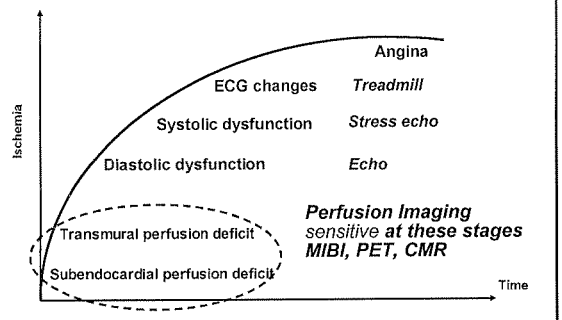
Myocardial Perfusion and Viability by Cardiac Magnetic Resonance Imaging

Dr Carmen WS Chan
Division of Cardiology,
Department of Medicine,
Queen Mary Hospital,
HKSAR

Outline

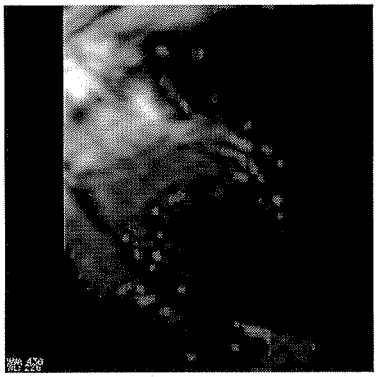
- **Overview of Myocardial perfusion**
  Is there a role of perfusion study for detection of ischemia?
- **Myocardial viability**
  Is there a "gold-standard test" for viability?
  Review of the viability imaging by cardiac MRI
- **Any algorithm to combine function, perfusion, and viability data of myocardial segments ?**
- **Case presentation**

The Ischemic Cascade



Higgins and De Roos, ed. Cardiovascular MRI & MRA, 2003

Myocardial Perfusion Study



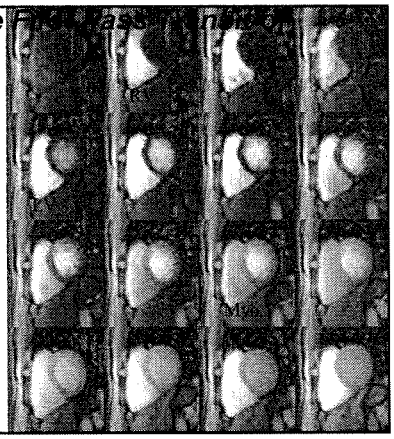
MRI Perfusion

1. Temporal resolution
2. Spatial resolution
3. T1 weighting
4. Ventricular slice coverage

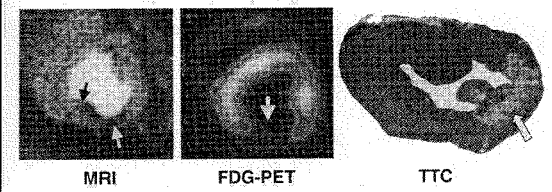
Capturing the First Pass of Gadolinium

EPI readout, ETL 4
In-plane resolution 2.5mm
Notch saturation: Tsat 130ms
1 image/slice/2 R-R intervals

LCE/NHLBI/NIH



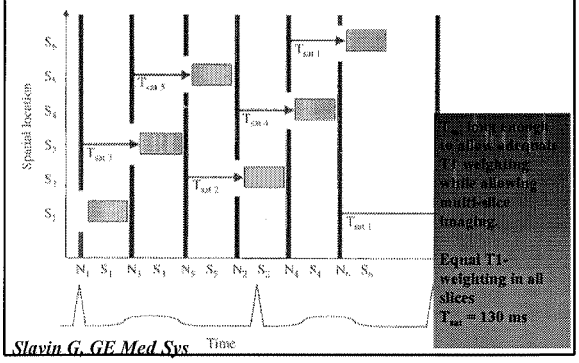
Spatial Resolution



Detection of endocardial ischemia is directly related to the sensitivity of an imaging technique in detection of coronary stenosis

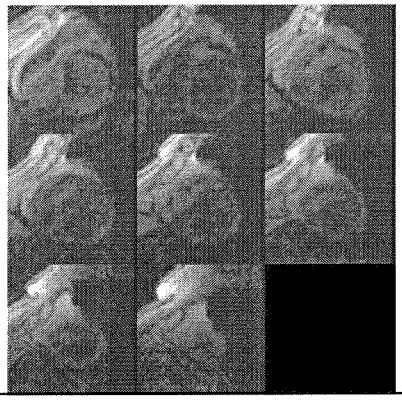
Manning, W. Cardiac MR 2002

Interleaved Notch Saturation Pulse to improve T1 weighting



Slavin G, GE Med Sys

Myocardial Perfusion Study



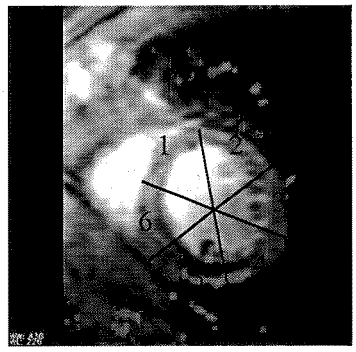
3 levels of perfusion analyses

Qualitative
- Easy to do
- Inter-observer bias
- Measures RELATIVE segmental blood flow only

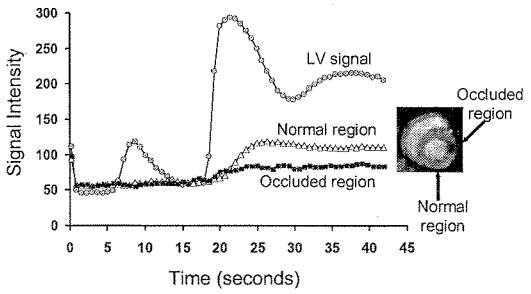
Semi-quantitative
- Some post processing
- Measures upslope of enhancement

Quantitative
- Most post-processing
- Requires mathematical modeling
- Measures ABSOLUTE global and regional blood flow

Semi-quantitative MR Perfusion

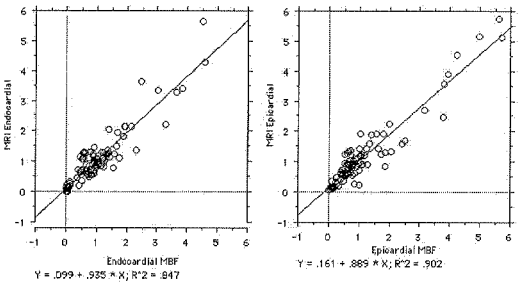


Semi-quantitative MR Perfusion



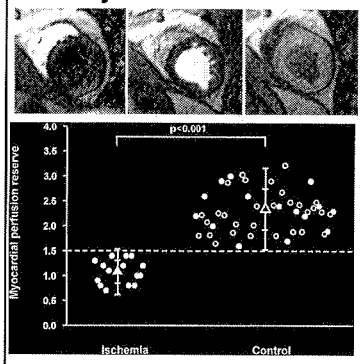
Endocardial and Epicardial Analysis

R = 0.92, P< 0.0001 | *R = 0.95, P < 0.0001*



Christian et al. AHA2001

Dipyridamole Stress First Pass Perfusion Myocardial Perfusion Reserve Index

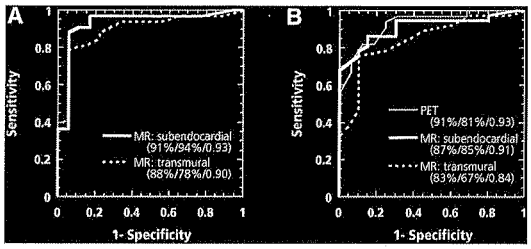


	MPR +	MPR -
CAD+	54	6
CAD -	7	35

Sensitivity 90%
Specificity 83%

Al-Saadi et al
Circ 2000; 101:1379

Dipyridamole Stress MRI vs PET and QCA



MRI Vs PET
Sensitivity 91%
Specificity 94%

MRI Vs QCA
Sensitivity 87%
Specificity 85%

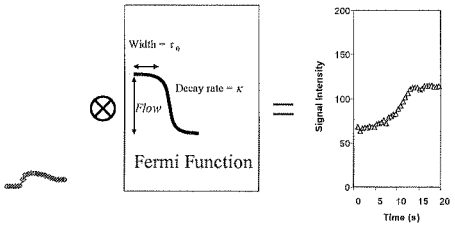
Schwitter et al. Circ 2001; 103:2230

MR Perfusion Trials

Year	Author	N =	Analysis	Stress	vs.	Sens	Spec
1998	Reisse	48	Semi-Quant	Adeno	Angio	88	78
1999	Wolff	47	Qualit	Adeno	Angio	72	80
2000	Al-Saadi	34	Semi-Quant	Dipyr	Angio	90	83
2000	Nagel	115	Semi-Quant	Dipyr	Angio	94	83
2000	WassmutArai	23	Qualit	Dobut	Angio	88	100
2003	Nagel	84	Semi-Quant	Adeno	Angio	88	90

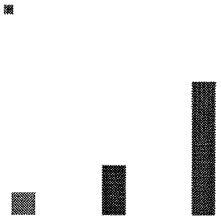
Quantitative Perfusion Analysis: Fermi Function Deconvolution

Input Function | **Mathematical Model** | **Myocardial Enhancement**



Estimates Absolute Myocardial Perfusion (ml/min/g)

Comparison of Absolute Myocardial Perfusion by MRI and Microspheres



Christian et al. AHA2001

Quantitative Analysis

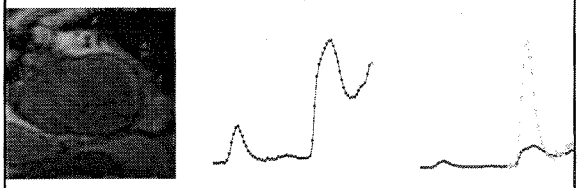
Points:

- Measures physiologic absolute blood flow in myocardium at different hemodynamic states
- Suggested to be less biased and more sensitive to lesser degree of regional perfusion reduction

Requirements:

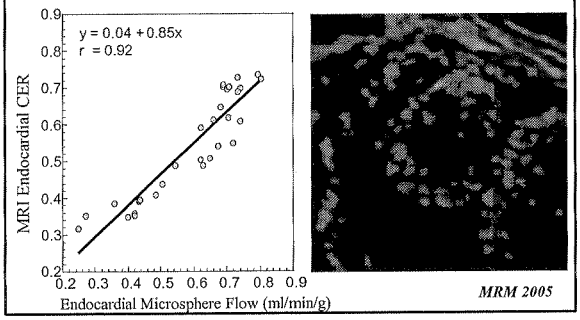
- Requires meticulous border tracings and slice registration
- Low dose of gadolinium to maintain linearity of signal to concentration relationship
- Injection at a fast rate 5-10 cc/sec to minimize dispersion
- Curve fitting and mathematical model to approximate the fitted curve.

Methods: Dipyridamole vasodilator stress (0.56 mg/kg) using a dual-bolus Gd-DTPA technique



Rhoads et al ISMRM 2003

Comparison of Endocardial Microsphere Blood Flow and Endocardial MRI Contrast Enhancement Ratio



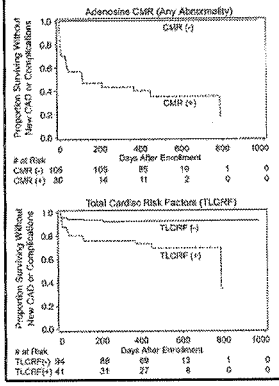
MRM 2005

Quantitative Analysis

Controversy:

- Additional utility in detection of significant CAD over semi-quant and qualitative approaches
- Applications in hypothesis driven research
  - cardiac physiology
  - drug and interventional Rx testing

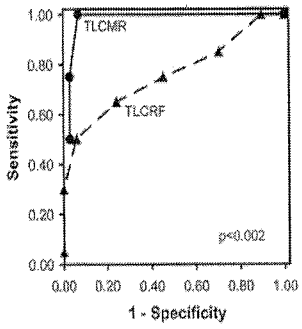
Prognosis of Negative adenosine MRI



Kaplan-Meier survival distributions based on presence or absence of any abnormalities on CMR and <=3 Vs >3 total risk factors (TLCRF)

W Ingkanisorn, et al.
JACC 47, Issue 7, 1427-1432

Prognosis of Negative adenosine MRI



Estimated receiver operating characteristic curve for TLCRF and TLCMR as a predictors of adverse cardiac outcomes

W Ingkanisorn, et al.
JACC 47, Issue 7, 1427-1432

Myocardial Viability

Viable myocardium

- Stunned myocardium
  - Delayed recovery of regional functions after transient ischemia, followed by reperfusion

Braunwald and Kloner et al 1982

- Hibernating myocardium
  - Viable but hypocontractile myocardium due to prolonged myocardial hypoperfusion at rest in attempt to minimize ischemia
  - Adaptive response ? Imperfect?

Rahimtoola et al Circulation 1985; 72 (V123)

** Co-exist in viable myocardium

Stages of Hibernation Sleep to death?

Chronic hibernation ↔ Repetitive stunning/ Ischemia

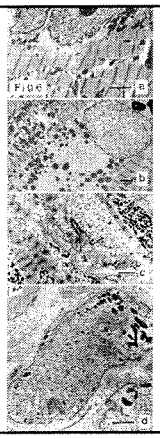
⇩

Reduction in contractile filaments and SR
Accumulation of glycogen
Myocyte de-differentiation

⇩

Cell death

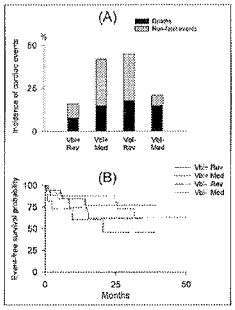
Elsasser et al Circulation 1994;90:735



What we require from viability imaging....

N = 202 underwent viability assessment
Before CABG by dob echo

16 months FU



EF <33% (n=108)

Anselmi et al AJC 1998

Recovery of function is not the only benefit

Recovery of segmental or global function after PCI

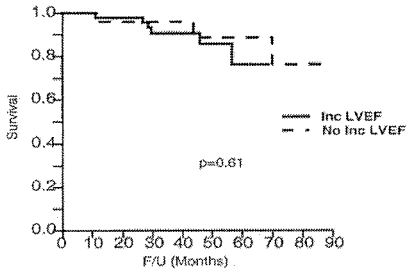
- Myocardial electrical stability
- Improved remodeling
- Open artery theory – vascular territory protection
- Symptomatic improvement

Mortality
Pump failure, recurrent injury, arrhythmia

Morbidity
Debilitating symptoms, arrhythmia

Survival benefits from Revascularization despite a lack of contractile recovery

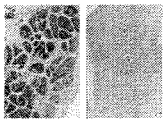
N = 128, successful revascularization with CABG, follow-up 32 months



Samady et al. Circulation 1999

Which is the "gold standard imaging test" for myocardial viability?

Clinical imaging techniques



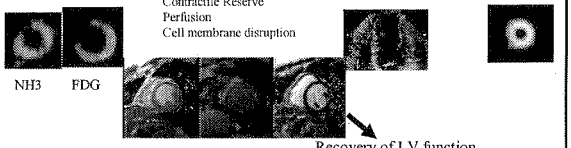
Reduction in contractile filaments
Degeneration of the sarcolemma
Accumulation of glycogen
Myocyte de-differentiation

PET
perfusion/FDG metabolism

MRI
Contractile Reserve
Perfusion
Cell membrane disruption

Echo
Contractile Reserve

Tl-201
TC-99 SPECT



NH3 FDG

Recovery of LV function

Morbidity and Mortality
Quality of Life

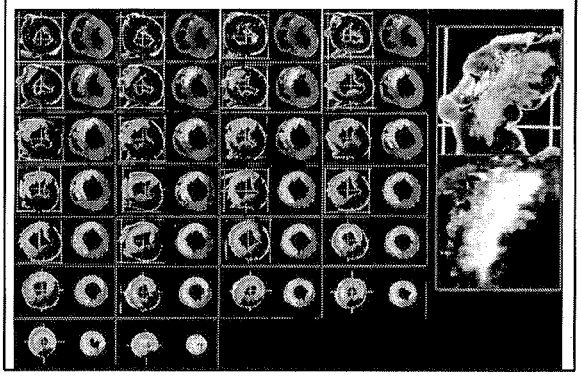
Gadolinium-enhanced MRI

The high spatial resolution of contrast enhanced MRI allows:

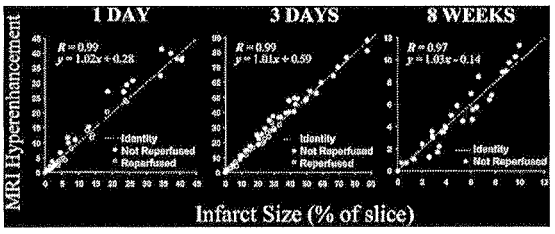
1. Accurate measurement of the transmural extent of irreversibly injured myocardial and prediction of recovery of segmental function

2. Detection of very small myonecrosis

Infarct Size: TTC vs MRI

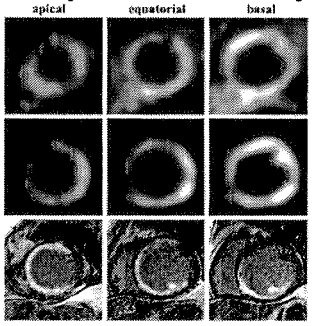


Correlation between MRI Infarct Size and TTC Staining



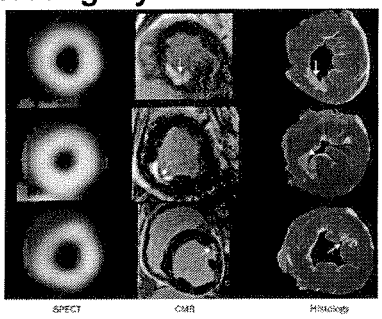
Kim R. et al. Circulation. 1999;100:1992-2002

Comparison of MRI and PET for Detecting Myocardial Viability



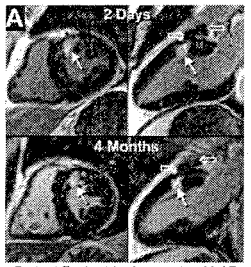
Klein et al. Circulation 2002; 105: 162

Comparison of MRI and SPECT for Detecting Myocardial Infarction



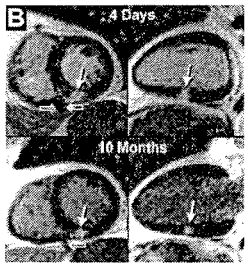
Wagner et al. Lancet 2003; 361: 374

Microinfarction after PCI associated with Minor Side Branch Occlusion



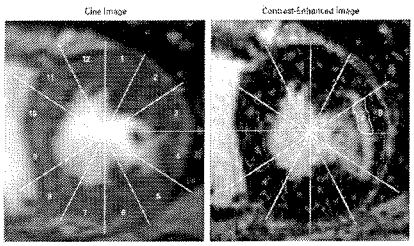
Patient 7: stent in the proximal LAD and minor side-branch occlusion

MI size = 0.7 to 12 g



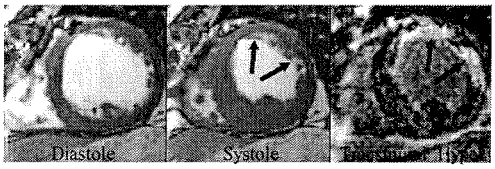
Patient 2: stent in the mid-PDA and minor side-branch occlusion

Ricciardi. Circulation 2001;103:2780-3

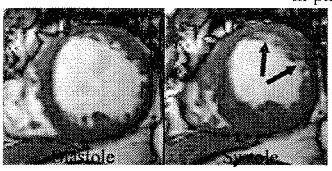


Kim. R et al New Engl J Med Nov 2000

Irreversible LV Dysfunction

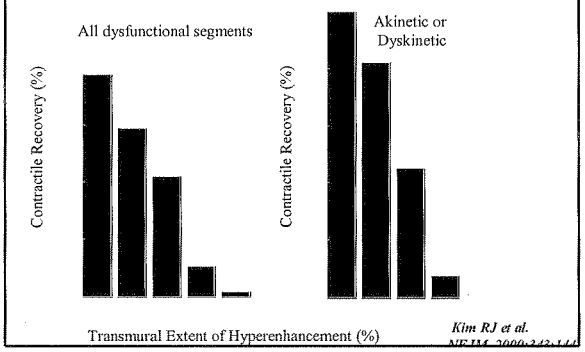


After revascularization In-plane resolution 1.3 X 2 mm



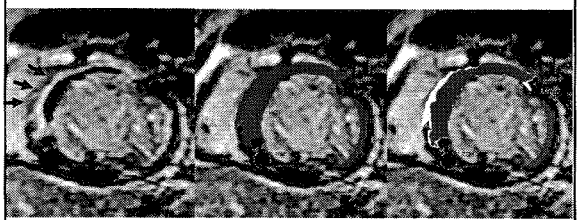
Kim RJ et al. NEJM 2000;343:1445

Transmural Extent of Hyperenhancement Predicts Recovery of Function



Kim RJ et al.

Peri-Infarct Zone Is a Poweful Predictor of Post Myocardial Infarct Mortality



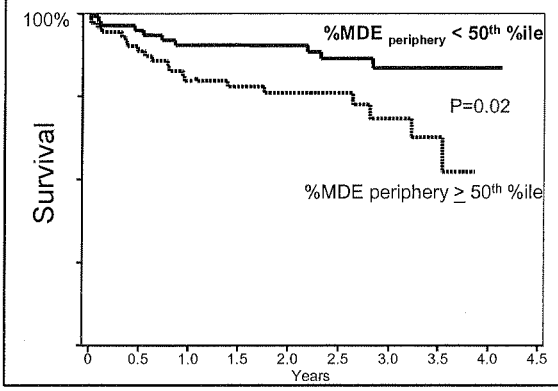
Total = remote + 2SD Core = remote + 3SD

Peri-infarct mass (g) = Total - Core

Peri-infarct% = (peri-infarct mass/Total)*100%

A Yan, C Chan et al, Circulation.2006;114:32-39

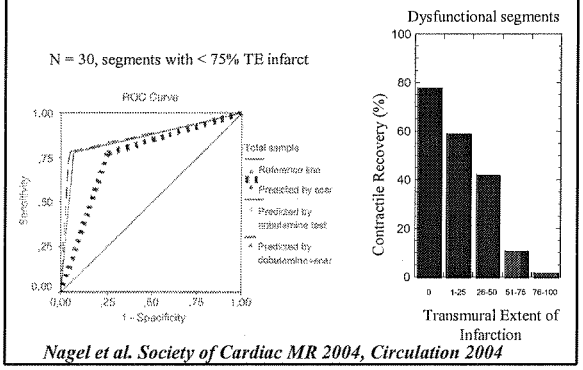
Results – KM Survival Distribution



MRI Approach for assessment of IHD

Normal	Normal	Normal	None
Stunning	RWMA	Normal	None
Hibernation	RWMA	Perfusion Defect	None
Infarction	RWMA	Perfusion Defect	Delayed Hyper
Dobutamine stress Ischemia	Stress RWMA	Perfusion Defect	None

Benefits of adding contractile reserve by dobutamine MRI, over "Resting Viability in Predicting Recovery of Segmental Function from successful revascularization



Nagel et al. Society of Cardiac MR 2004, Circulation 2004

Case Presentation

Conclusions

- CMR provides a one stop service for assessment of segmental wall thickness and function, myocardial perfusion and transmural extent of infarction in registered scan planes.
- In addition to the accurate detection of significant coronary artery disease, it accurately predicts the survival benefits from successful revascularization.
- Recent studies demonstrated that the result obtained from CMR has incremental prognostic value on long term mortality and morbidity

Acknowledgements

Dr C H Luk
Consultant Cardiologist,
Sir Run Run Heart Centre,
St Teresa's Hospital, HKSAR