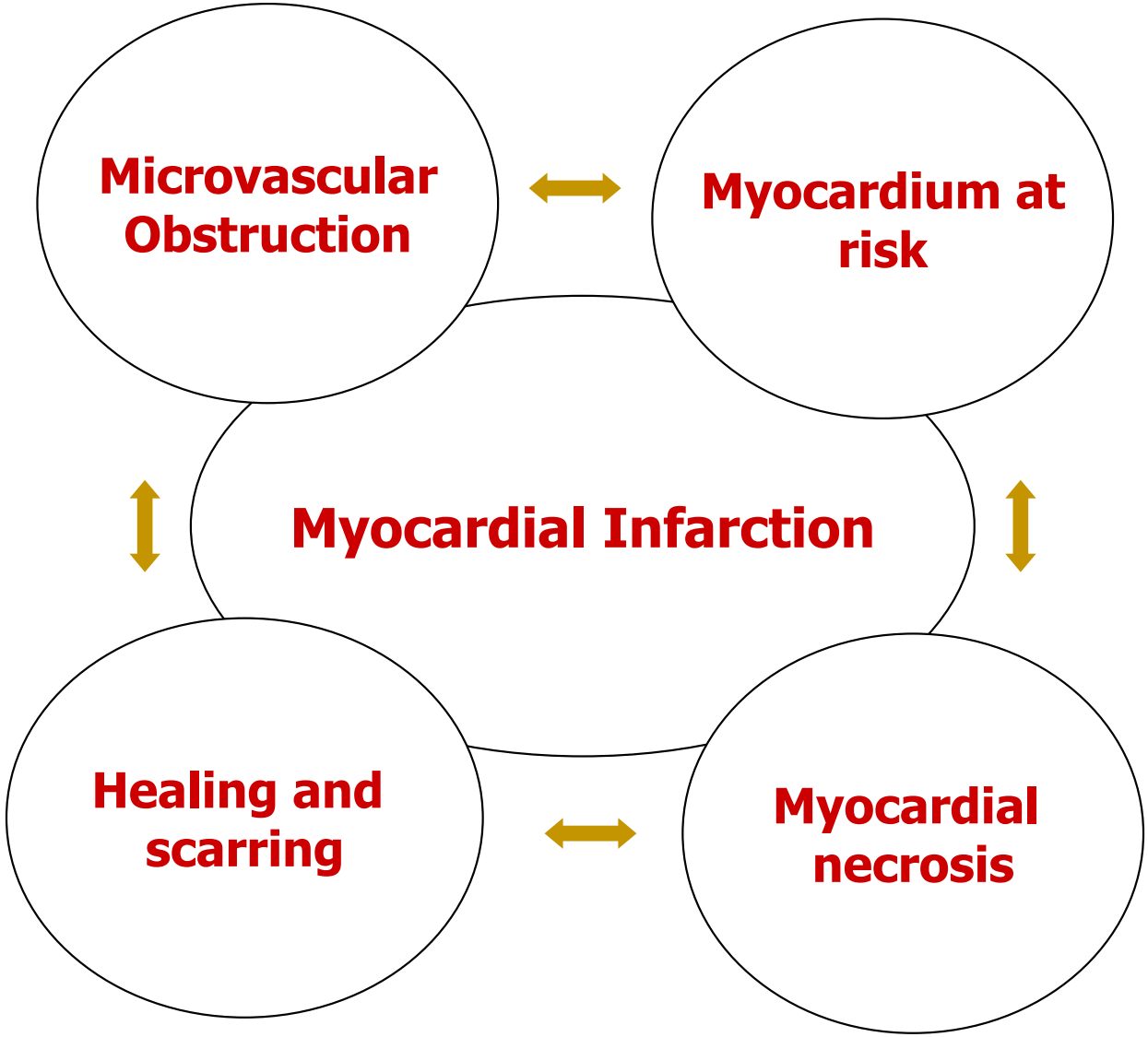
# MRI Utility in Myocardial Infarction

**Pier Giorgio Masci, MD**
U.O. di RM e di Medicina Cardiovascolare
Fondazione Regione Toscana/CNR “G. Monstaterio“ - Pisa

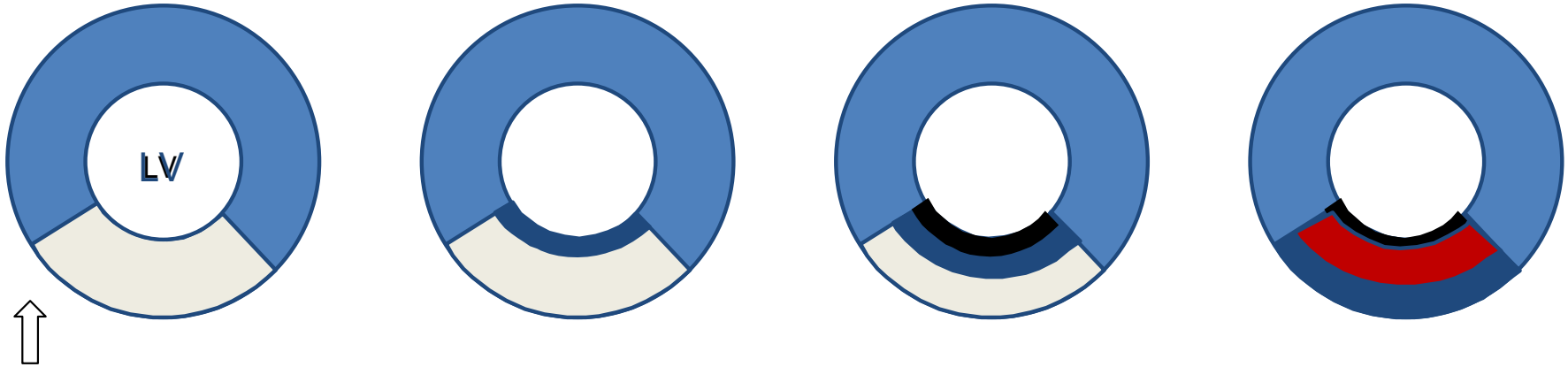
**Great Innovation in Cardiology**
**Torino 14-15 Ottobre 2010**

# Myocardial Infarction



# Myocardial Infarction

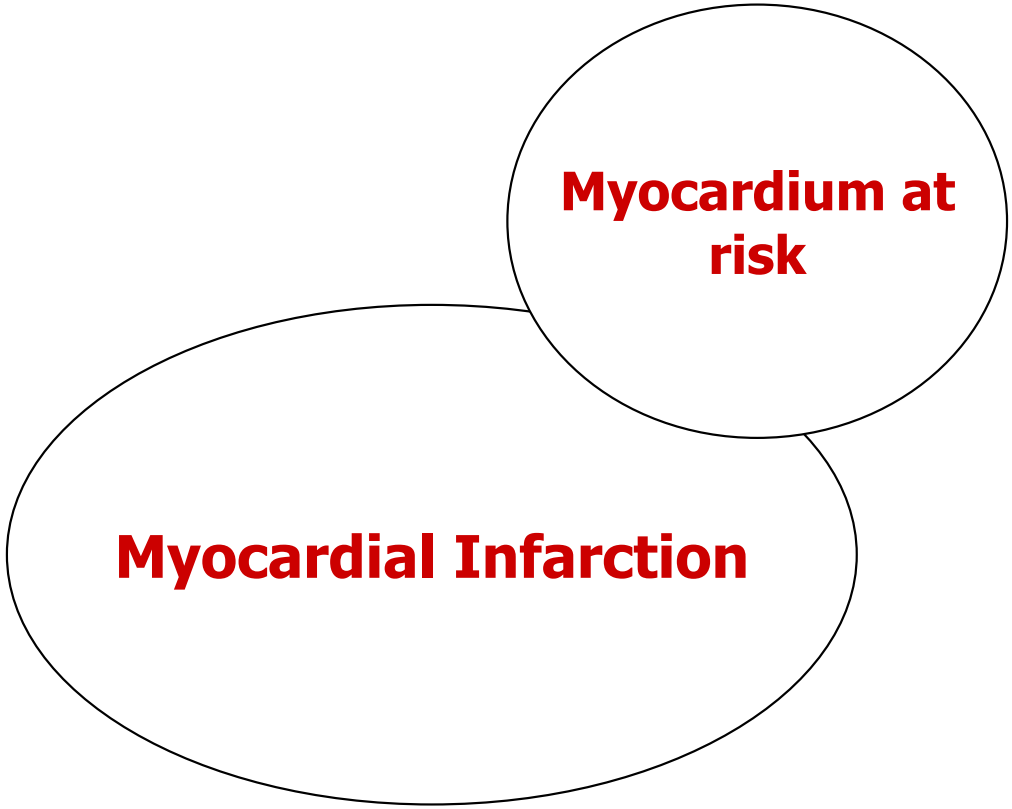
Reversible injury ⟷ Irreversible injury




*Reperfusion*

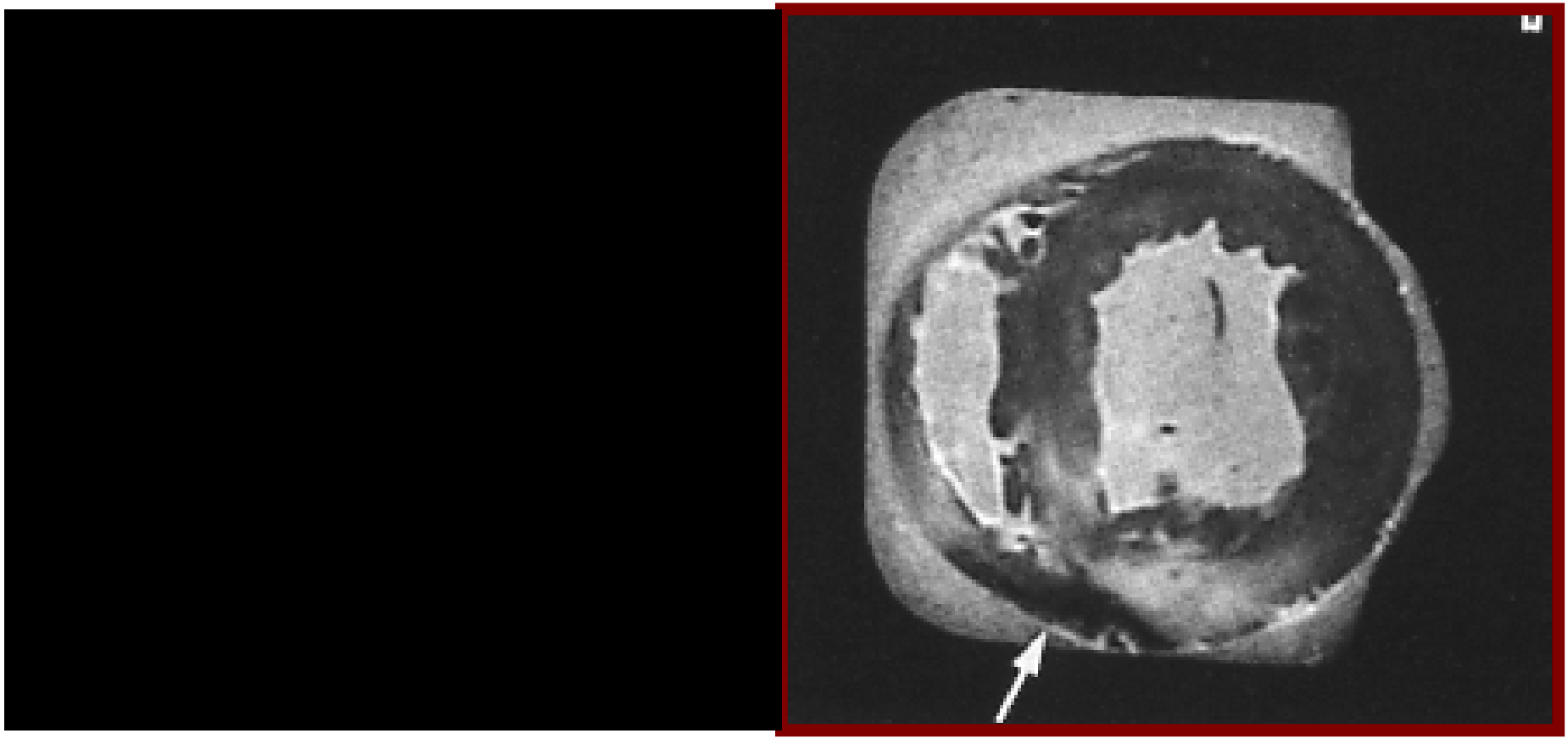
- Myocardium at risk
- Subendocardial necrosis (salvage of outer layers)
- Necrosis extends into midmyocardium, subepicardium
  - Microvascular Obstruction
- Near transmural (negative LV remodeling)
  - Hemorrhagia

# Myocardial Infarction



# Myocardial Infarction

**- Myocardium at risk -**



Late gadolinium Enhancement (LGE)

T2-weighted Imaging

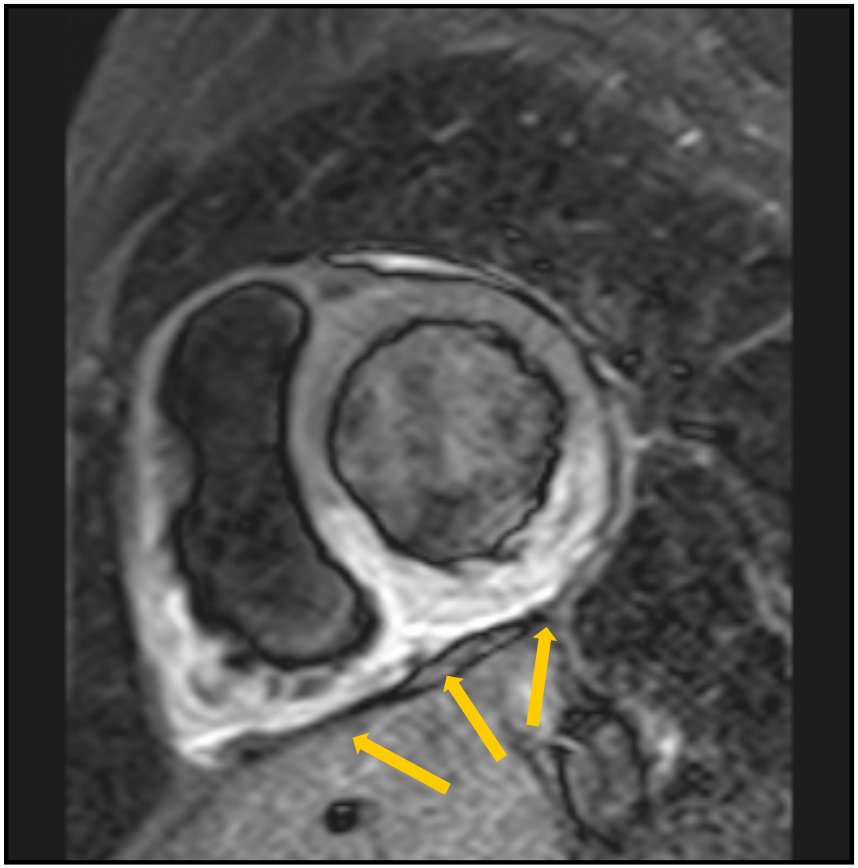
# Myocardial Infarction

## - Myocardium at risk -

**Always Transmural Extension**

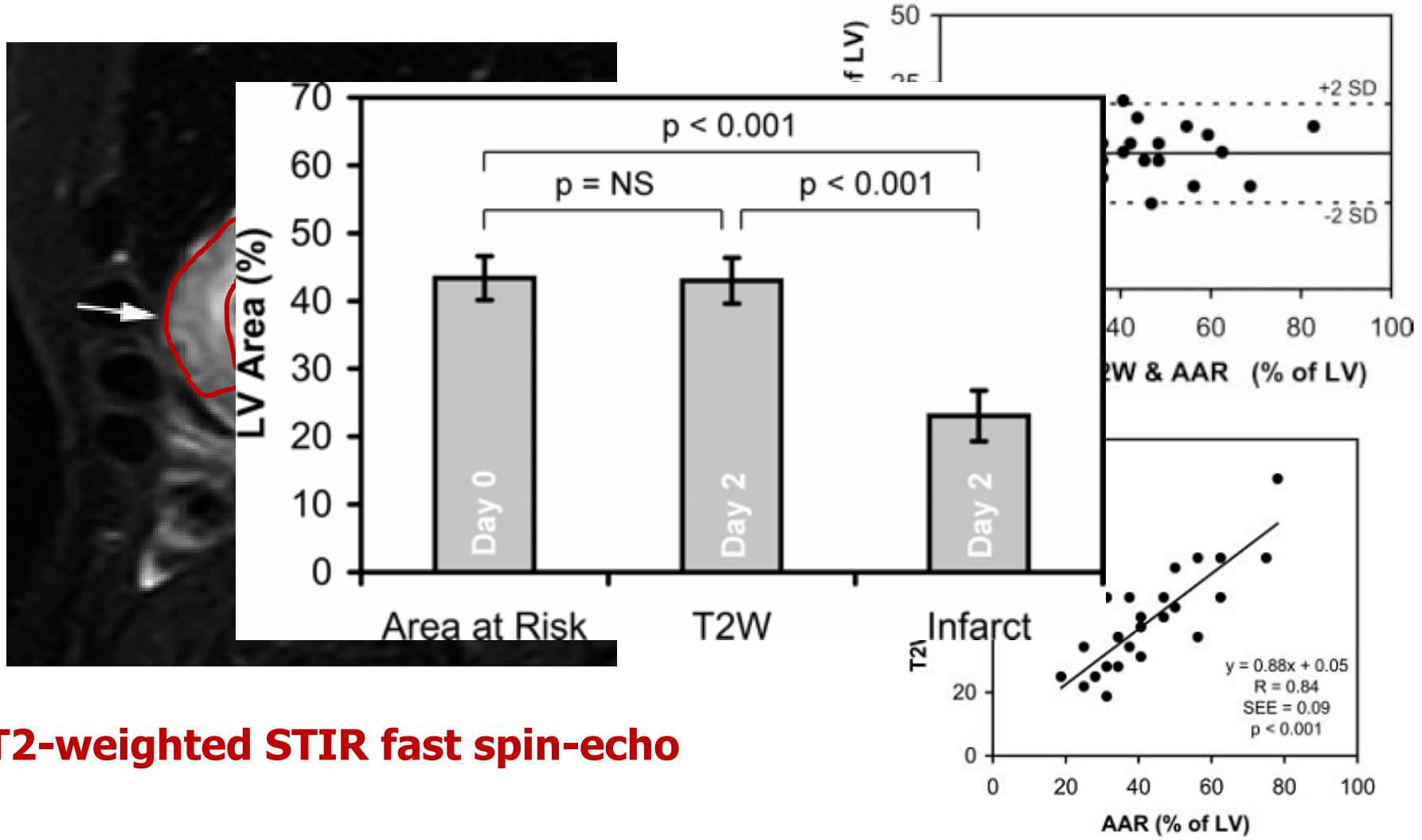
**SI is related to tissue water**
(both intra- and extracellular)

**Long lasting T2-w abnormalities**
(retrospective determination of myocardium at-risk)



# Myocardial Infarction

## - Myocardium at risk -



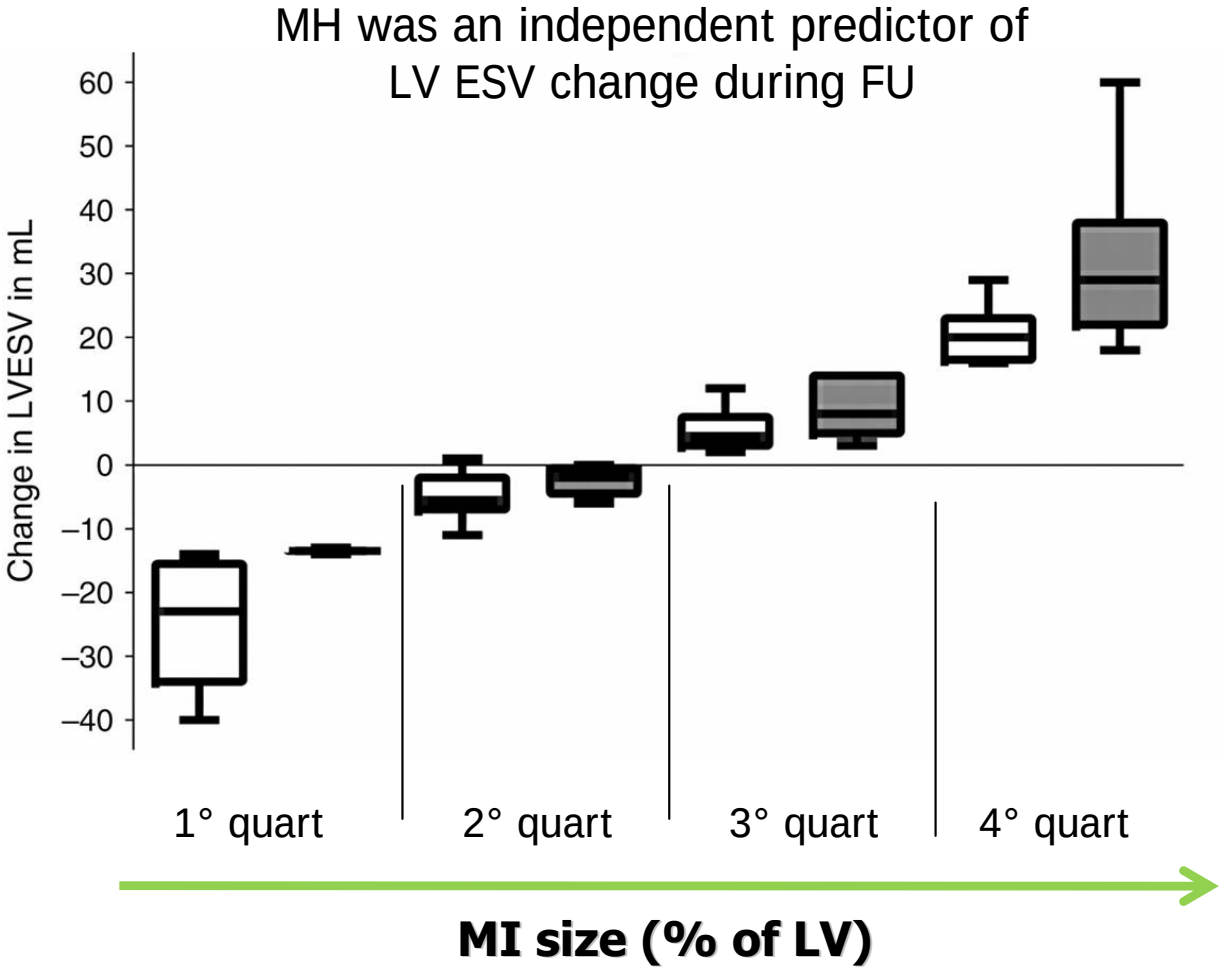

**T2-weighted STIR fast spin-echo**

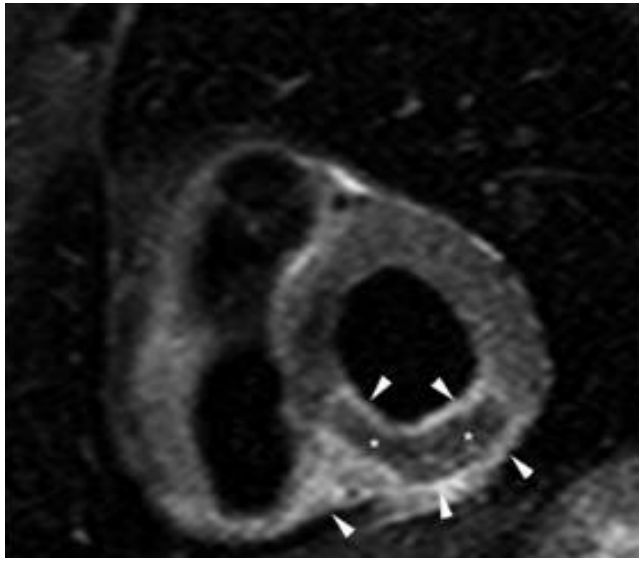
*Aletras et al. Circulation 2006*

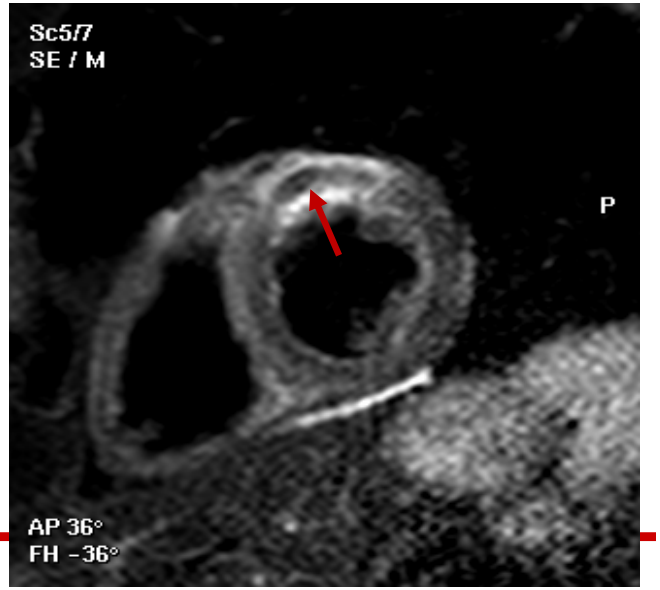
# Myocardial Infarction

## - Myocardium at risk -

Myocardial Hemorrhagia

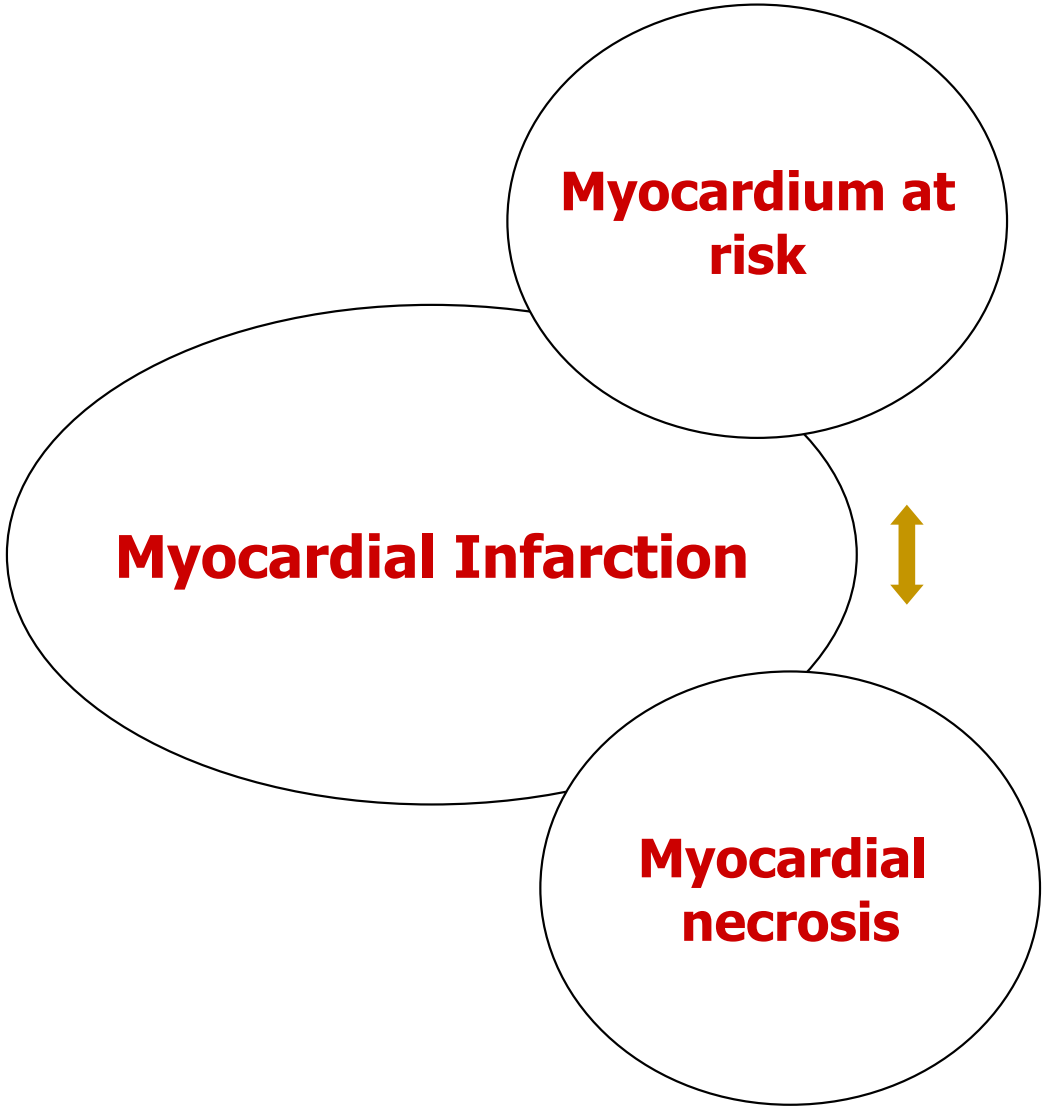





*Ganame J, Bogaert J et al. EHJ 2009*

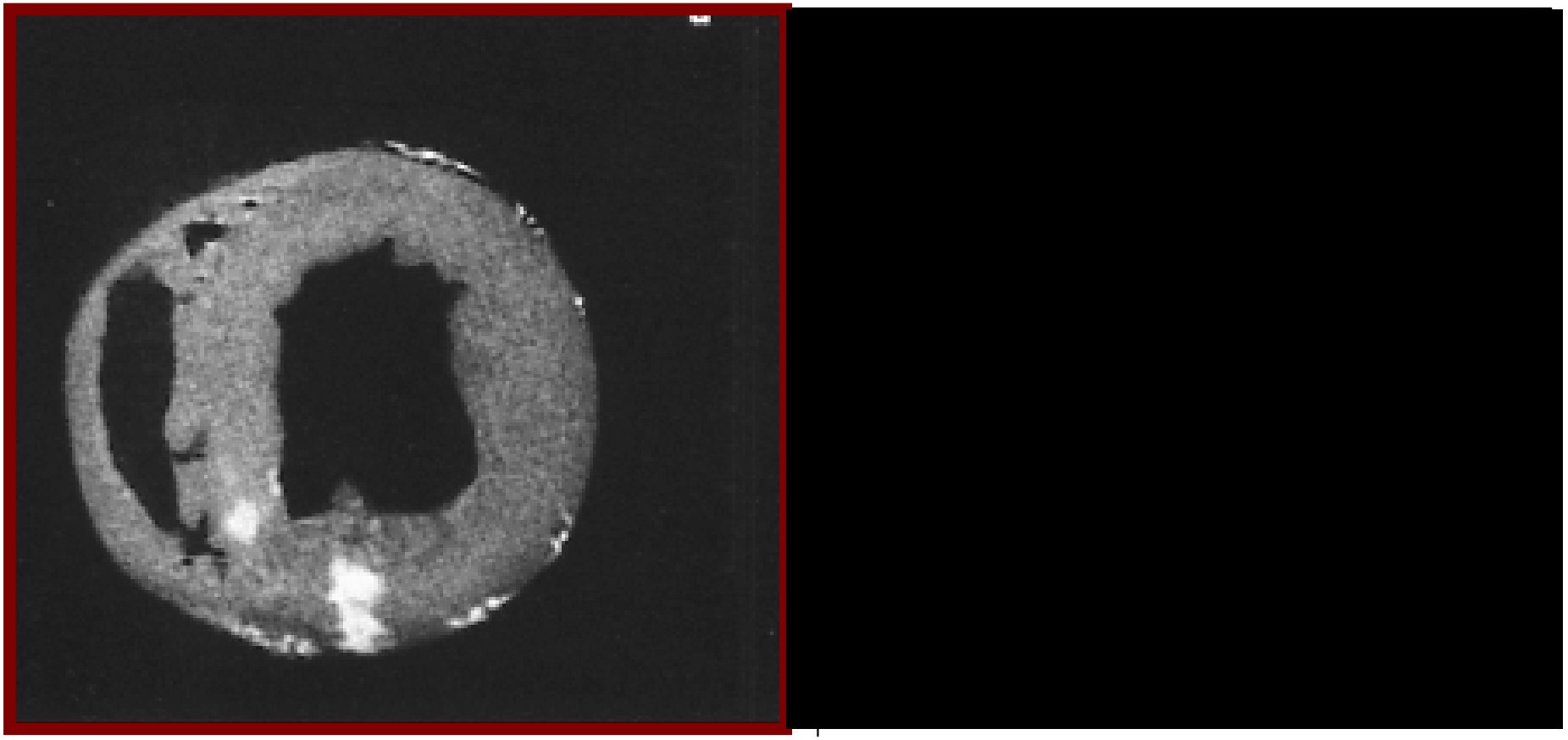
# Myocardial Infarction



# Myocardial Infarction

**-Myocardial Necrosis –**

Late Gadolinium Enhancement (LGE) Imaging



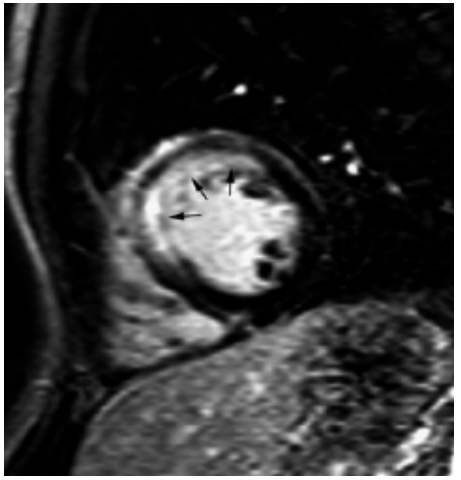
Late Gadolinium Enhancement (LGE)

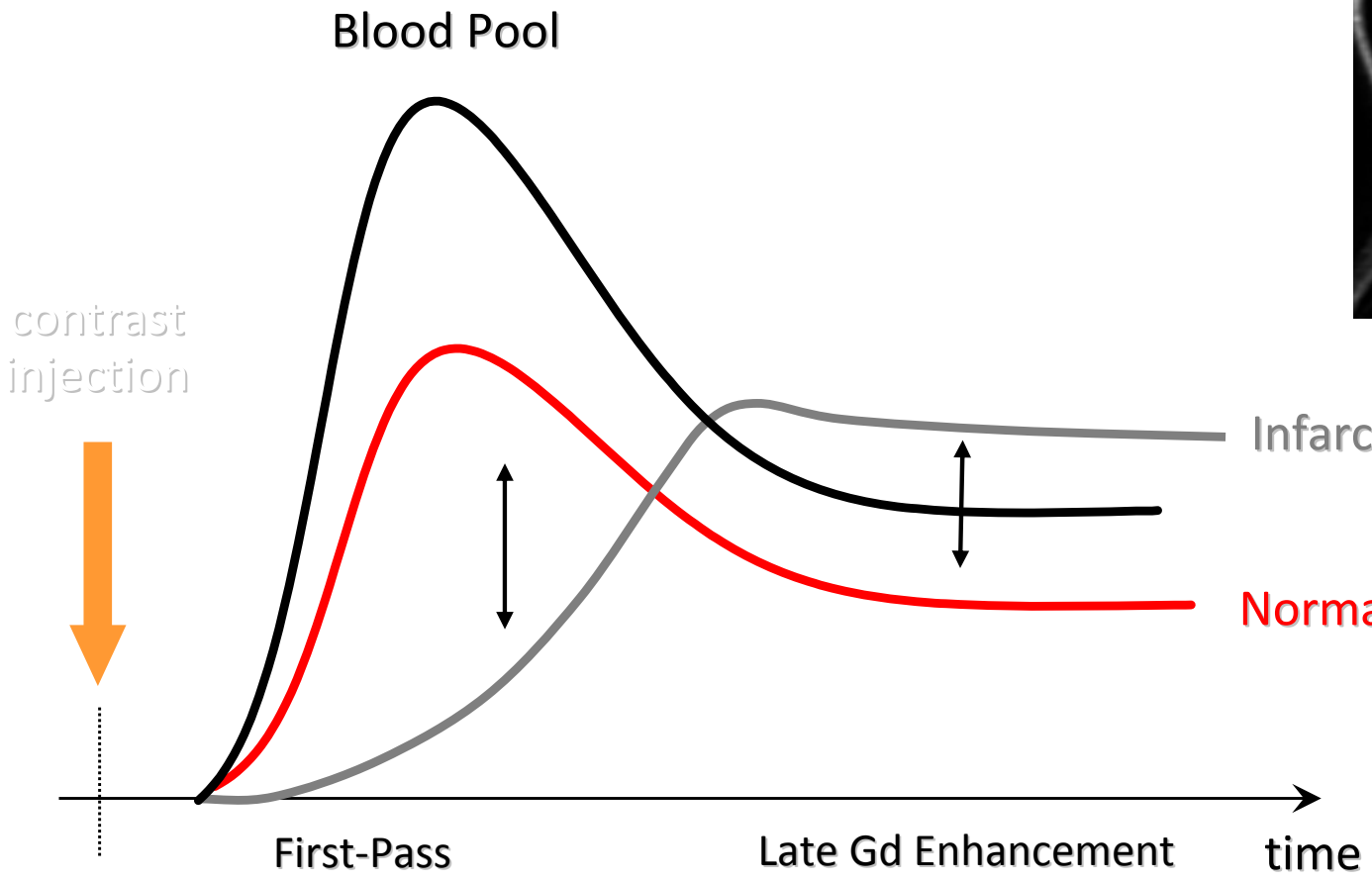
T2-weighted Imaging

# Cardiomyopathies

## -Myocardial Necrosis –

Late Gadolinium Enhancement

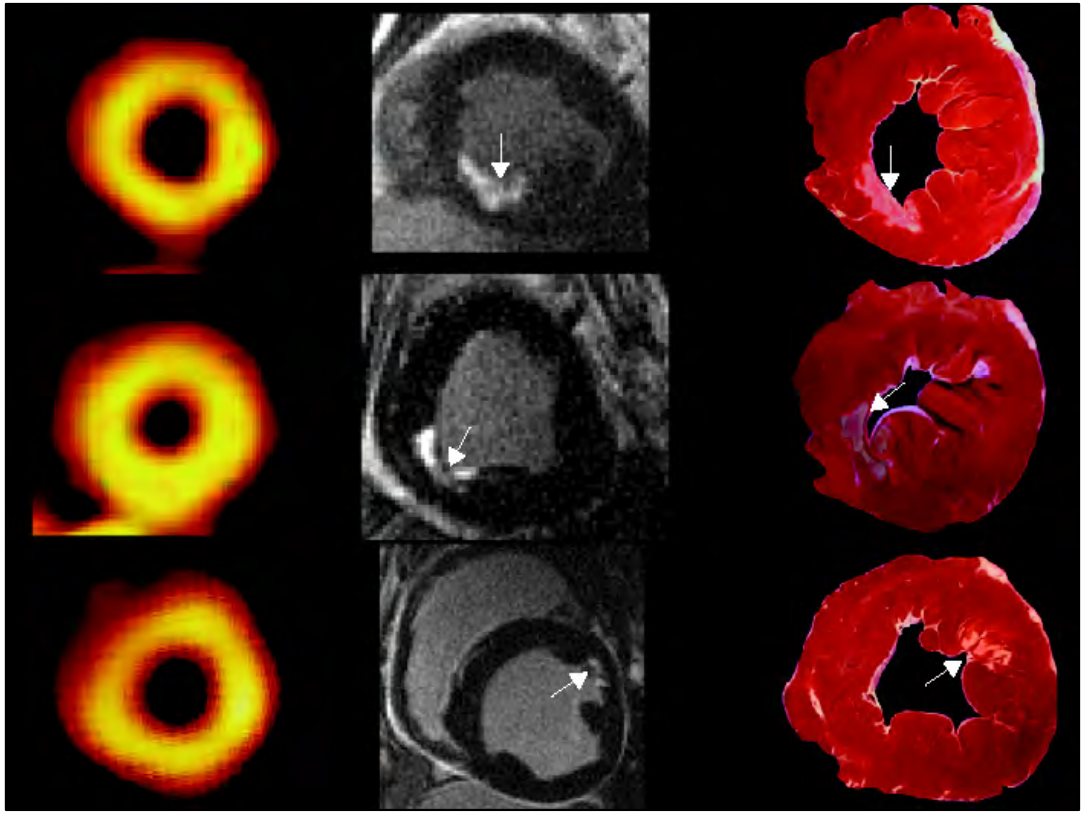


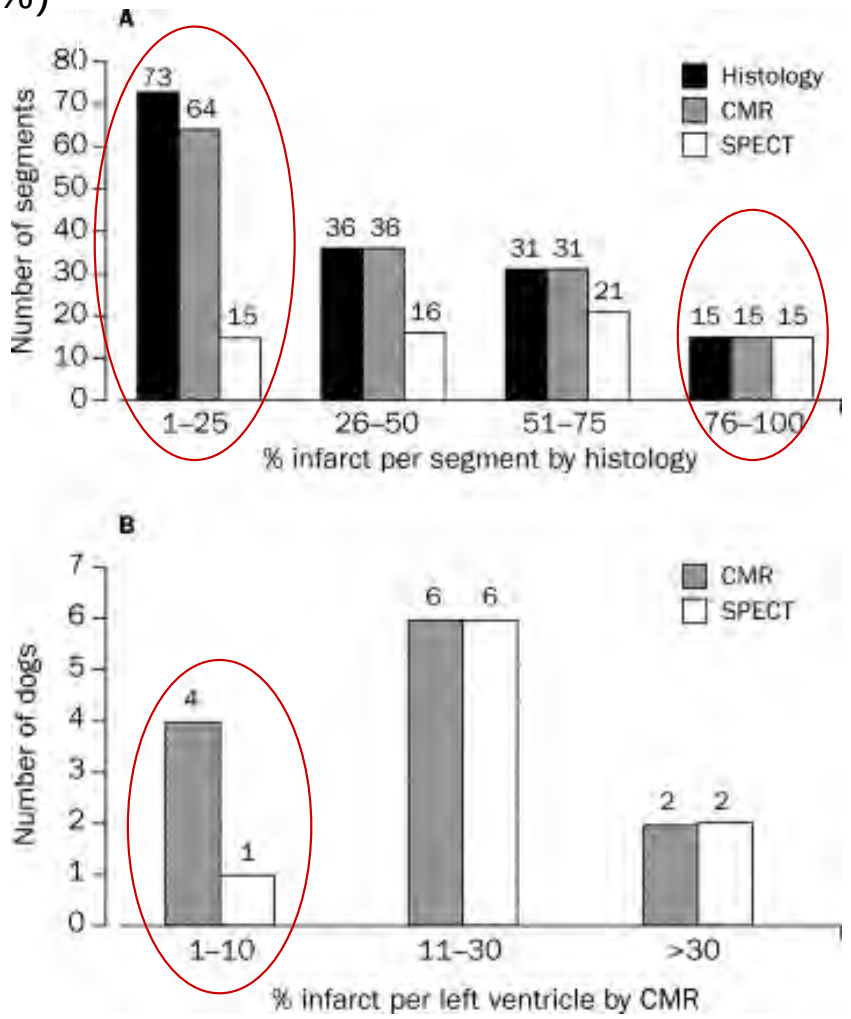


# Myocardial Infarction

## - Myocardial Necrosis -

LGE had a sensitivity of 92% for sub-endocardial infarcts (<50%)
SPECT only 28%.

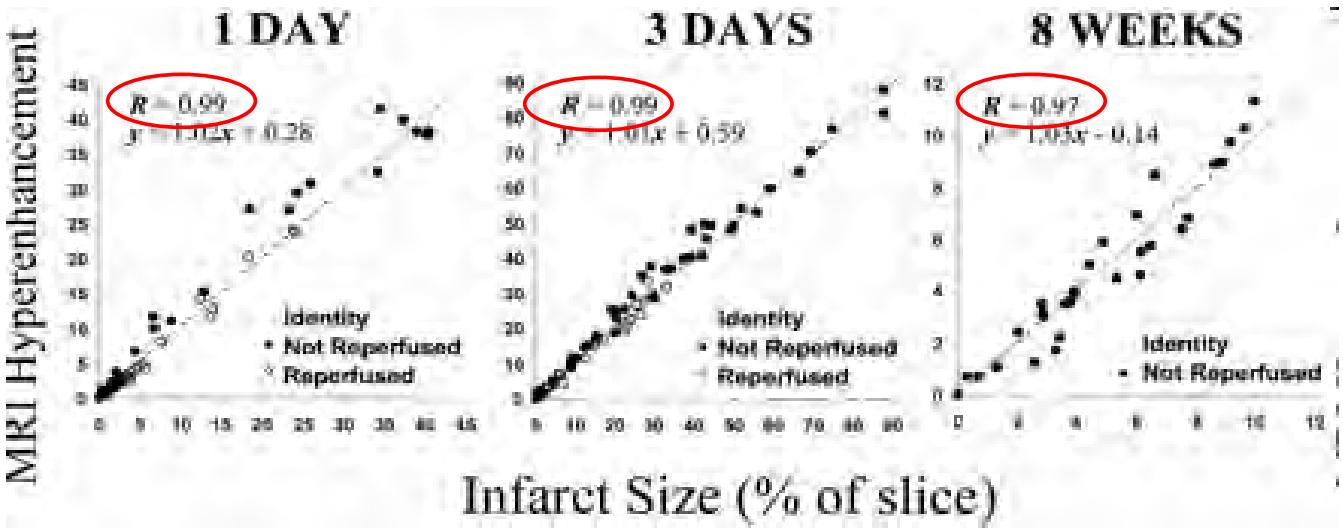


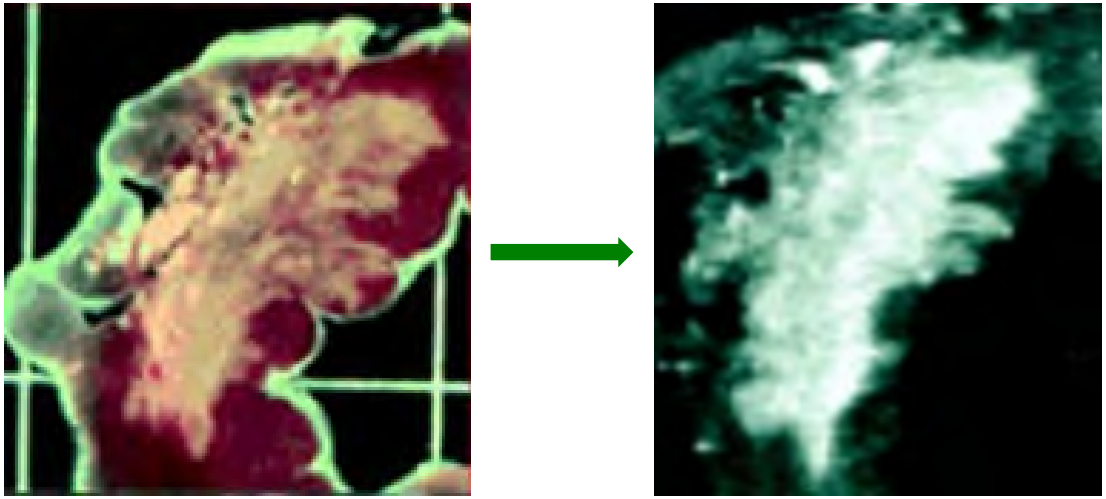



*A. Wagner et al. Lancet 2003*

# Myocardial Infarction

## - Myocardial Necrosis -

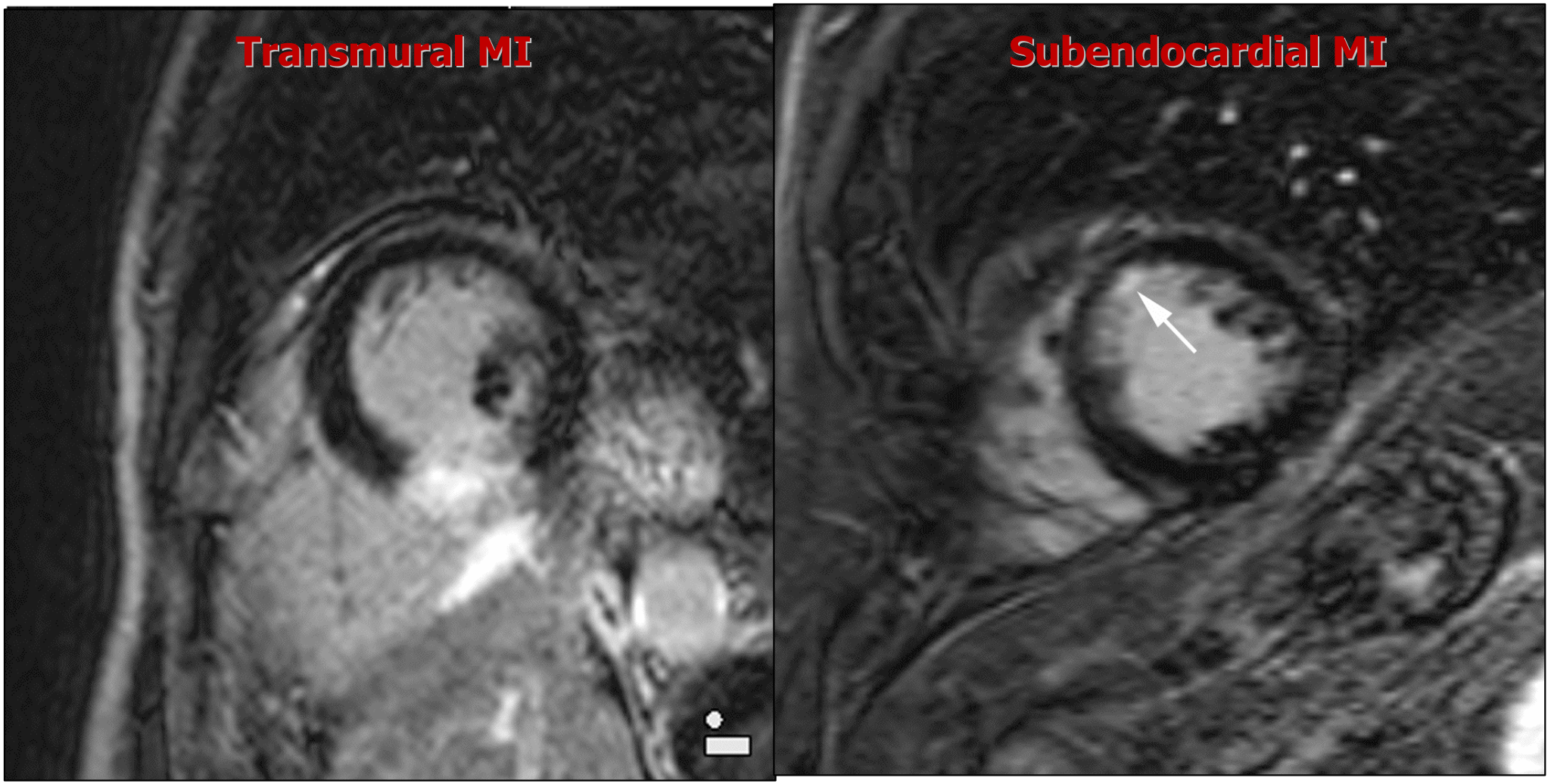


*Kim et al. Circulation 1999*

# Myocardial Infarction

## - Myocardial Necrosis -




*Masci PG et al Circulation 2007*

# Myocardial Infarction

**- Combination of T2-w and LGE imaging -**

## 1- Differentiation between Acute vs Chronic MI

## 2- Determination of Myocardial Salvage

# Myocardial Infarction

**- Combination of T2-w and LGE imaging -**

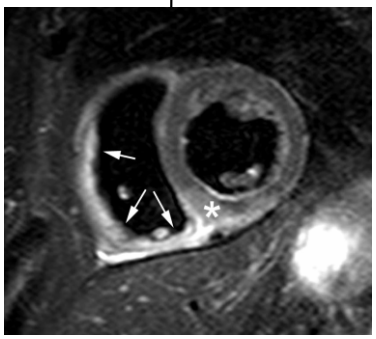
## 1- Differentiation between Acute vs Chronic MI

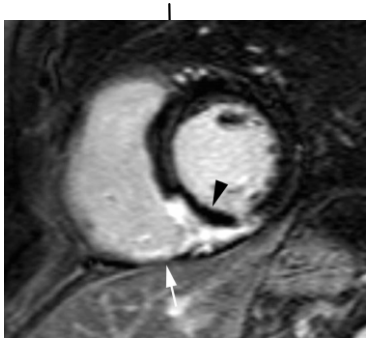
## 2- Determination of Myocardial Salvage

# Myocardial Infarction

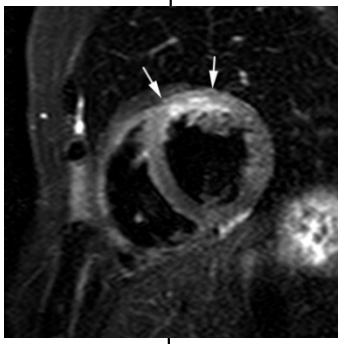
**- Combination of T2-w and LGE imaging -**

**Recent or Old Myocardial Infarction ?**

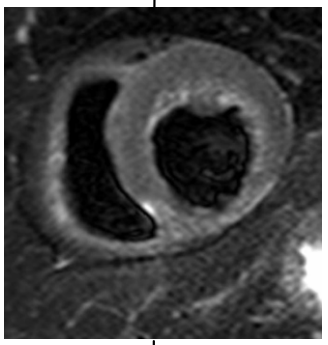




**Recent MI**
**(acute or subacute)**



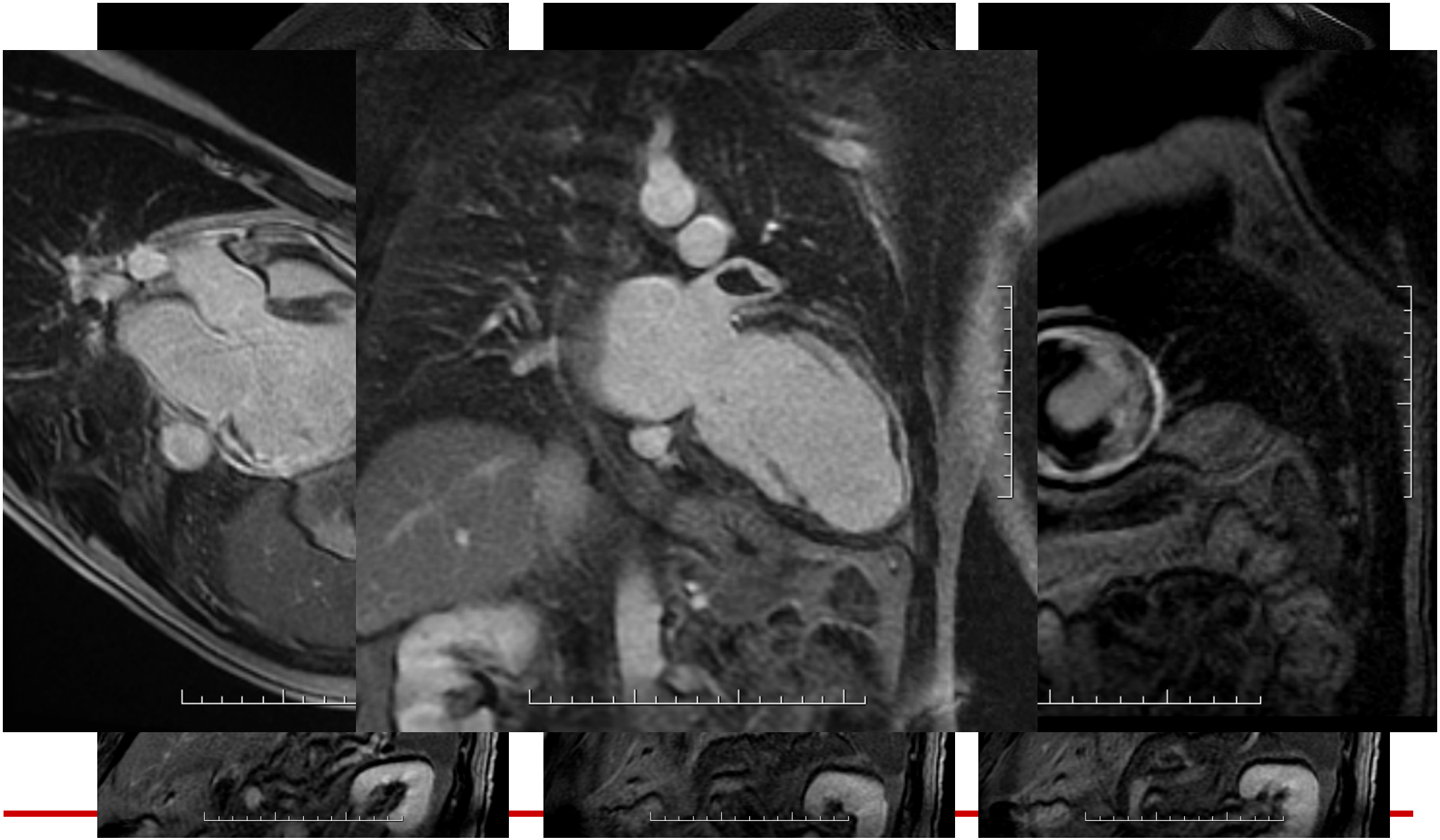
**Aborted MI**
**(in acute setting)**



**Old MI**
**(Chronic MI)**

# Myocardial Infarction

## - Case Presentation -



# Myocardial Infarction

**- Combination of T2-w and LGE imaging -**

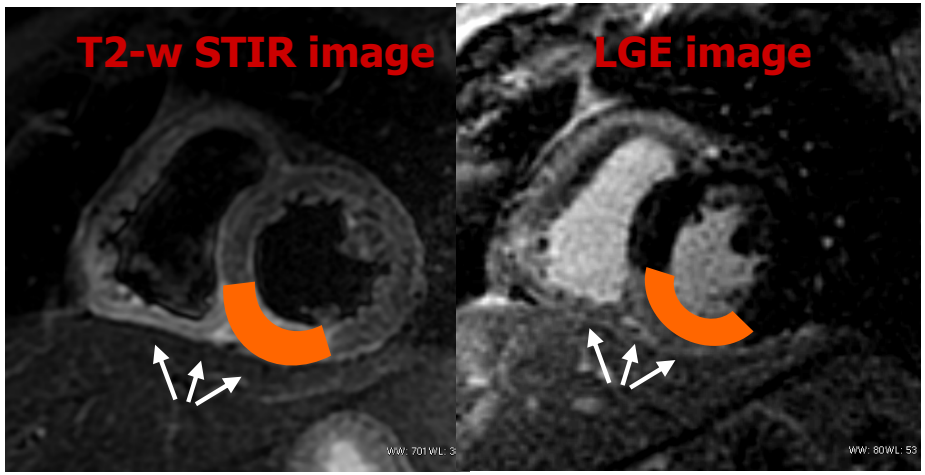
## 1- Differentiation between Acute vs Chronic MI

## 2- Determination of Myocardial Salvage

# Myocardial Infarction

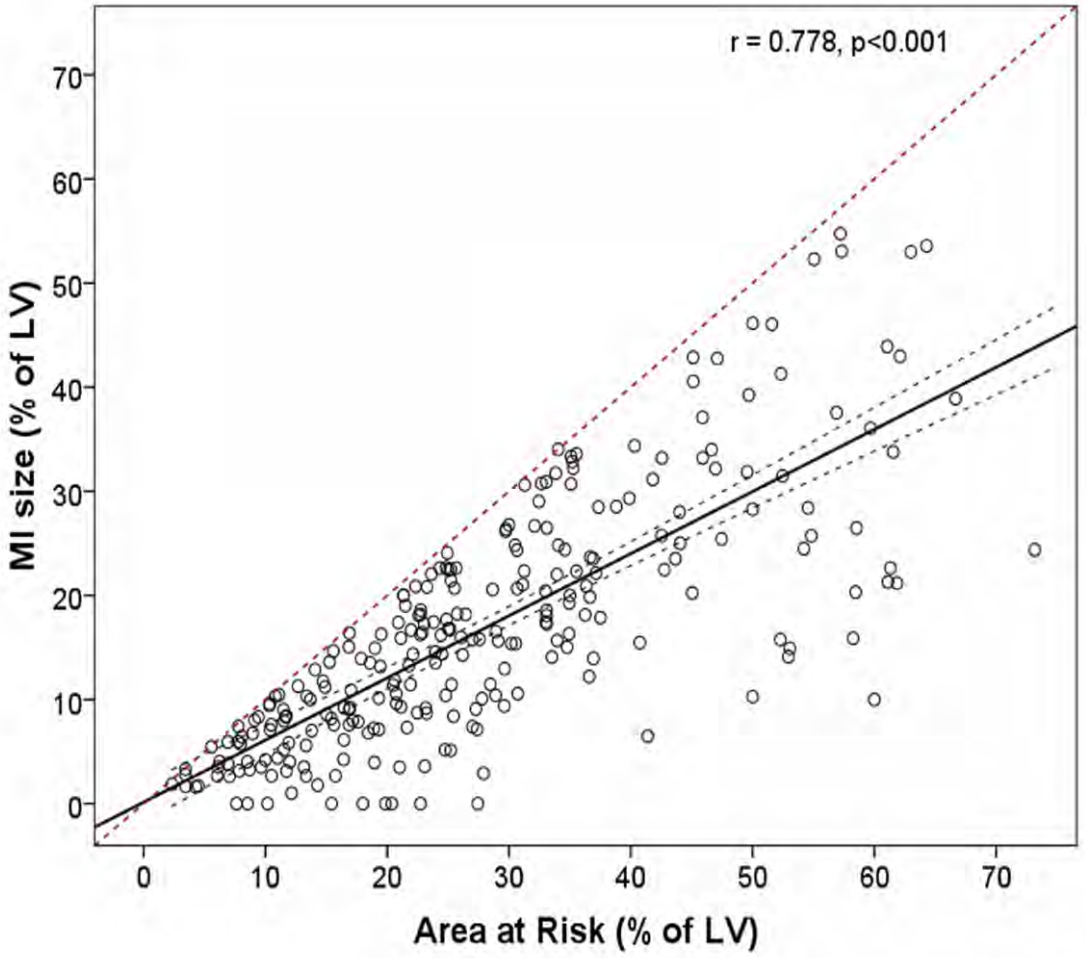
## - Combination of T2-w and LGE imaging –

Myocardial Salvage




**Myocardial Salvage Index (MSI) =**

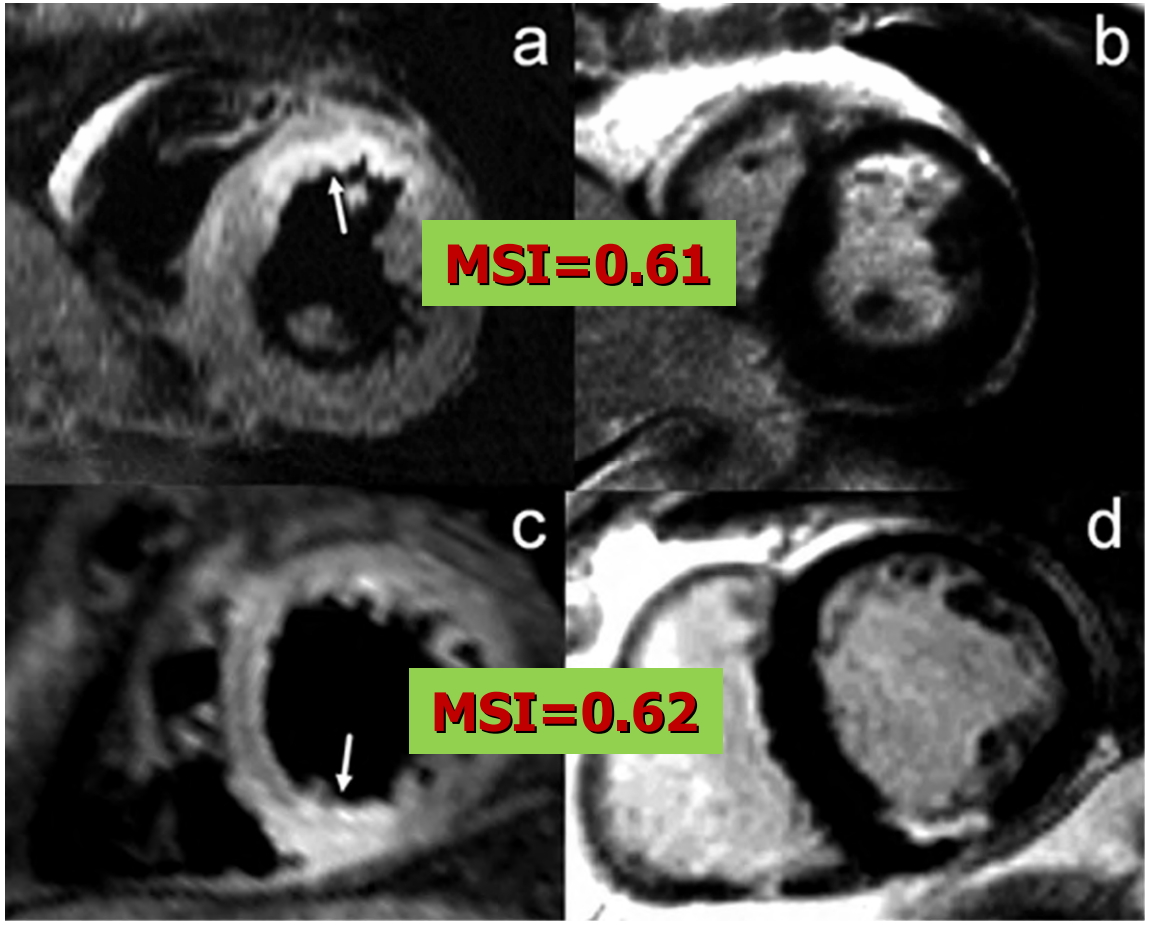
**[ AAR extent – MI size ] / AAR extent**



# Myocardial Infarction

## -Combination of T2-w and LGE imaging –

Myocardial Salvage




Myo. at risk= 23% of LV
MI size= 9% of LV

Myo. at risk= 13% of LV
MI size= 5% of LV

# Myocardial Infarction

JACC: CARDIOVASCULAR IMAGING
VOL. 3, NO. 1, 2010

ISSN 1936-878X/10/$36.00
PUBLISHED BY ELSEVIER INC.
DOI:10.1016/j.jcmg.2009.06.016

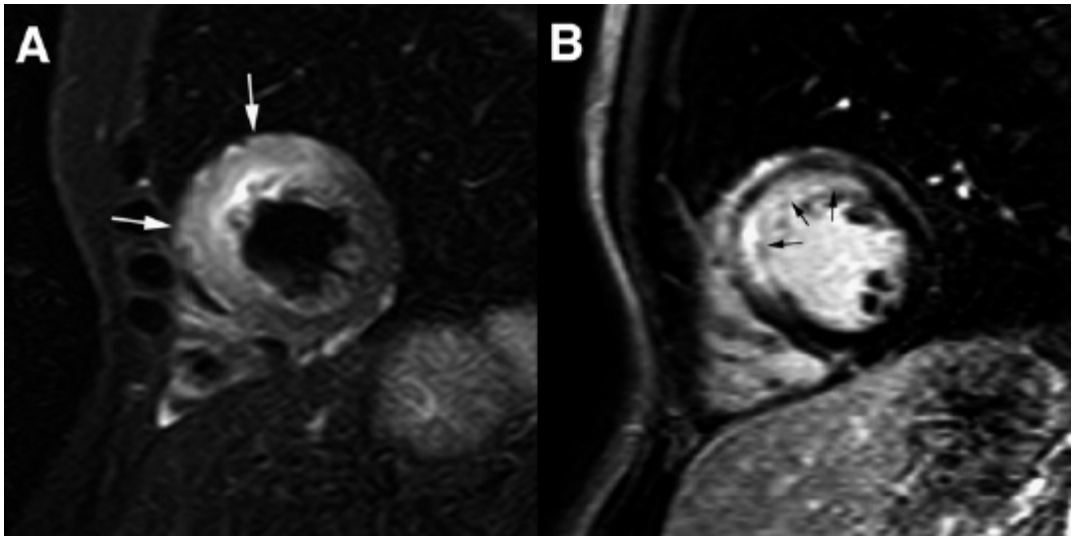
## Myocardial Salvage by CMR Correlates With LV Remodeling and Early ST-Segment Resolution in Acute Myocardial Infarction

Pier Giorgio Masci, MD,* Javier Ganame, MD, PHD,†‡ Elisabetta Strata, MD,*
Walter Desmet, MD,‡ Giovanni Donato Aquaro, MD,* Steven Dymarkowski, MD, PHD,†
Valentina Valenti, MD,§ Stefan Janssens, MD, PHD,‡ Massimo Lombardi, MD,*
Frans Van de Werf, MD, PHD,‡ Antonio L'Abbate, MD,‖ Jan Bogaert, MD, PHD†
*Pisa and Rome, Italy; and Leuven, Belgium*

*Masci PG et al. JACC Img 2010*

# Myocardial Infarction

## - Myocardial Salvage -




| Variables | Acute Phase (1 Week) | Chronic Phase (4 Months) | p Value |
|---|---|---|---|
| LV end-diastolic volume (ml) | 158 ± 38 | 167 ± 41 | <0.0001 |
| LV end-systolic volume (ml) | 82 ± 24 | 87 ± 30 | 0.032 |
| LV mass (g) | 124 ± 29 | 111 ± 25 | <0.0001 |
| LV ejection fraction (%) | 48 ± 8 | 50 ± 10 | 0.007 |
| Myocardial infarct size (% of LV) | 18 ± 13 | — | — |
| Myocardial infarct transmurally (%) | 72 ± 28 | — | — |
| Area at risk (% of LV) | 32 ± 15 | — | — |
| Myocardial salvage index | 0.46 ± 0.24 | — | — |
| Microvascular obstruction | 69 (50) | — | — |
| Microvascular obstruction extent (% of LV) | 6 ± 9 | — | — |

*Masci PG et al. JACC Img 2010*

# Myocardial Infarction

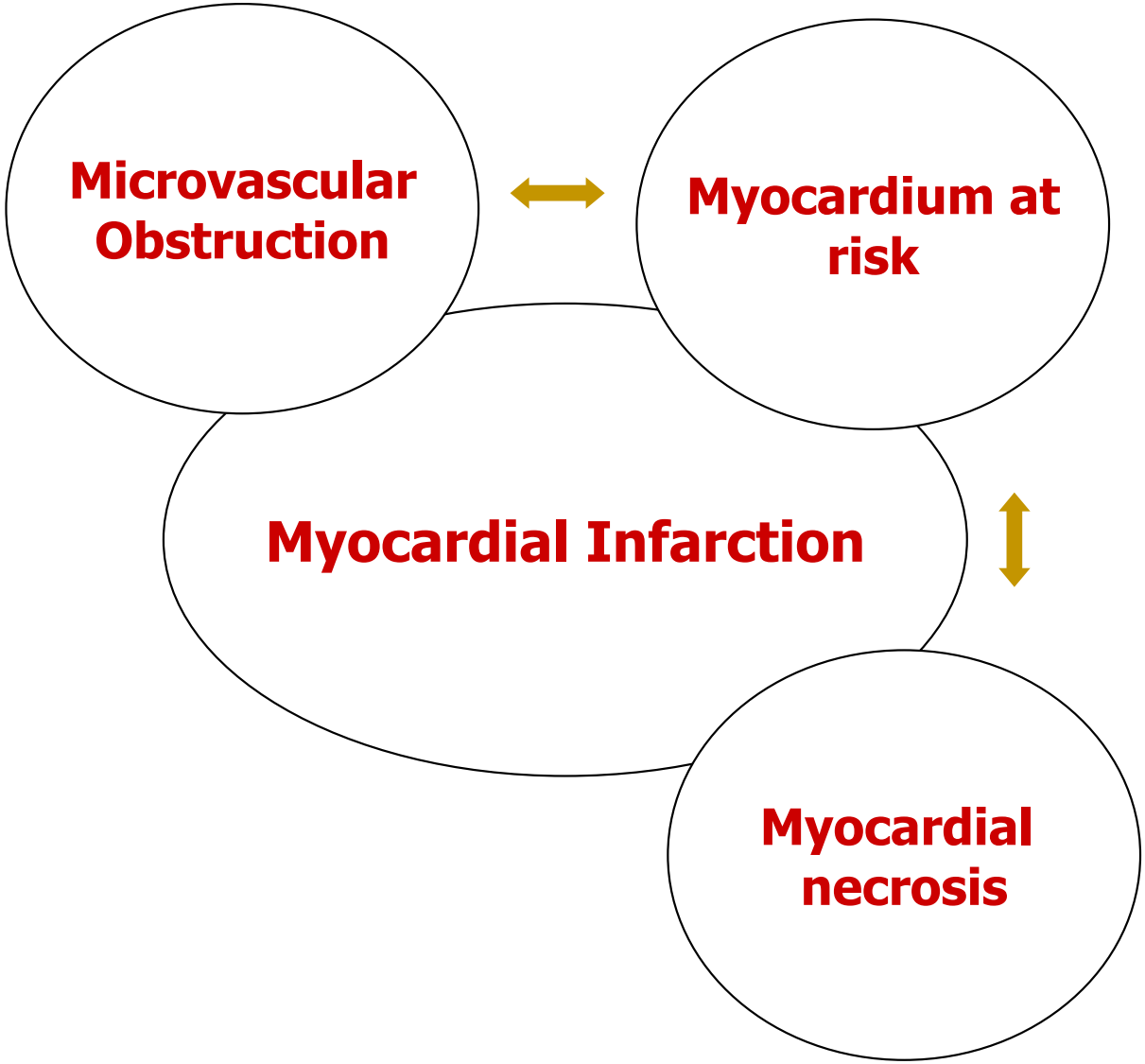
## - Myocardial Salvage -

| | Adverse LV Remodeling | | | |
|---|---|---|---|---|
| | Univariate | | Multivariate | |
| Baseline Variables | OR (95% CI) | p Value | OR (95% CI) | p Value |
| MI transmurally (%) | 1.04 (1.01–1.07) | 0.005 | — | — |
| AAR (% of LV) | 1.04 (1.01–1.07) | 0.003 | 1.04 (1.01–1.08) | 0.001 |
| MSI (for 0.10 increment) | 0.58 (0.46–0.75) | <0.0001 | 0.64 (0.49–0.84) | 0.001 |
| Presence of MO | 6.79 (2.55–18.06) | <0.0001 | — | — |
| Time to reperfusion (min) | 1.00 (0.99–1.00) | 0.588 | — | — |
| Age (for 10-yr increment) | 1.22 (0.87–1.72) | 0.241 | — | — |
| Anterior vs. nonanterior MI | 2.27 (1.02–5.04) | 0.044 | — | — |
| LV ejection fraction | 0.92 (0.87–0.97) | 0.003 | — | — |

**Myocardial salvage** was also independently associated with **early ST-segment resolution** (*β-coefficient=0.61, p<0.0001*)

*Masci PG et al. JACC Img 2010*

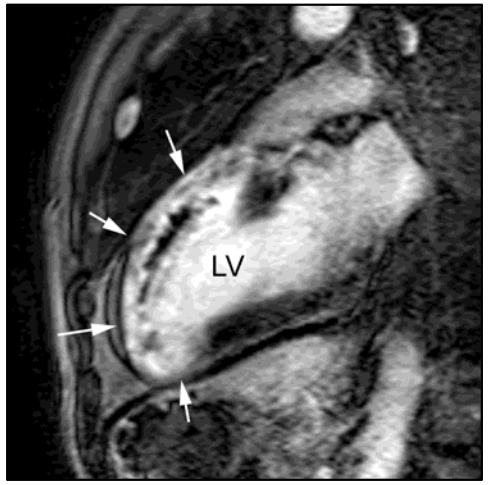
# Myocardial Infarction



# Myocardial Infarction

## - Microvascular Obstruction -

- Impaired Reperfusion at Tissue Level
  - Severe edema compressing intramural vessels
  - Endothelial cells swelling
  - Erythrocites and leucokites cells plugging
  - Microvasculature necrosis
  - Distal embolization




## Main Determinants

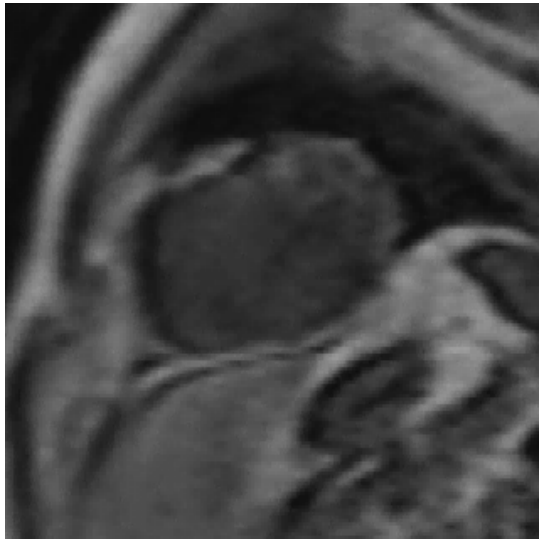
**Myocardial Ischemia**

**Reperfusion Injury**

**Degree of myocardial necrosis**

# Myocardial Infarction

## - Microvascular Obstruction -

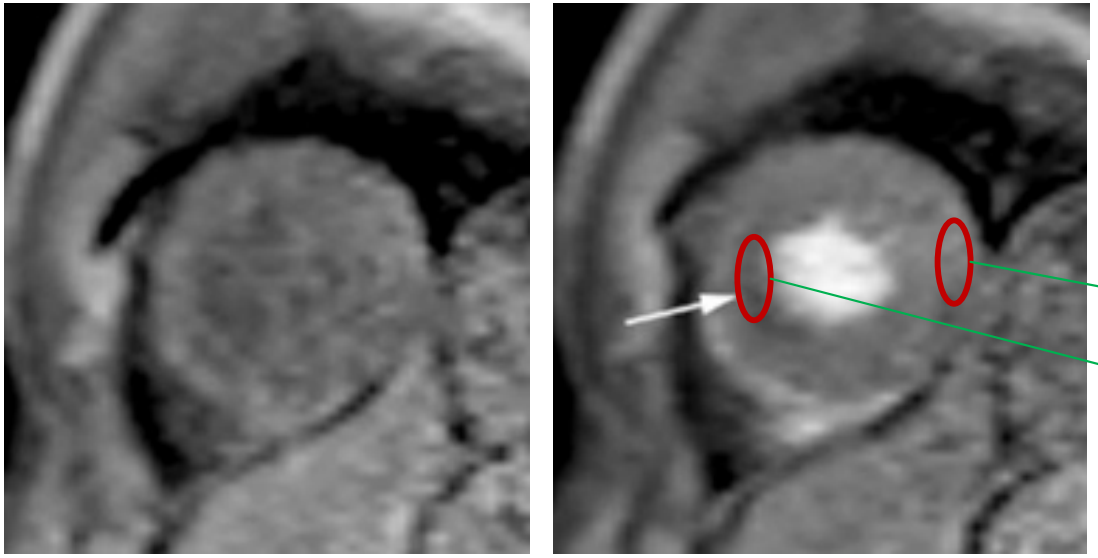


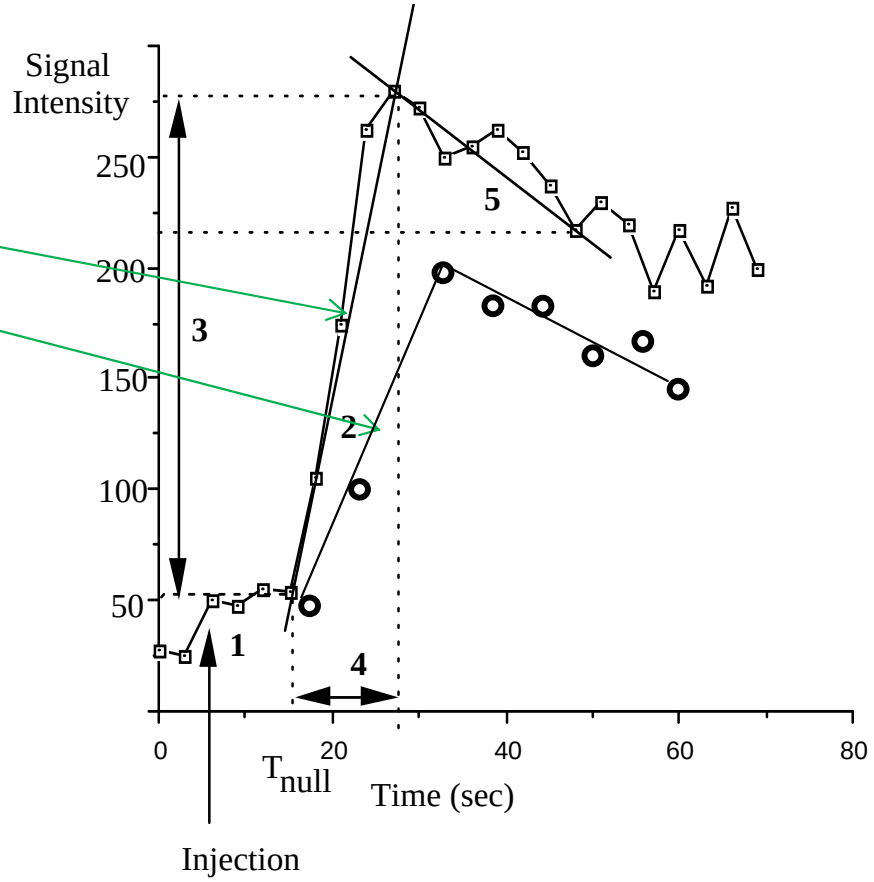
First-pass Perfusion

Late Gadolinium Enhancement

# Myocardial Infarction

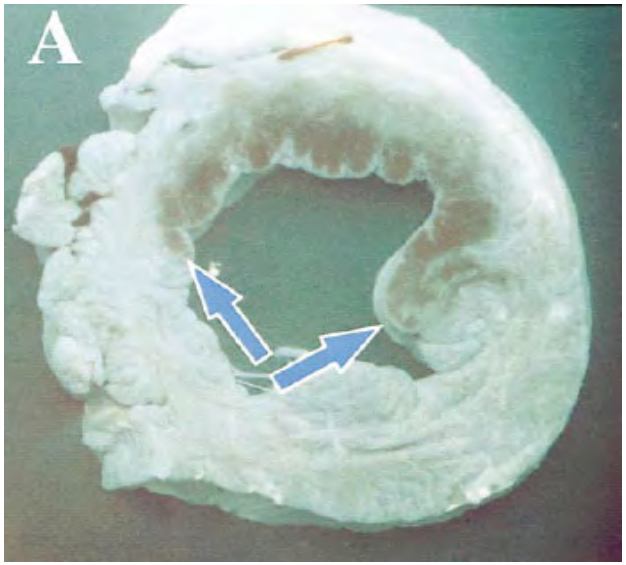
## - Microvascular Obstruction -

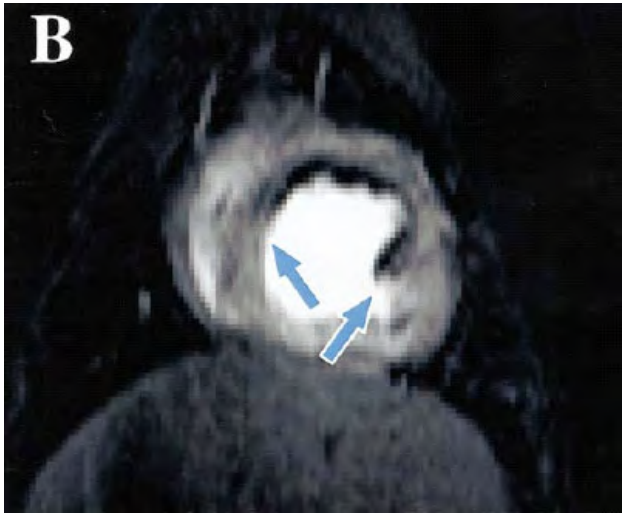


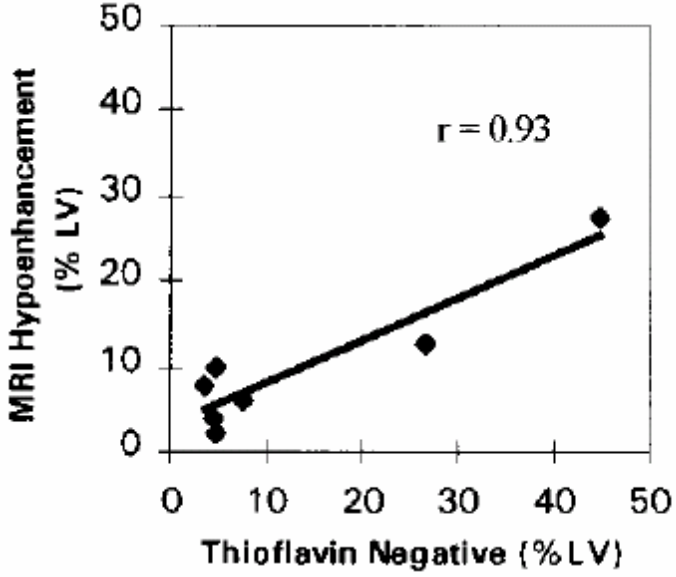


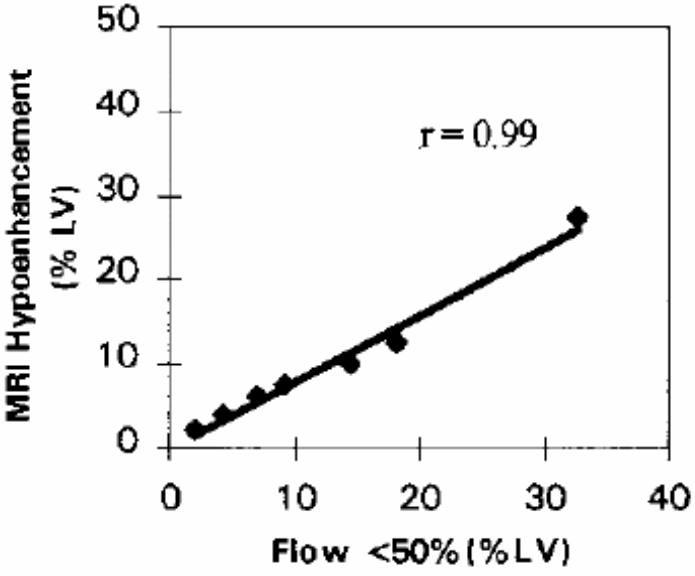
# Myocardial Infarction

## - Microvascular Obstruction -



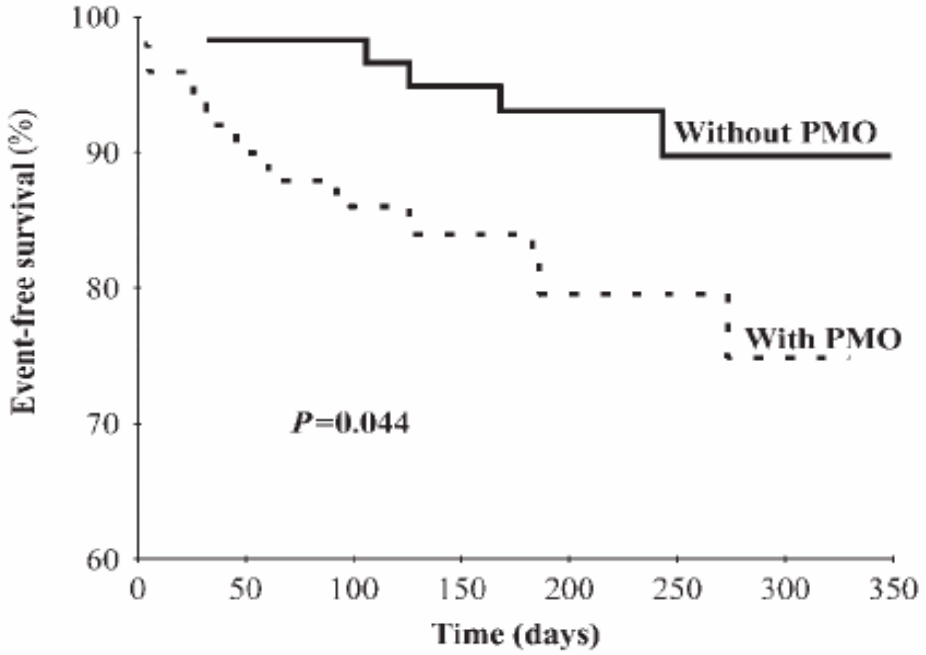



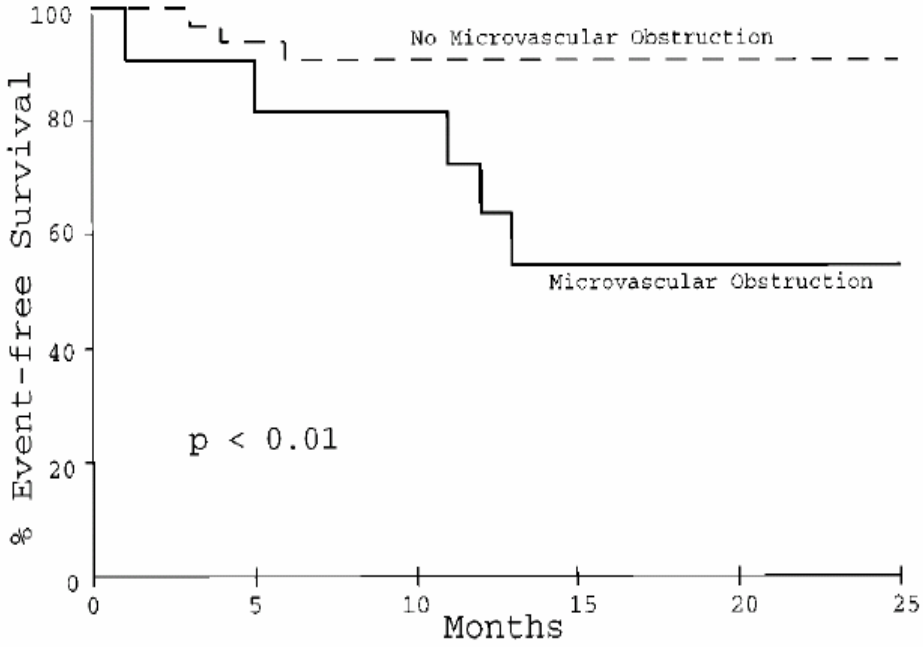



# Myocardial Infarction

## - Microvascular Obstruction -



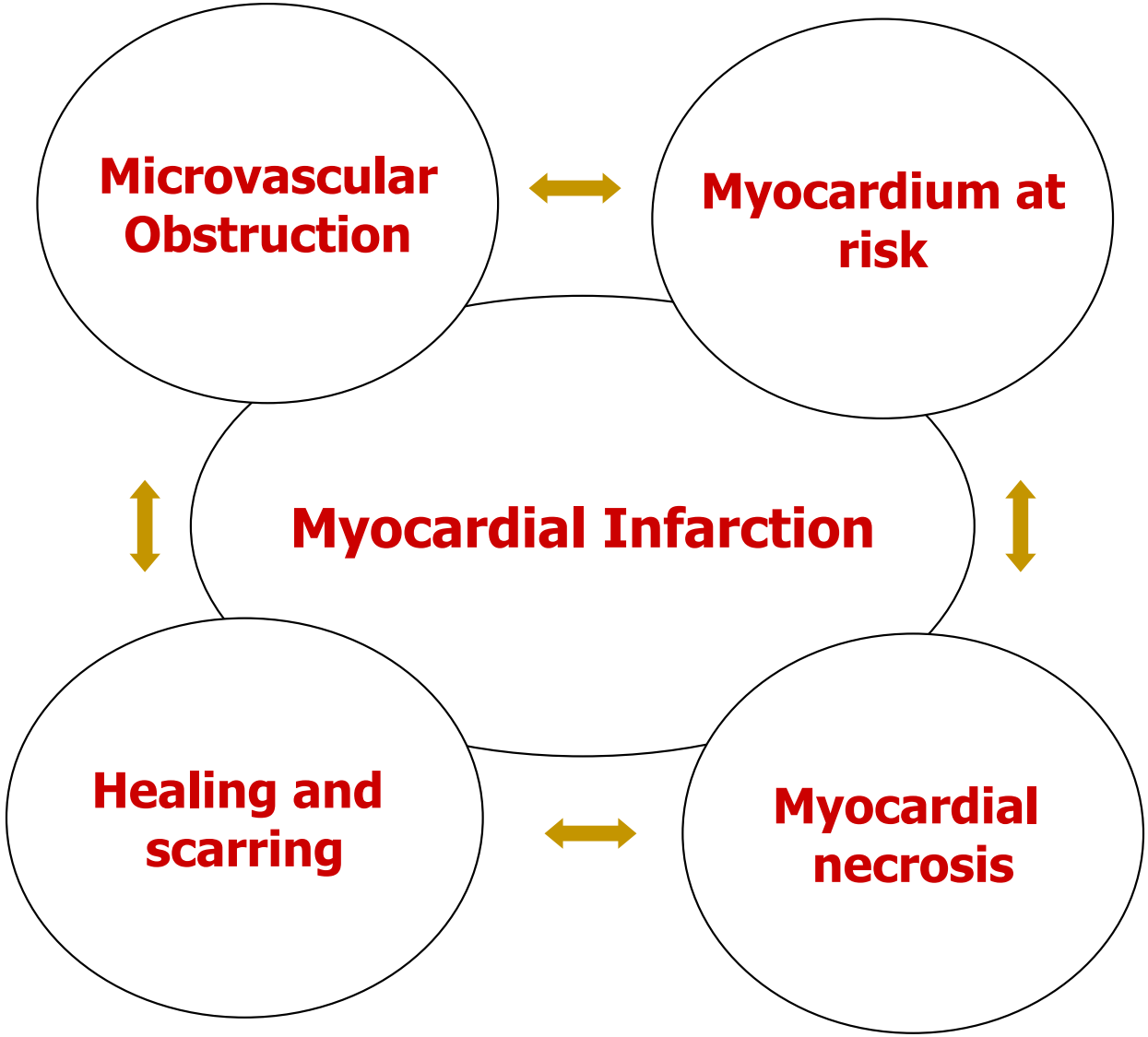




**Microvascular Obstruction** is a **negative prognostic** predictor at Cox-multivariate analysis after correction for MI size

*Hombach et al EHJ 2005 26, 549-557*

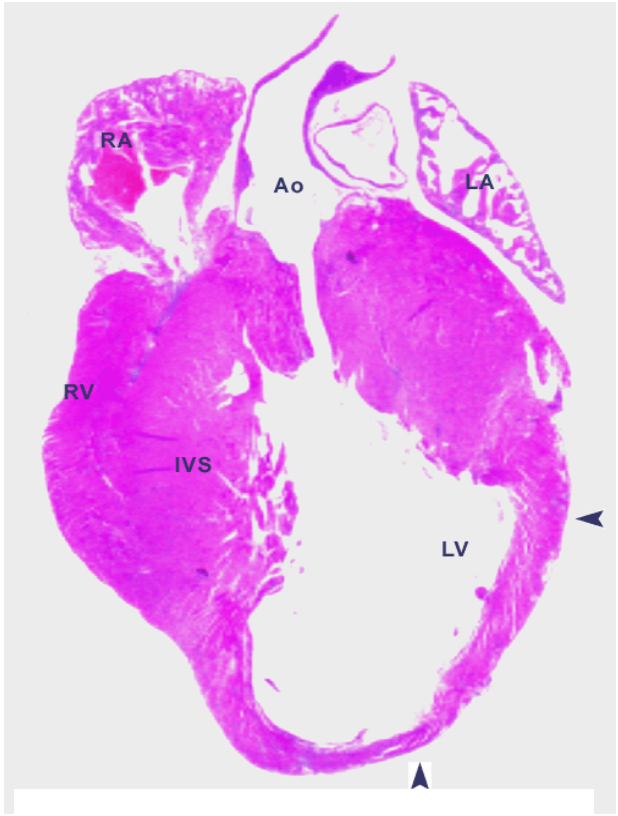
*Wu et al Circulation 1998; 97: 765-772*

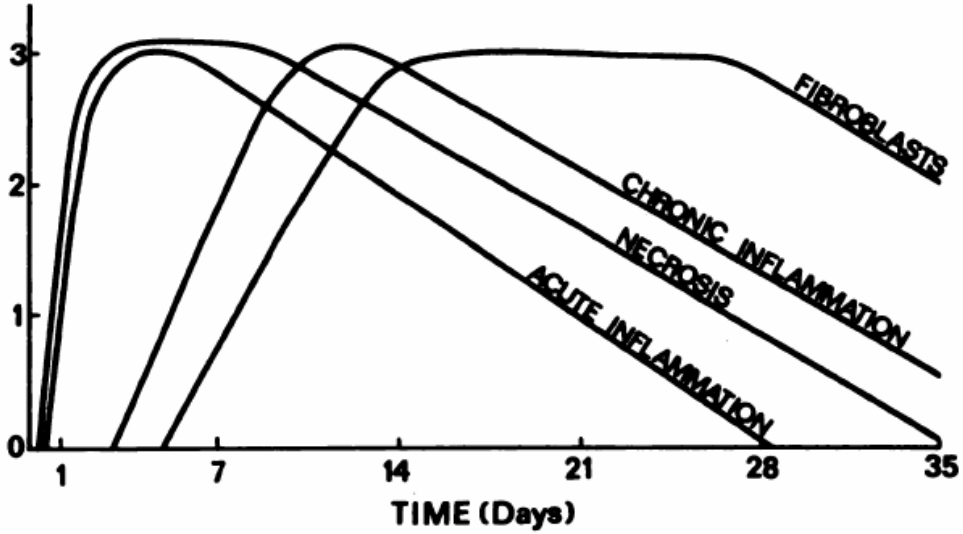
# Myocardial Infarction

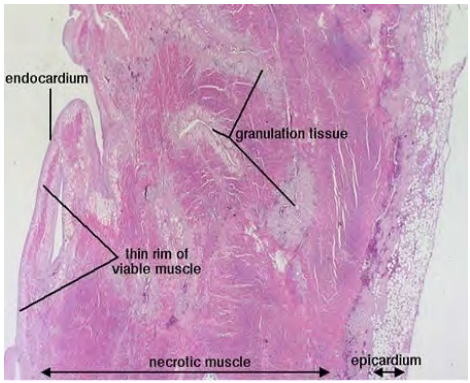


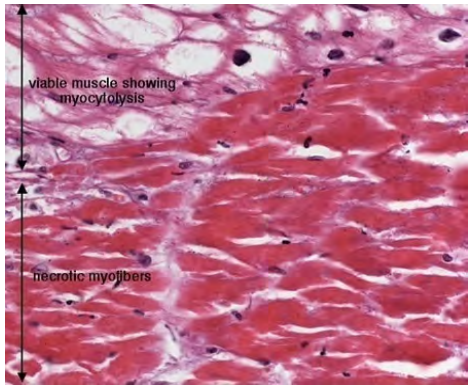
# Myocardial Infarction

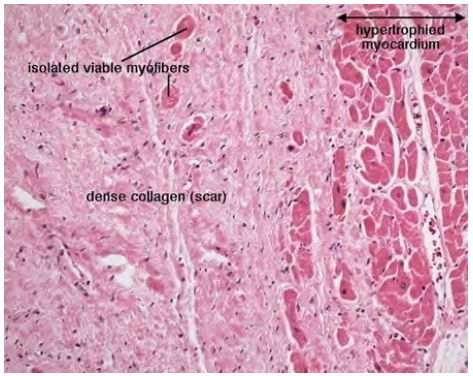
## - Infarct Healing -




Time

# Myocardial Infarction

## - Infarct Healing -

Eur Radiol
DOI 10.1007/s00330-010-1963-8

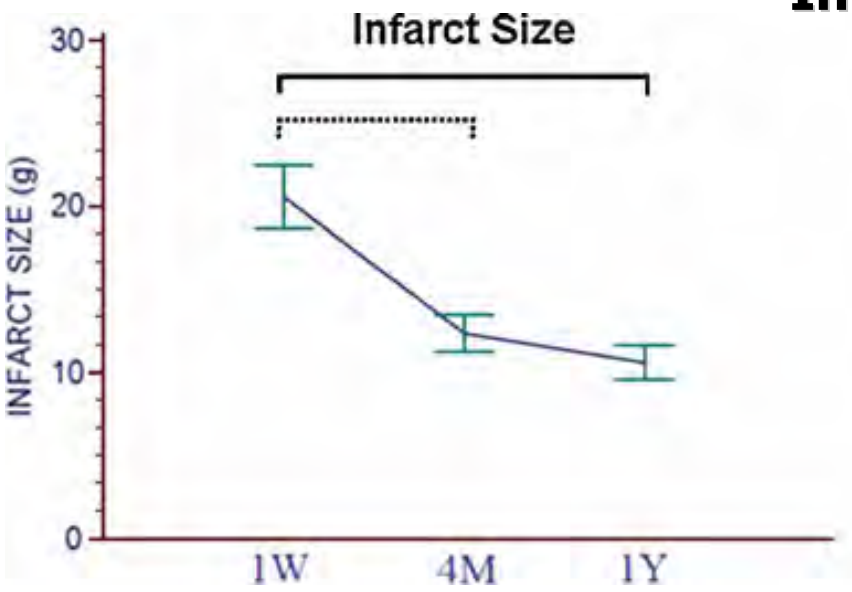
CARDIAC

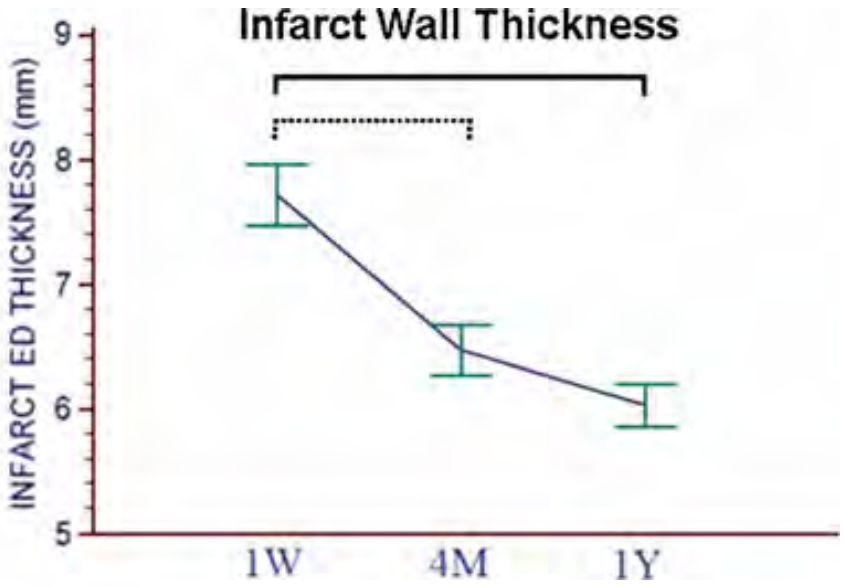
# Time course of infarct healing and left ventricular remodelling in patients with reperfused ST segment elevation myocardial infarction using comprehensive magnetic resonance imaging

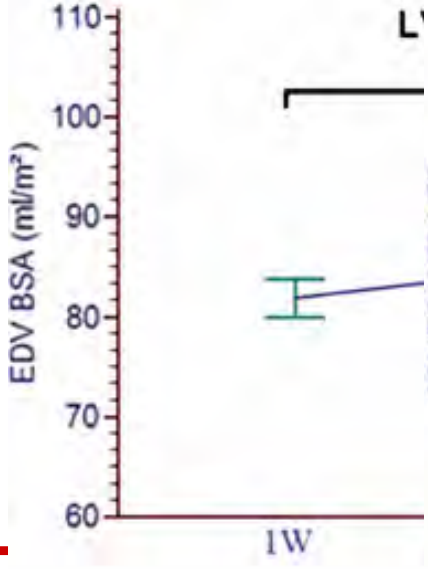
Javier Ganame · Giancarlo Messalli · Pier Giorgio Masci · Steven Dymarkowski · Kayvan Abbasi · Frans Van de Werf · Stefan Janssens · Jan Bogaert

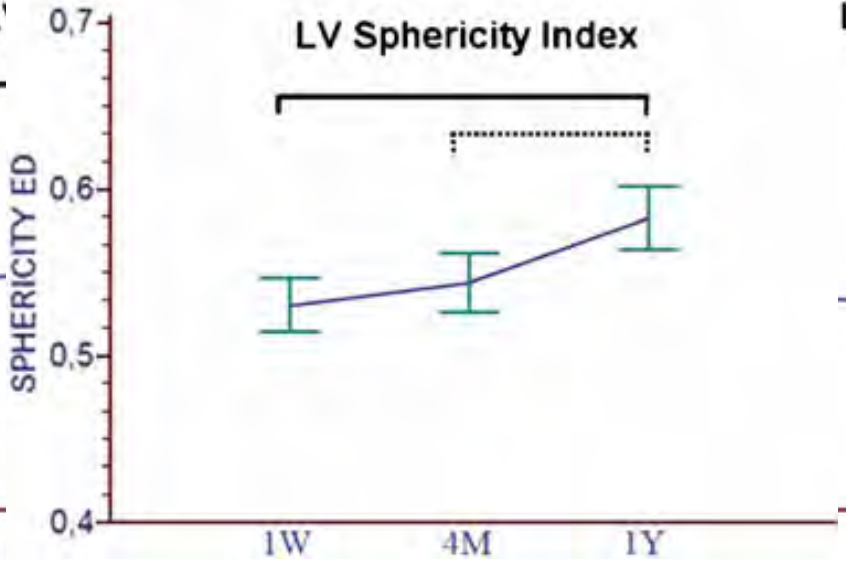
# Myocardial Infarction

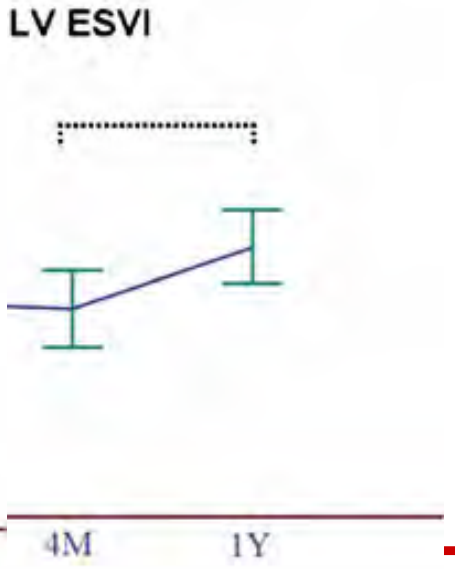
## - Infarct Healing -



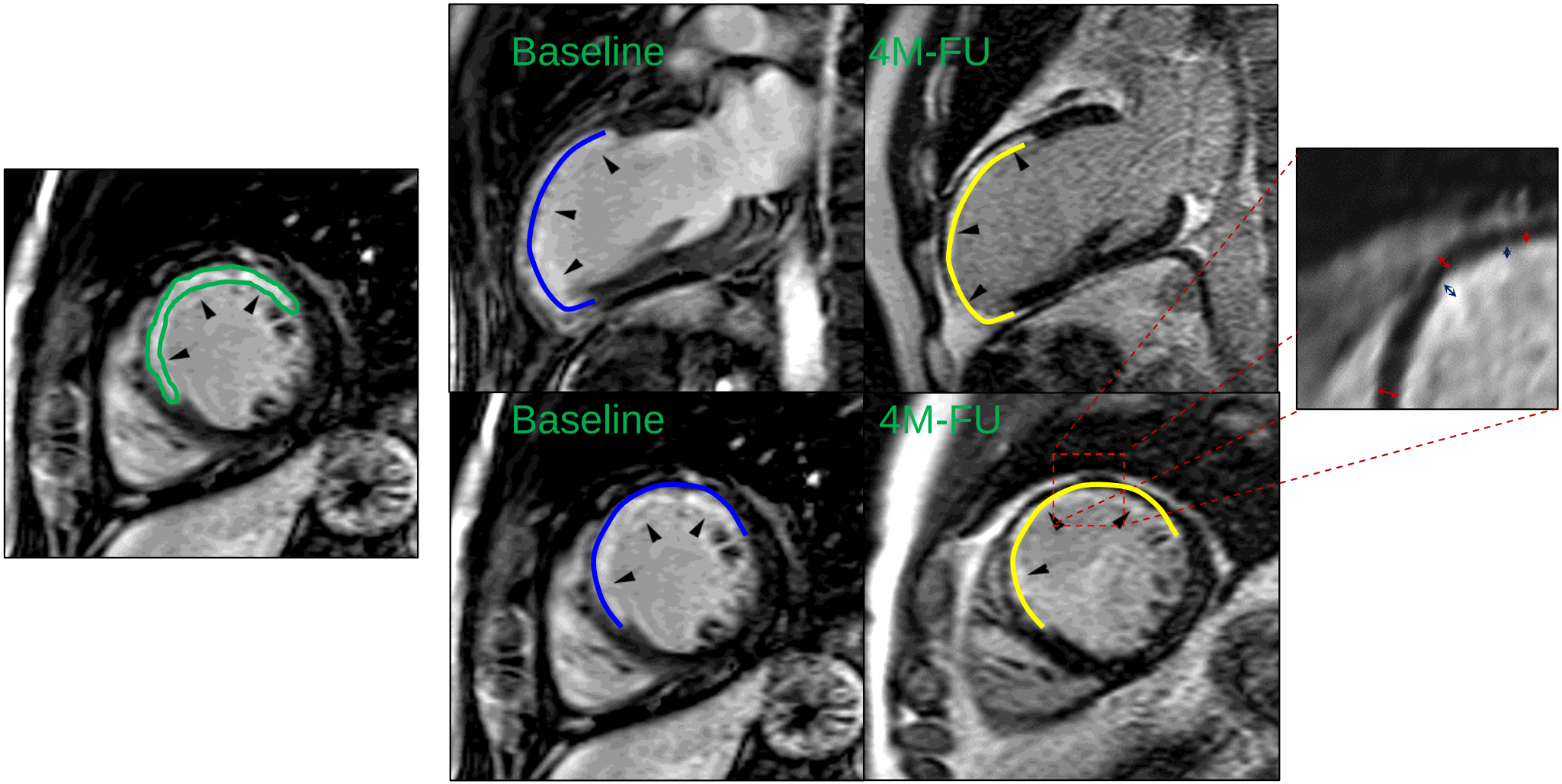



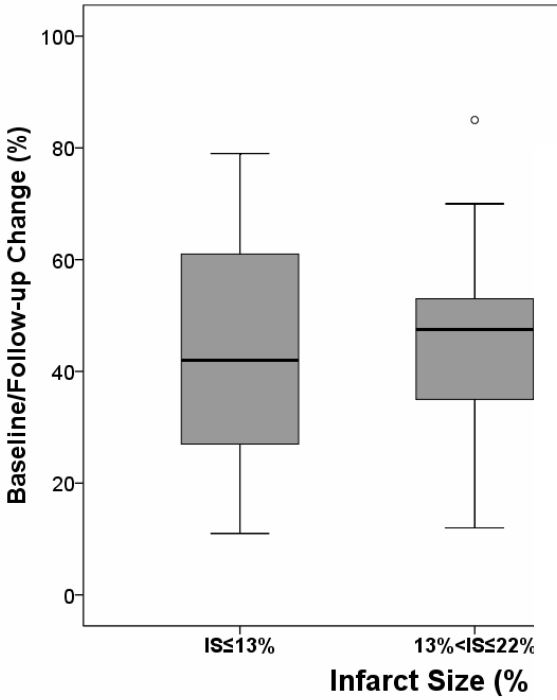
# Myocardial Infarction

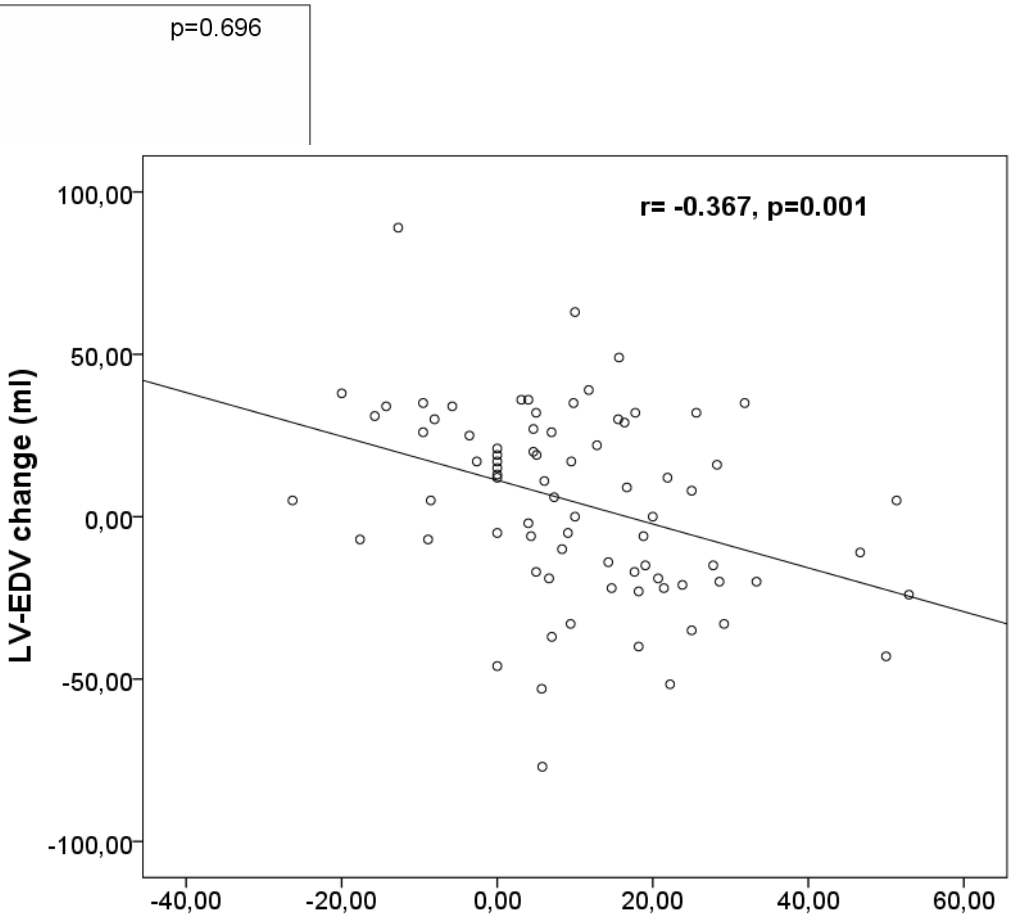
## - Infarct Healing -

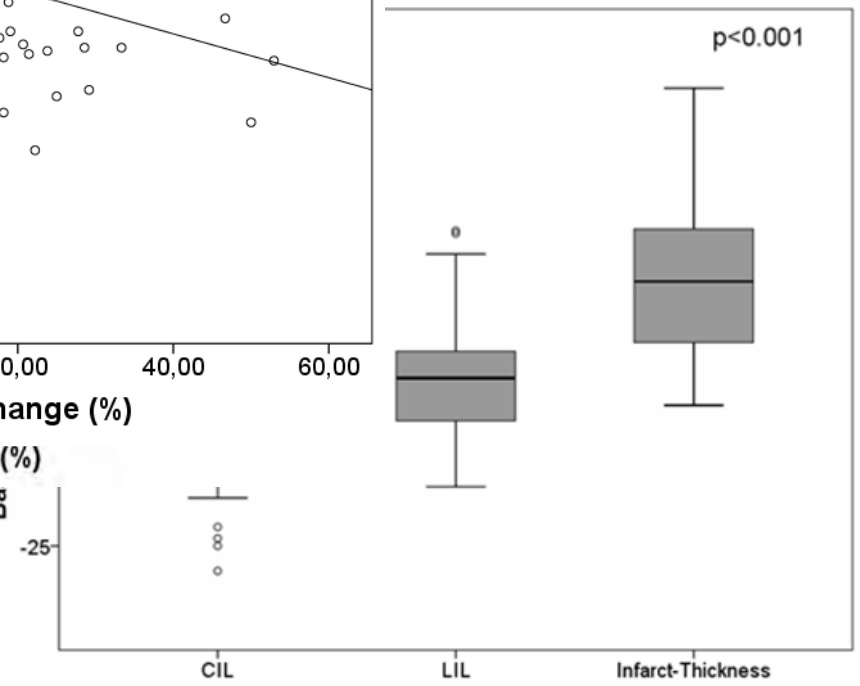


# Myocardial Infarction

## - Infarct Healing -



# Myocardial Infarction

## - RV Infarction -

# Right Ventricular Ischemic Injury in Patients With Acute ST-Segment Elevation Myocardial Infarction

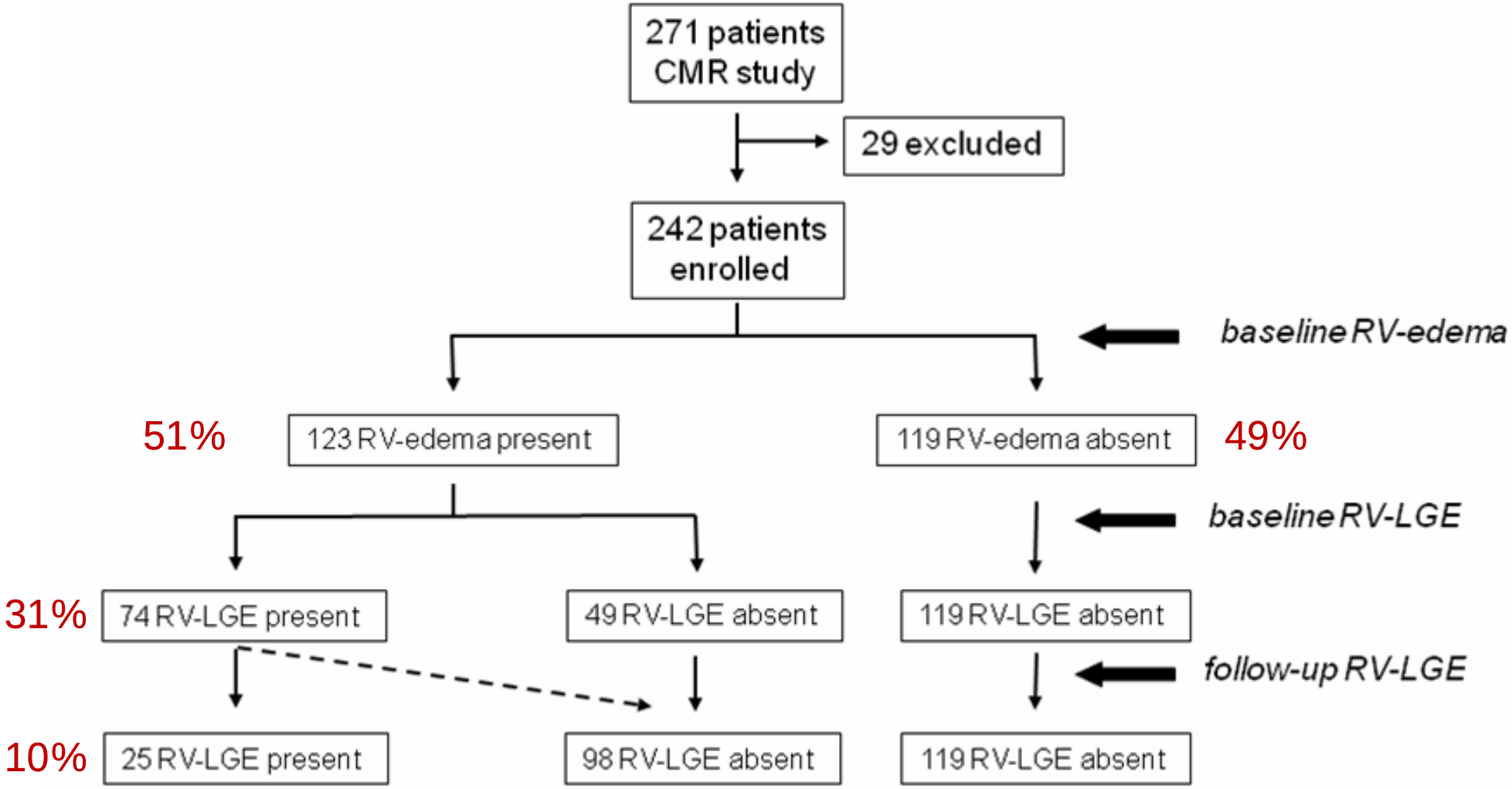
## Characterization With Cardiovascular Magnetic Resonance

Pier Giorgio Masci, MD; Marco Francone, MD, PhD; Walter Desmet, MD, PhD; Javier Ganame, MD, PhD; Giancarlo Todiere, MD; Rocco Donato, MD; Valeria Siciliano, MSc; Iacopo Carbone, MD; Matteo Mangia, MD; Elisabetta Strata, MD; Carlo Catalano, MD; Massimo Lombardi, MD; Luciano Agati, MD; Stefan Janssens, MD, PhD; Jan Bogaert, MD, PhD

(*Circulation*. 2010;122:1405-1412.)

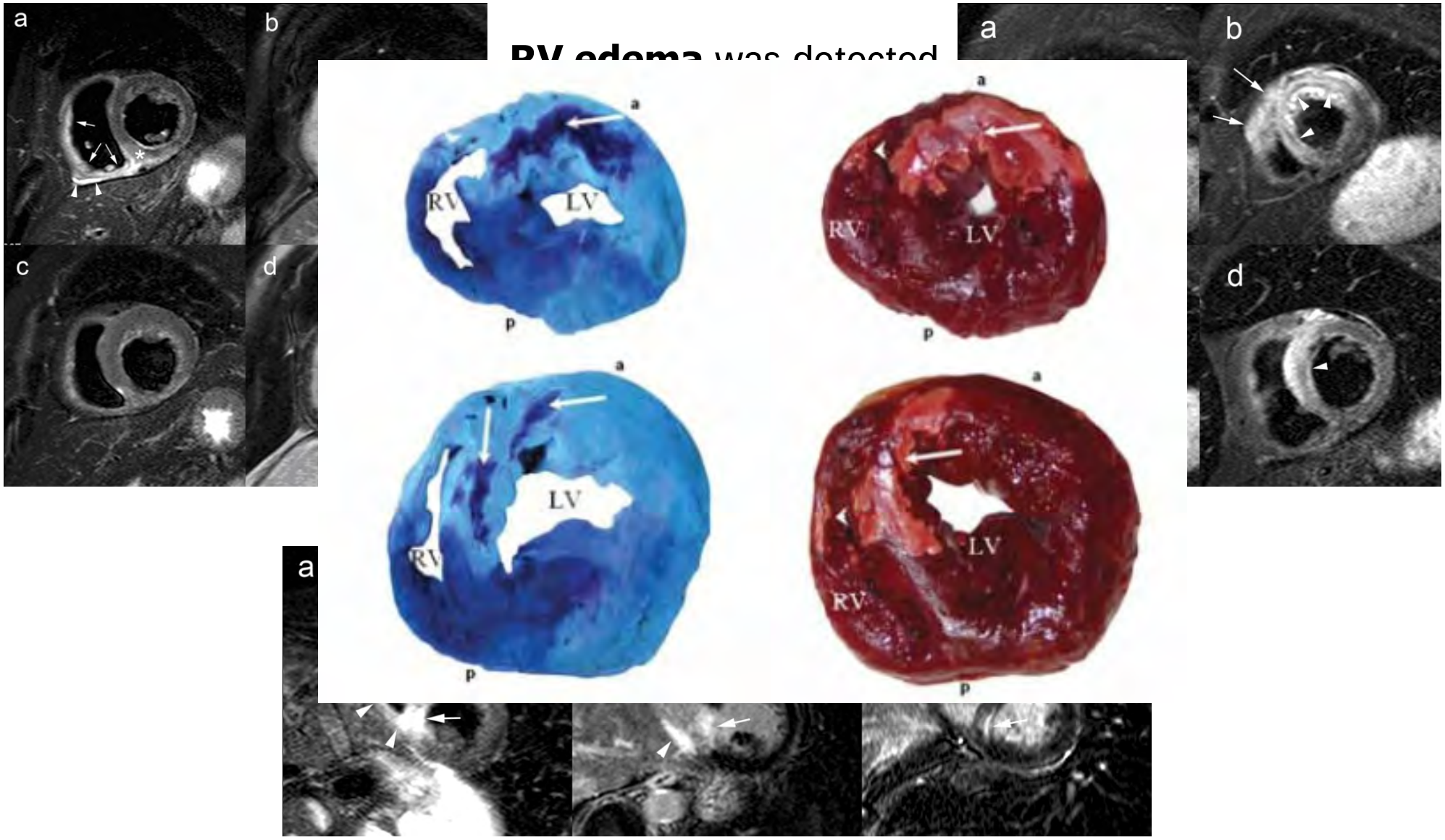
# Myocardial Infarction

## - RV Infarction -




*Masci PG et al Circulation 2010*

# Myocardial Infarction



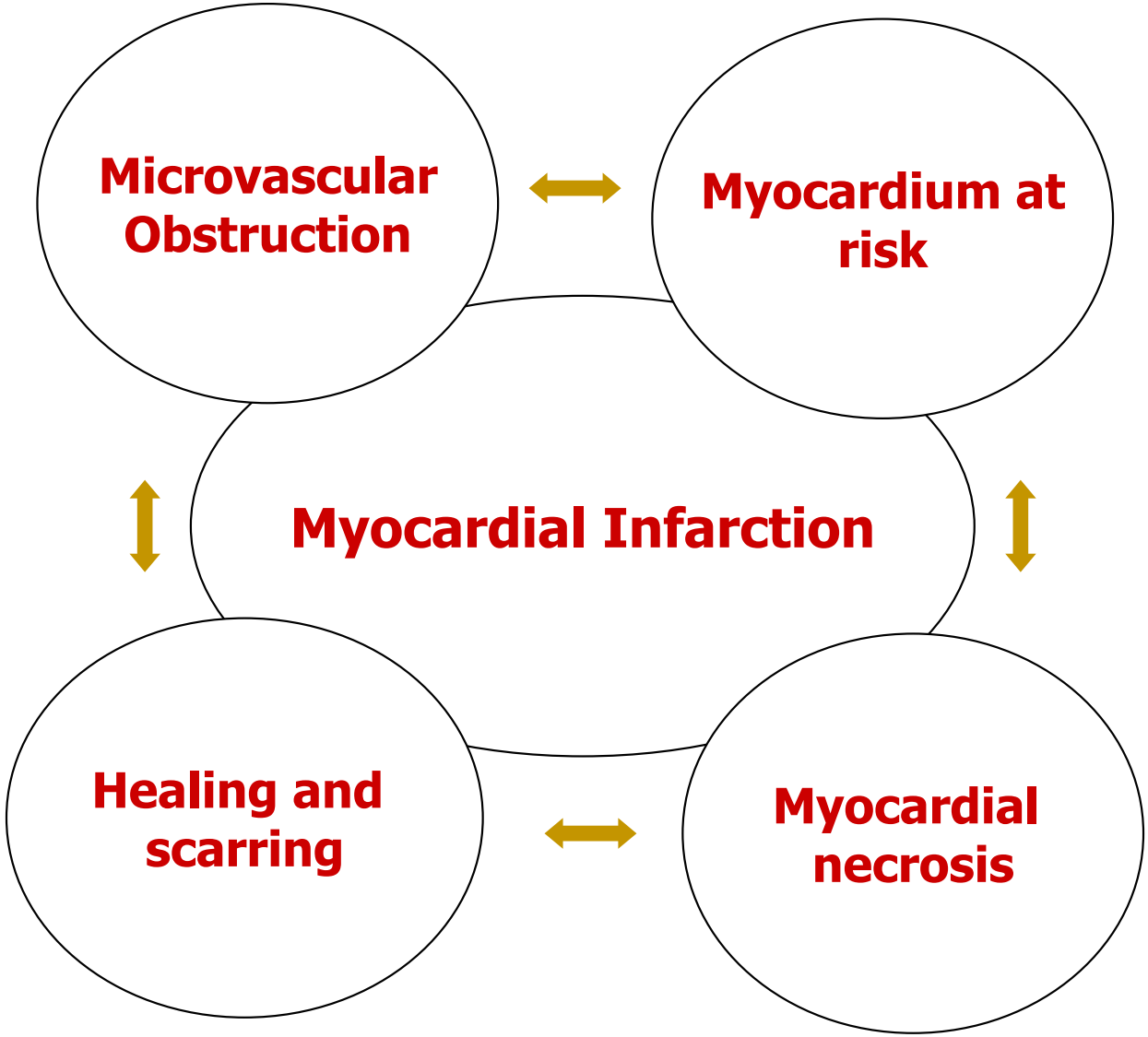

*Masci PG et al Circulation 2010*

# Conclusions

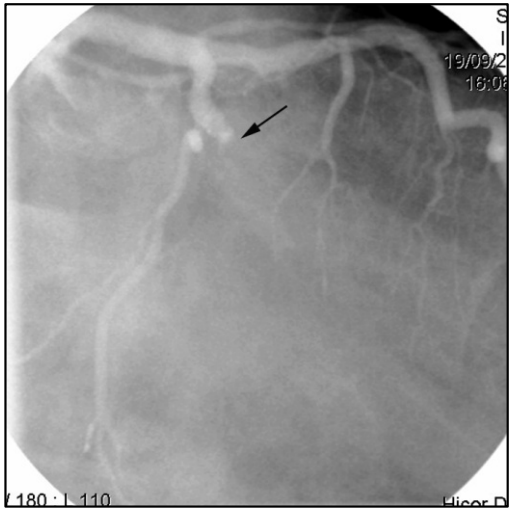

**Fondazione Monasterio**
**CNR/Regione Toscana**
**Pisa**
**Italy**

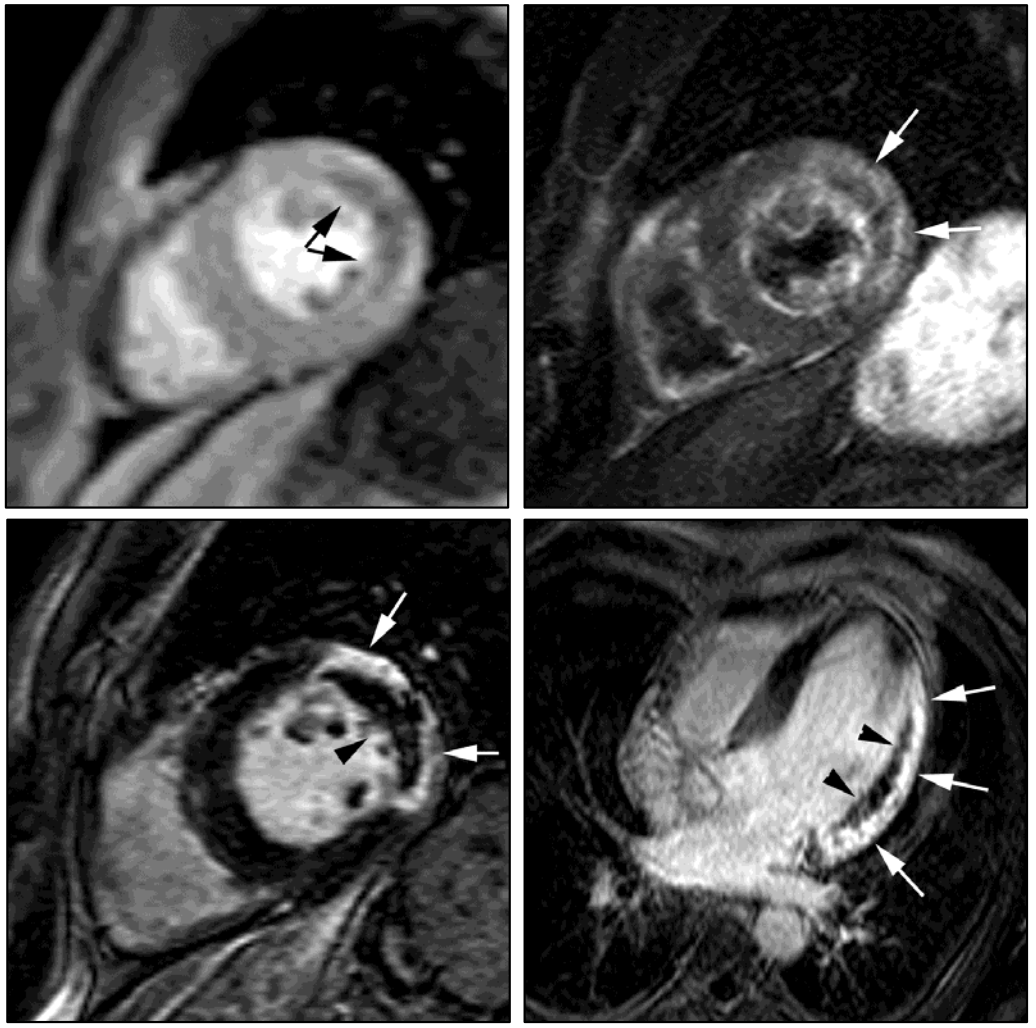
**Gasthuisberg University Hospital**
**Leuven**
**Belgium**

# Myocardial Infarction

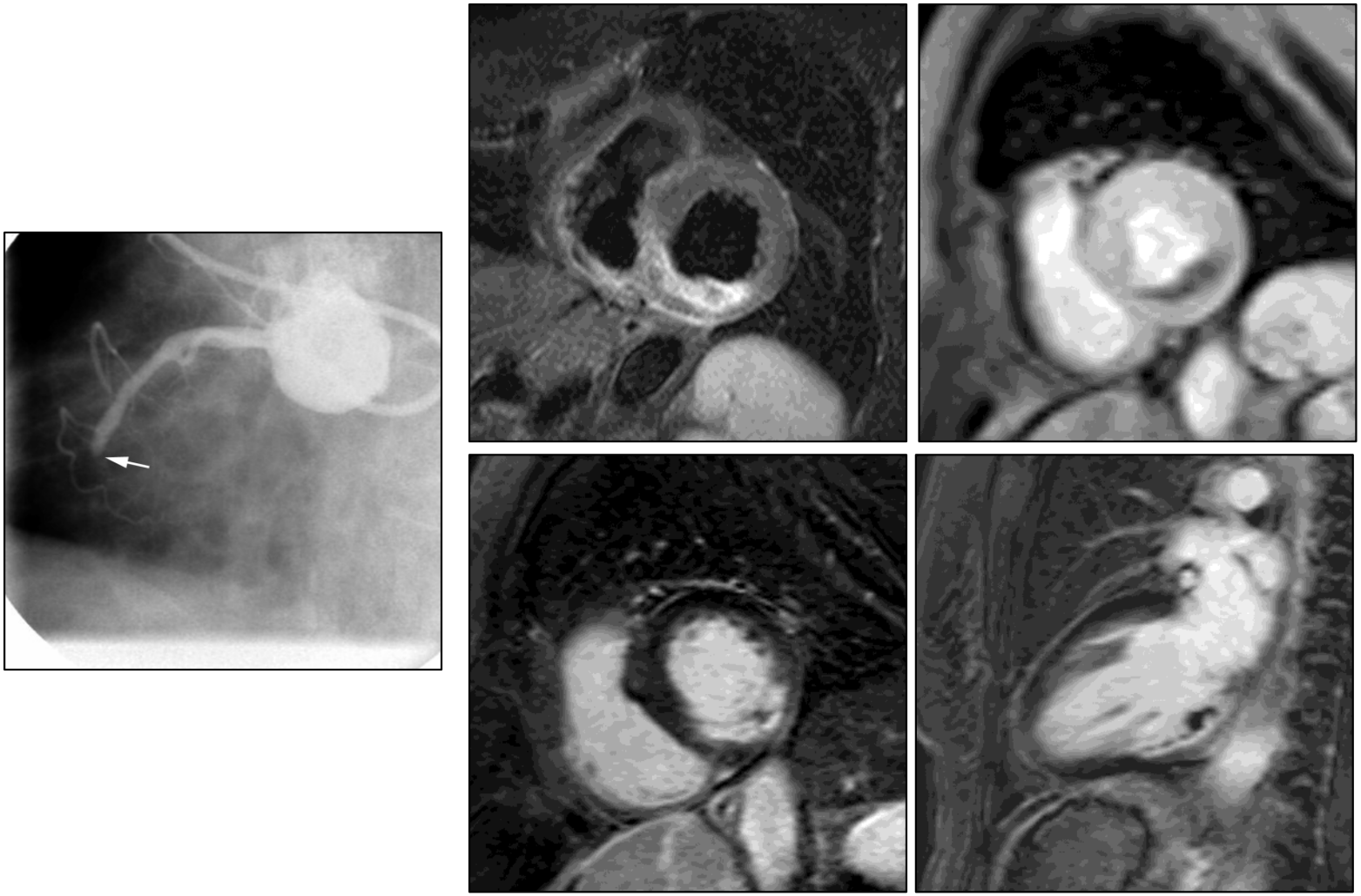


# Myocardial Infarction

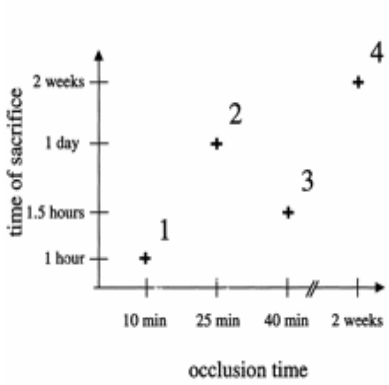


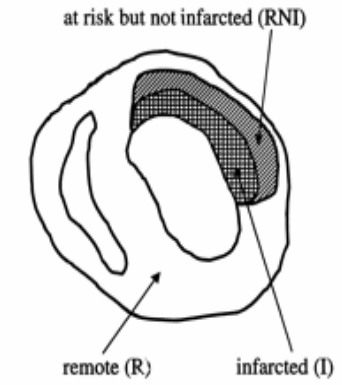


# Myocardial Infarction

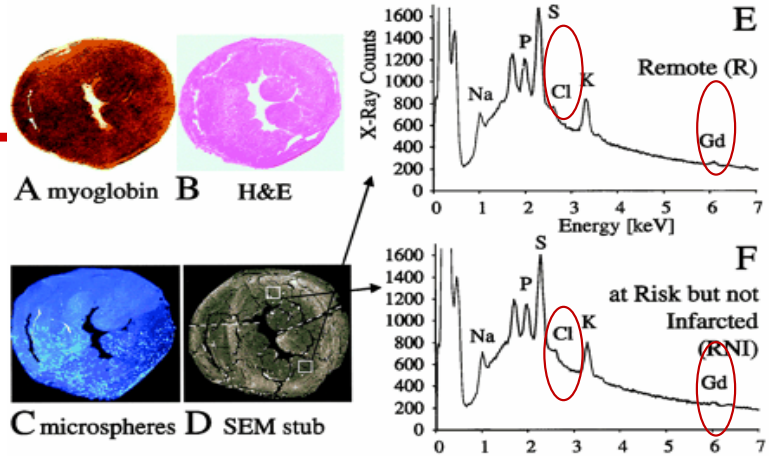


# Myocardial Necrosis

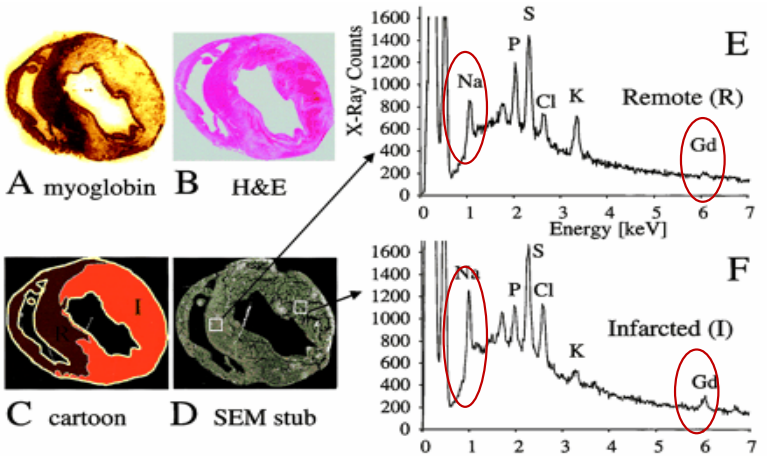


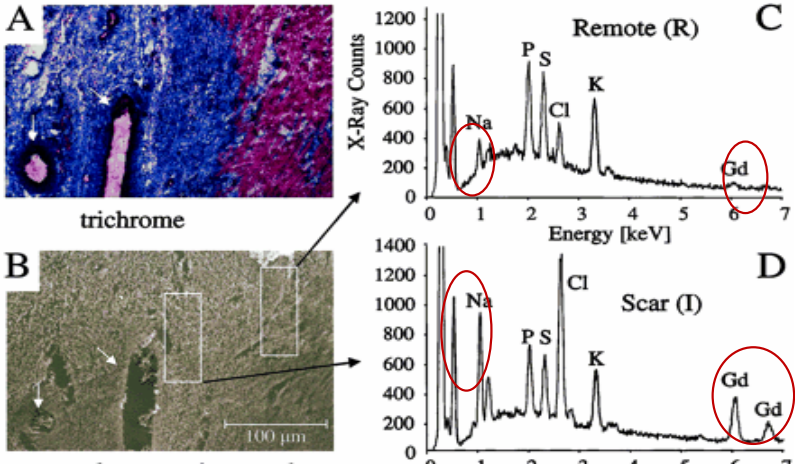

RNI region



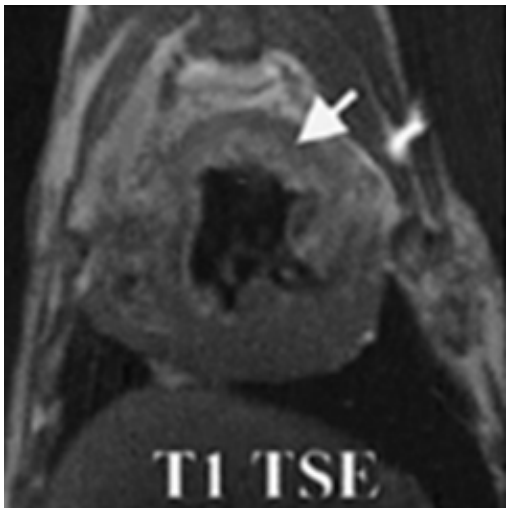

Acute MI

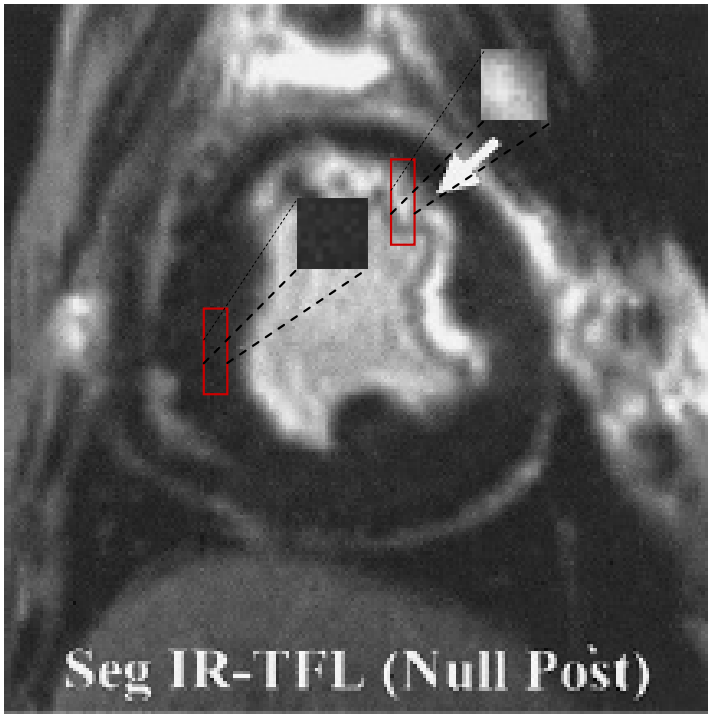


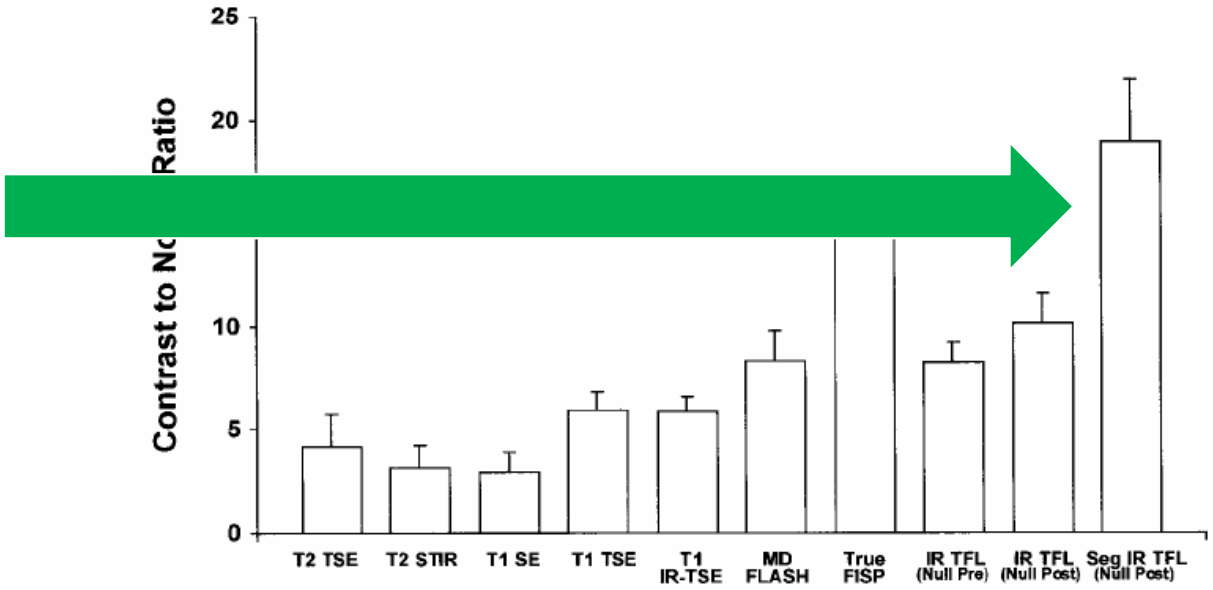

Chronic MI



# Myocardial Necrosis




Simonetti O et al Radiology 2001

# Myocardial Infarction

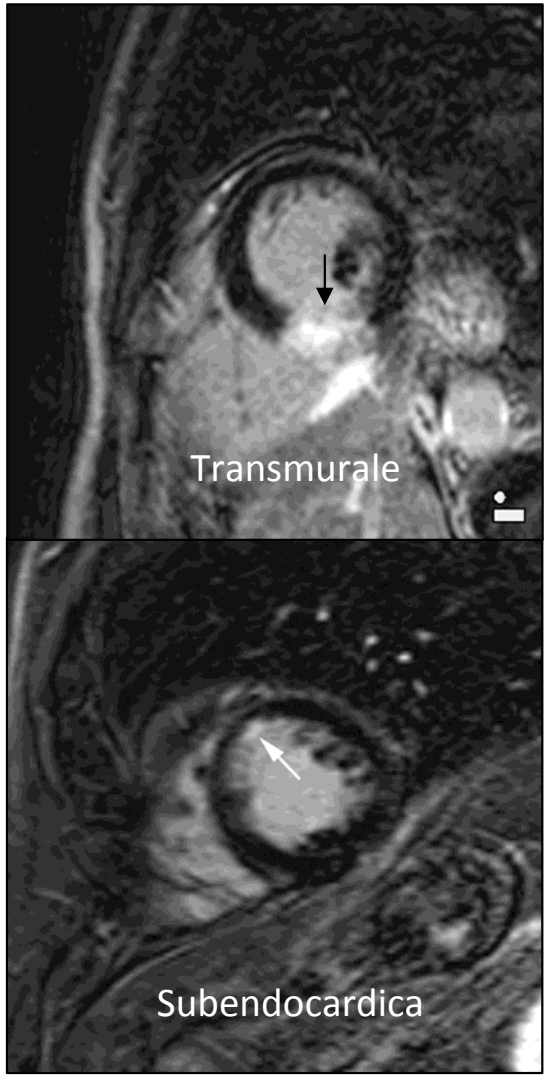
1) Immagini tardive post-contrasto **T1-w GRE IR** :
**“delayed enhancement”**

2) Eccellente correlazione con i modelli animali (aree TTC negative)

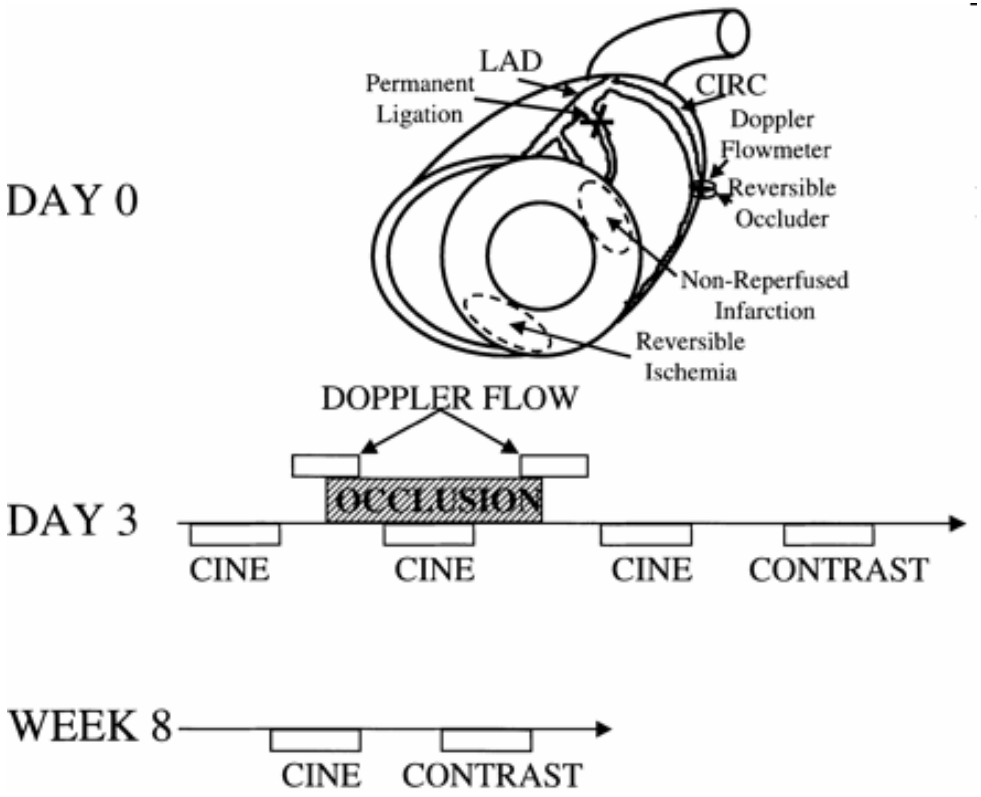
3) Ottima risoluzione spaziale

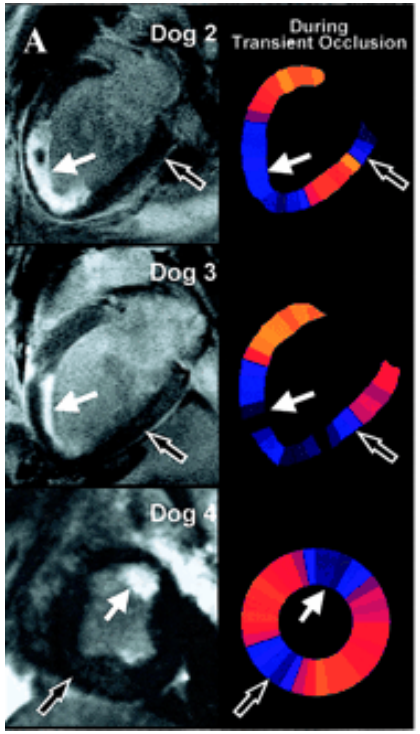
4) Eccellente SNR e CNR

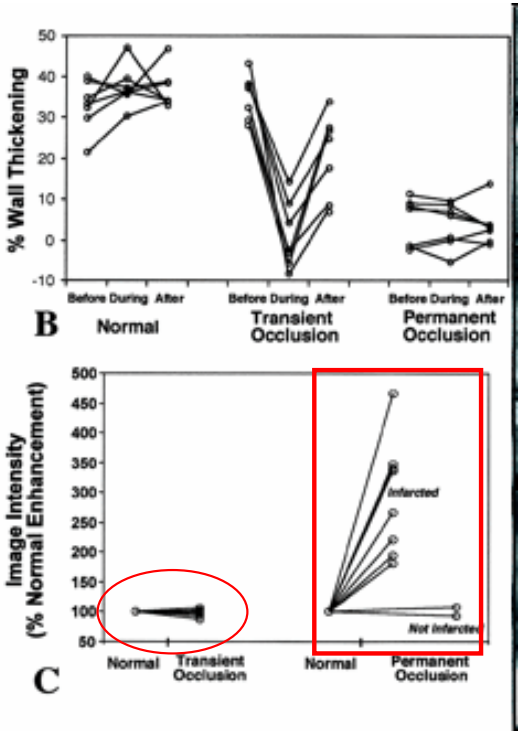
5) (SI area necrotica/SI miocardio sano)x100 = ~ 500%



# Myocardial Necrosis, Stunning



# Myocardial Infarction

## - Myocardial Salvage -

**Comprehensive CMR study in ST-segment elevation MI**

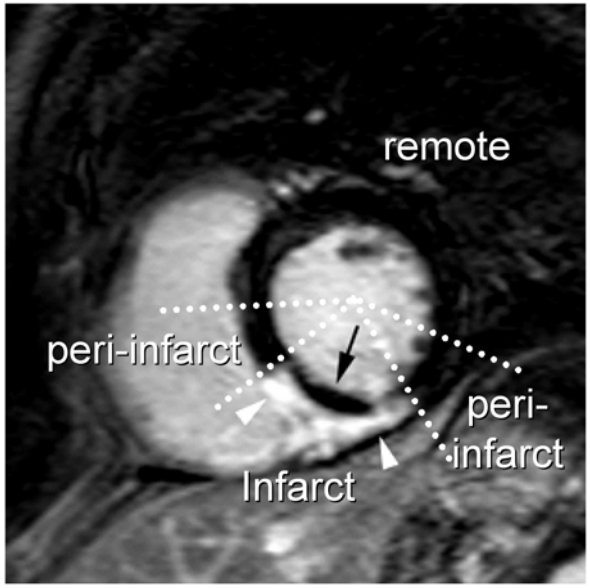
**Determination of the Myo. at risk by T2-w STIR imaging**

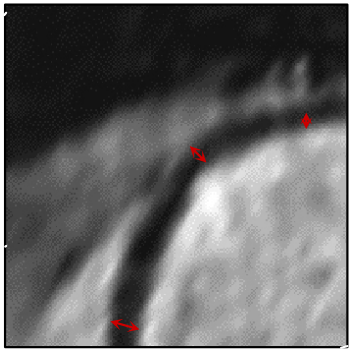
**MI size quantification by late gadolinium enhancement (LGE)**

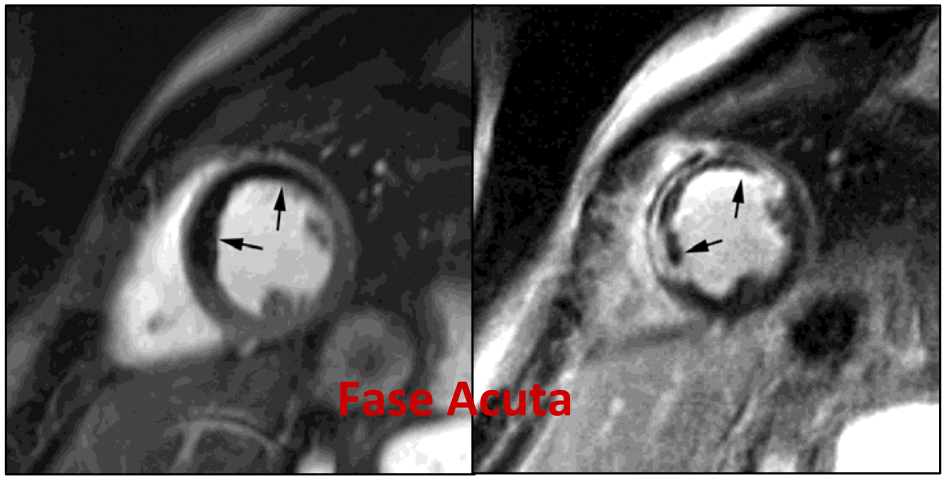
**Myocardial Salvage**

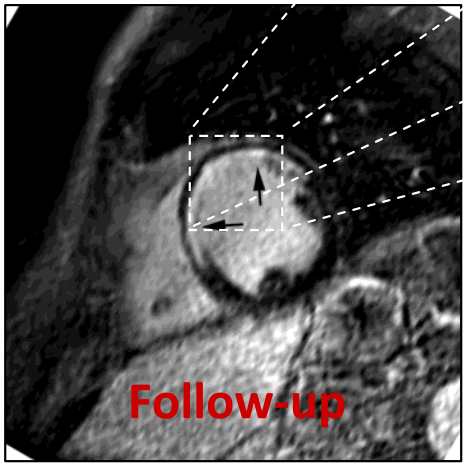
# Post Myocardial Infarction Remodeling

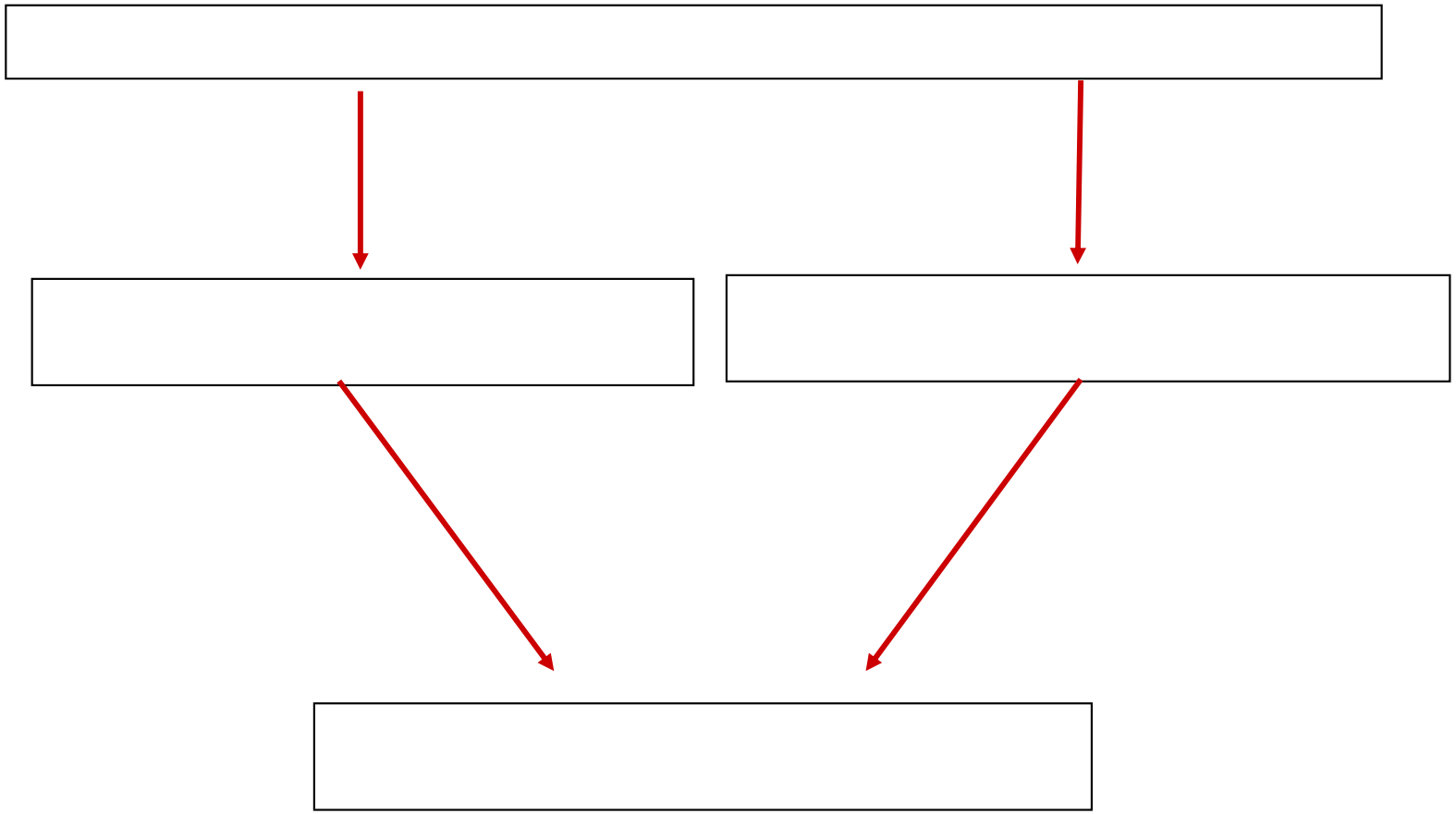
- SWT e SWM
- Tagging
- Spessore parietale
- Riduzione dell'area di DE ("infarct shrinkage")



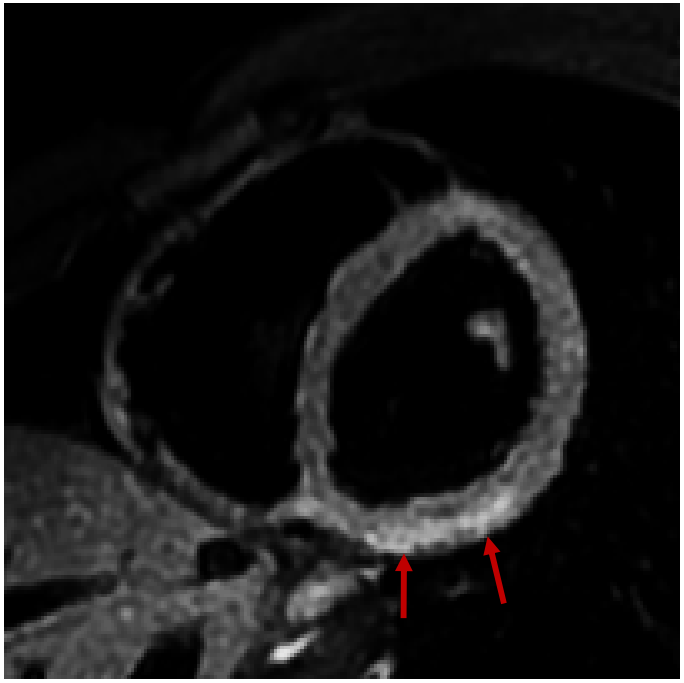


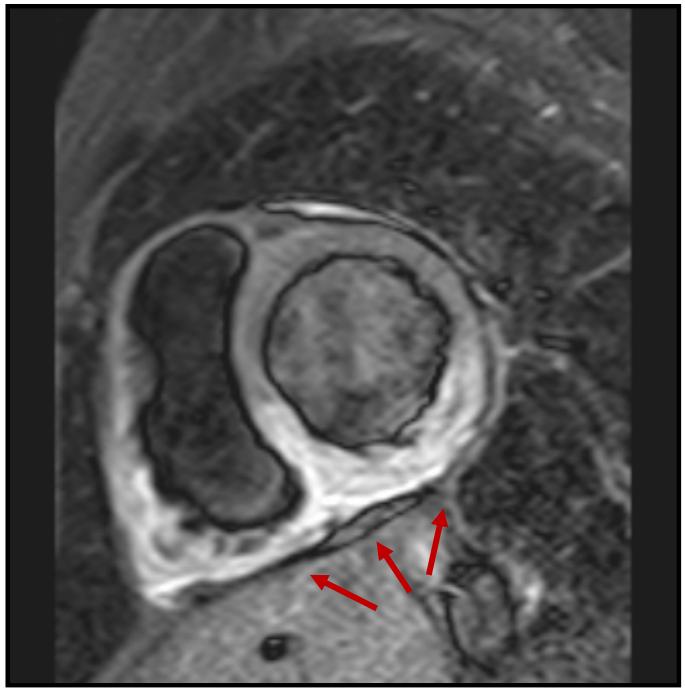


# Myocardial Infarction

- **Myocardium at risk –**
T2-weighted imaging



Acute Myocarditis

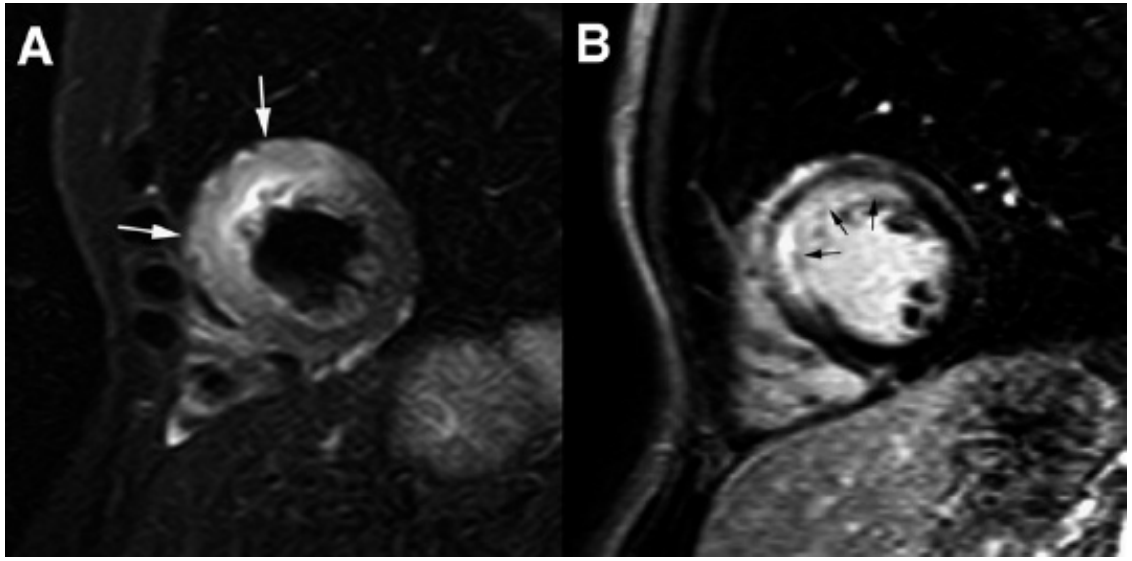


Acute Myocardial Infarction

# - Ischemic Pattern -

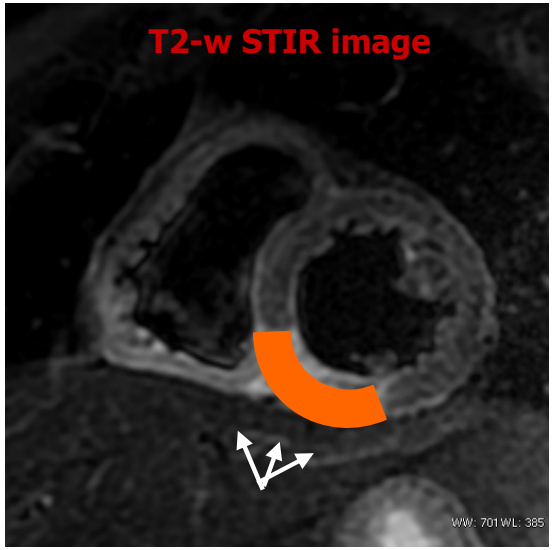
**Table 1. Baseline Characteristics (n = 137)**

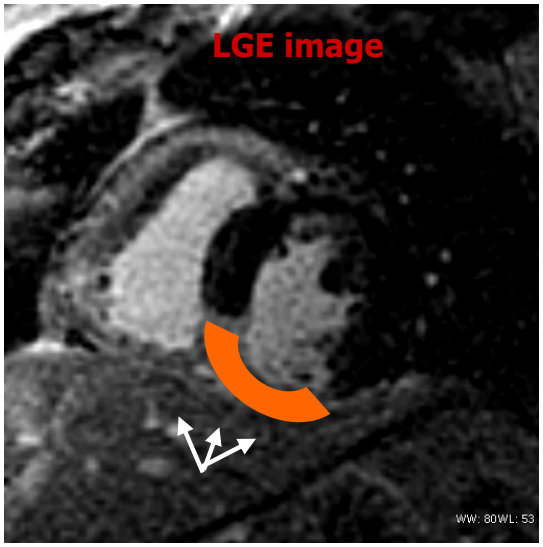
| | |
|---|---|
| Age (yrs) | 61 ± 12 |
| Male | 111 (81) |
| Cardiovascular risk factors | |
| Current smoker | 46 (34) |
| Familial history of coronary artery disease | 49 (36) |
| Diabetes mellitus | 21 (15) |
| Hypertension | 73 (53) |
| Hyperlipidemia | 82 (60) |
| Time to reperfusion (min) | 224 ± 123 |
| Glycoprotein inhibitor IIb/IIIa | 130 (95) |
| Infarct-related artery | |
| Left anterior descending artery | 67 (49) |
| Right coronary artery | 59 (43) |
| Left circumflex coronary artery | 11 (8) |
| Maximum serum troponin I (μg/l) | 92.4 ± 32.3 |
| Medication at discharge | |
| Angiotensin-converting enzyme inhibitor | 113 (82) |
| Angiotensin II inhibitor | 16 (12) |
| Beta-blocker | 119 (87) |
| Statin | 122 (89) |
| Diuretics | 13 (9) |




Masci PG et al J Am Coll Cardiol Img 2010

- Ischemic Pattern -




**Myocardial Salvage Index (MSI)** = **[ AAR extent – MI size ] / AAR extent**

**Adverse LV remodeling** = **increase of LV ESV ≥ 15%**

Masci PG et al J Am Coll Cardiol Img 2010

# - Ischemic Pattern -

**Table 3. Univariate and Multivariate Analyses for the Prediction of Adverse LV Remodeling**

| | Adverse LV Remodeling | | | |
|---|---|---|---|---|
| | Univariate | | Multivariate | |
| Baseline Variables | OR (95% CI) | p Value | OR (95% CI) | p Value |
| MI transmurally (%) | 1.04 (1.01–1.07) | 0.005 | — | — |
| AAR (% of LV) | 1.04 (1.01–1.07) | 0.003 | 1.04 (1.01–1.08) | 0.001 |
| MSI (for 0.10 increment) | 0.58 (0.46–9.75) | <0.0001 | 0.64 (0.49–0.84) | 0.001 |
| Presence of MO | 6.79 (3.55–18.06) | <0.0001 | — | — |
| Time to reperfusion (min) | 1.00 (0.99–1.00) | 0.588 | — | — |
| Age (for 10-yr increment) | 1.22 (0.87–1.72) | 0.241 | — | — |
| Anterior vs. nonanterior MI | 2.27 (1.02–5.04) | 0.044 | — | — |
| LV ejection fraction | 0.92 (0.87–0.97) | 0.003 | — | — |

**Table 4. Univariate and Multivariate Analyses for the Prediction of Early ST-Segment Resolution**

| | Early ST-Segment Resolution (%) | | | |
|---|---|---|---|---|
| | Univariate | | Multivariate | |
| Baseline Variables | *B* | p Value | *B* | p Value |
| MI transmurality (%) | −0.79 | <0.0001 | −0.31 | 0.002 |
| AAR (% of left ventricle) | −0.48 | 0.007 | — | — |
| MSI | 0.85 | <0.0001 | 0.61 | <0.0001 |
| Presence of MO | 0.14 | 0.371 | — | — |
| Time to reperfusion | −0.23 | 0.130 | — | — |
| Age (yrs) | 0.01 | 0.941 | — | — |
| Anterior vs. nonanterior MI | −0.41 | 0.007 | −0.16 | 0.020 |
| LV ejection fraction (%) | 0.45 | 0.011 | — | — |

Masci PG et al J Am Coll Cardiol Img 2010

# Microvascular Obstruction

# Microvascular Obstruction

**Alterazioni morfo-strutturali associate a no-reflow :**

**Maggiori fattori determinanti l'estensione del no-reflow:**

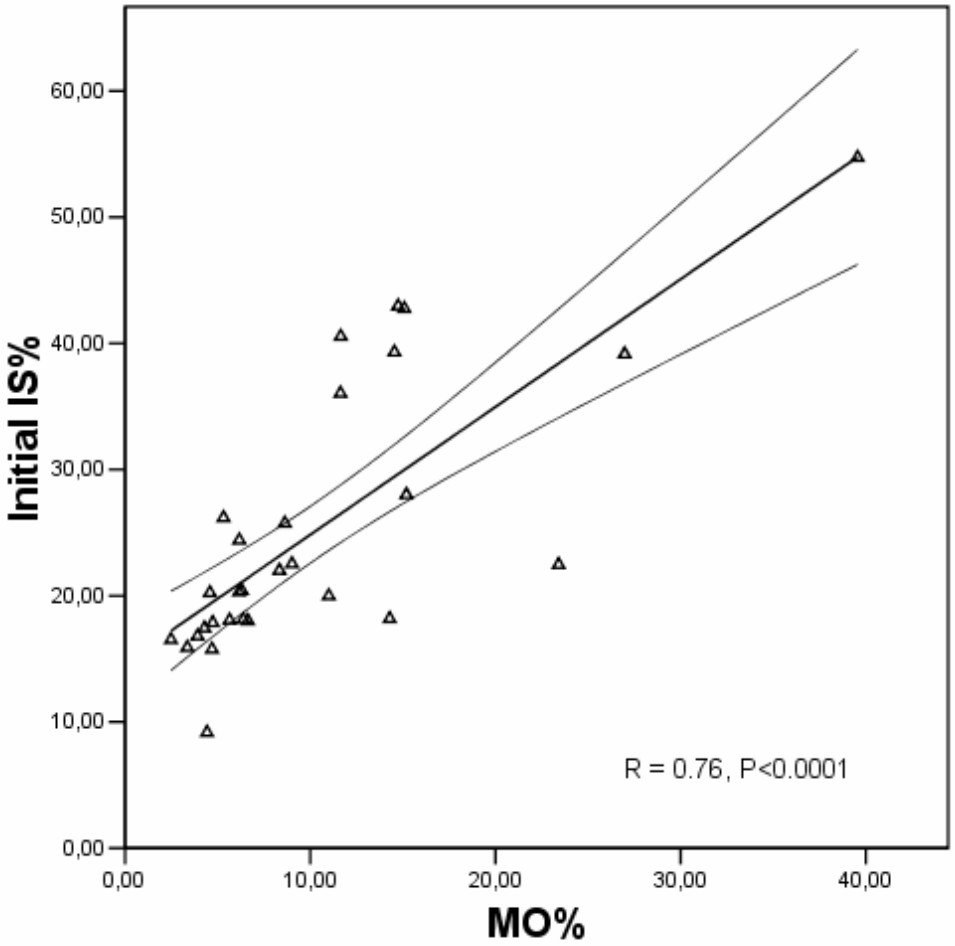
# Post Myocardial Infarction Remodeling

- 58 pazienti(88% uomini) con STEMI trattati con PCI primaria

- CeMRI in fase acuta(1W) e FU(4M)

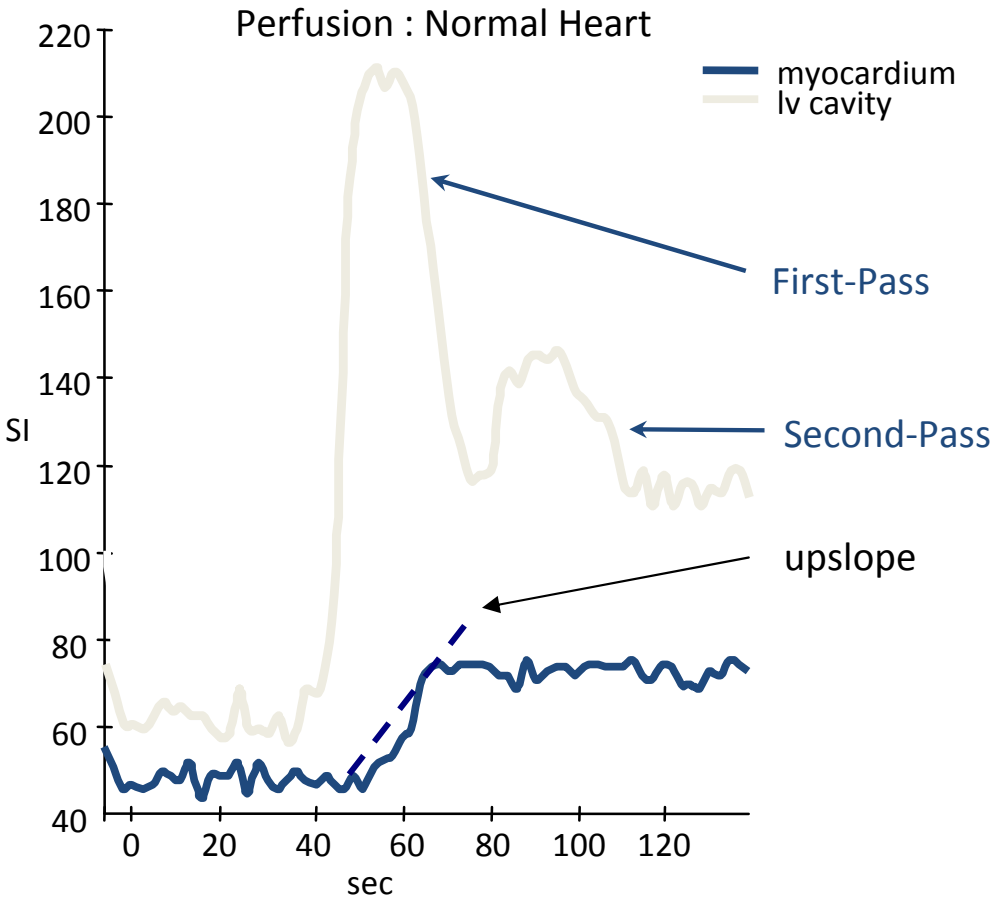
- IS% ≥ 9.2% » MO

- MO variabile indipendente di sfavorevole rimodellamento Vsx (VDT ≥20%)



# Studio dell'ostruzione del microcircolo con la Risonanza Magnetica Cardica

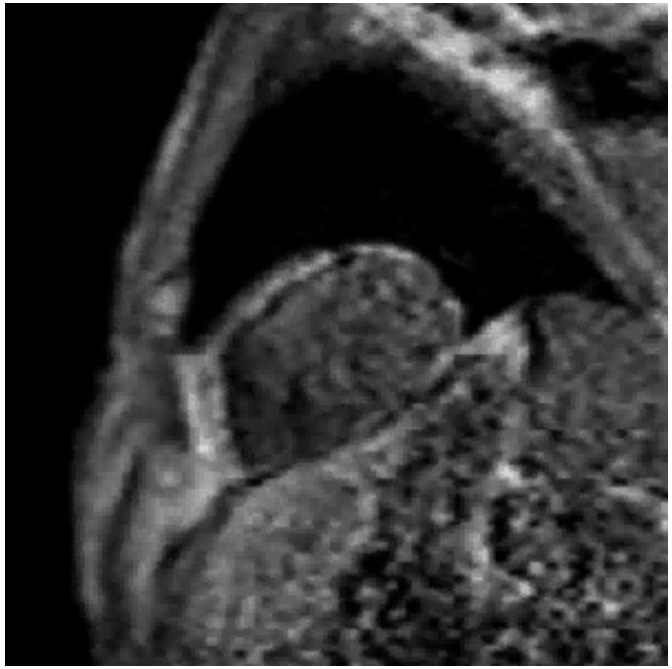
# Microvascular Obstruction




-Sequenze rapide con acquisizione di almeno 1 immagine ogni intervallo RR

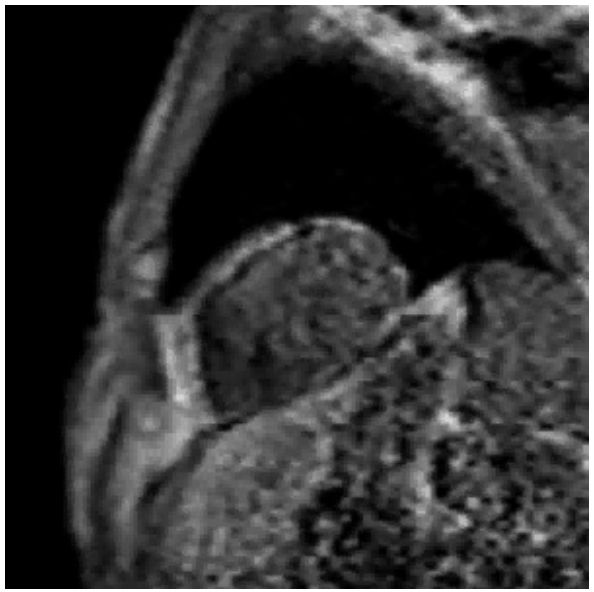
-Sequenza T1-pesate

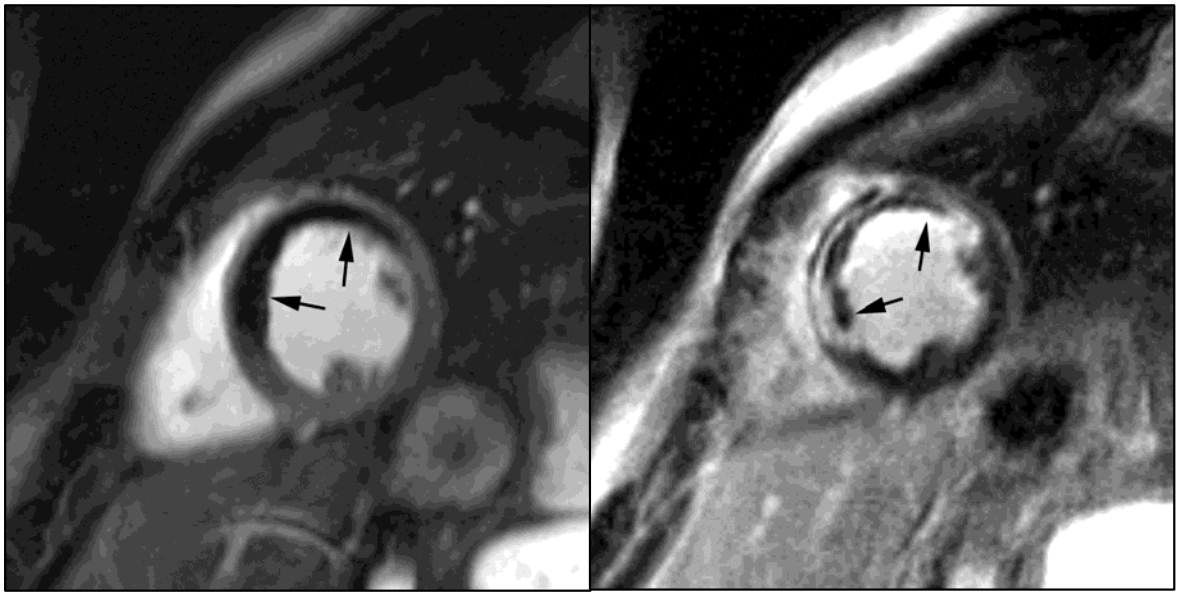
-Tecnica di primo passaggio "First-Pass Perfusion"



# Myocardial Infarction

## - Microvascular Obstruction -





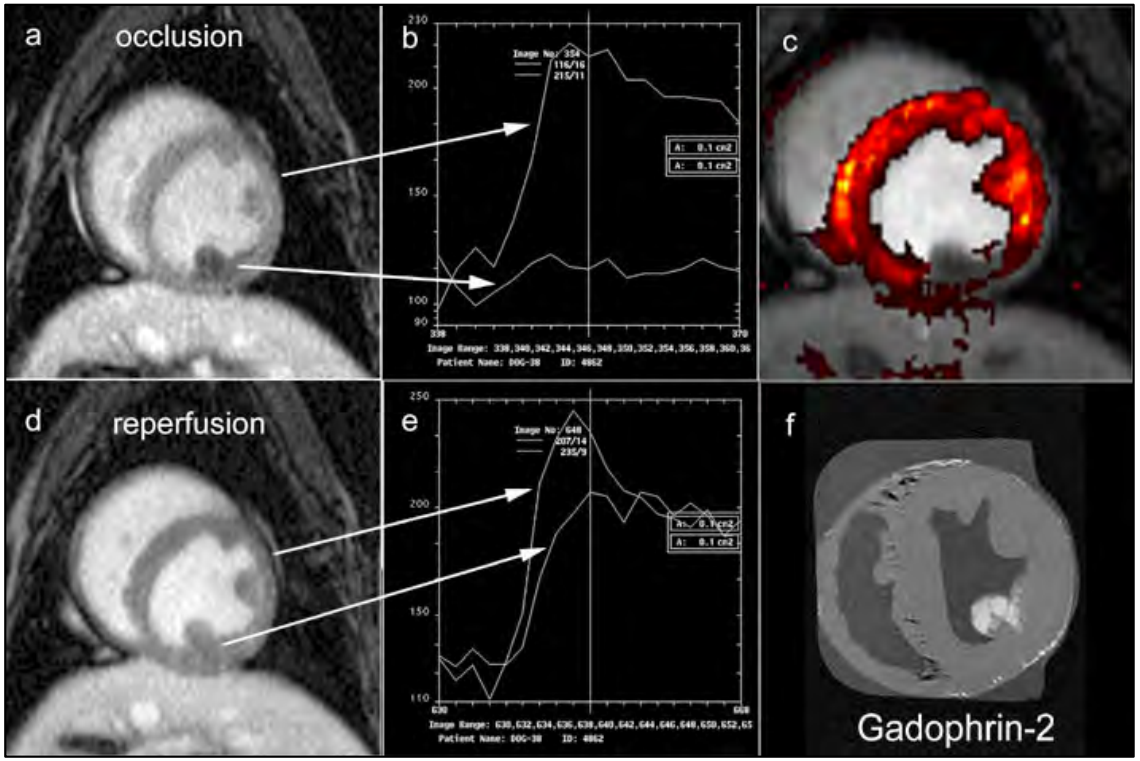
Early after Gd

20 minutes after Gd

**First-pass Perfusion**

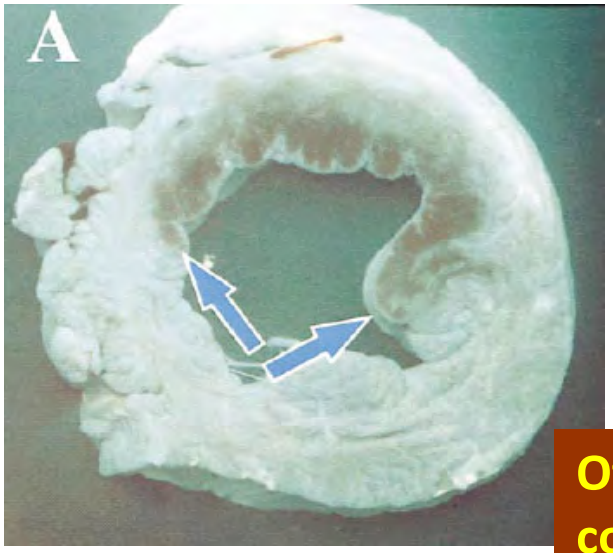
**Postcontrast Imaging**

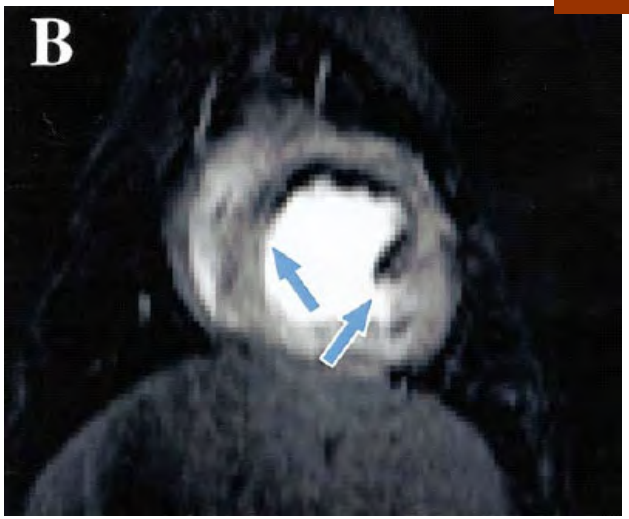
# Microvascular Obstruction



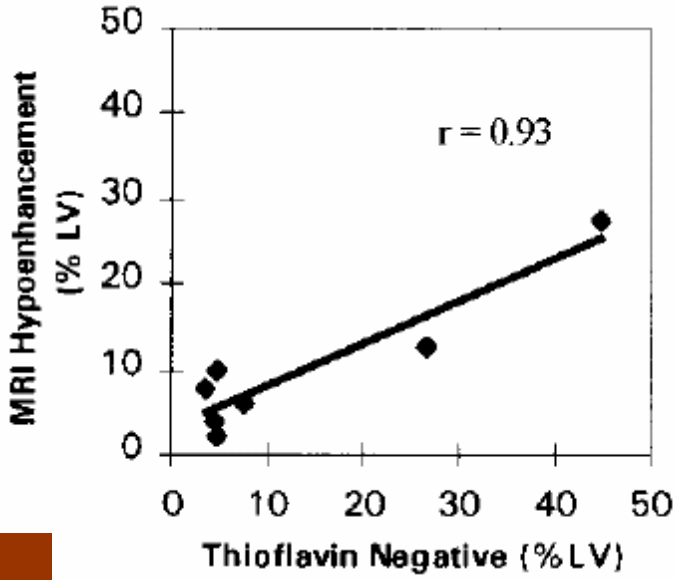

**Misure semiquantitative**

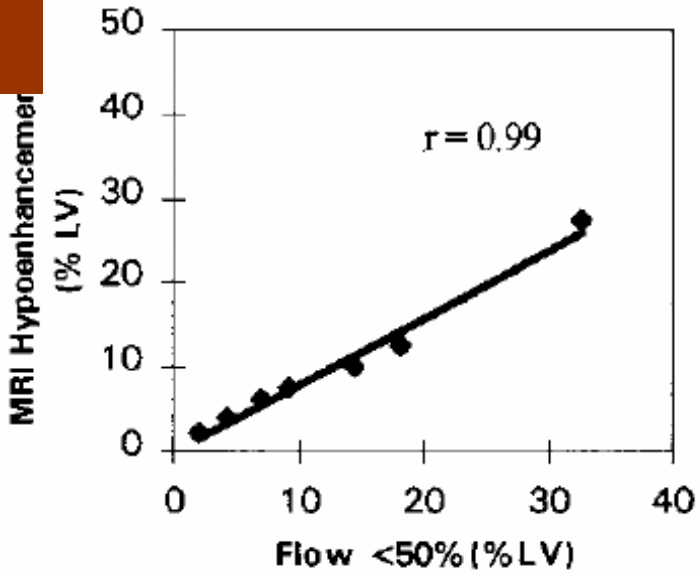
# Microvascular Obstruction



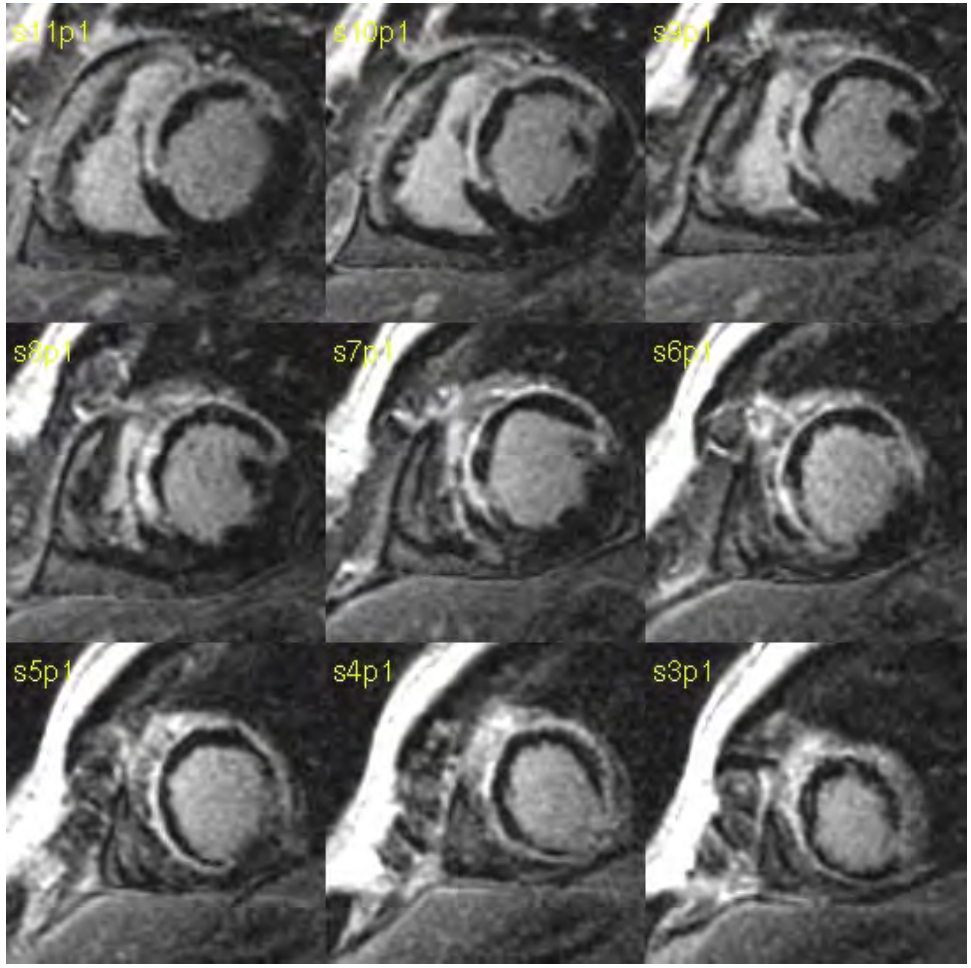

**Ottima correlazione con i dati sperimentali**

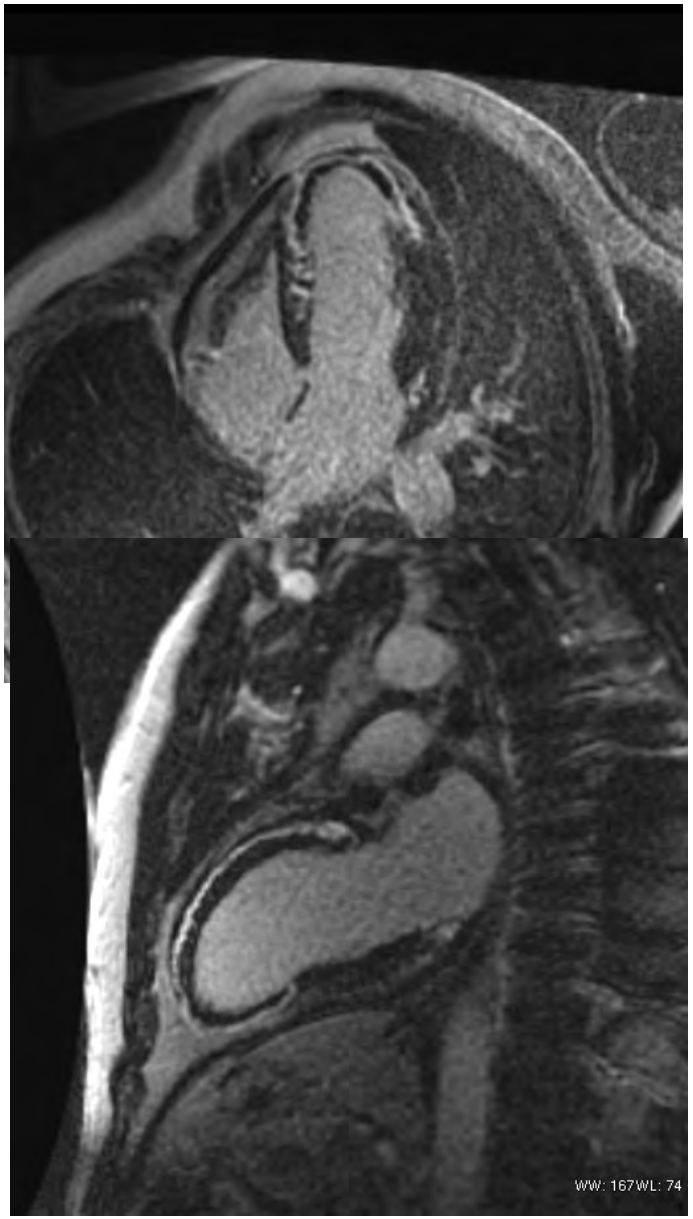


# Microvascular Obstruction

## Immagini segmented T1-w GRE IR



# Microvascular Obstruction

## Clinical Impact of Microvascular Obstruction