmural scars (1% to 74%).
- Low dose DSMR: superior to DE-MRI as a predictor of functional recovery and does not depend on the transmurality of scar.
- DE-MRI and DSMR provide complementary information.

Wellnhofer et al, Circulation 2004

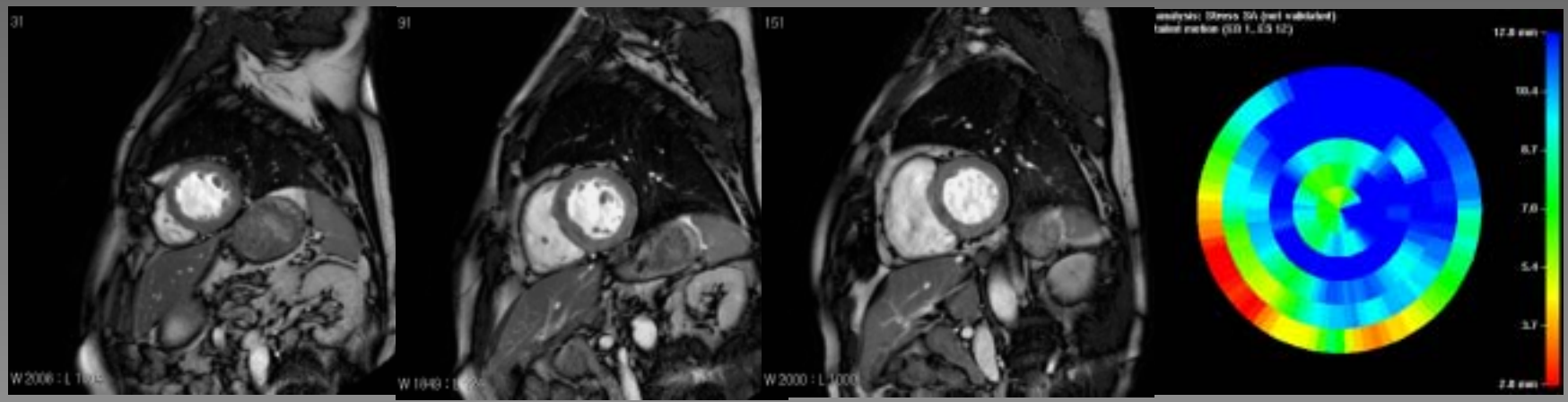
DSE *vs* DSMR



Low Dose DSMR



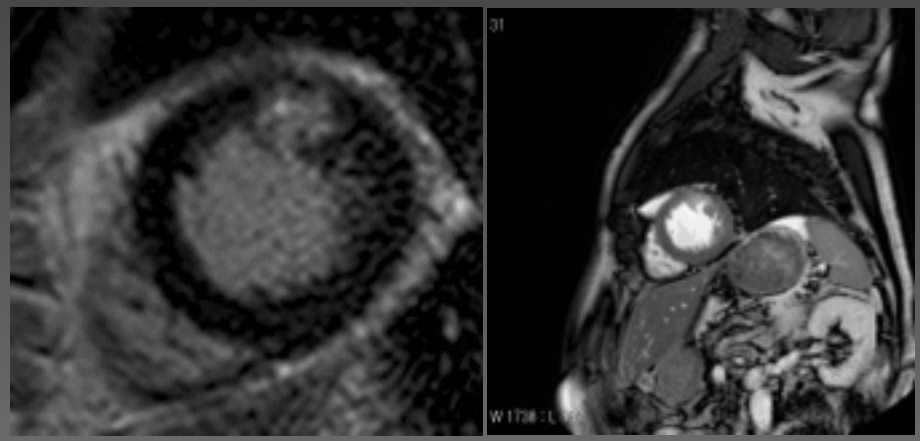
Rest MRI

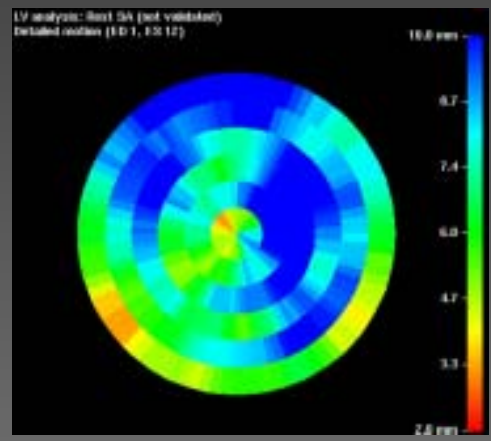


Low dose DSMR

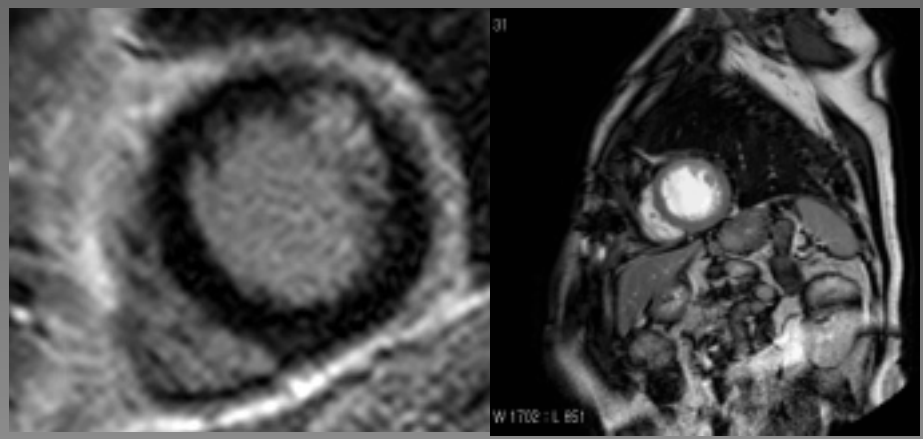
Low Dose DSMR

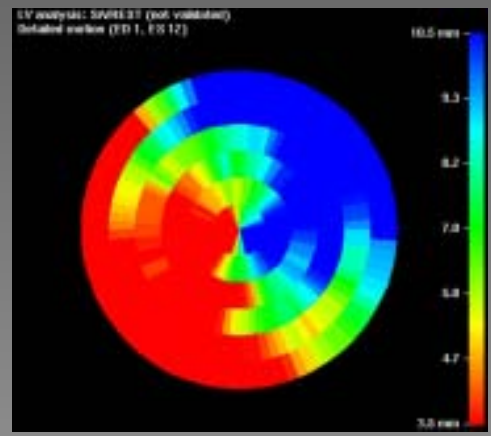
Pre CABG





Post CABG

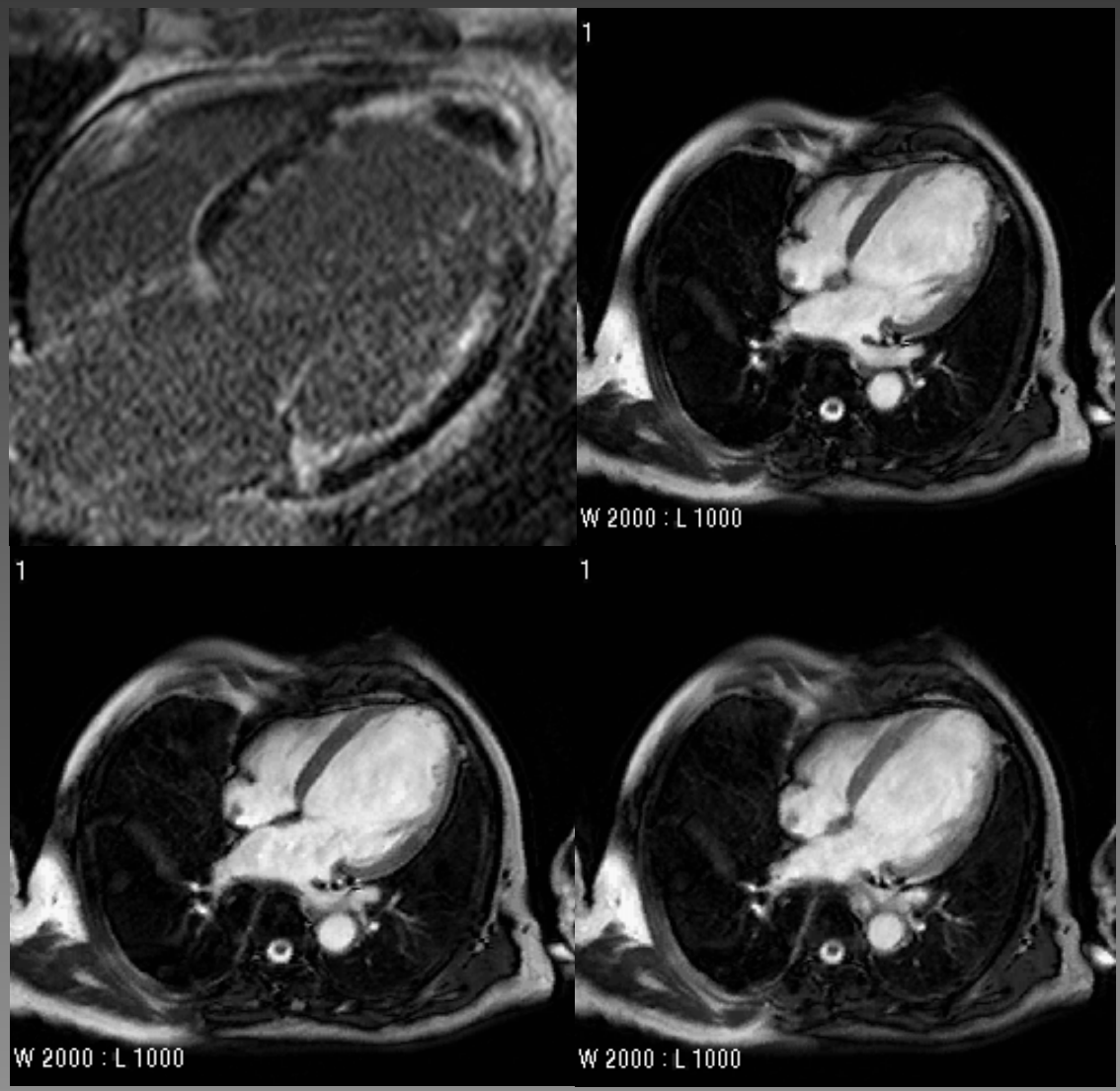




Low Dose DSMR

Viability

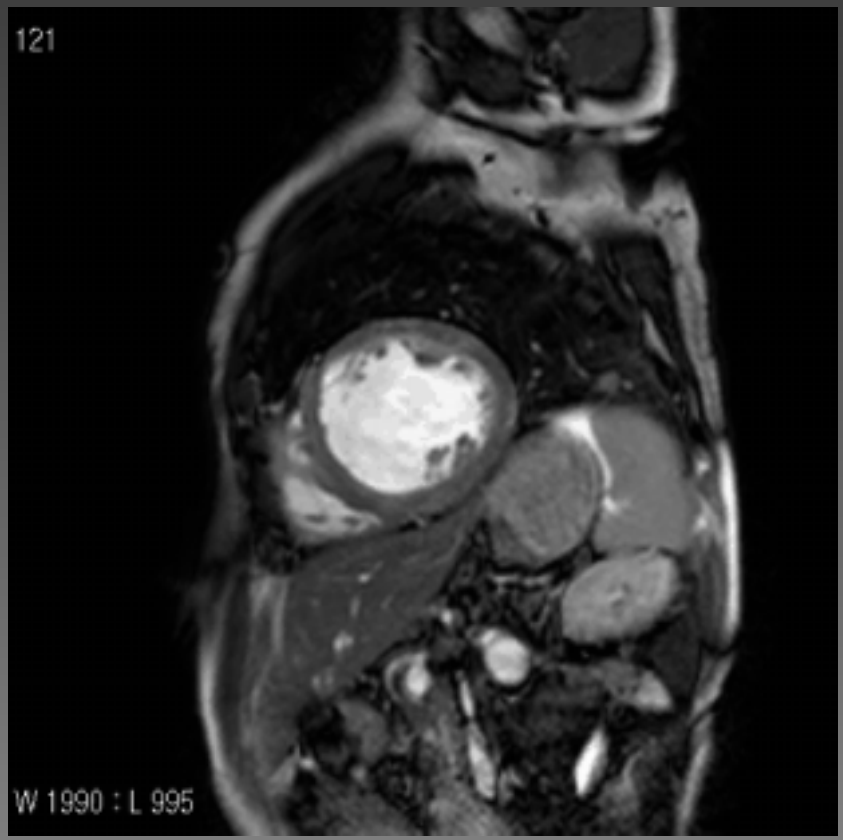
Rest

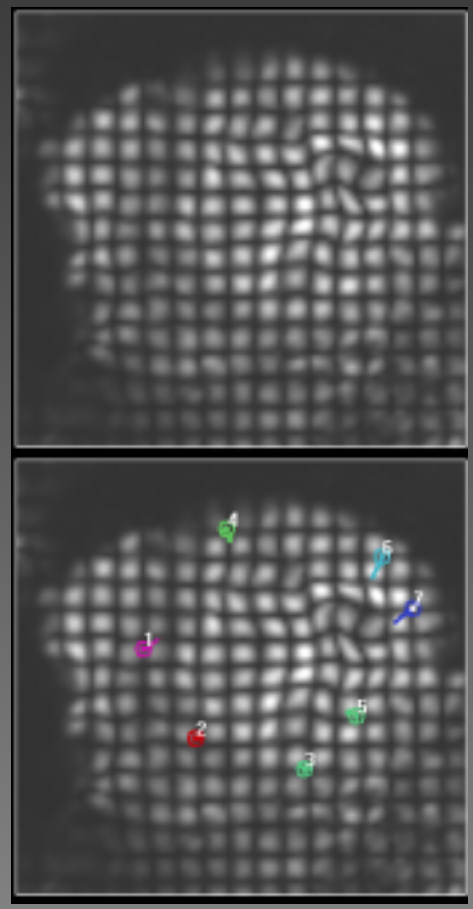


10µg

20µg

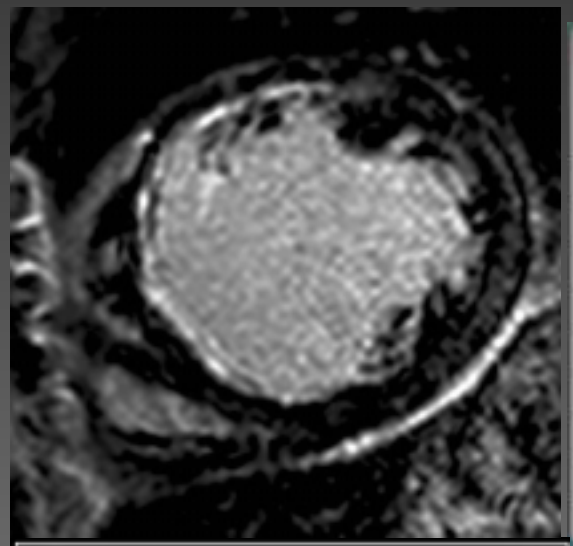
2. LV Function: *Tagged MRI*

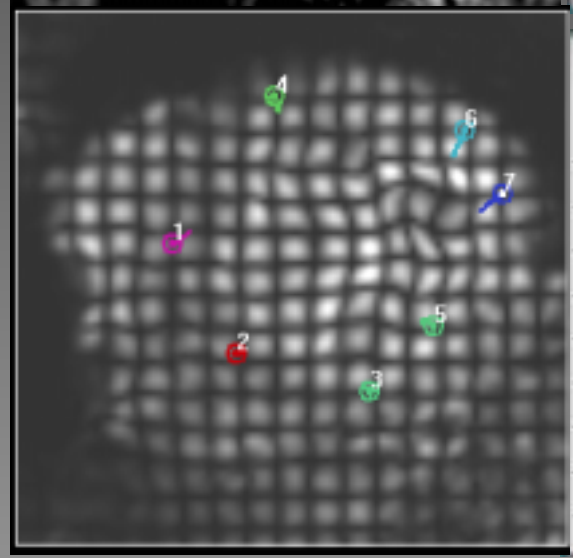


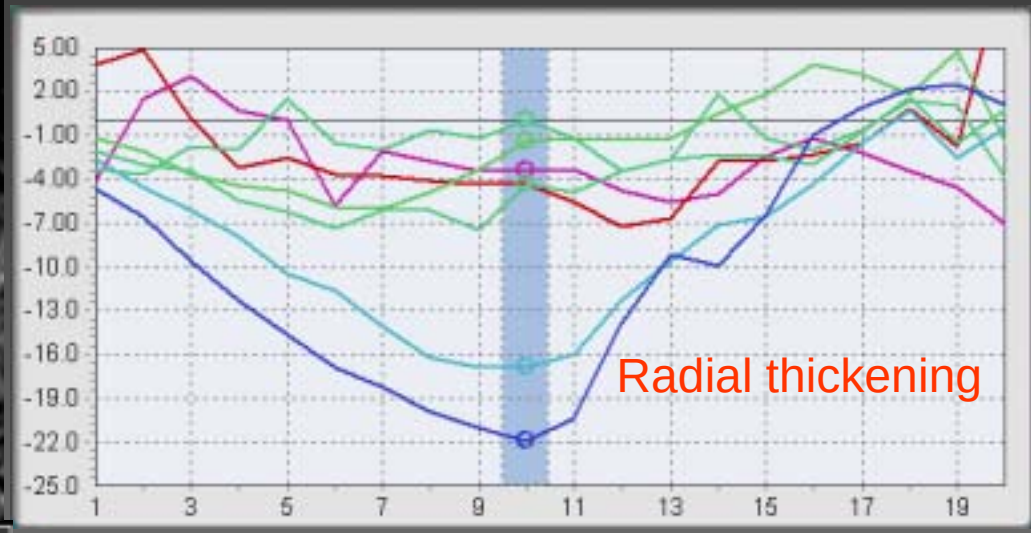


Wall Motion Abnormality due to ICMP

Tagged MRI




4
6
7
1
5
2
3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2.00
-1.00
-4.00
-7.00
-10.0
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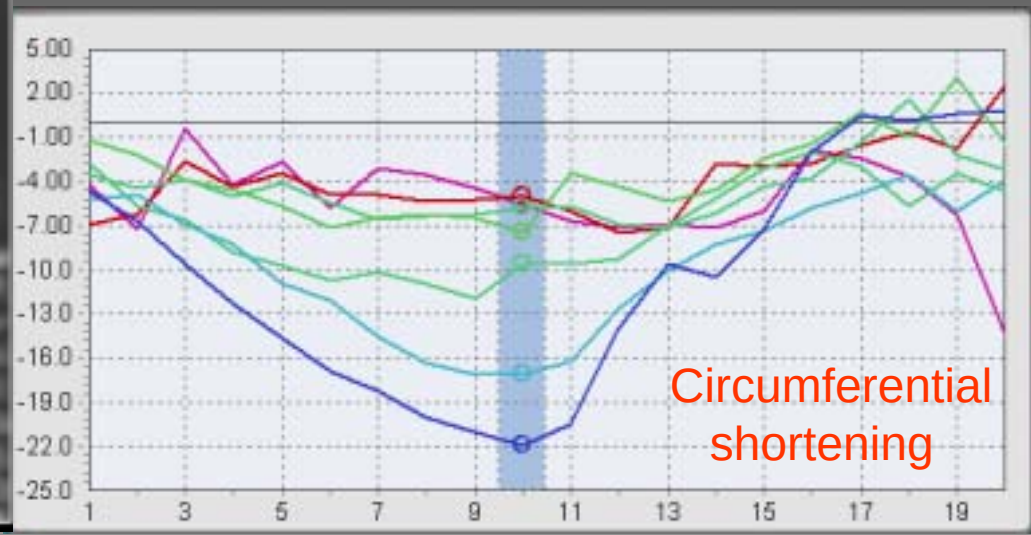
1
3
5
7
9
11
13
15
17
19
Radial thickening


5.00
2.00
-1.00
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-13.0
-16.0
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Circumferential shortening

Conclusion

1. Delayed enhancement MRI
   - Detection of area with myocyte necrosis
   - Acute MI vs. chronic MI (with T2 MRI)
   - Prediction of functional recovery
2. Cine MRI / Tagged cine MRI / DSMR
   - Myocardial mass
   - Contractile function
   - inotropic reserve

Thank You !!

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