Cardiac MRI : Assessment of Viability

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Viability Imaging

- SPECT
  - 201-Thallium: Active cellular transport
  - 99mTc-Sestamibi: Preserved mitochondrial function
- PET : Perfusion-metabolism mismatch
- Echo : Contractile reserve for inotrophic stimulation

MR Assessment of Viablilty

- Cellular level : delayed hyperenhancement
- Clinical definition : Contractile reserve
  - functional response to dobutamine
  - functional response to revascularization
- Metabolic level: spectroscophy

MR Assessment of Viablilty

- Cine MRI: wall thickness and motion
- T2 WI: acute vs. chronic infarction
- Perfusion MRI: Myocardial perfusion reserve & microvascular integrity
- low dose Dobutamine stress MRI(DS MRI)
- Myocardial tagging c DS MRI
- Delayed enhance MRI (DE-MRI)
- VENC MRI : Coronary flow reserve

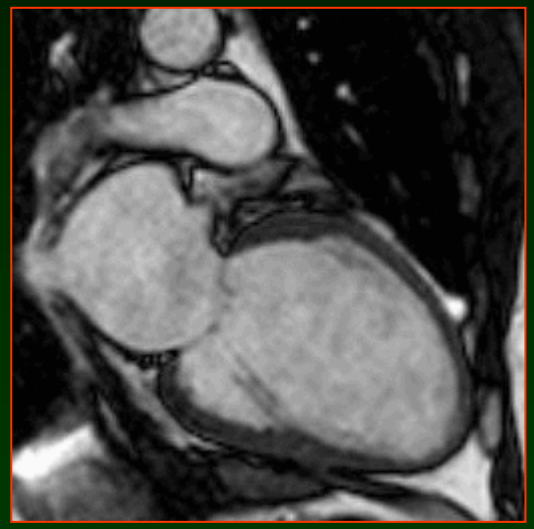
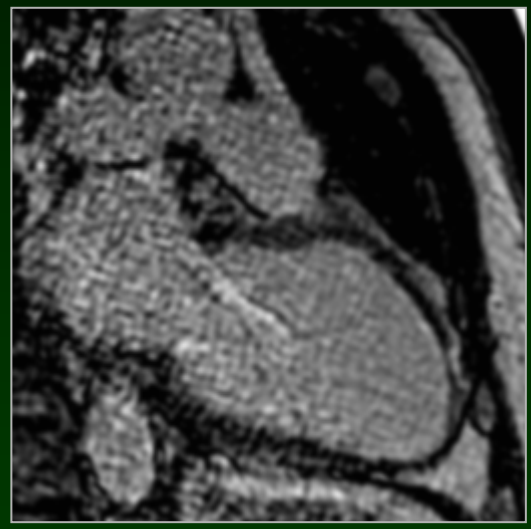
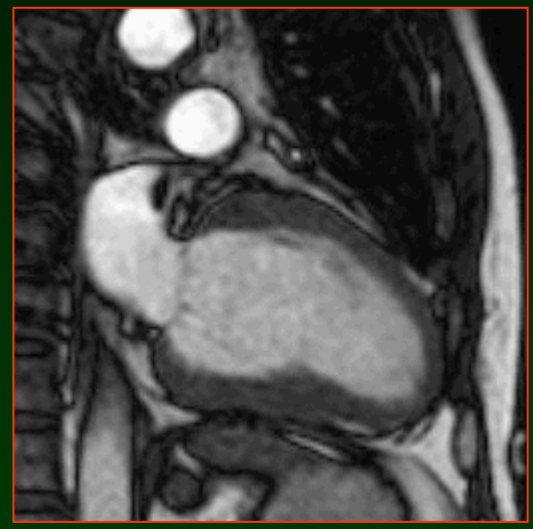
Cine MRI

- Non-viable myocardium
  - End diastolic wall thickness ≤ 6 mm
  - Systolic wall thickening ≤ 1.5 mm
- Wall thinning after MI takes 6 wks
- In chronic MI : Sensitive, but not sepecific
- Wall thinning or akinetic myocardium at rest may not be a reliable marker of viability.

- *JACC 2000;35:1152 Cwajg JM et al.*
  Wall thickness by 2D echo vs Tl SPECT and DSE
- End diastolic wall thickness ≤ 6 mm → Non-viable

Cine MRI

54/M 3VD LV dysfx

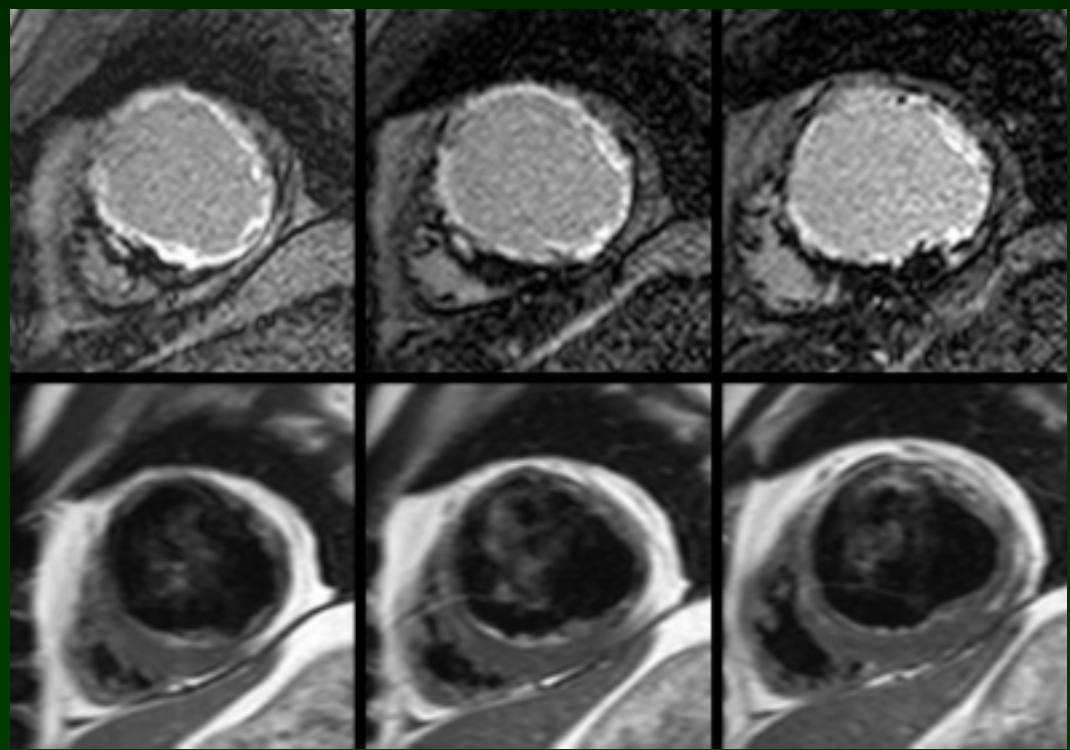
T2 weighted image

- *Abdel-Aty. Circulation 2004;109. T2-weighted CMR in MI*
- edema in AMI : high signal
- fibrosis in OMI : low signal

65/M 3VD ICMP stent

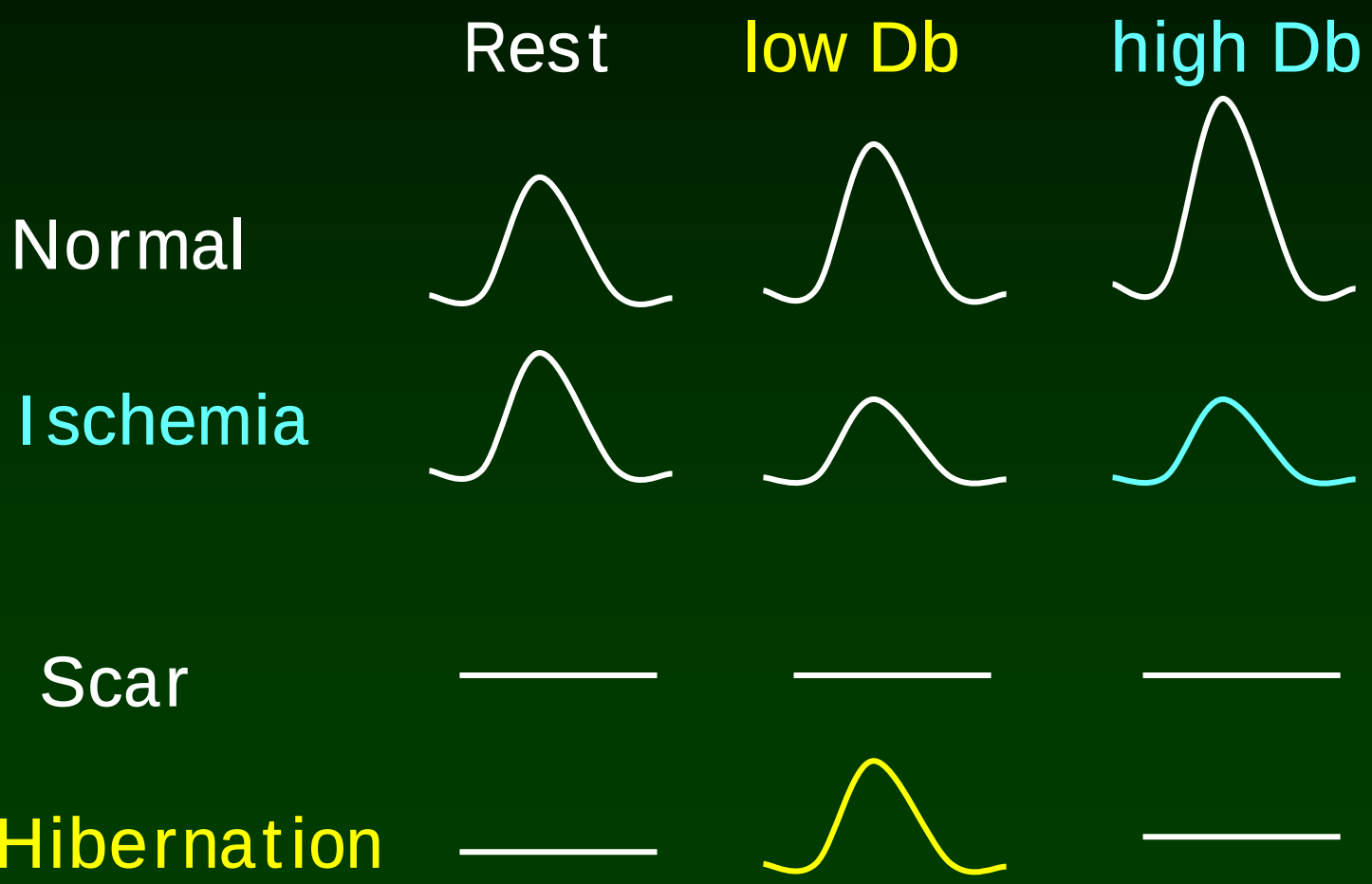
DE MRI

T2 WI



Dobutamine stress

: ↑ myocardial contractility - rate/force

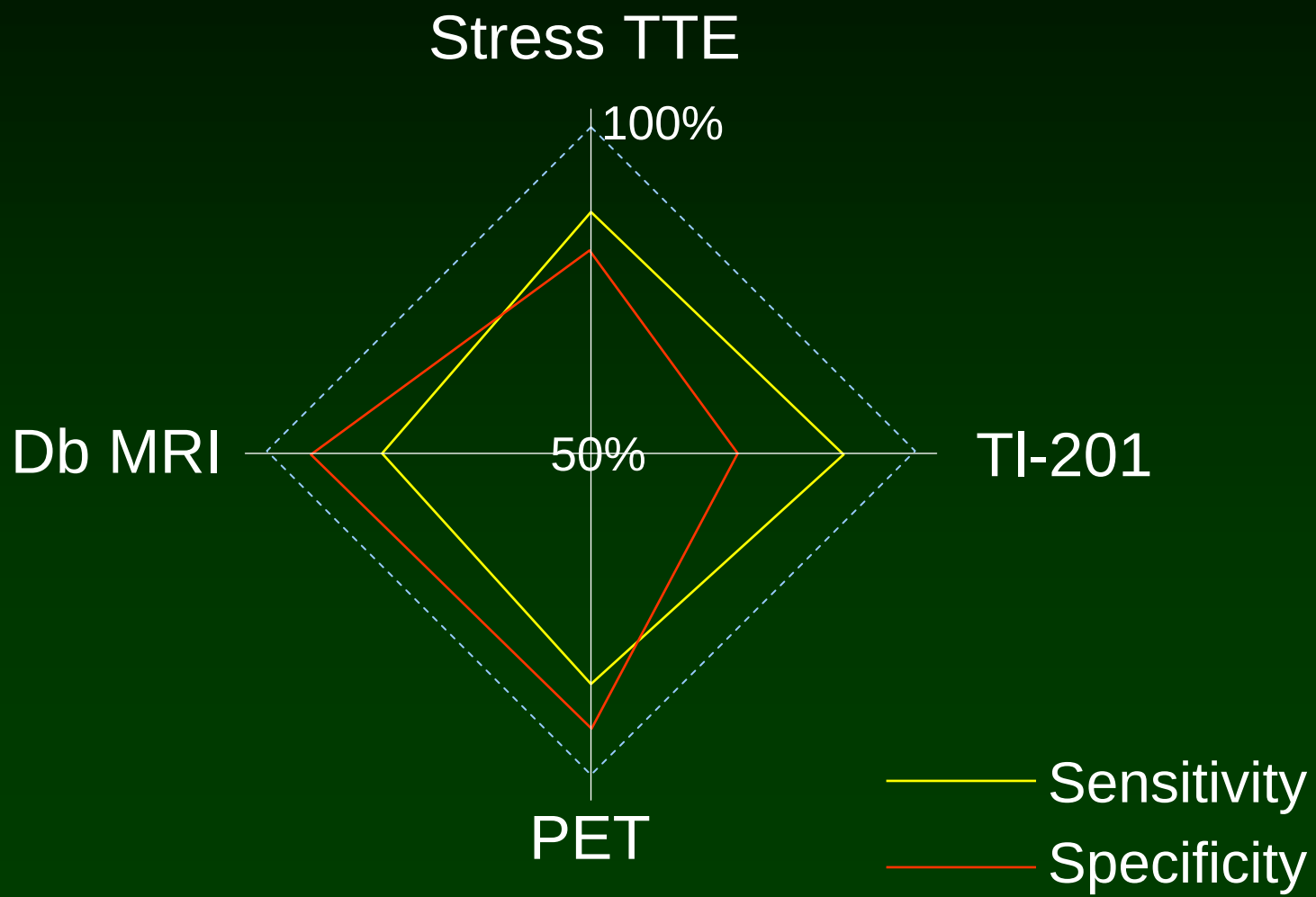


Dobutamine Stress : Echo vs. MR

- *Nagel E, Circulation 1999;99:763*
  Dx. of ischemia-induced wall motion abnormalities with the use of high-dose dobutamine stress MRI : comparison with dobutamine stress echocardiography

	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

Low-dose Dobutamine Stress MR: Dection of Hibernation

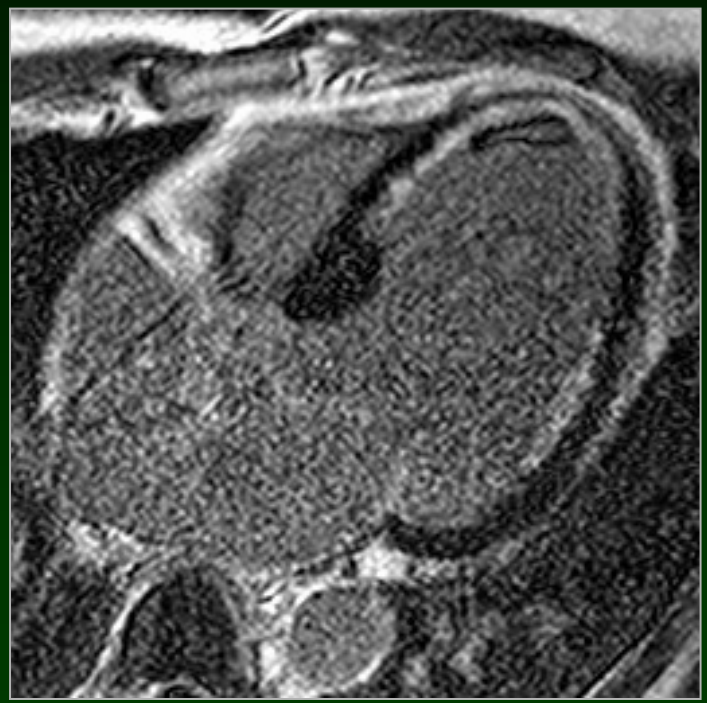


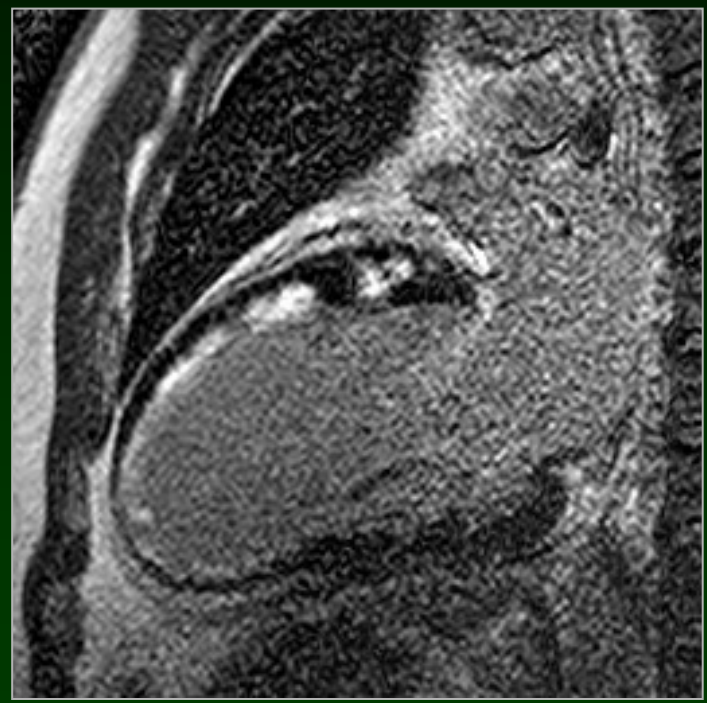
Viability assessment by DS MRI

- Viability assessment by DS MRI in pts with severe LV dysfx
  - modest sensitivity : 50%-82%
  - high specificity : 81%-93%

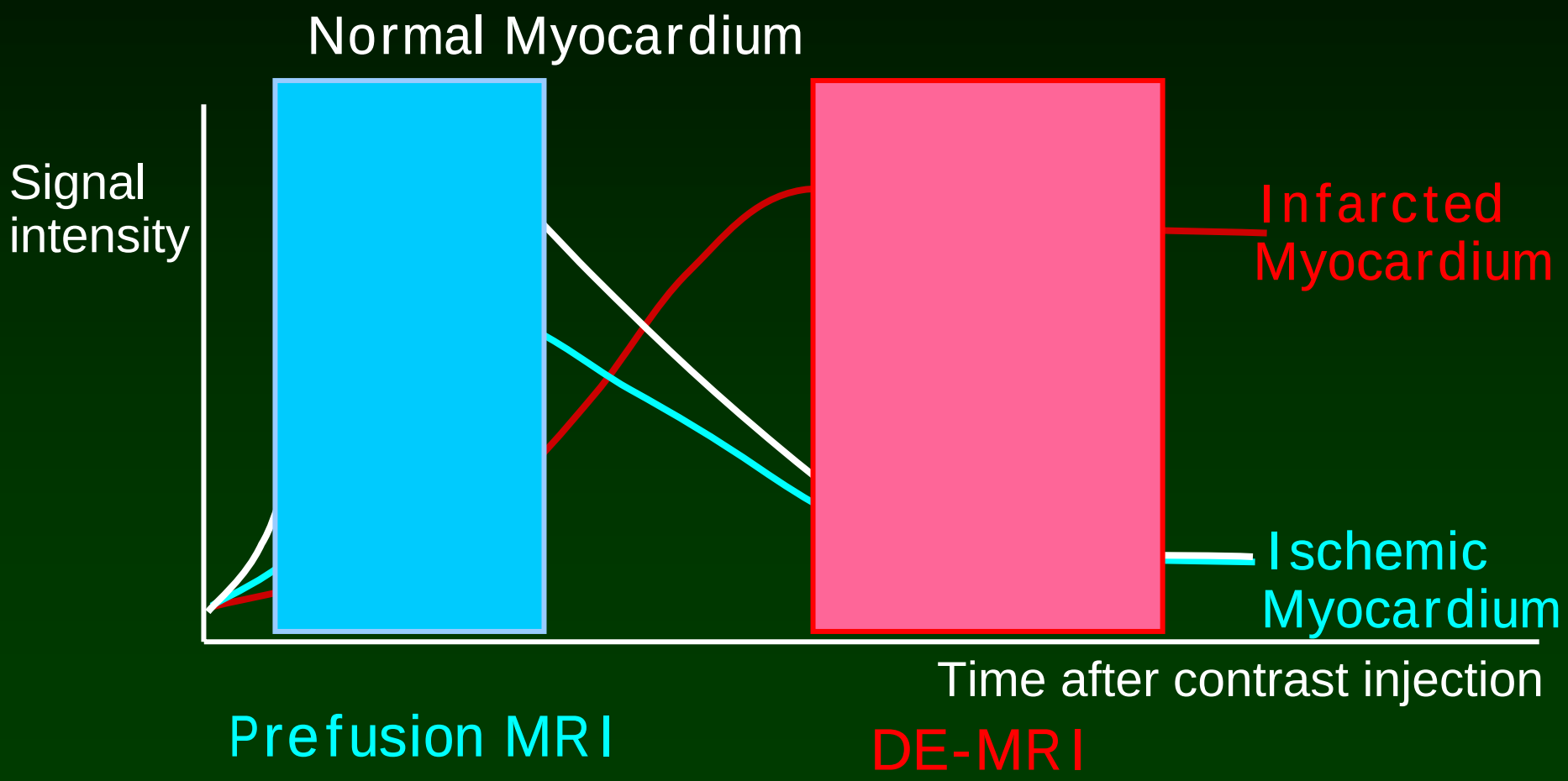
	No	LV dysfx	EF %	sensitivity	specificity
Baer	43	mild	42±10	82	81
Gunning	30	severe	24±8	50	81
Sandstede	27			61	90
Wellnhofer*	29	severe	32±8	75	93

Delayed Enhancement





Kinetics of contrast media : time-intensity curve



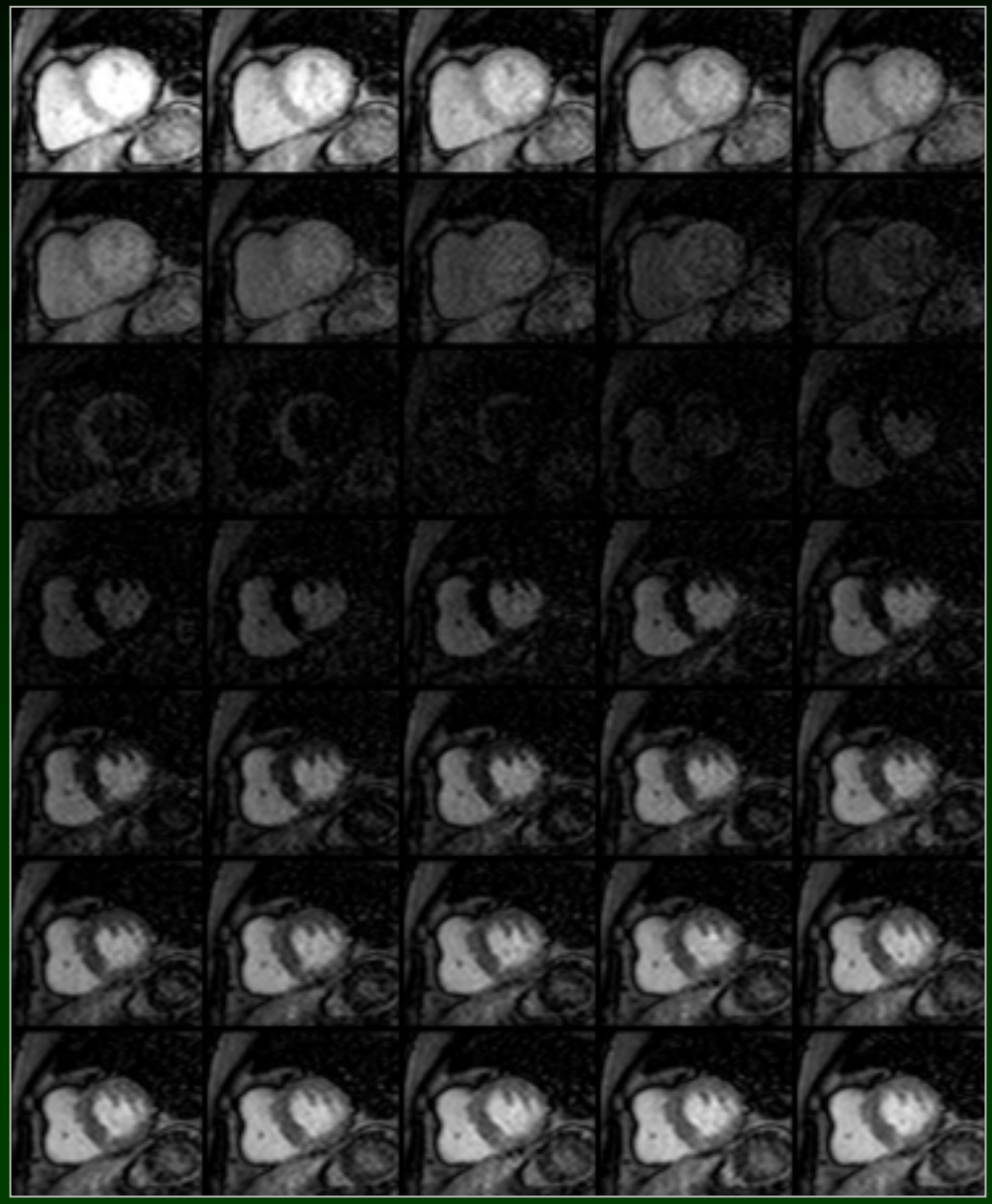
Delayed Hyperenhancement

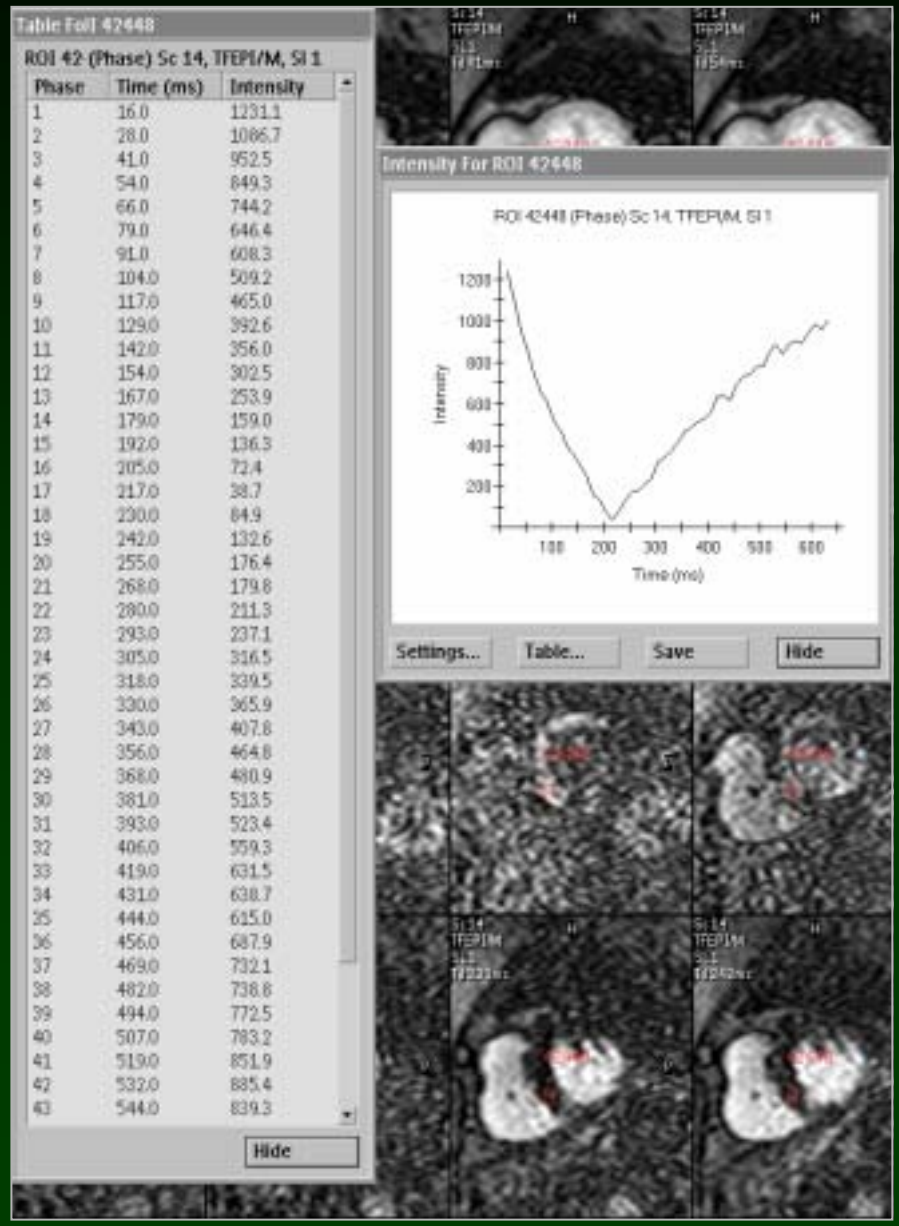
- Acute Myocardial Infarction
  - Increased volume distribution of Gd-DTPA due to sarcolemmal rupture
  - Prolongation of wash-in and wash-out time constant of injured muyocardium
  - Spatial extent of hyperehancement matches that of myocyte necrosis in acute myocardial infarction
- Chronic Myocardial Infarction
  - larger interstitial compartment in collagen filled fibrous scar

DE MRI: Technical aspect

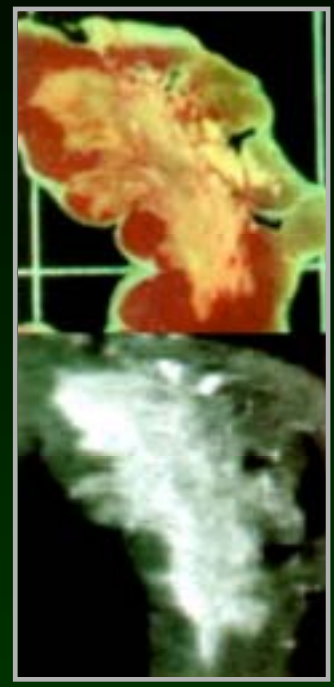
- Dose of contrast media: single dose
- Scan delay time: 10-30 min
- Inversion time (TI) : Look-locker, diffuse DE
- Breat-holding time: 3D navigator echo
- Acquisition window: temporal resolution
- Slice thickness: Partial volume averaging

IR-Balanced-TFE "Look-Locker"





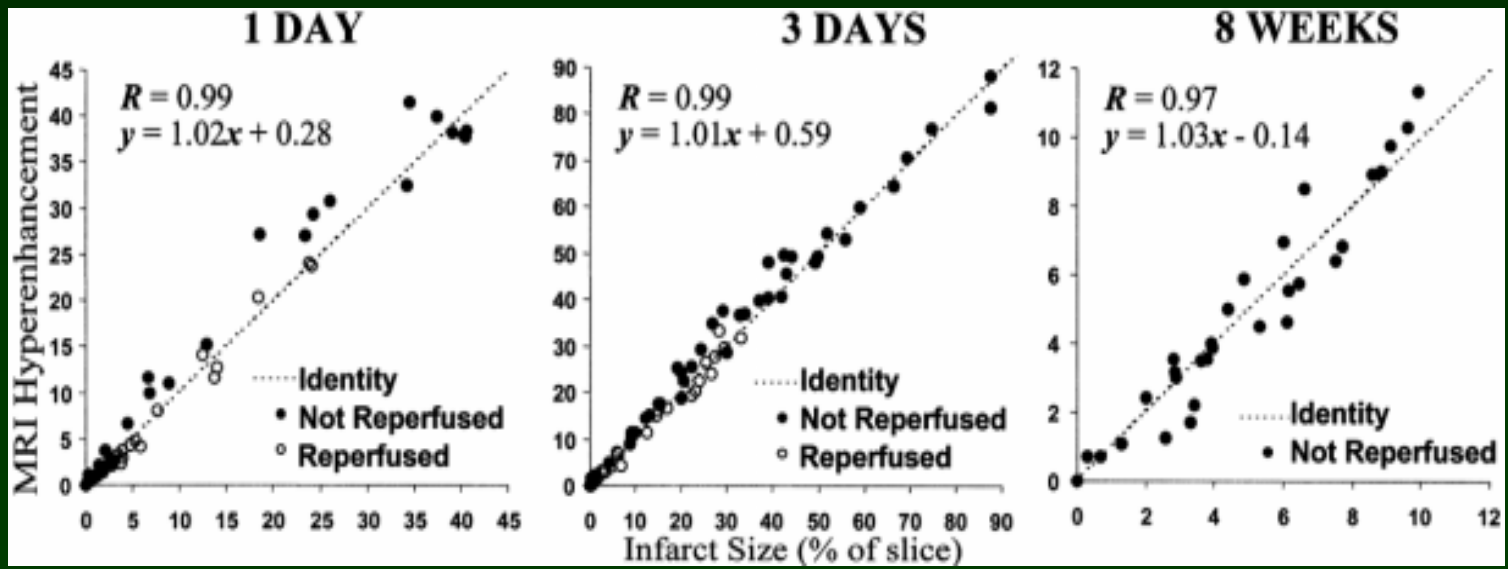
TTC staining vs. Delayed enhancement



Kim RJ, Relationship of MRI Delayed Contrast Enhancement to Irreversible Injury, Infarct Age, and Contractile Function, Circulation 1999;100:1992-2002

Delayed Hyperenhancement

- "Bright is dead"
- Size and shape of regions exhibiting DE are identical to regions of irreversible injury
- DE does not occur in reversibly injured regions.
- it is not necessary to consider wall motion in the MRI definition of viability

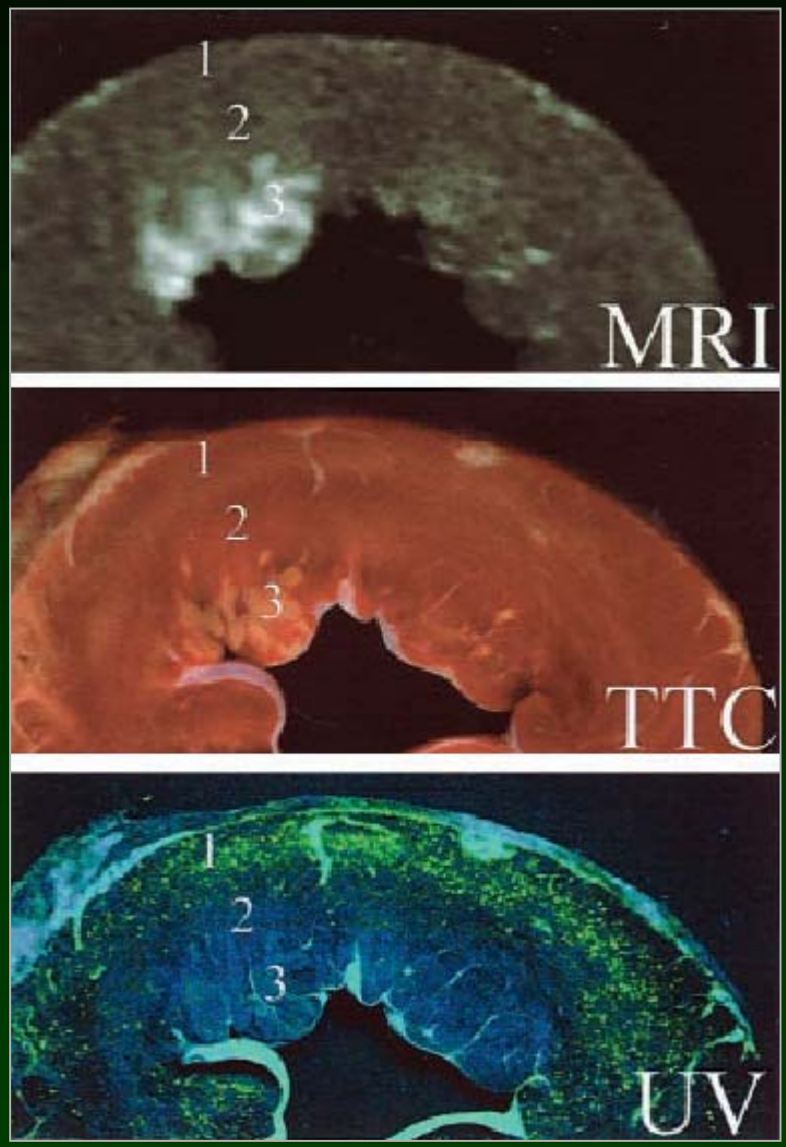


DE vs. TTC vs. Fluorescent

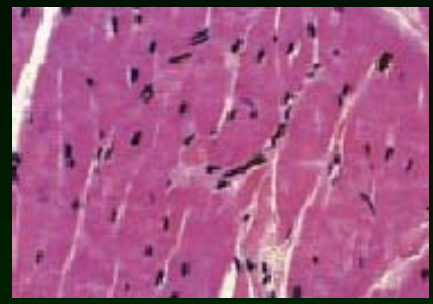
DE

TTC

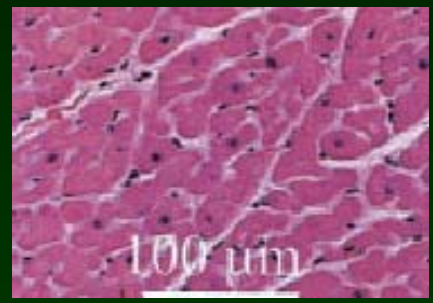
Fluo-
rescent



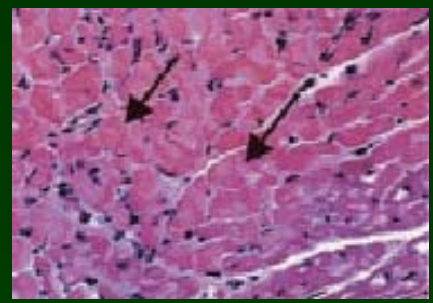
1. not at risk, not infarcted



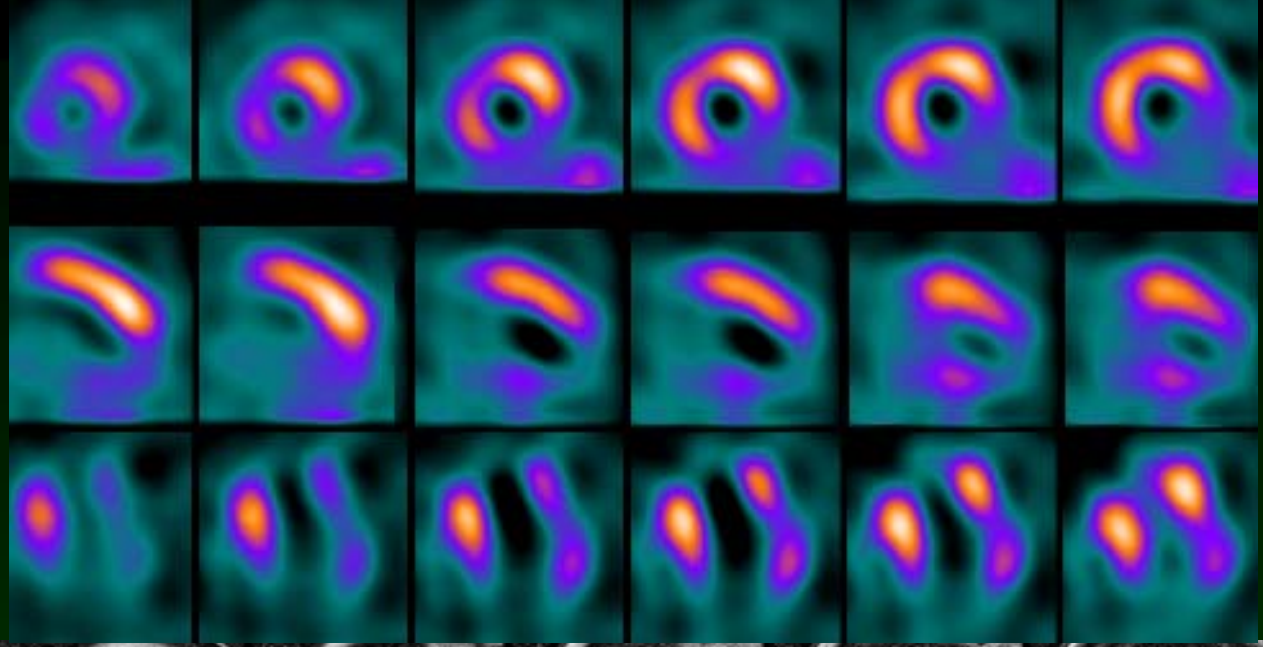
2. at risk, but not infarcted

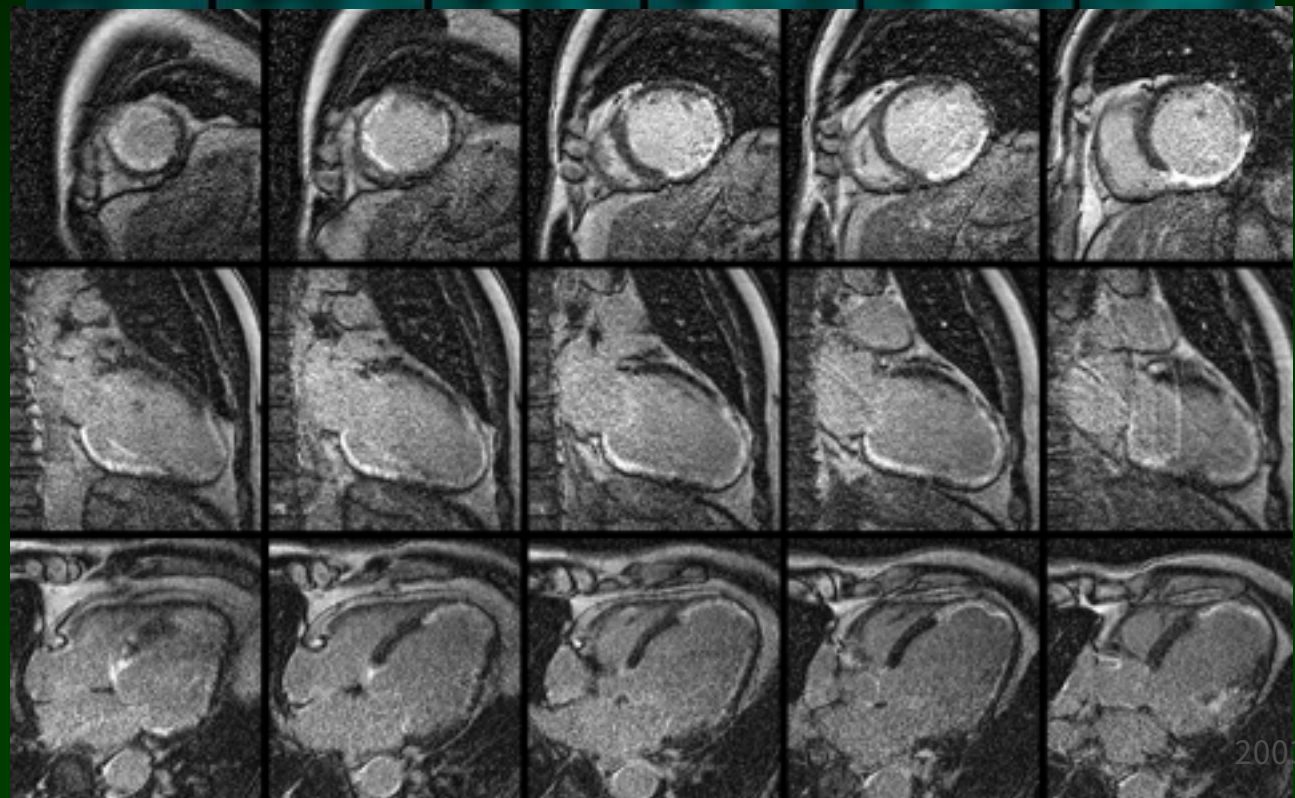


3. infarcted

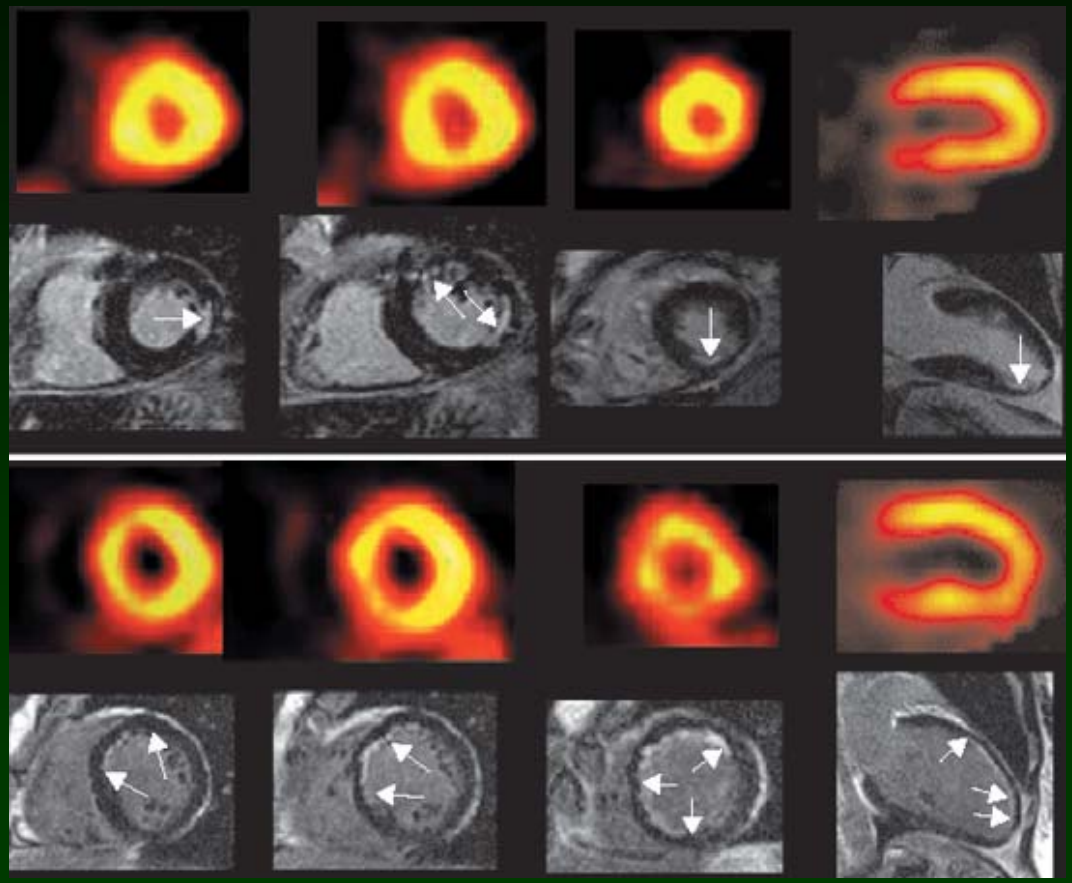


Fieno DS, Contrast MRI of myocardium at risk, JACC 2000;36:1985



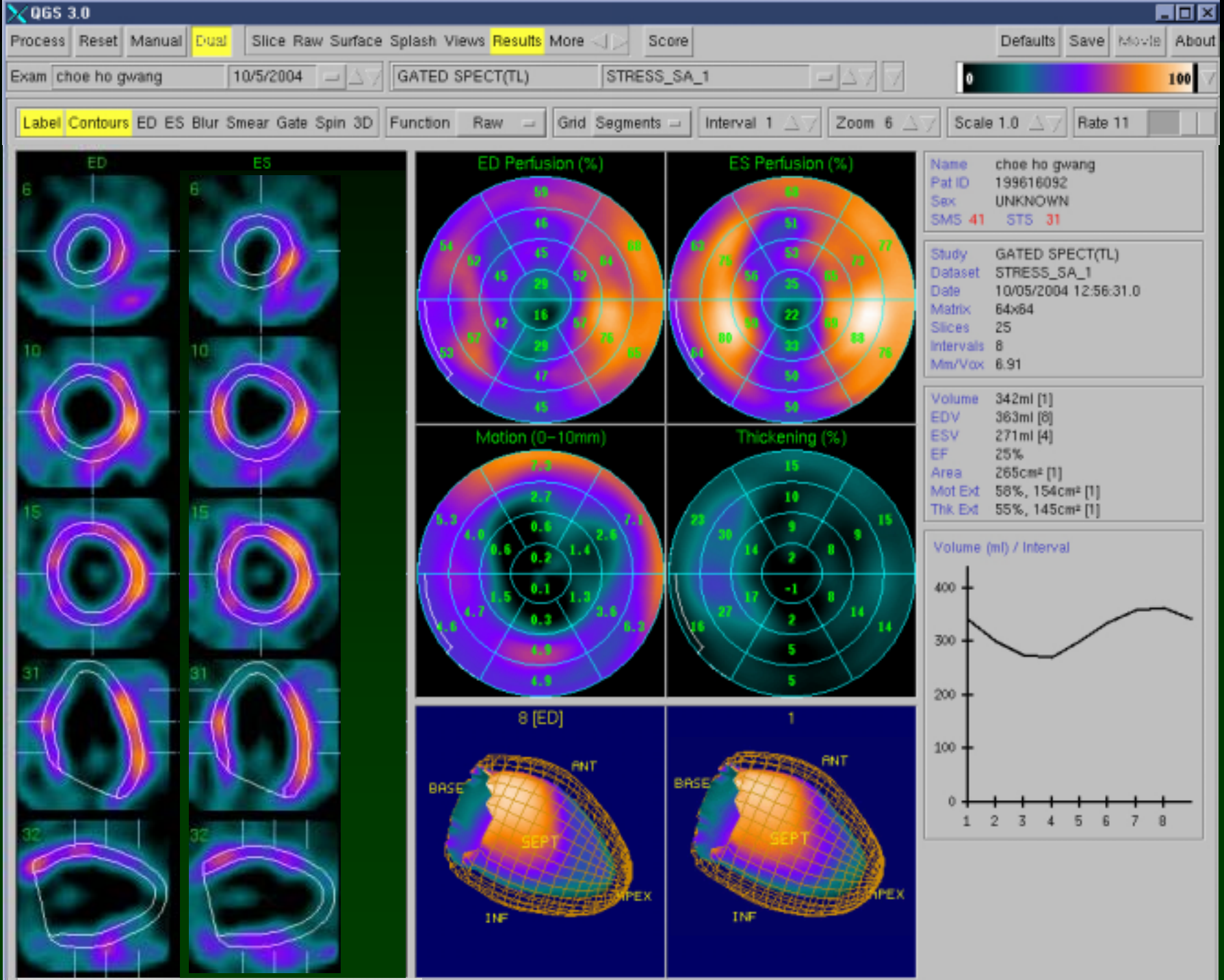


SPECT vs. MRI : Subendocardial Infartion



	Animal study	Human study
MRI	92%	100%
SPECT	28%	53%

Wagner A, CE MRI and SPECT for detection of subendocardial infarcts Lancet 2003 361 374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Intervals 8
Mm/Vox 6.91
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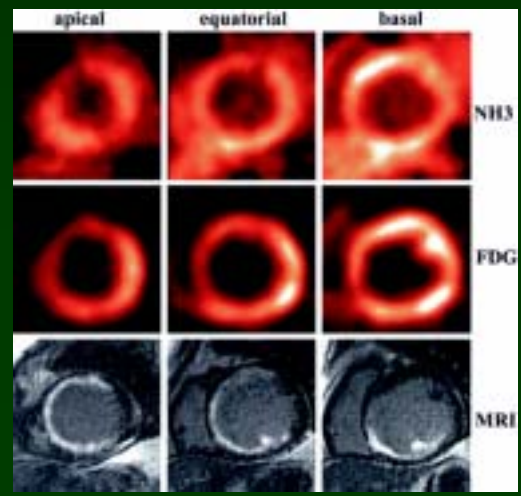
EDV 363ml [8]
ESV 271ml [4]
EF 25%
Area 265cm² [1]
Mot Ext 58%, 154cm² [1]
Thk Ext 55%, 145cm² [1]
Volume (ml) / Interval
400
300
200
100
0
1 2 3 4 5 6 7 8

Viability : DE MRI vs. PET

- *Klein. Circulation 2002;105:162*
  Myocardial Viability With CE MRI vs PET
- 31 pts with severe ischemic heart failure (LV EF 28±9%),
  Comparision of CE-MRI and PET (1023 segments)
- DE area correlated with areas of decreased flow and metabolism
- MRI seems to identify scar tissue more frequently than PET, reflecting the higher spatial resolution
- MRI hyperenhancement as a marker of myocardiac scar closely agrees with PET data :
  Sensitivity/specificity : 0.86/0.94



DE MRI vs. PET: segmental analysis

- 5% with matched PET defect - no DE
- 11% of normal PET - DE(+)
- 3/34 mismatch PET defect(hibernating myocardium) - transmural DE
- 55% of non-transmural DE - normal PET

	PET (t)	PET (nt)	PET (m)	PET (v)	
MRI (t)	126	11	3	38	178
MRI (nt)	7	27	8	51	93
MRI (v)	13	21	23	695	752
	146	59	34	784	1023

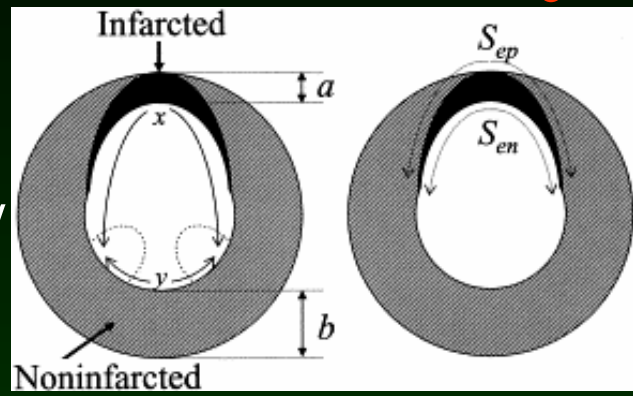
5%

11%

t:transmural, nt:non-transmural, m:mismatched, v:no defect or DE

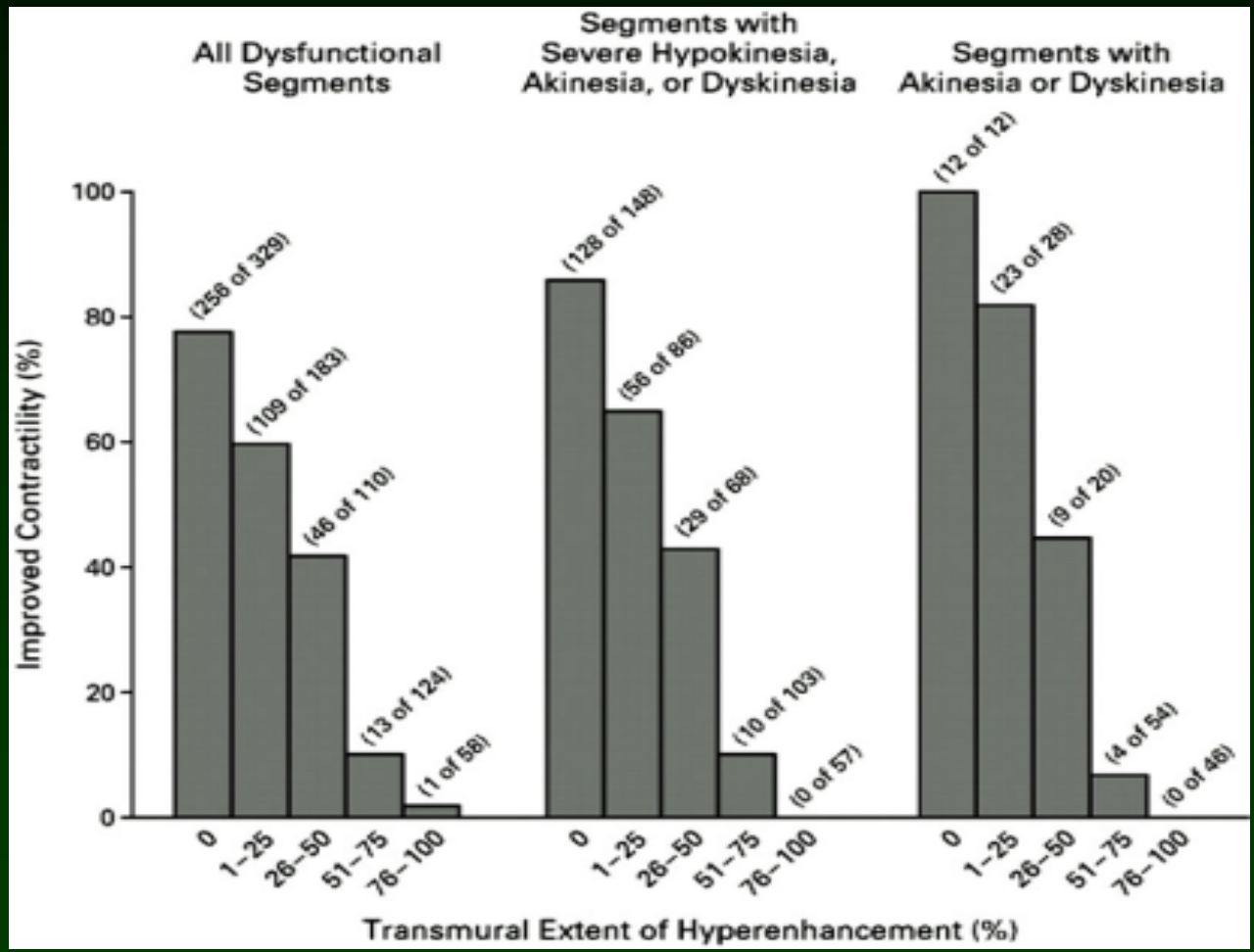
DE MRI: ventricular remodeling patterns

- *Fieno DS. JACC 2004;43:2124.*
- *Infarct resorption, compensatory hypertrophy, and differing patterns of ventricular remodeling following myocardial infarction*



- Infarct mass decreased progressively between 3 days and 8 weeks; terminal values=24±3% of those at 3 days
- Radial infarct thickness decreased progressively, whereas changes in circumferential and longitudinal extent of infarction were variable.
- Radial infarct thinning without expansion vs. true infarct expansion.
- Reperfusion accelerated infarct resorption.
- Histologic reductions in nucleus-to-cytoplasm ratios corresponded with increases in noninfarcted ventricular mass.

Transmurality of DE vs. Improvement of contractility

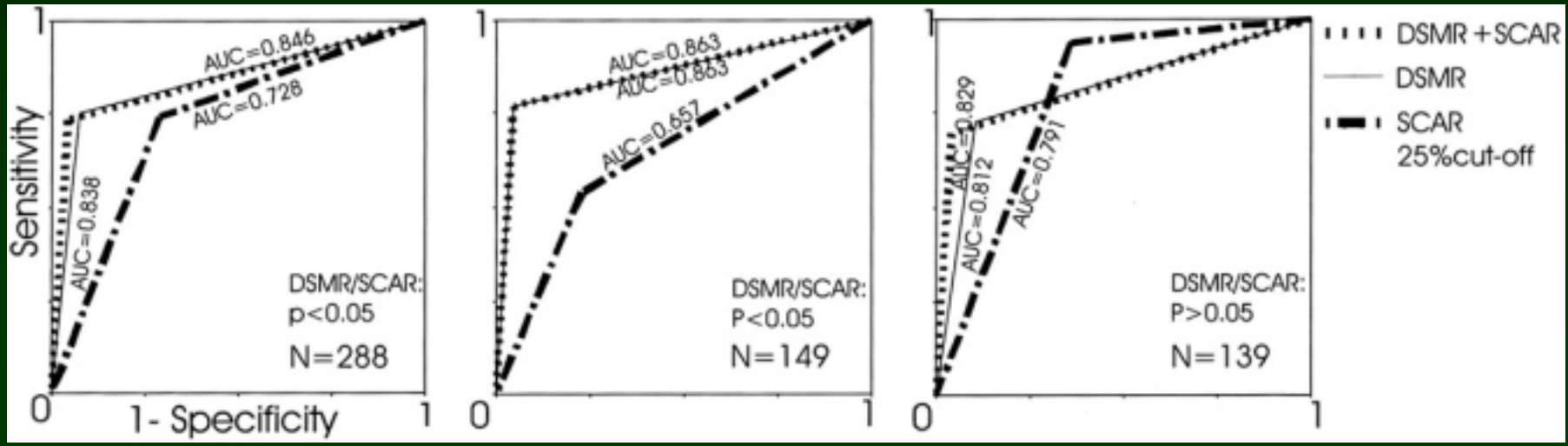


Kim RJ. N Engl J Med 2000;343:1445-1453

The use of CE MRI to identify reversible myocardial dysfunction 2005 춘계 순환기학회

Viability : DS MRI vs. DE MRI

- *Wellnhofer, et al. Circulation 2004;109:2172*
  Dobutamine stress MR and DE MRI for prediction of functional recovery
- DS MRI and DE MRI for 29 pts with CAD before and 3 months after revascularization.
- DS MRI: sensitivity (75%), specificity (93%)
- Correct identification of hibernation : 85%(DS MRI) > 73% (DE MRI)
- Superiority of DS MRI was for segments with 1-74% hyperenhancement



all segments

segments with 1-74% transmurality

segments with ≥75% or 0% transmurality

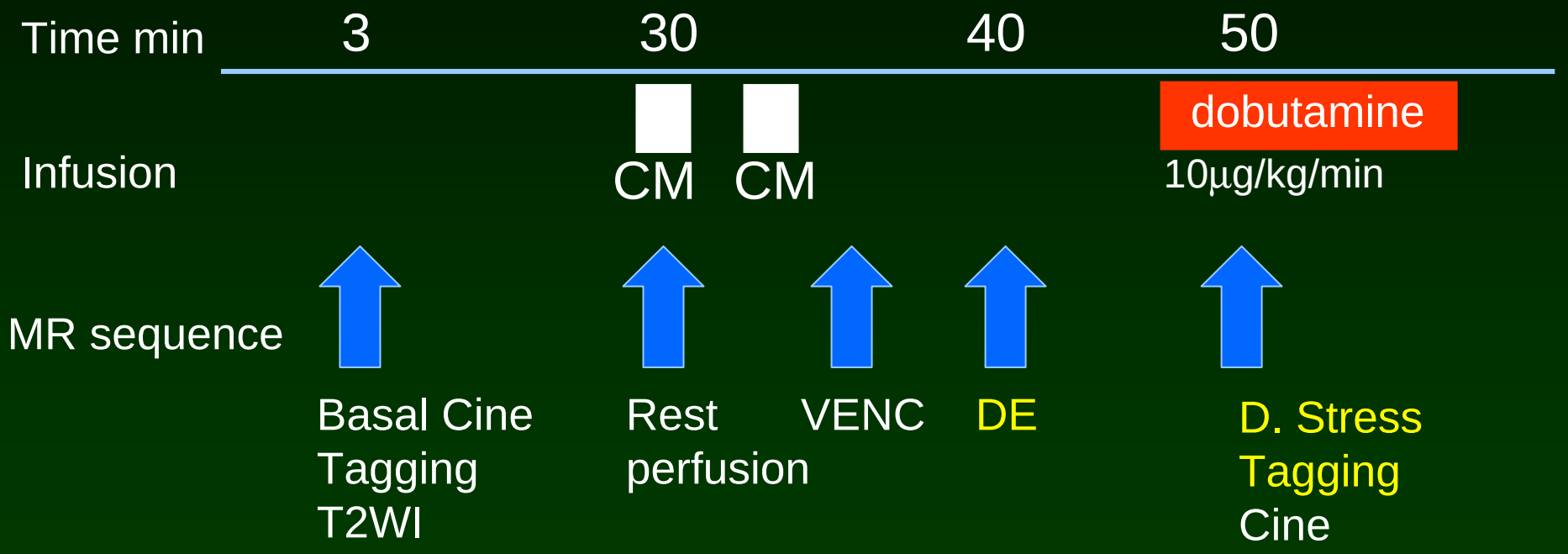
Viability assessment for severe LV dysfx

- *Kim RJ. Circulation 2004;109:2476*
  Viability assessment by DE CMR: will low-dose dobutamine dull the shine?
- DS MRI
  - Contractile reserve has reduced predictive accuracy if more severe dysfunction is present at rest.
  - Inotropic stimulation merely results in ischemia and precludes the ability for enhanced contractility.
- DE MRI
  - have greater accuracy in segments with the most severe dysfunction

Viability : DS MRI vs. DE MRI

- Improvement of myocardial contractility after reperfusion can be predicted by transmural extent of delayed enhancement and Dobutamine stress MRI.
- Improved wall motion according to transmural extent of DE
  - Subendocardial < 25% : high likelyhhod of viability
  - Transmural > 75% : very low likelyhhod of viability
- DE MRI has greater accuracy in segments with the severe LV dysfunction
- DS MRI has superior accuracy in nontransmural scars (1% to 74%).

Comprehensive Viability Study Protocol



Consideration of imaging for viability assessment

- Availability
- Accuracy
- Cost
- resource utilization
- Safety- no infusion of stress agent in magnet, less intense monitoring
- ease of implementation
- Easy and fast interpretation

Pitfall of clinical definition

- histologic definition of viability - presence of living myocytes : not practical in a clinical setting
- clinical definition - the improvement in contractile function after revascularization)
- presence of viability without functional improvement
  - time course of recovery may be up to 14 months - single evaluation of ventricular function soon after revascularization may lead to an underestimation of the true rate of functional recovery
  - even if technically successful, coronary revascularization may be incomplete, particularly in patients with extensive atherosclerosis and diffuse disease
  - tethering of regions with extensive scarring to viable regions may inhibit the response of viable regions to revascularization

Take Home Messages

- Speckled appearance of the myocardium
  - if the TI is very close to the optimal inversion delay, often one might see some speckled appearance (suppressed myocardium interspersed with white spots).
  - in this case, increase the TI by just 10ms to attain optimal suppression.
- Dark signal at the endocardial boundary:
  - the effective TI of the tissue at the blood - myocardial interface is often slightly shorter, due to mixing (especially if the voxel size is too big).
  - this indicates that the TI delay is too short.
  - Increase the TI to obtain uniform suppression of the myocardium.

Tips and Hints

• Insufficient suppression/lack of contrast of myocardium over a broad range of TI:

- this indicates either that the contrast has either washed out (i.e. the scanning is done much later, e.g. more than 30 min after injection), or insufficient amount of contrast agent was injected.

it may be helpful to check if the entire double dose of contrast agent was given (check for leaks etc).

The blood-pool appears too dark

•- the TI is too short.

increase the TI to allow sufficient recovery.

Less contrast between blood-pool and injured myocardium

- typically, this means that the TI is too long.

- decrease the TI.

Viable myocardium

Dysfunctional but viable myocardium

- Stunned myocardium
  - result of an ischemic insult leading to contractile dysfunction despite adequate reperfusion.
- Hibernating myocardium
  - prolonged reduction in perfusion
    → downregulation of myocyte metabolism
  - repetitive episodes of myocardial stunning

Detection of Healed Infarction

- 44 patients with enzymatically proven myocardial necrosis
  - peak total CK>125 IU/L and peak CKMB >9.0 μg/L
- Follow up DE-MRI
  - Group I : 3 months after index event, 29/32 (91%) patients showed hyper-enhancement on DE-MRI
  - Group II : 14 months after index event, 19/19 (100%) patients showed hyper-enhancement on DE-MRI
- Presence, location, and transmural extent of healed Q-wave and non-Q-wave myocardial infarction can be accurately determined by CE-MRI

Wu E , Lancet 2001 357 21-28. Visualisation of presence, location, and transmural extent of healed Qwave and non-Qwave mayocardial infarction

Dobutamine stress MR

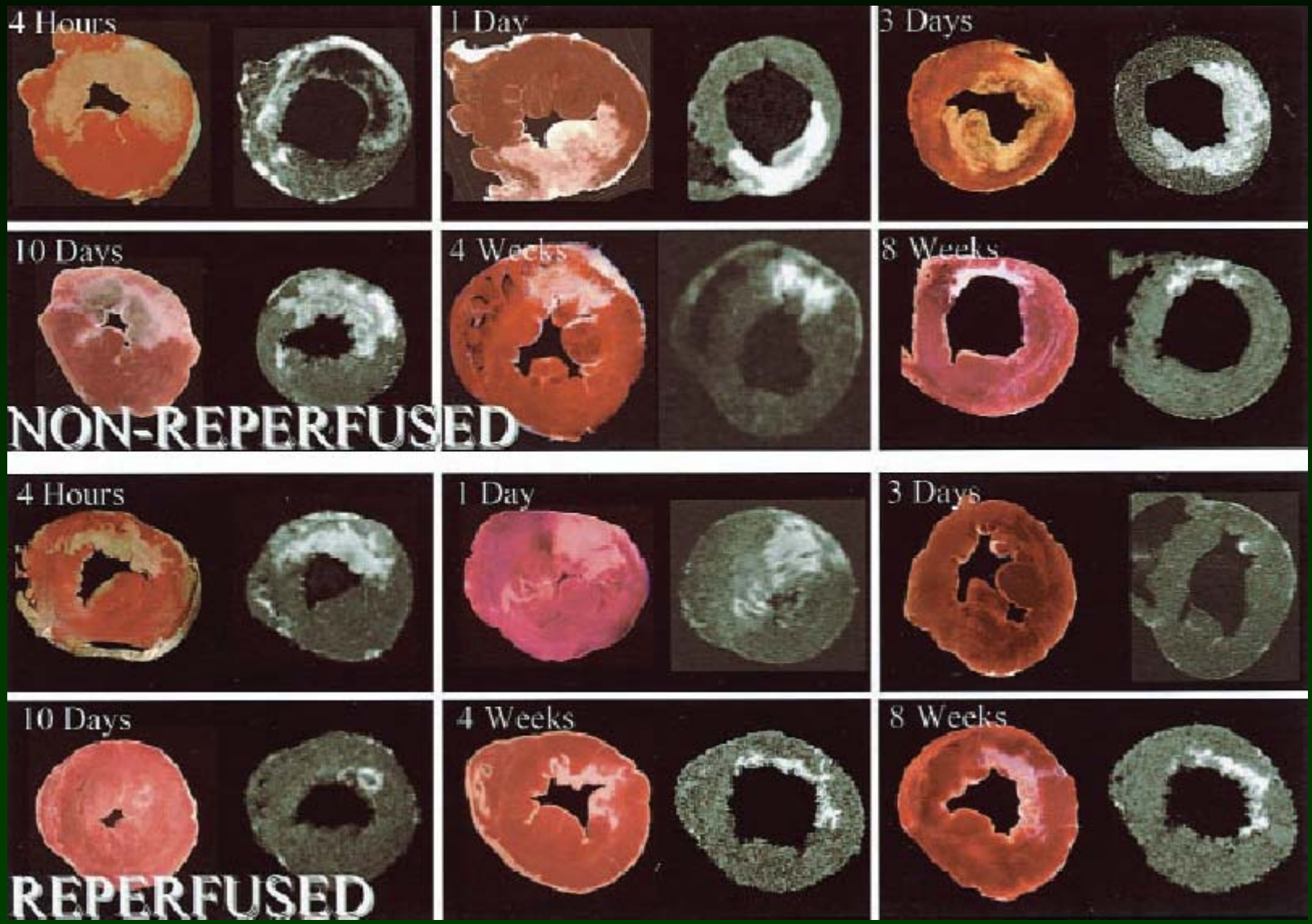
- The presence of contractile reserve can be accurately demonstrated by low-dose DSMR and is a marker for myocardial viability.
- DSMR has the advantage of full visualization of the myocardium, whereas DSE suffer from impaired image quality in patients with poor acoustic windows.
- DE-MRI localizes and quantifies scar but has impaired specificity as a predictor of functional recovery in nontransmural scars (1% to 74%).
- Low dose DSMR is superior to DE-MRI as a predictor of functional recovery and does not depend on the transmurality of scar.

DS MRI with Tagging

- New WMA at dobutamine-CMR
  - without tagging : detected in 58 patients
  - with tagging : detected in 68 patients (P=0.002, McNemar).
- Positive CAG in 65/68 (96%)
- 112 pts with a negative dobutamine-CMR study
  - without baseline wall motion abnormalities
  - cardiovascular occurrence-free survival rate : 98.2% during the mean follow-up period of 17.3 months

Kuijpers D, et al. Circulation. 2003;107(12):1592-7.
Dobutamine CMR for detection of MI using myocardial tagging.

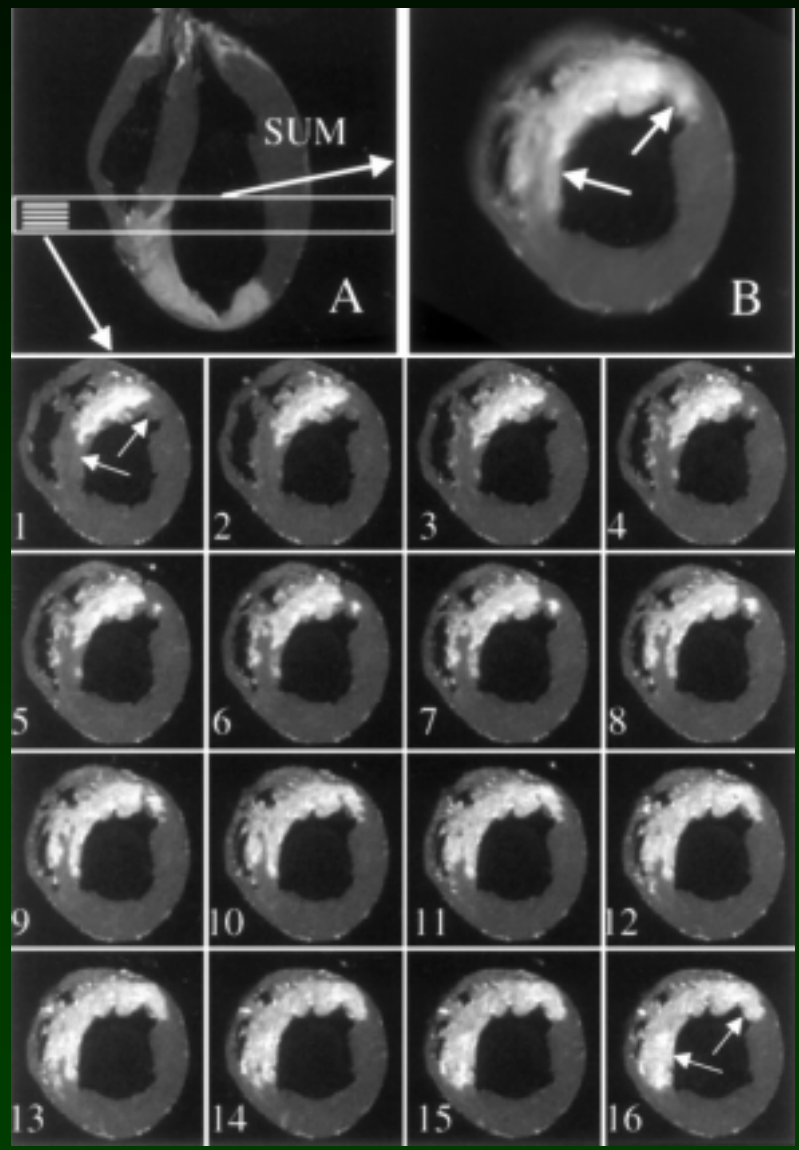
TTC staining vs. Delayed Hyperenhancement



Fieno DS, Contrast MRI of myocardium at risk, JACC 2000;36:1985

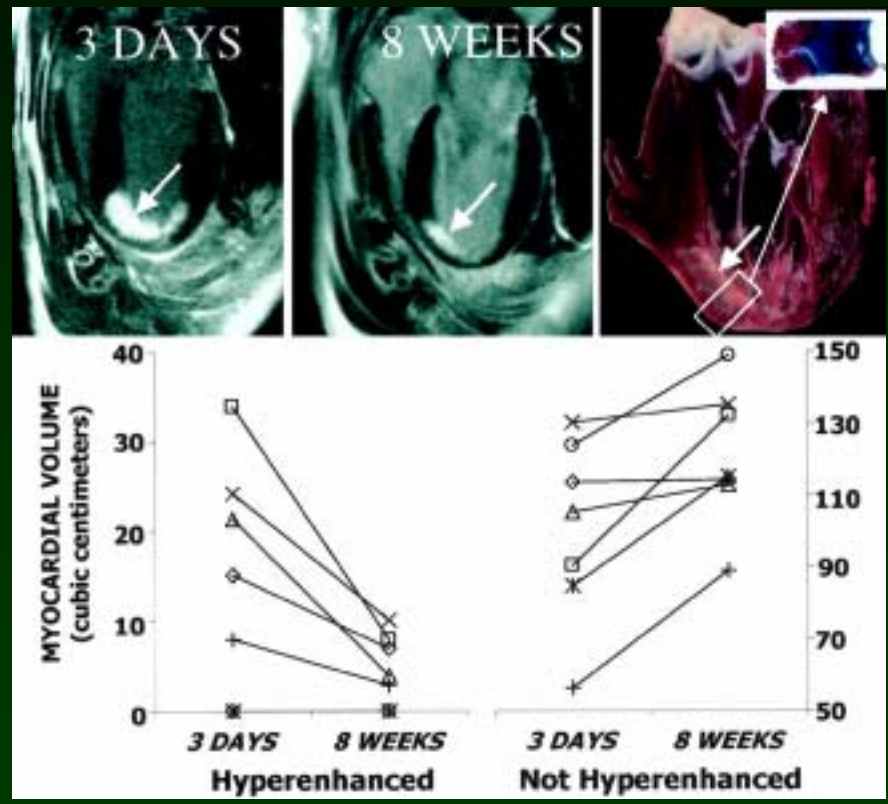
DE MRI : partial volume artifact

- Blurring along the periphery of hyperenhancement zone (arrows) due to partial-volume effects and the complex 3D shape of infarct
- Thin slice: sharp, distinct borders that migrated significantly from slice to slice
- may also play a role in the overestimation of infarct size



DE MRI

- absolute volume of hyperenhanced myocardium decreased by a factor of 3.4 between 3 days and 8 weeks
- hyperenhancement includes both acutely necrotic regions and surrounding reversibly injured regions at 3 days but that by 8 weeks?
- spatial extent of collagenous scar at 8 weeks was 3.4 times smaller than the spatial extent of acute myocyte necrosis at 3 days
- infarcts shrink 4-fold between 4 days and 6 weeks
- infarct shrinkage during the transition from myocyte necrosis to collagenous scar. compensatory hypertrophy



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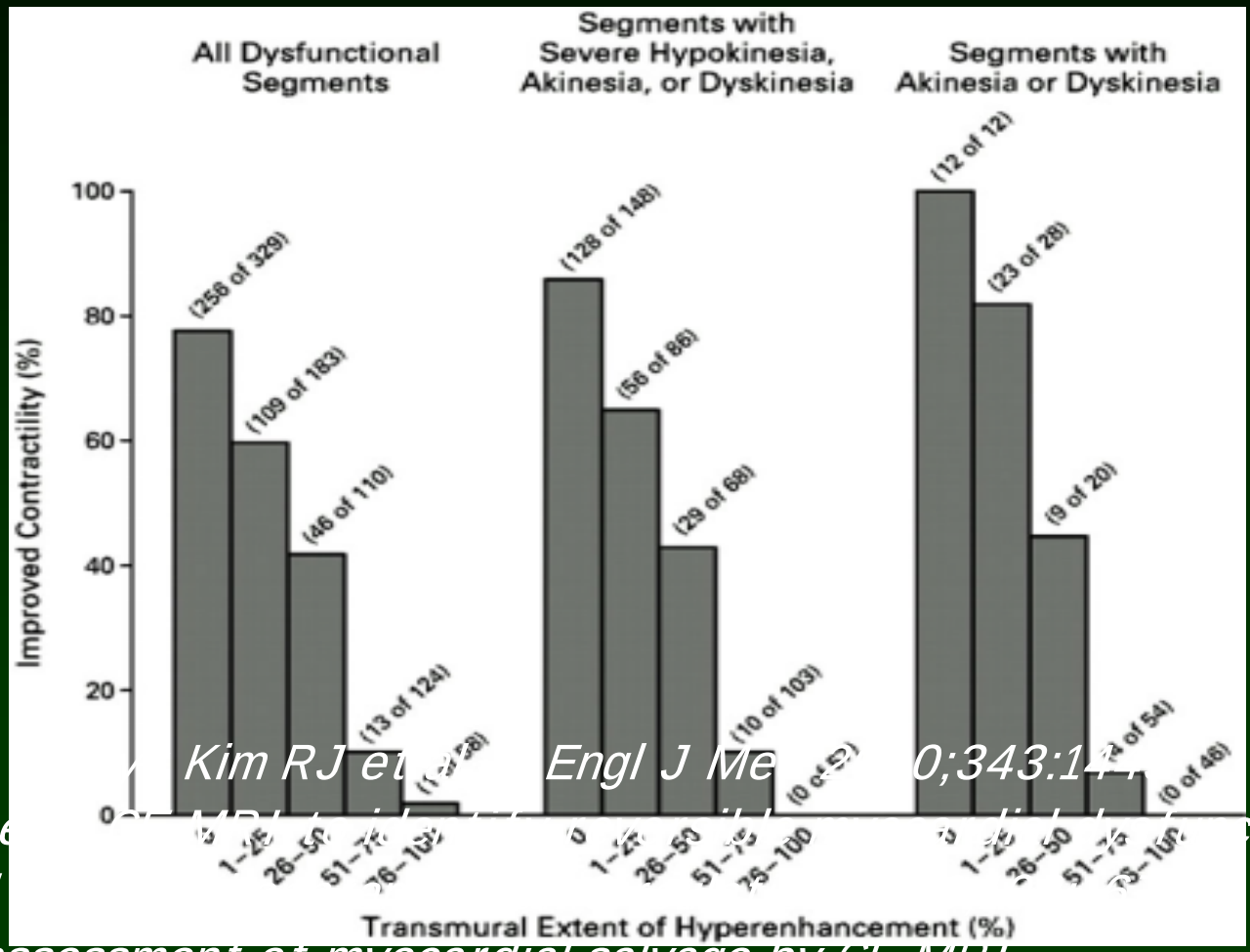

Human … Kim RJ et … Engl J Me… 0;343:14…
The use … MRI to … reversible … ction
Animal …
Early assessment of myocardial salvage by CE MRI

Kim RJ. N Engl J Med 2000;343:1445-1453

The use of CE MRI to identify reversible myocardial dysfunction

Viability : DS MRI vs. DE MRI

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  Viability assessment by DE CMR: will low-dose dobutamine dull the shine?
- Viability assessment by DS MRI for severe LV dysfx
  - Modest sensitivity but high specificity
- Wellnhofer * study :
  - relatively small study from a single site
  - 19% discordant wall motion assessments by 2 experienced observers