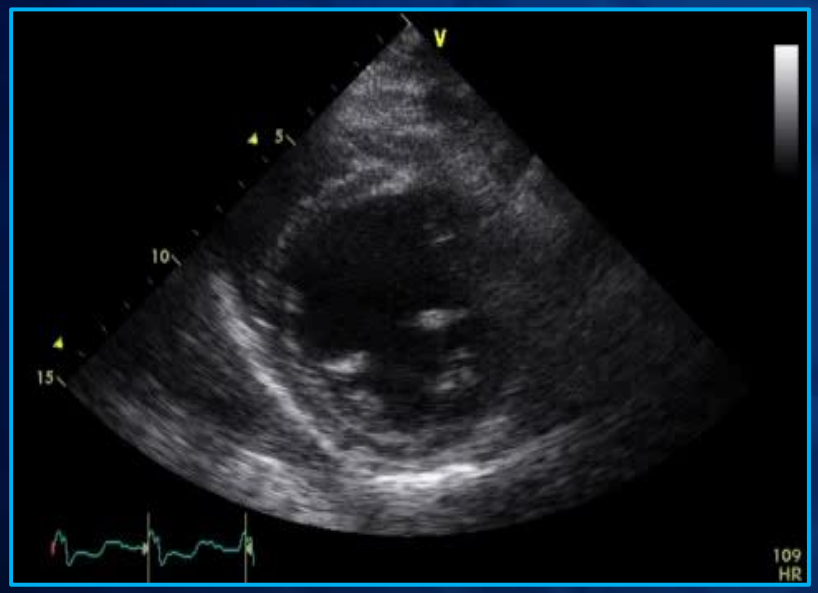
CMR Perfusion and Viability
A STICH Out of Time?

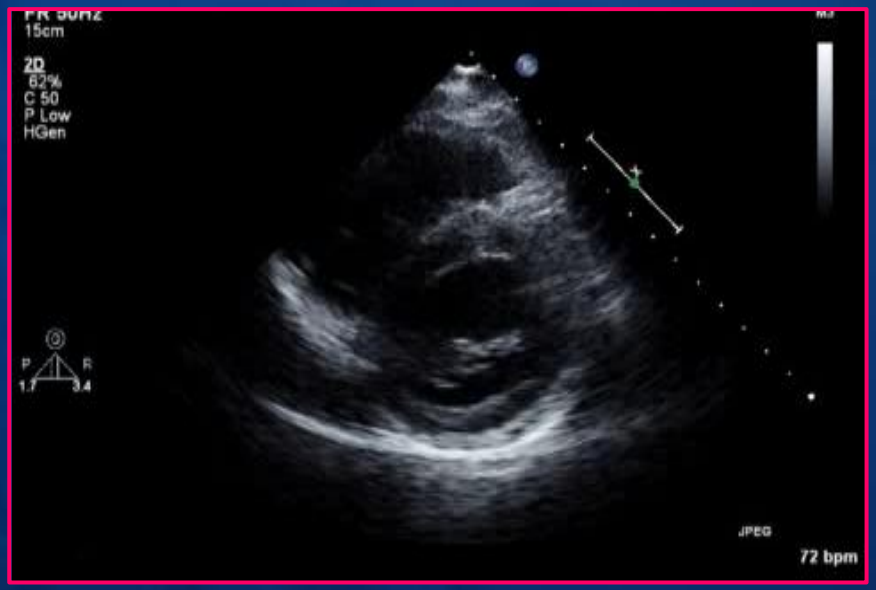
Sung A Chang

Department of Internal Medicine, Division of Cardiology, Sungkyunkwan University School of Medicine, Samsung Medical Center

Can Imaging Improve Patient's Outcome ?

Myocardial viability in ischemic heart disease

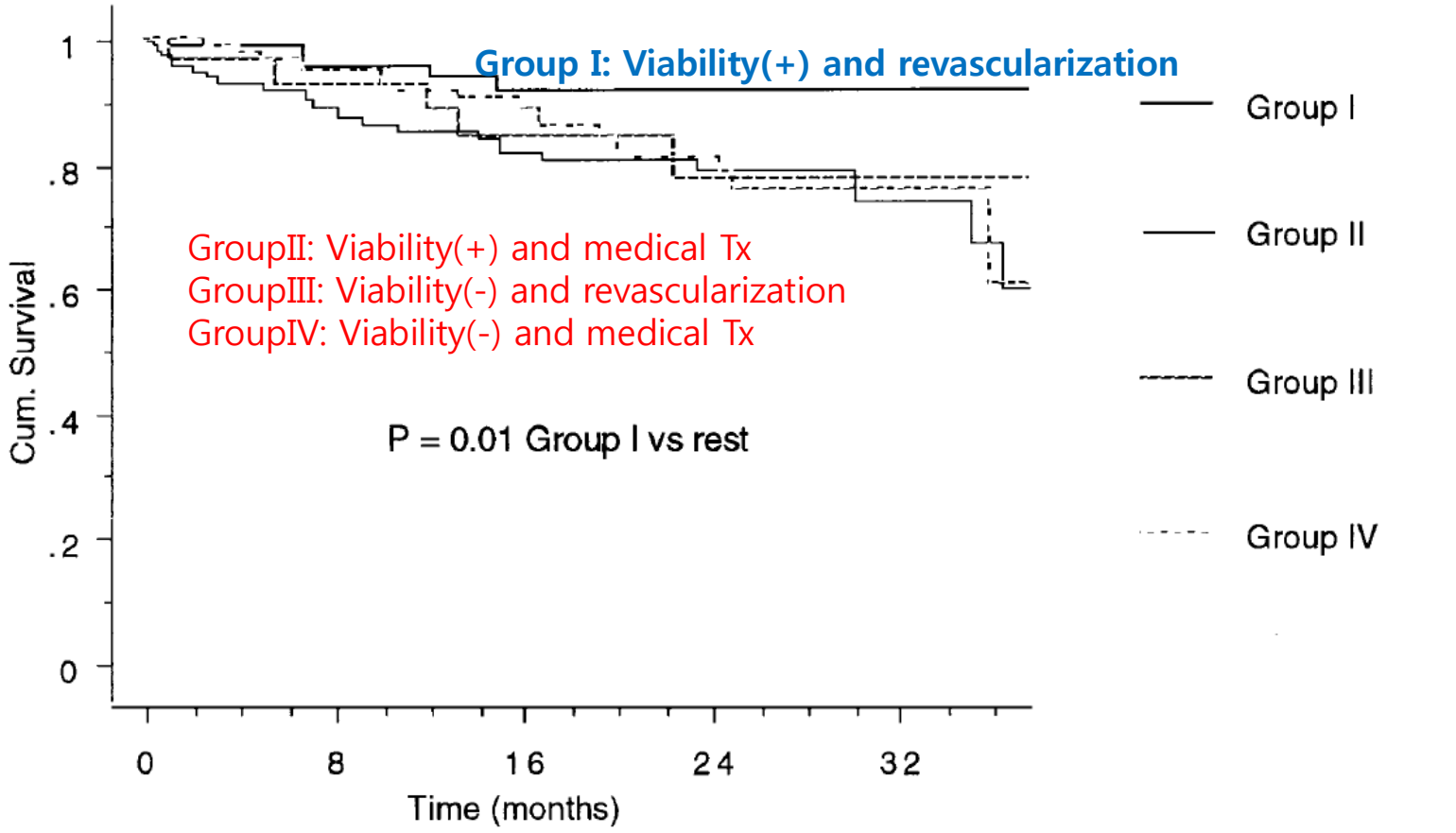




Myocardial Viability

dysfunctional myocardium subtended by diseased coronary arteries with limited or absent scarring that therefore has the potential for functional recovery

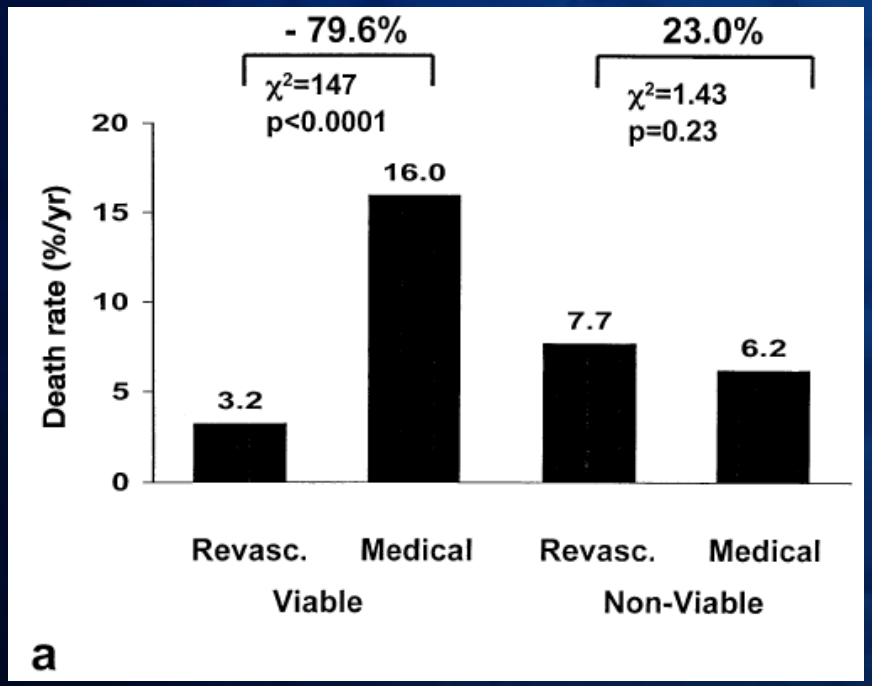
Myocardial Viability and Survival in patients with CAD and Severe LV Dysfunction

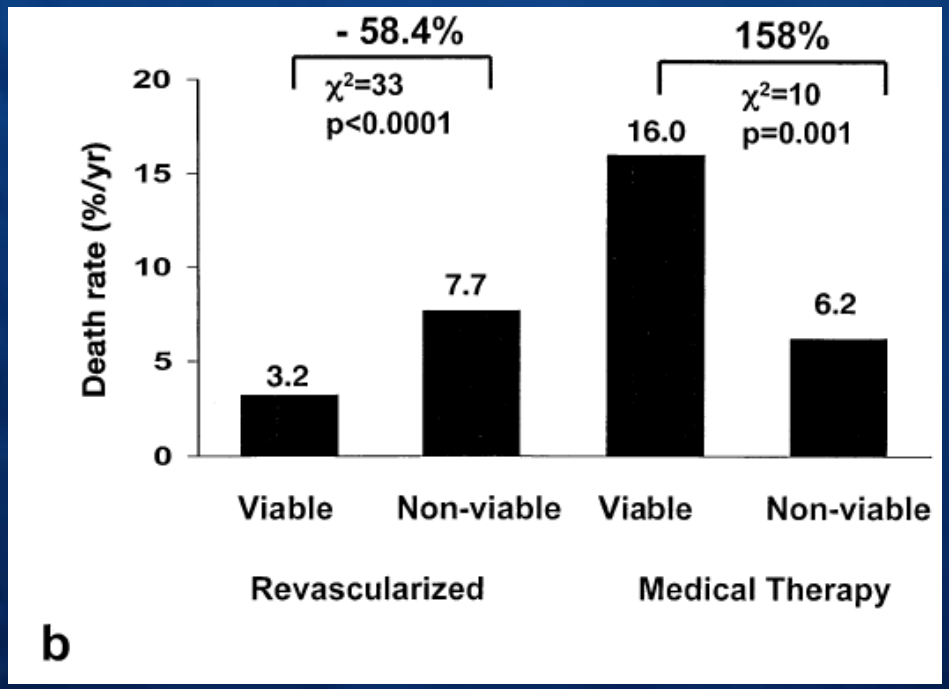


AFRIDI I et al. J Am Coll Cardiol 1998;32:921– 6

Myocardial Viability Testing and Impact of Revascularization

Meta analysis of 3088 patients (DSE/SPECT/ PET)





Allman et al. JACC Vol. 39, No. 7, 2002

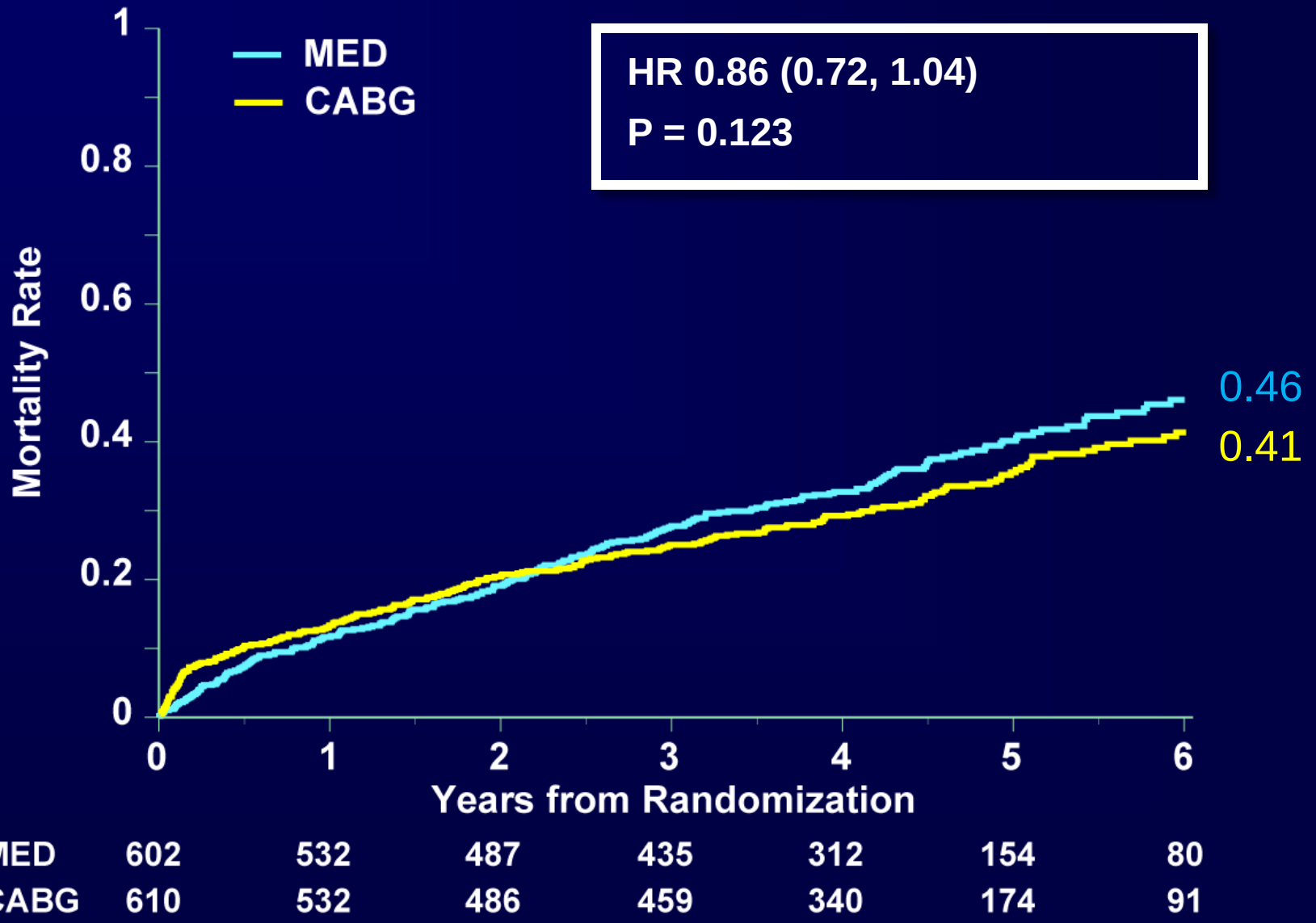
STICH

Coronary Artery Bypass Graft Surgery in Patients with Ischemic Heart Failure

Eric J. Velazquez, MD
on behalf of the STICH Investigators

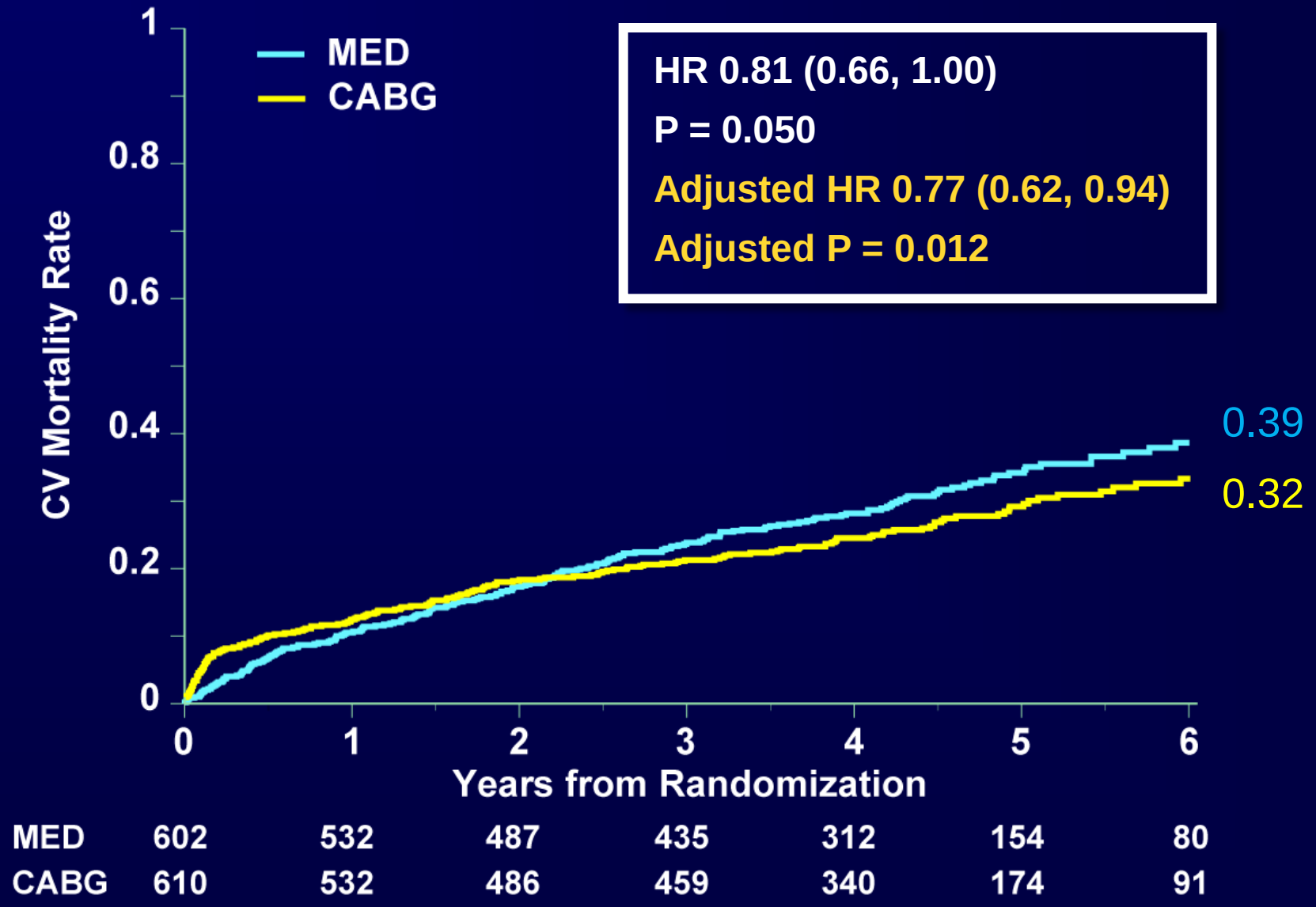
SAMSUNG MEDICAL CENTER

All-Cause Mortality — As Randomized



N Engl J Med 2011;364:1607-16

Cardiovascular Mortality — As Randomized



N Engl J Med 2011;364:1607-16

STICH substudy

The NEW ENGLAND JOURNAL of MEDICINE

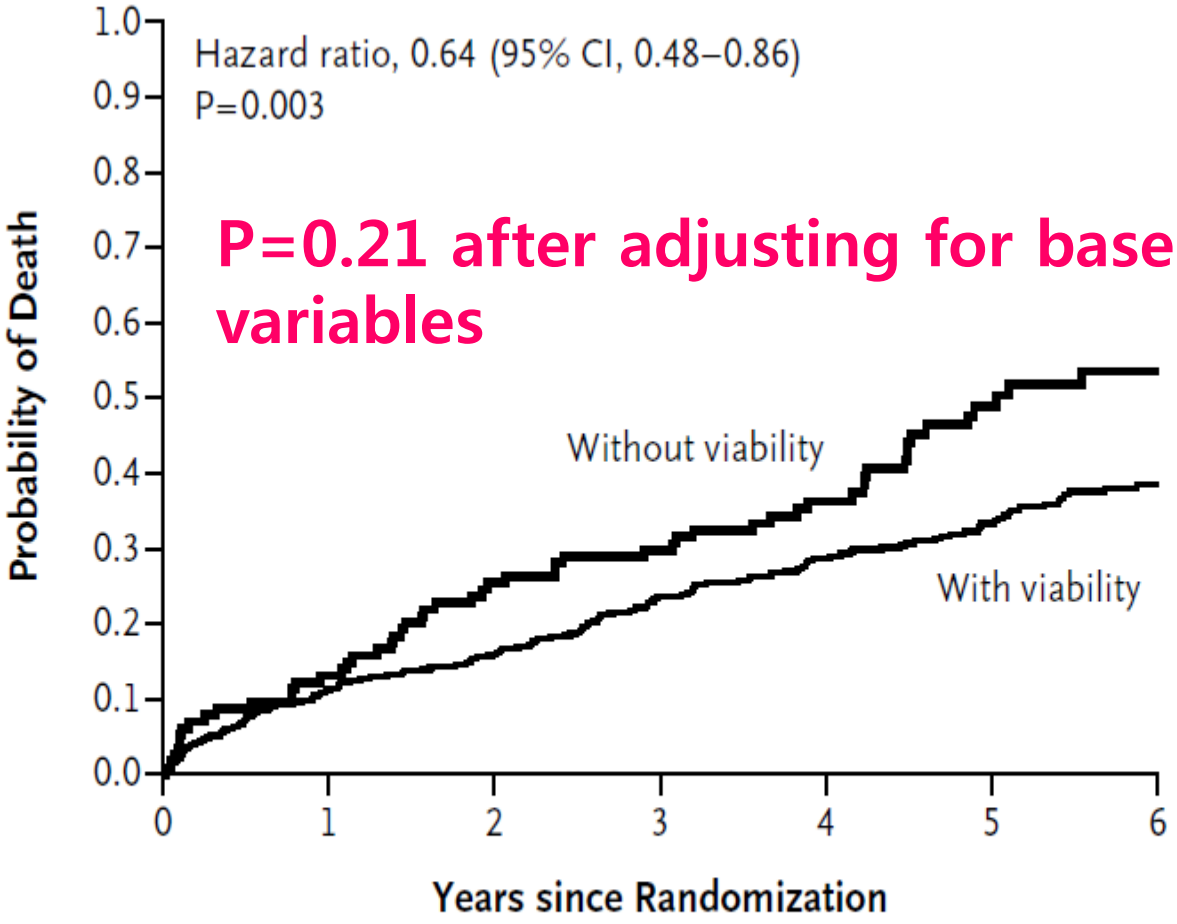
ORIGINAL ARTICLE

Myocardial Viability and Survival in Ischemic Left Ventricular Dysfunction

Robert O. Bonow, M.D., Gerald Maurer, M.D., Kerry L. Lee, Ph.D., Thomas A. Holly, M.D., Philip F. Binkley, M.D., Patrice Desvigne-Nickens, M.D., Jaroslaw Drozdz, M.D., Ph.D., Pedro S. Farsky, M.D., Arthur M. Feldman, M.D., Torsten Doenst, M.D., Ph.D., Robert E. Michler, M.D., Daniel S. Berman, M.D., Jose C. Nicolau, M.D., Ph.D., Patricia A. Pellikka, M.D., Krzysztof Wrobel, M.D., Nasri Alotti, M.D., Ph.D., Federico M. Asch, M.D., Liliana E. Favaloro, M.D., Lilin She, Ph.D., Eric J. Velazquez, M.D., Robert H. Jones, M.D., and Julio A. Panza, M.D., for the STICH Trial Investigators*

N Engl J Med 2011;364:1617-25

K-M analysis of the probability of death

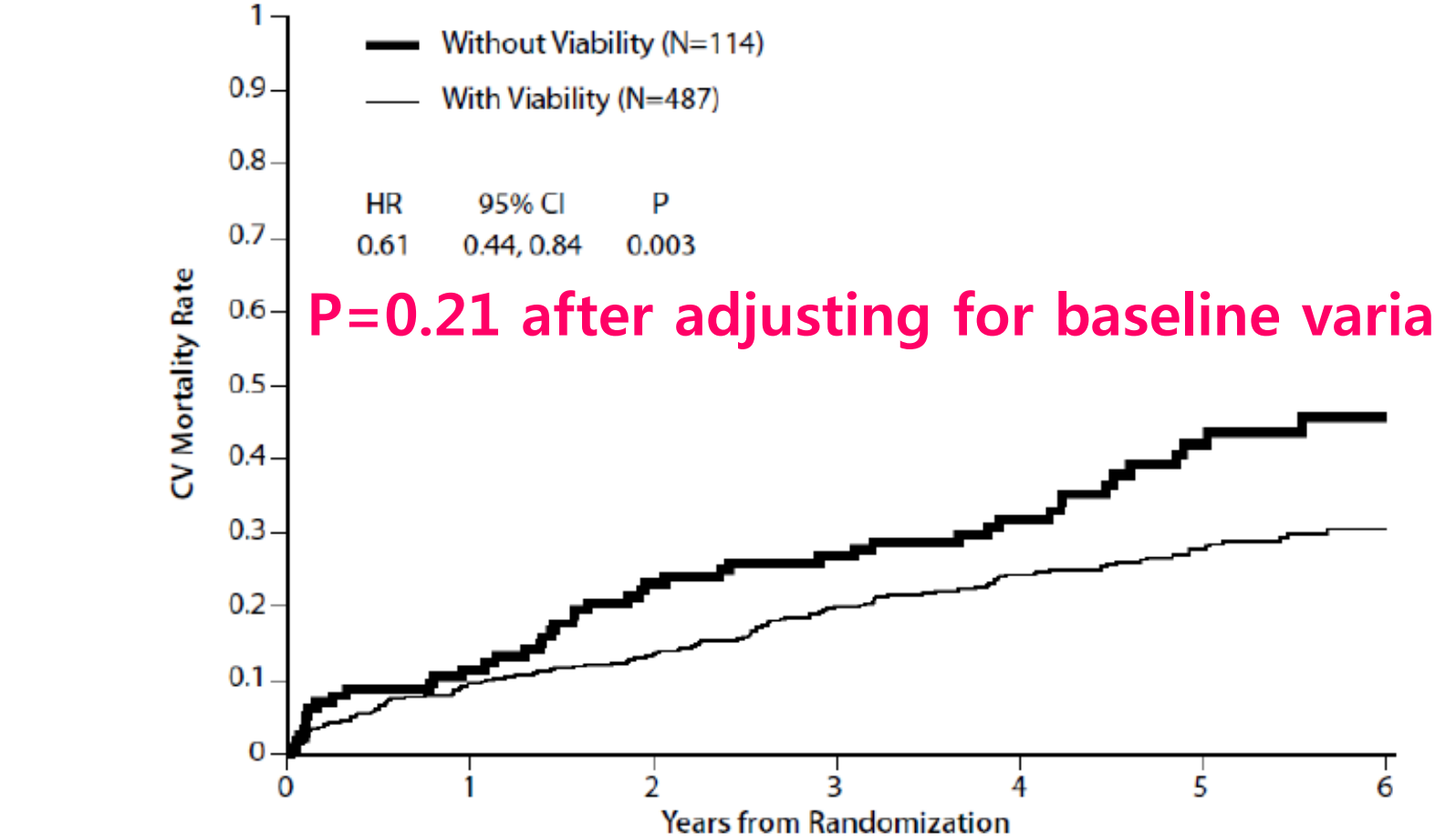


No. at Risk

Without viability	114	99	85	80	63	36	16
With viability	487	432	409	371	294	188	102

N Engl J Med 2011;364:1617-25

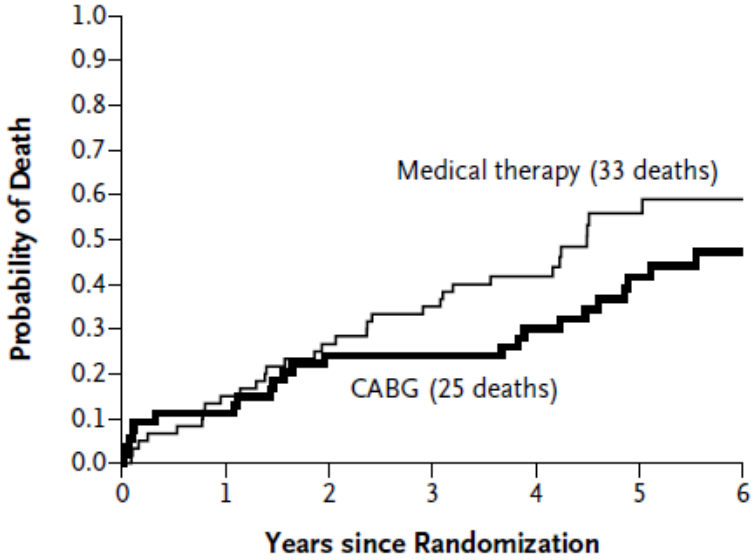
K-M analysis of CV mortality



P=0.21 after adjusting for baseline variables

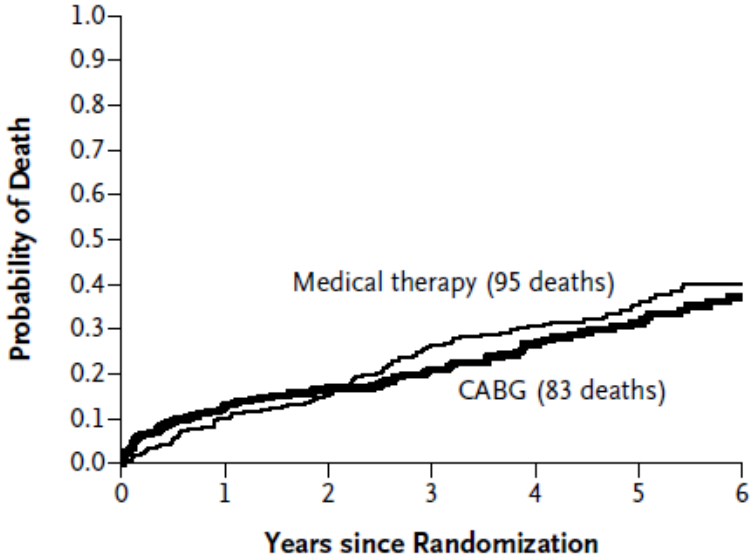
N Engl J Med 2011;364:1617-25

A Without Myocardial Viability



No. at Risk							
Medical therapy	60	51	44	39	29	14	4
CABG	54	48	41	41	34	22	12

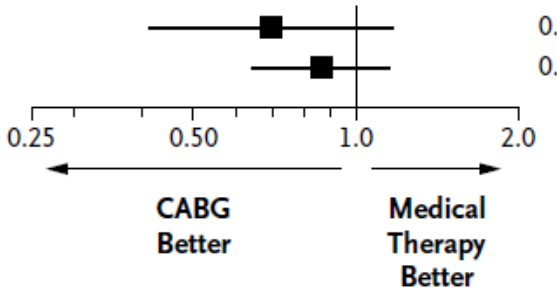
B With Myocardial Viability



No. at Risk							
Medical therapy	243	219	206	179	146	94	51
CABG	244	213	203	192	148	94	51

C

Subgroup	No.	Deaths	Hazard Ratio (95% CI)	P Value for Interaction
Without viability	114	58	0.70 (0.41–1.18)	0.53
With viability	487	178	0.86 (0.64–1.16)	



Viability Testing for Myocardium

Cardiac Imaging for Viability

- ***Echo***
- ***Nuclear test***
- ***Cardiac MR***
- ***Cardiac CT***

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

by SPECT or dobutamine echo

Myocardial Viability and Survival in Ischemic Left Ventricular Dysfunction

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N Engl J Med 2011;364:1617-25

Limitations of the STICH viability substudy

Lack of randomization in viability substudy

Optional viability testing performed at clinician's discretion

Only about one-half of eligible patients from the main trial

Significant differences in baseline characteristics between those with versus those without viability testing.

Acceptable viability tests do NOT have highest sensitivity or negative predictive value for identifying viable myocardium

JACC CV Imaging 2012;5:550-558

Some cardiologists say .....

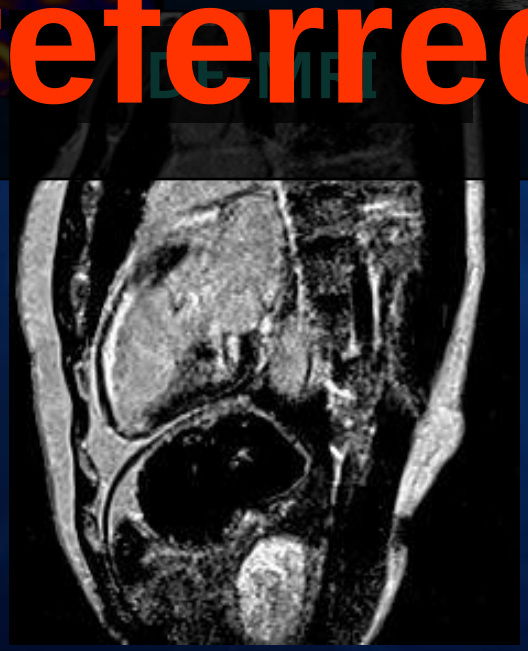
Results might be different if they used other imaging modality like CMR !

Viability imaging tests

Nuclear scan

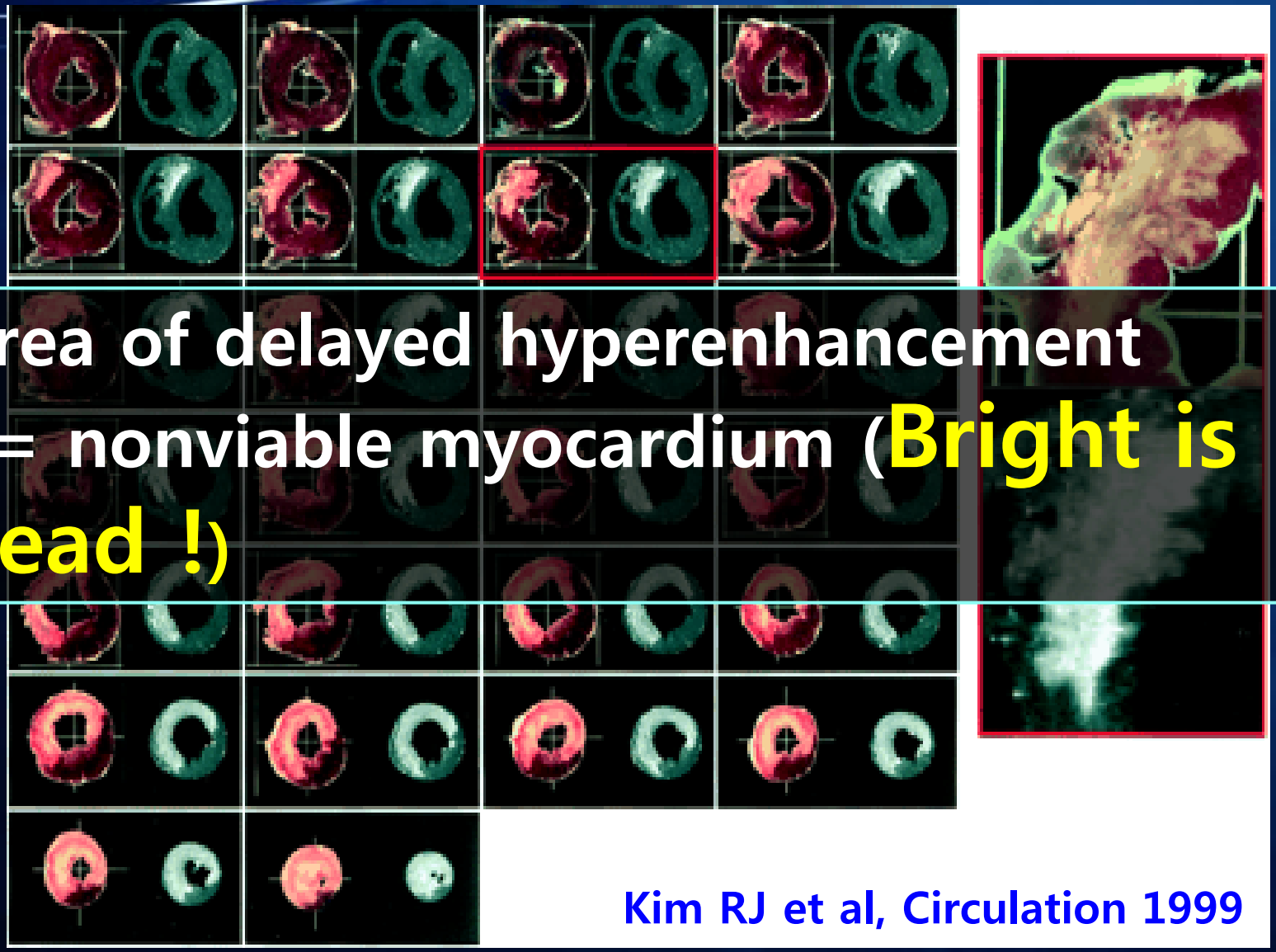
Dobutamine/exercise stress

Which test is preferred ?



CMR assessment of viability ; DE-CMR

Fibrosis Imaging

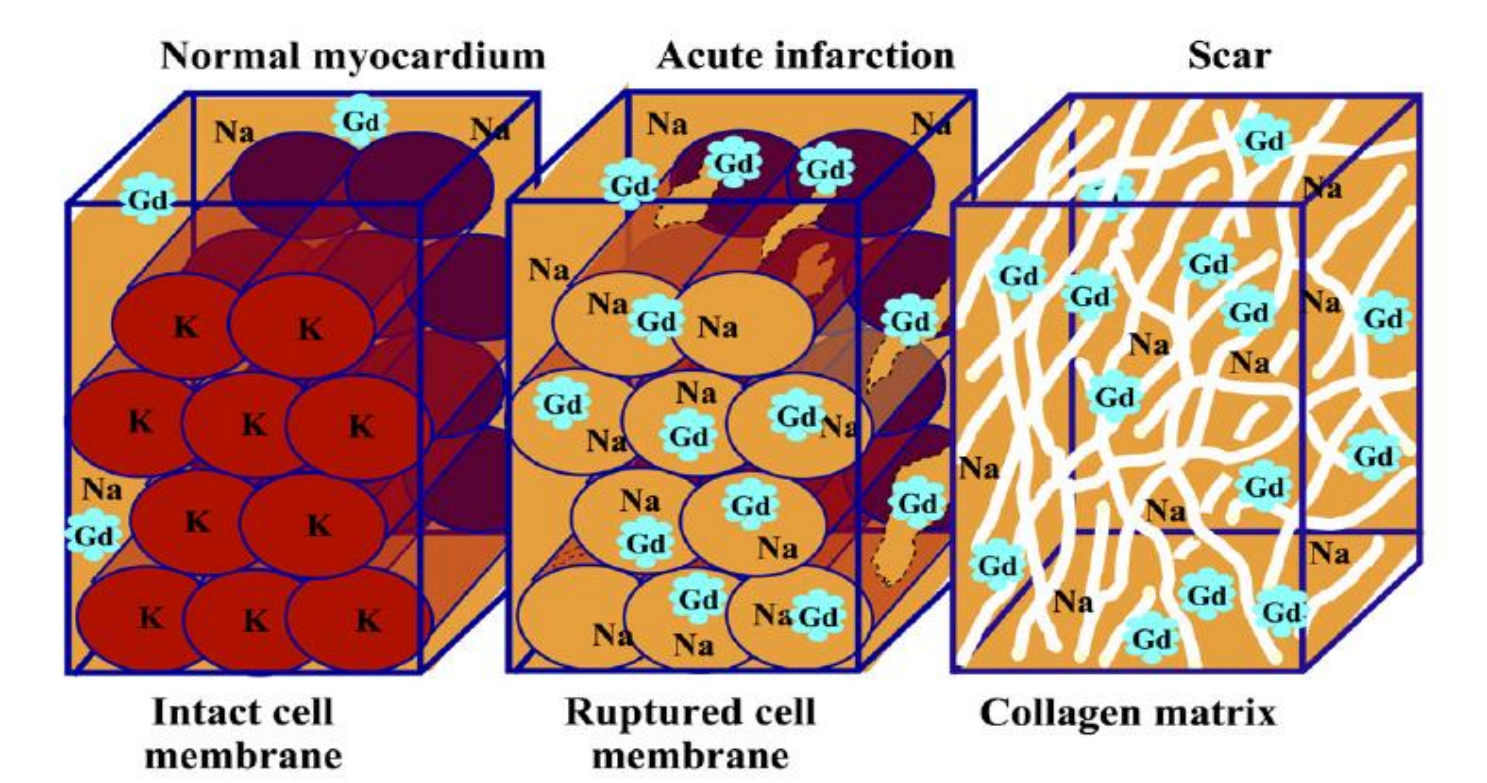


Area of delayed hyperenhancement
= nonviable myocardium (**Bright is dead !**)

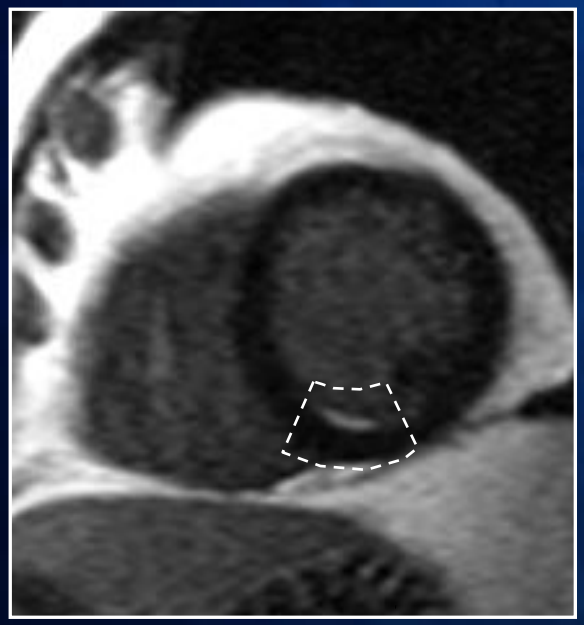
Kim RJ et al, Circulation 1999

Delayed Enhancement CMR

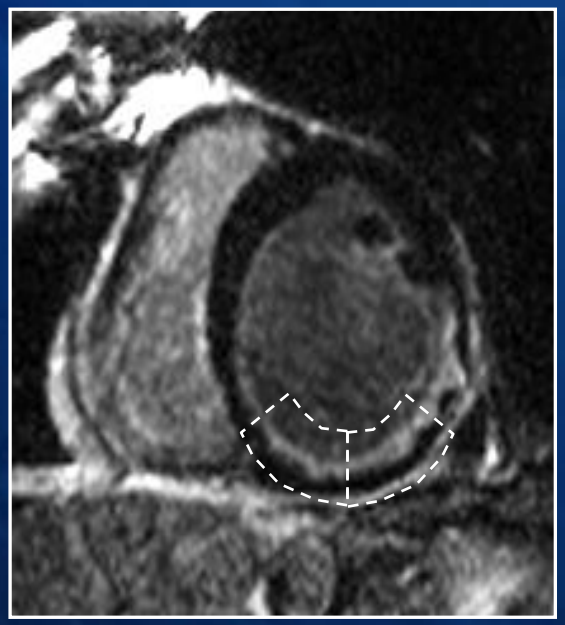
Physiological basis



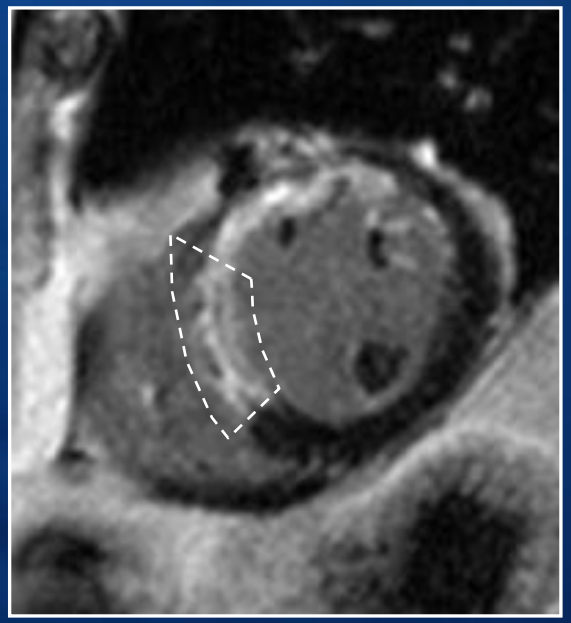
CMR assessment of viability ; DE-CMR



1-25% DE



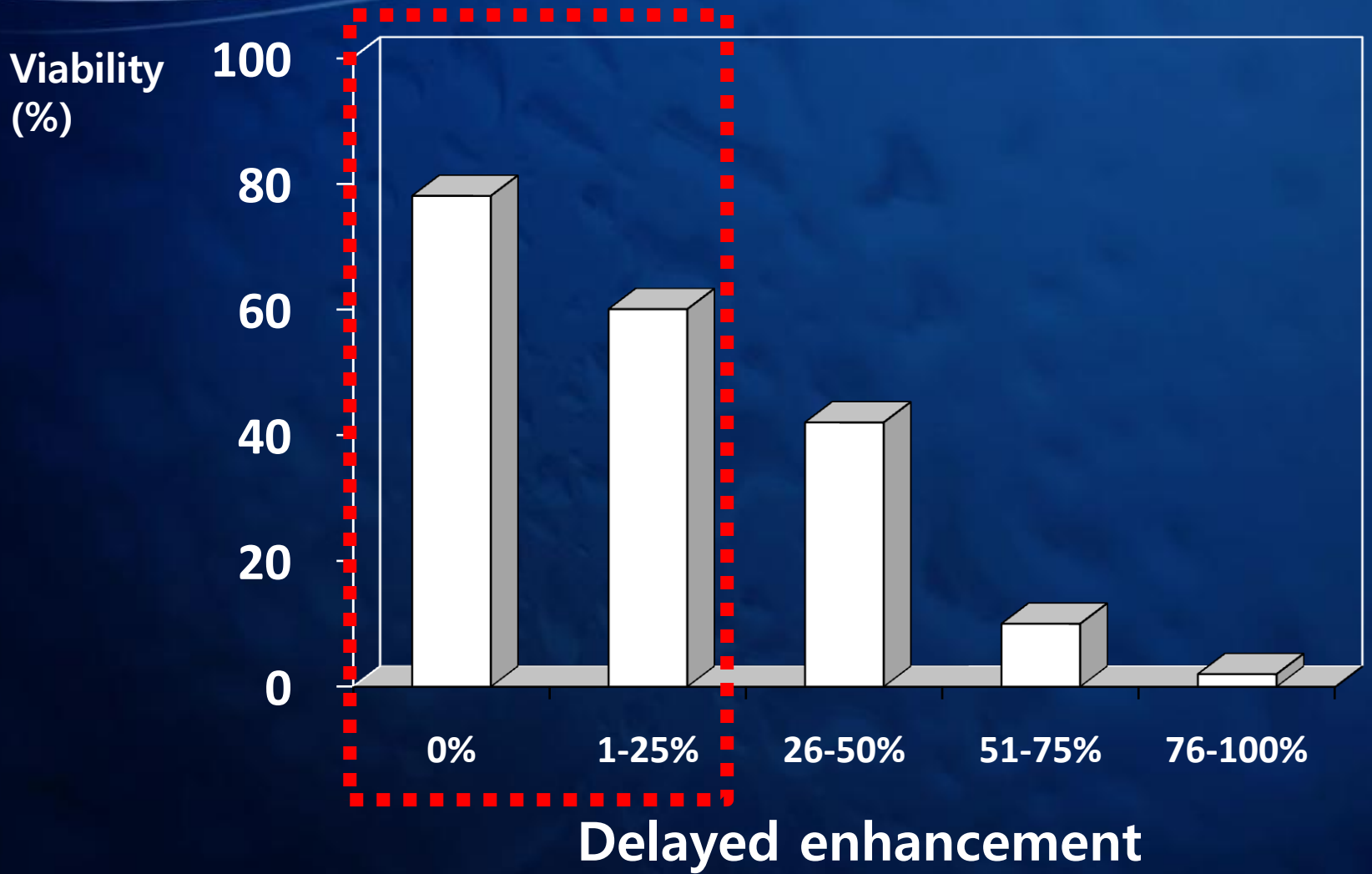
Left: 26-50% DE
Right: 51-75% DE



76-100% DE

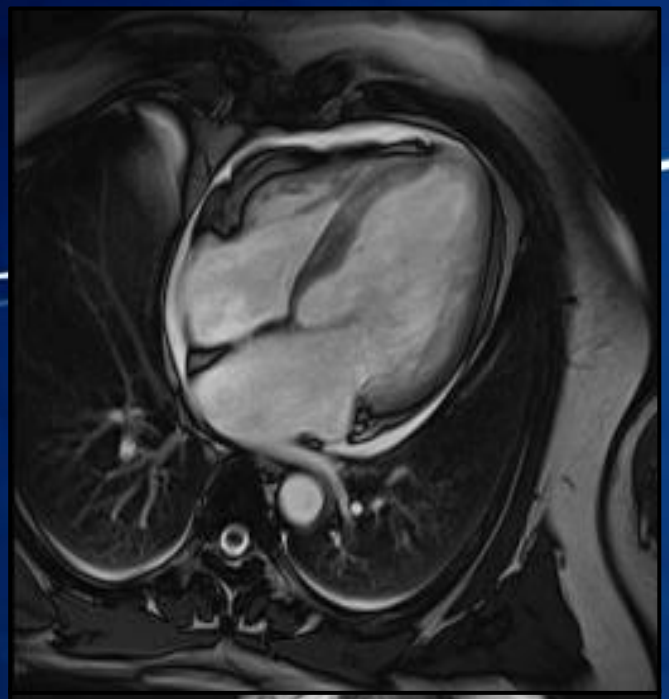
Kim RJ et.al., J Cardiovasc Magn Reson

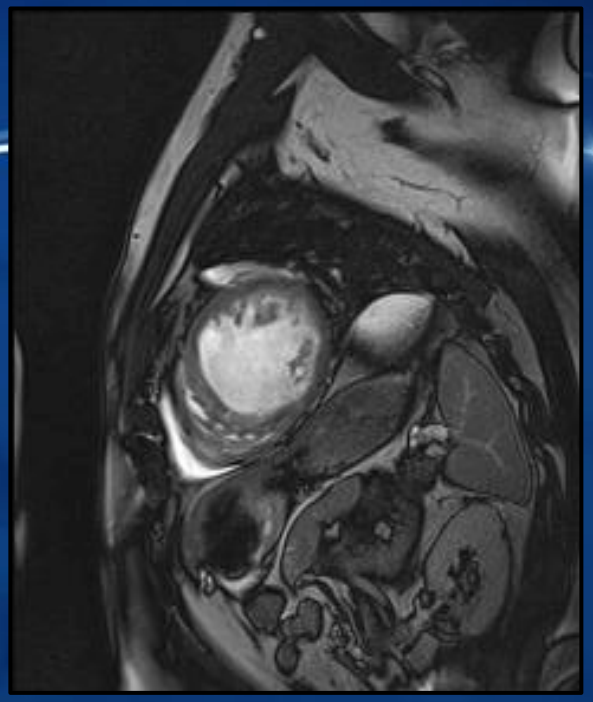
CMR assessment of viability ; DE-CMR

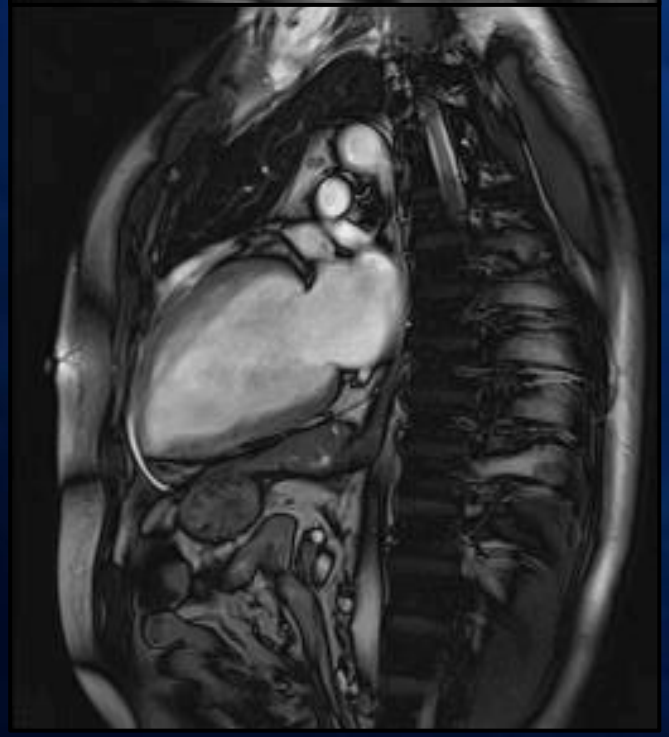


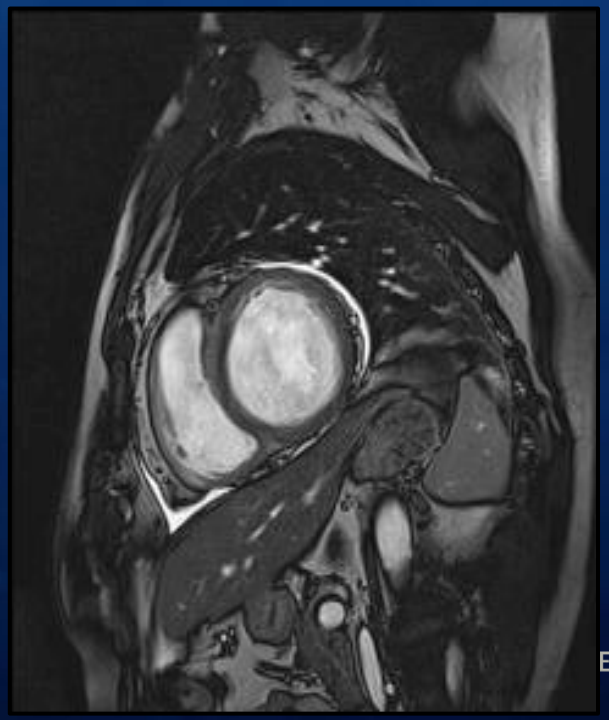
Kim RJ et.al. N Engl J Med 2000

CMR

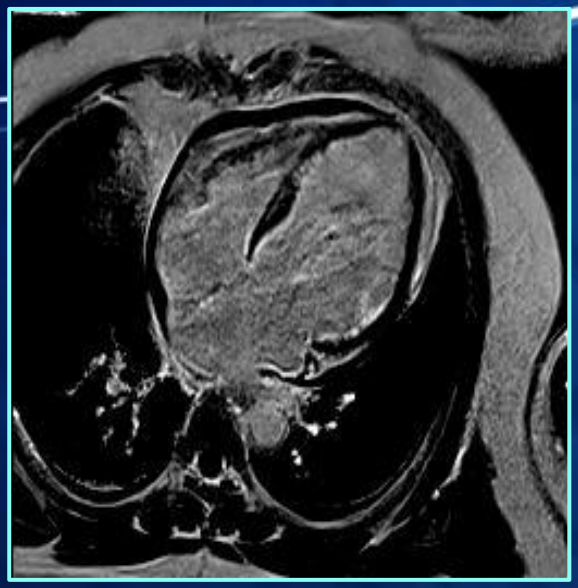


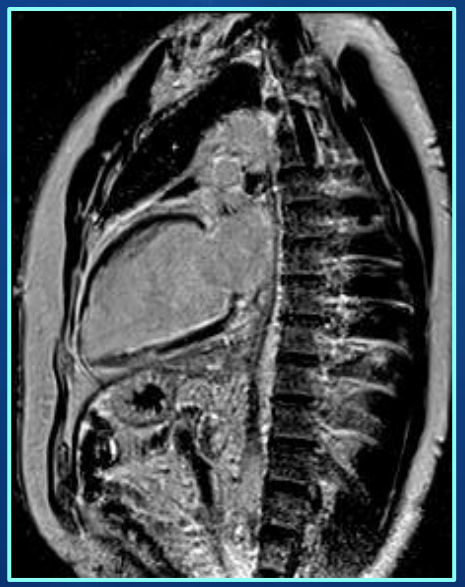


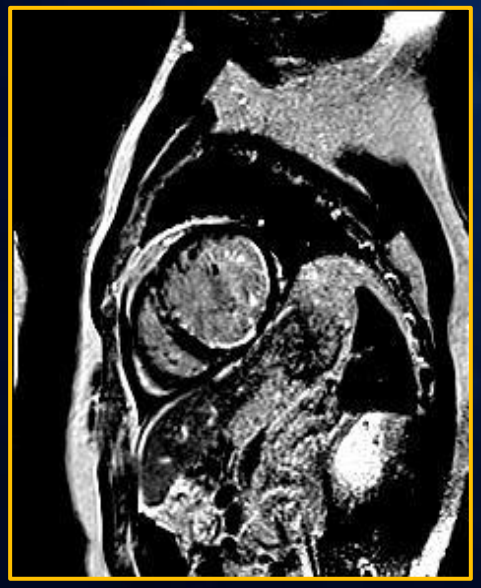


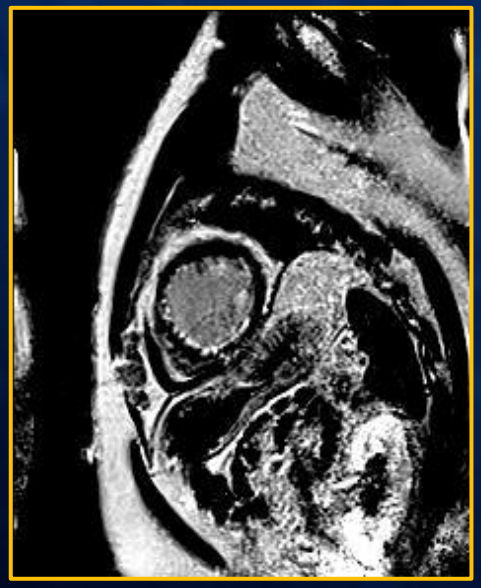


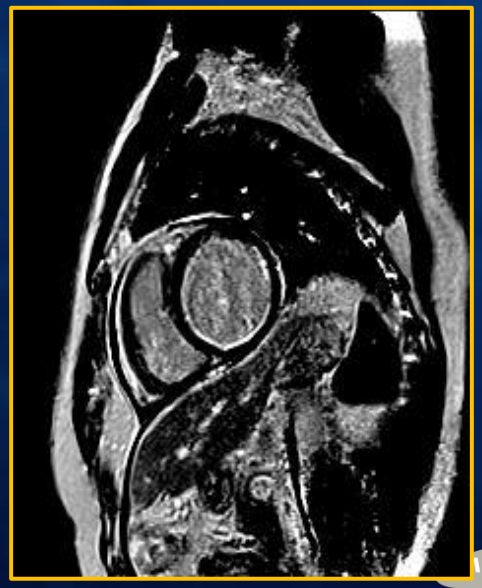
DE - CMR

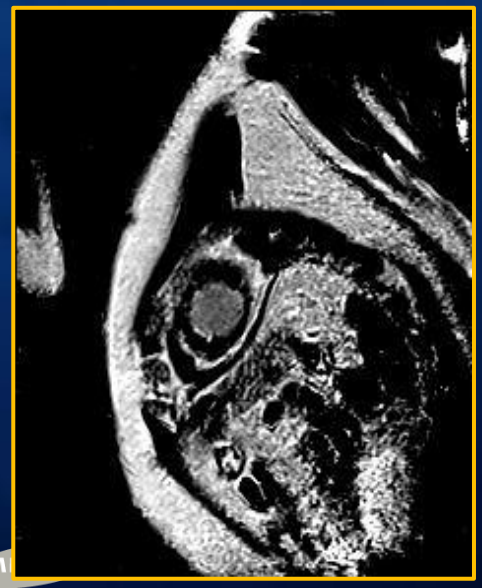




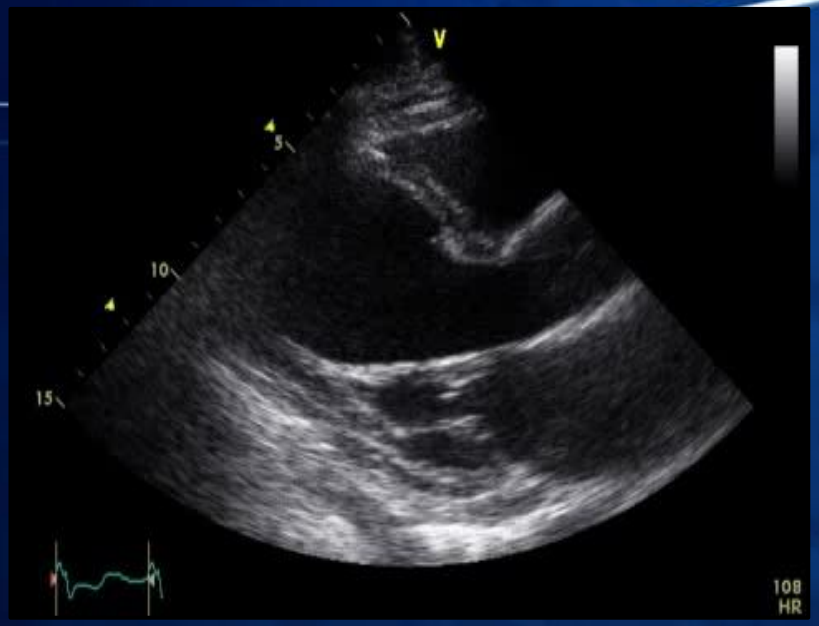


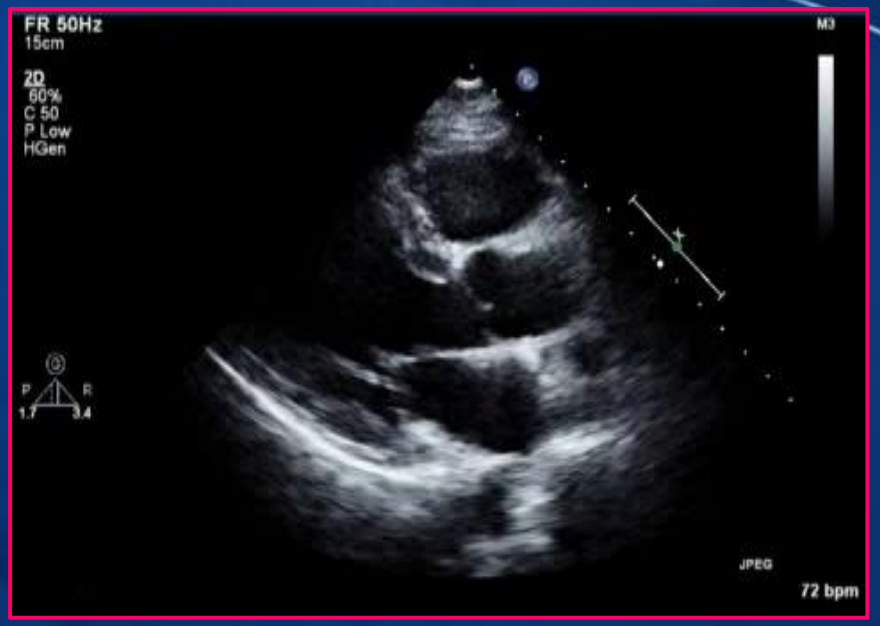


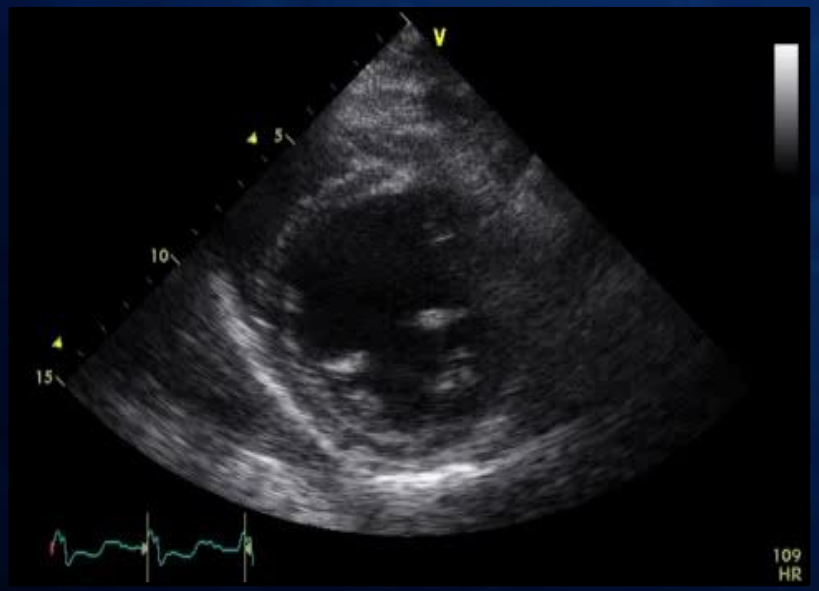


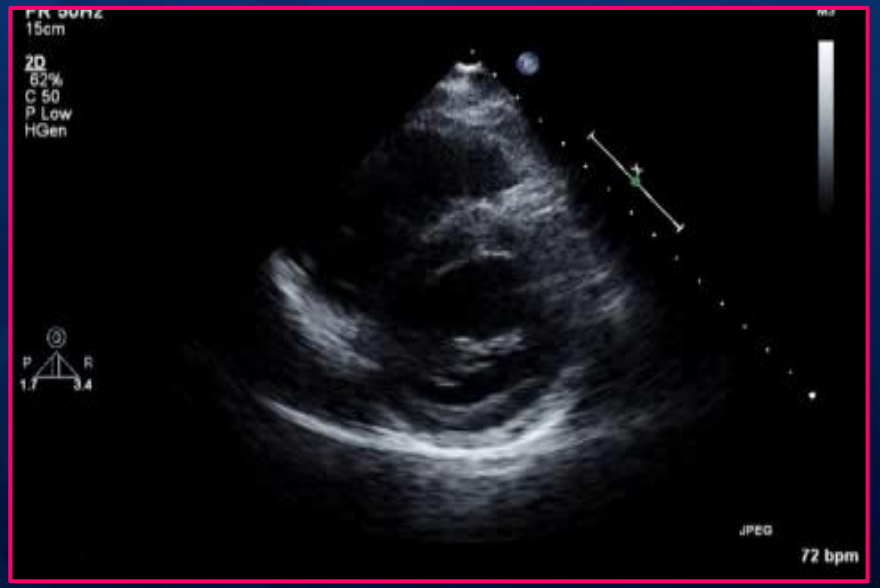


After CABG…

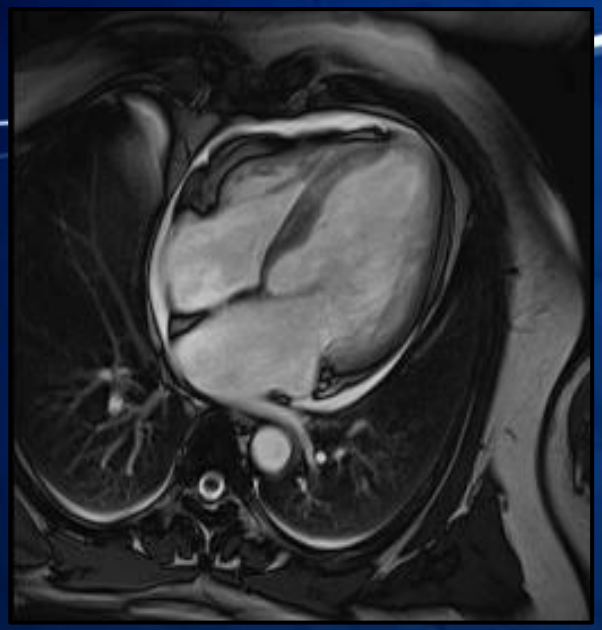

V
5
10
15
108
HR

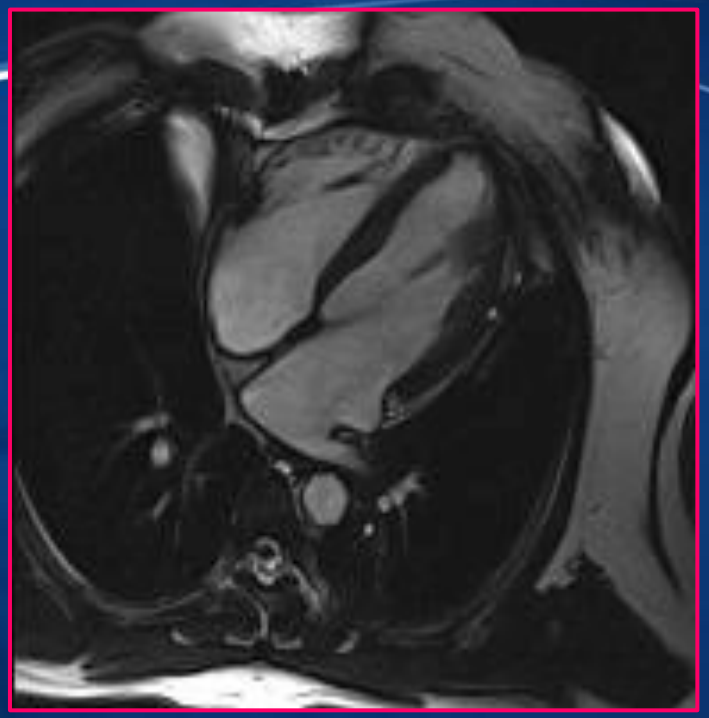

FR 50Hz
15cm
2D
60%
C 50
P Low
HGen
M3
P
R
1.7
3.4
JPEG
72 bpm

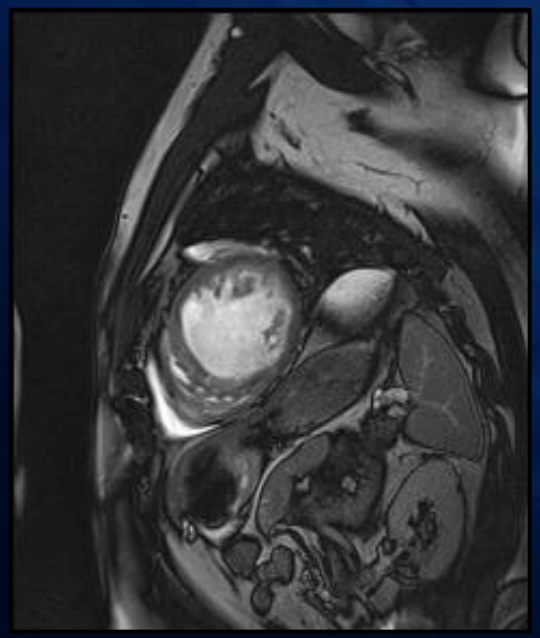

V
5
10
15
109
HR

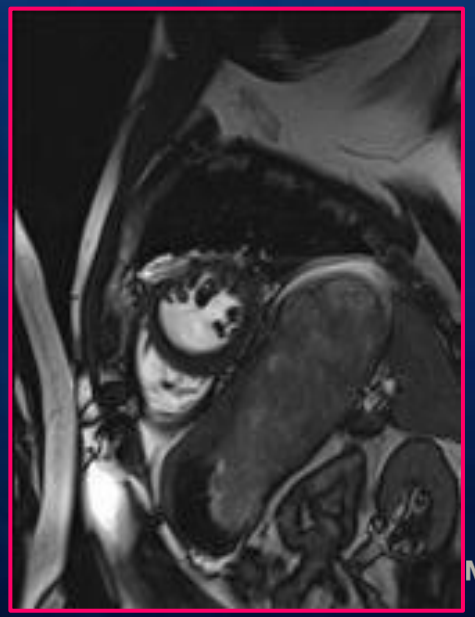

15cm
2D
62%
C 50
P Low
HGen
P
R
1.7
3.4
JPEG
72 bpm

After CABG…





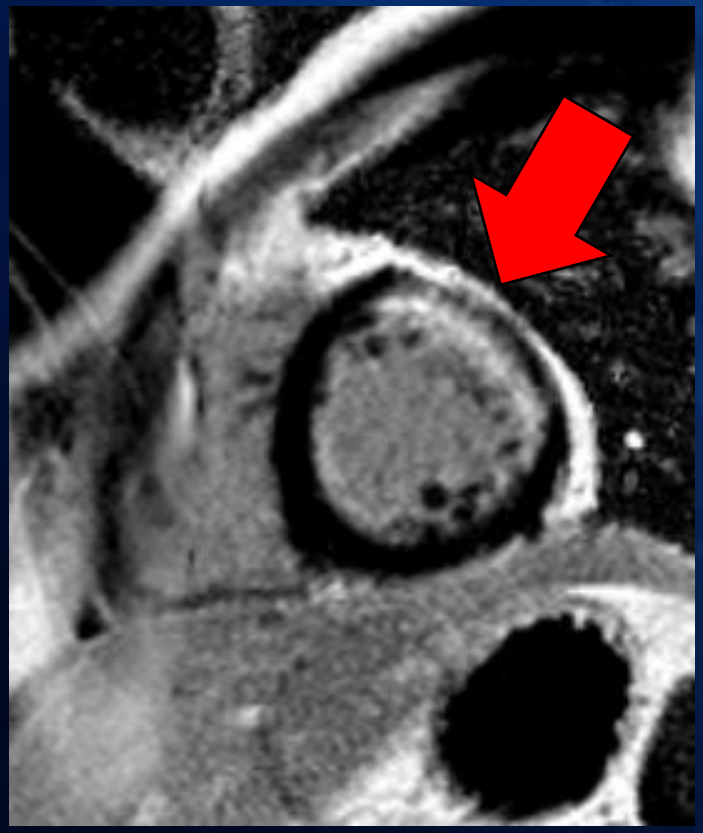




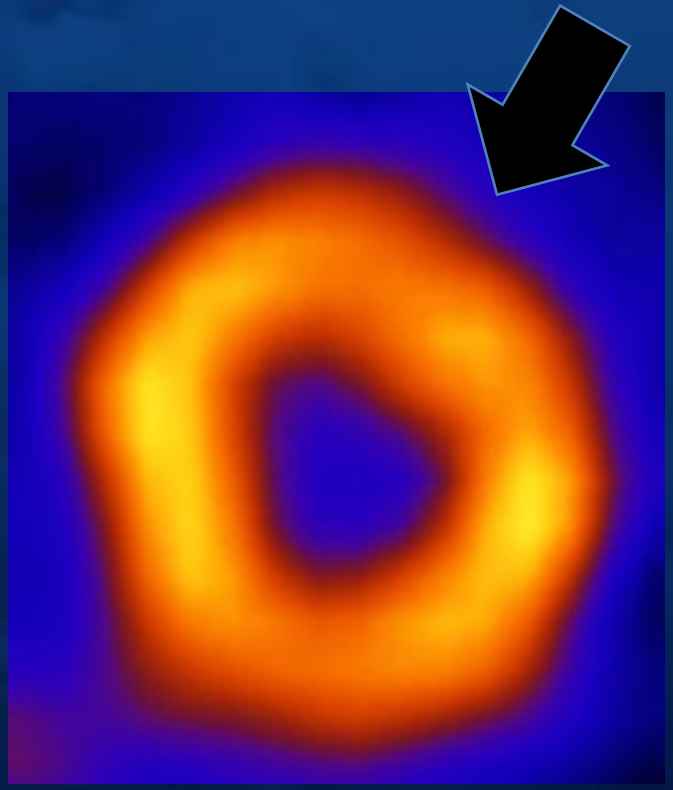
Advantages of CMR

Higher spatial resolution as compared with SPECT

- 42 year-old male with NSTEMI

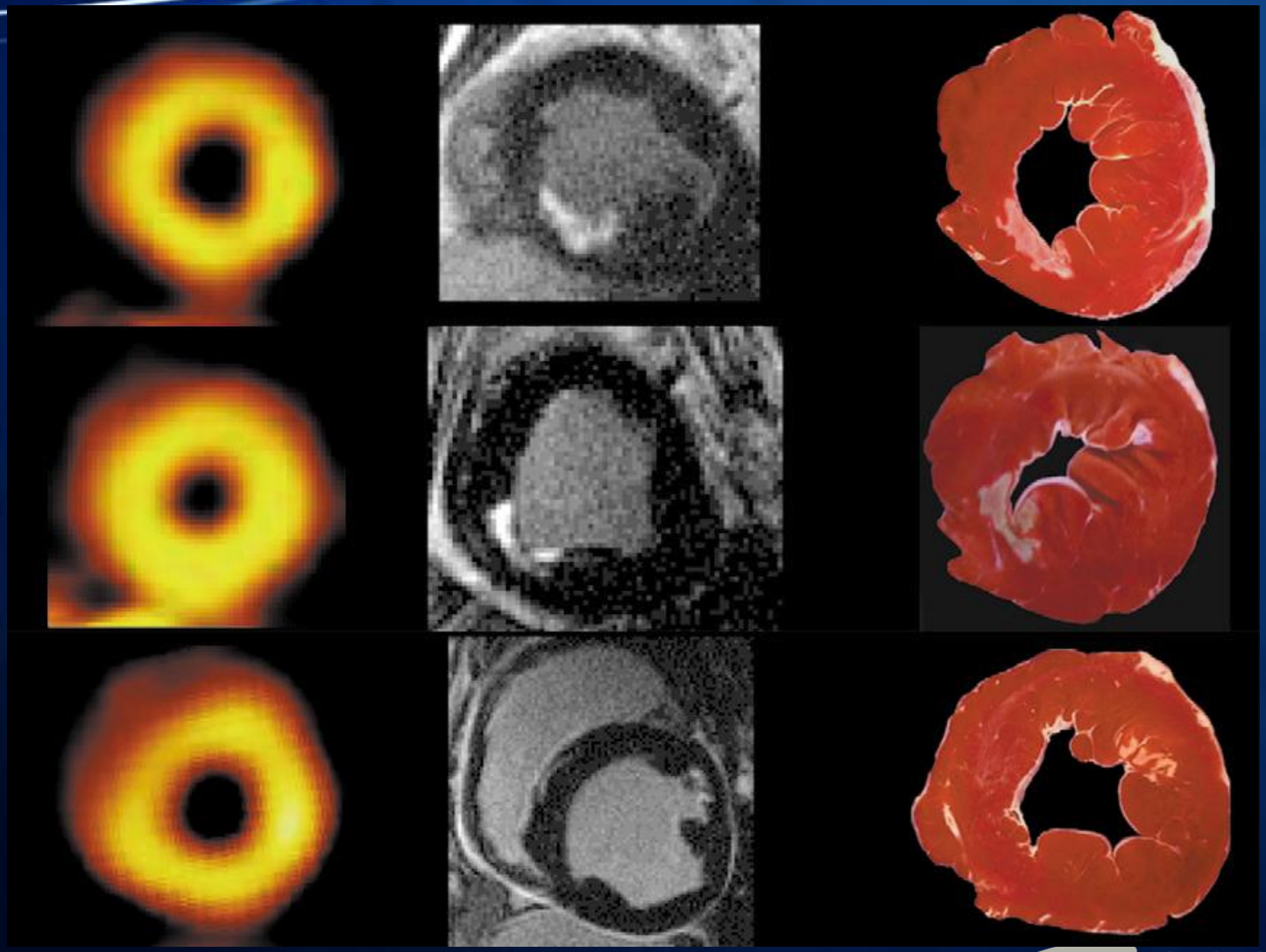


Perfusion defect (-)



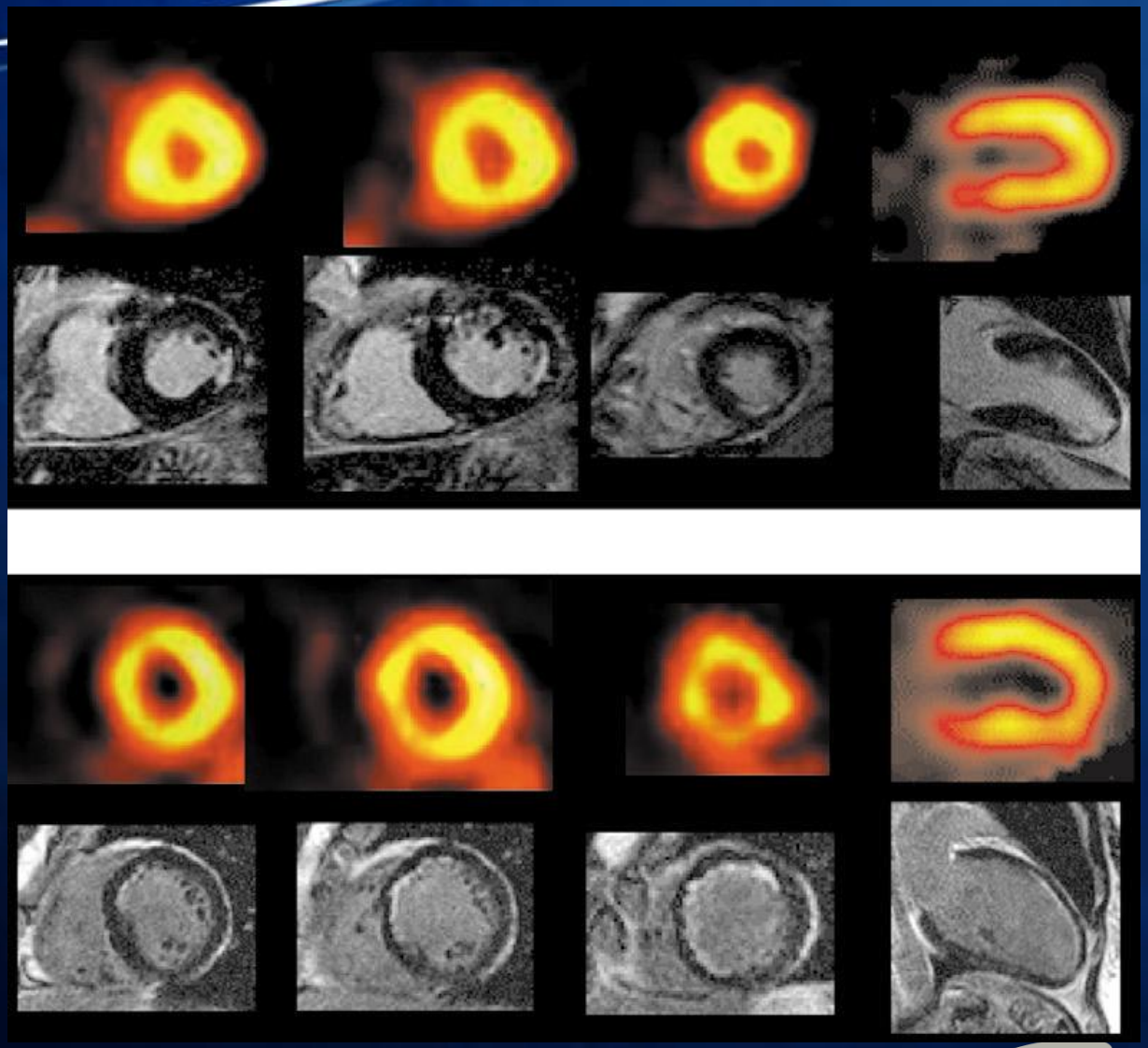
Advantages of CMR

Direct visualization of nonviable tissue



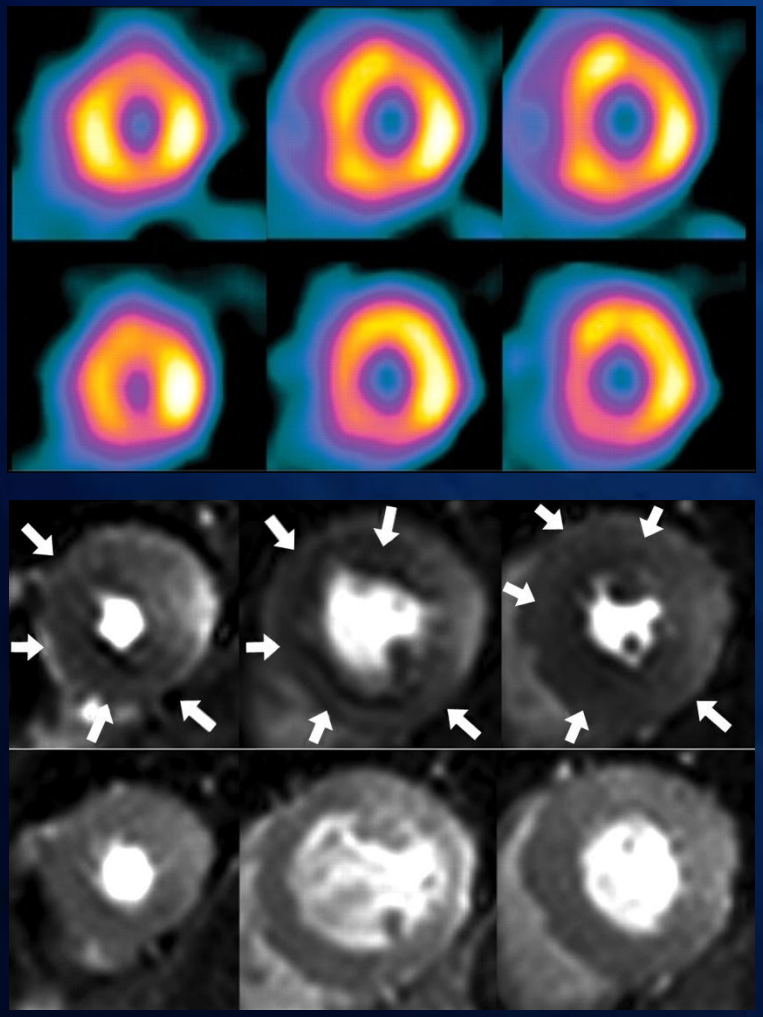
A Wagner, R Judd, R Kim et al. Lancet 2003:361:374

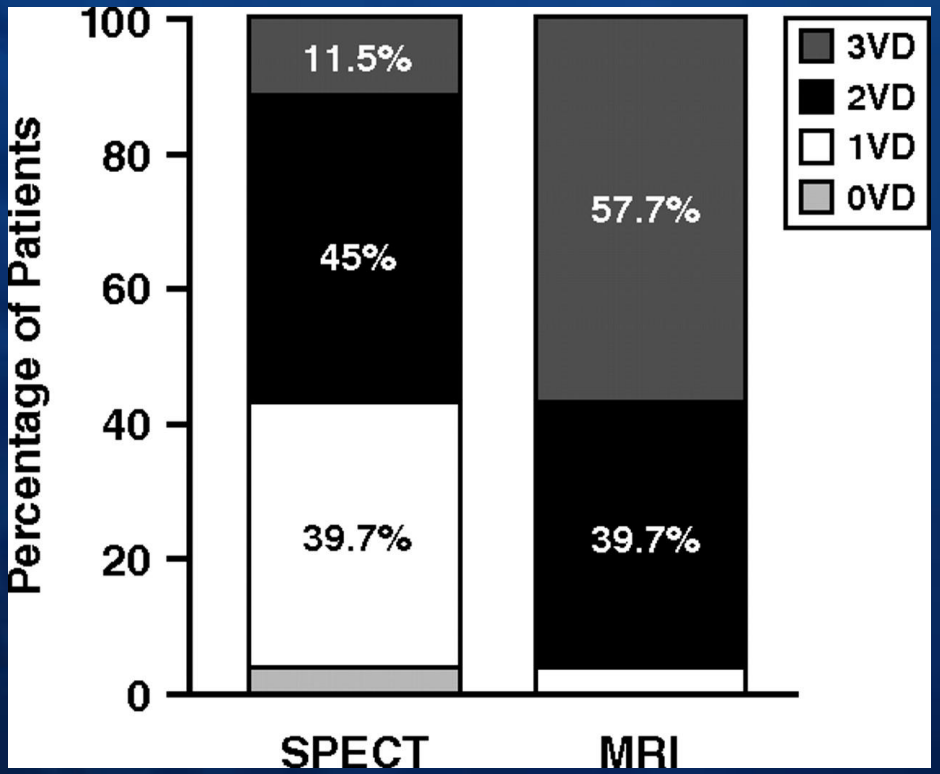
Strong images in small or shallow lesions



A Wagner, R Judd, R Kim et al. Lancet 2003:361:374

Comparison with SPECT in Three-vessel Diseases





Chung and Choi, AJR 2011

JACC: CARDIOVASCULAR IMAGING
VOL. 2, NO. 1, 2009

PUBLISHED BY ELSEVIER INC.
ISSN 1936-878X/09/$36.00
DOI:10.1016/j.jcmg.2008.09.010

Extent of Left Ventricular Scar Predicts Outcomes in Ischemic Cardiomyopathy Patients With Significantly Reduced Systolic Function

A Delayed Hyperenhancement Cardiac Magnetic Resonance Study

Deborah H. Kwon, MD,* Carmel M. Halley, MD,* Thoma
Victoria Zysek, DO,† Zoran B. Popovic, MD, PHD,* Rando
Paul Schoenhagen, MD,*‡ Randall C. Starling, MD, MPH,
Milind Y. Desai, MD*‡

Cleveland, Ohio

Segmental scar score
0 = absence of DHE
1 = DHE of 1% to 25% of LV segment
2 = DHE extending to 26% to 50%
3 = DHE extending to 51% to 75%
4 = DHE extending to 76% to 100%

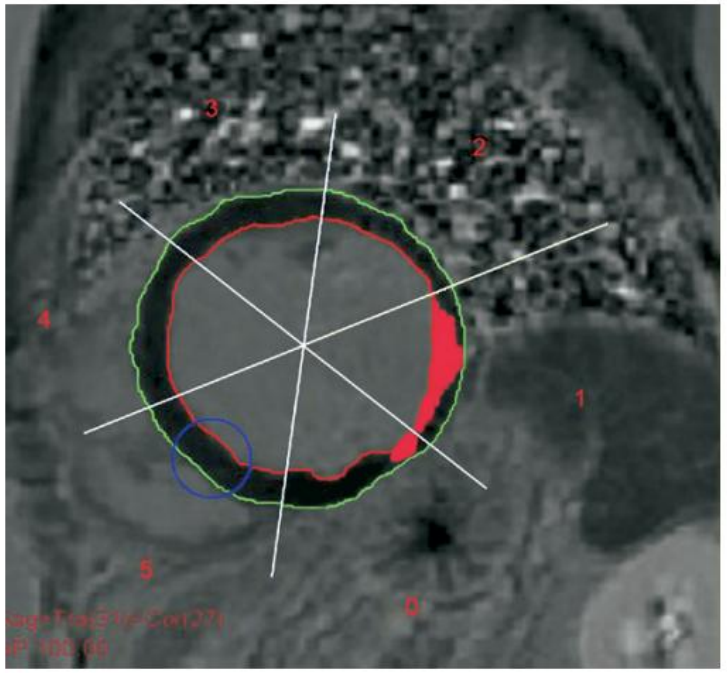
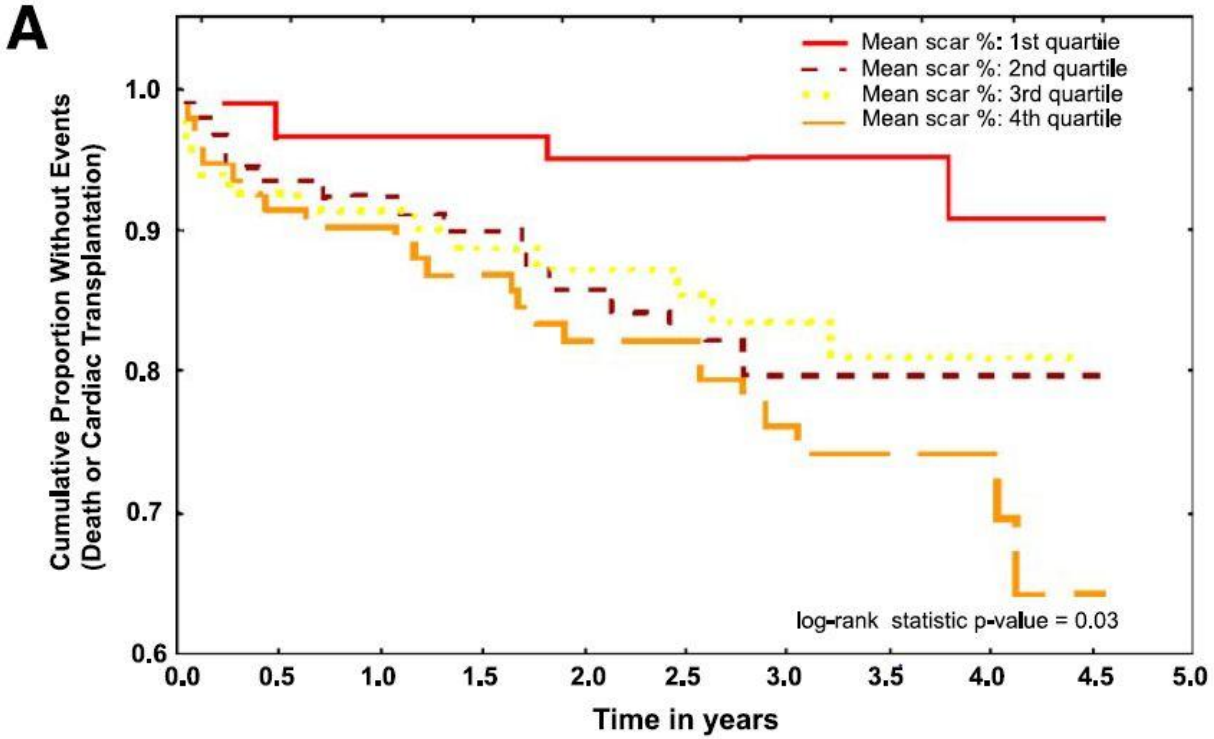


Figure 1. Short-Axis Delayed Hyperenhancement Image, Loaded on Custom VPT Software (Siemens Research), for Scar Analysis

Kaplan-Meier Curves Demonstrating Difference in Outcomes Among 4 Quartiles



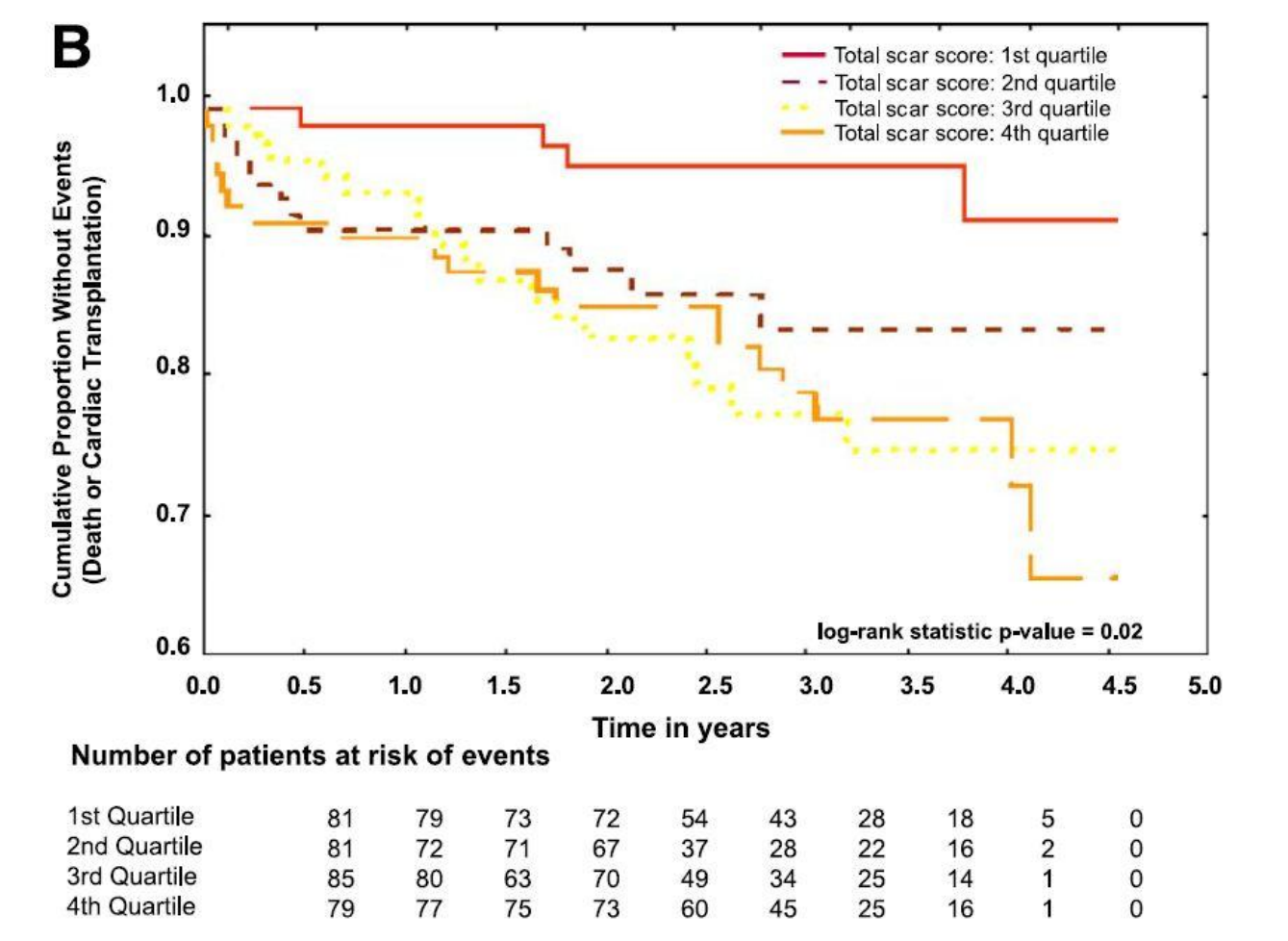
Number of patients at risk of events

1st Quartile	82	80	73	60	53	41	27	17	5	0
2nd Quartile	85	78	71	55	39	30	23	15	2	0
3rd Quartile	75	70	63	57	46	37	26	16	0	0
4th Quartile	84	82	75	67	60	42	24	16	2	0

automatically derived scar: >2SD above viable myocardium

Deborah H Kwon et al. JACC : Cardiovascular Imaging 2009;2:1

Kaplan-Meier Curves Demonstrating Difference in Outcomes Among 4 Quartiles

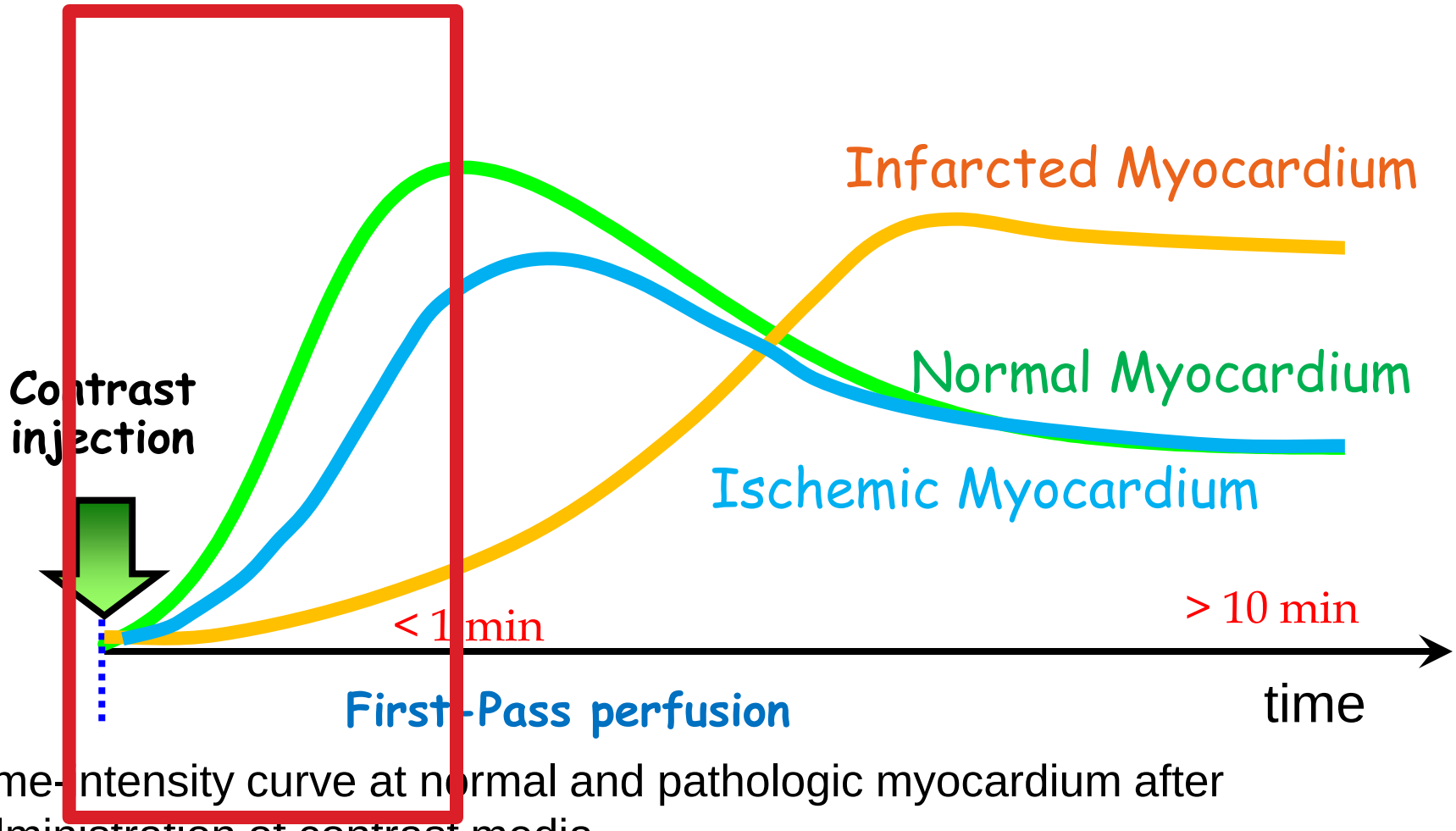


Total scar score : summed segmental scar scores/patient divided by 17

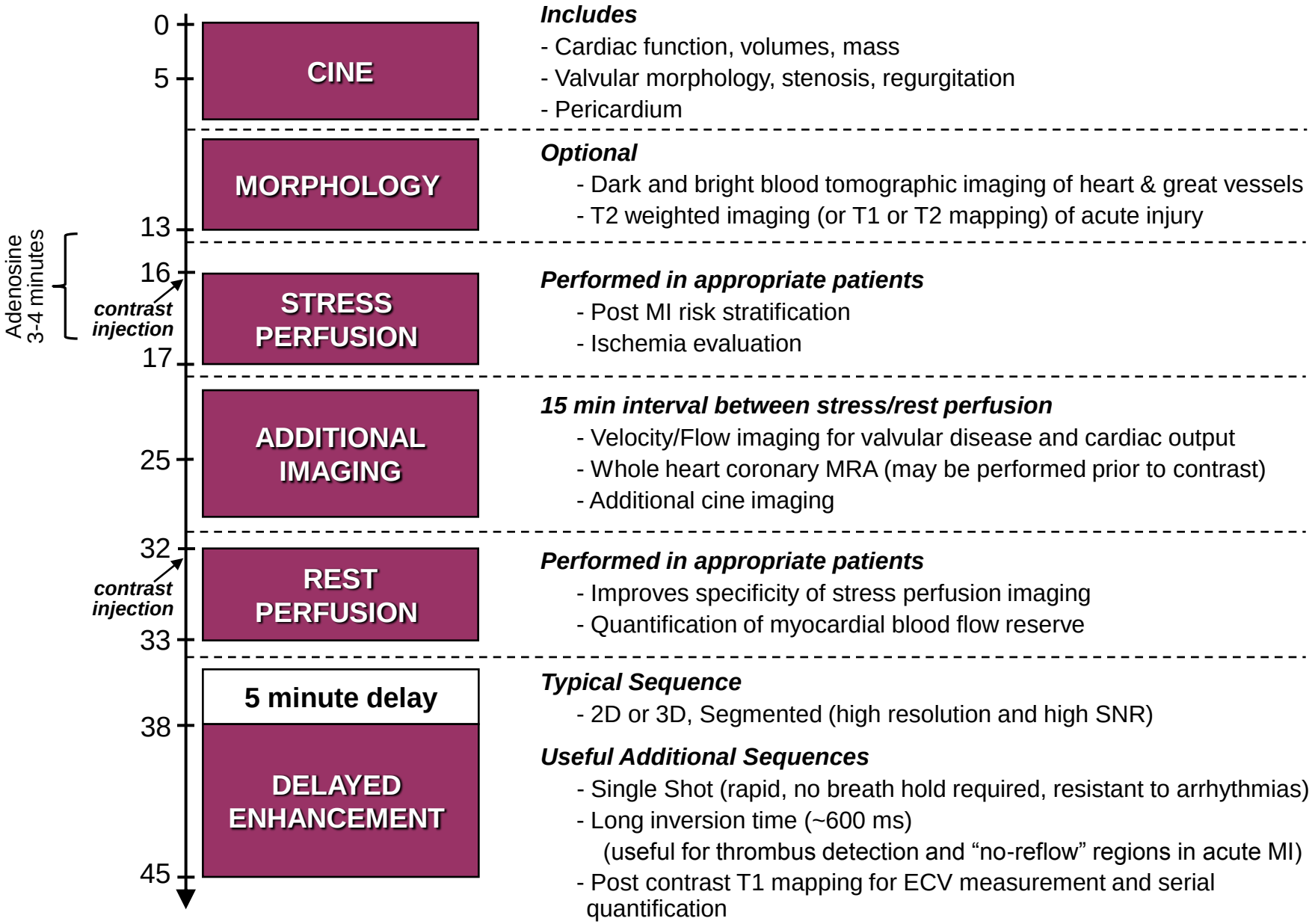
DeborahH Kwon et al. JACC : Cardiovascular Imaging 2009;2;1

Adenosine Stress Perfusion CMR

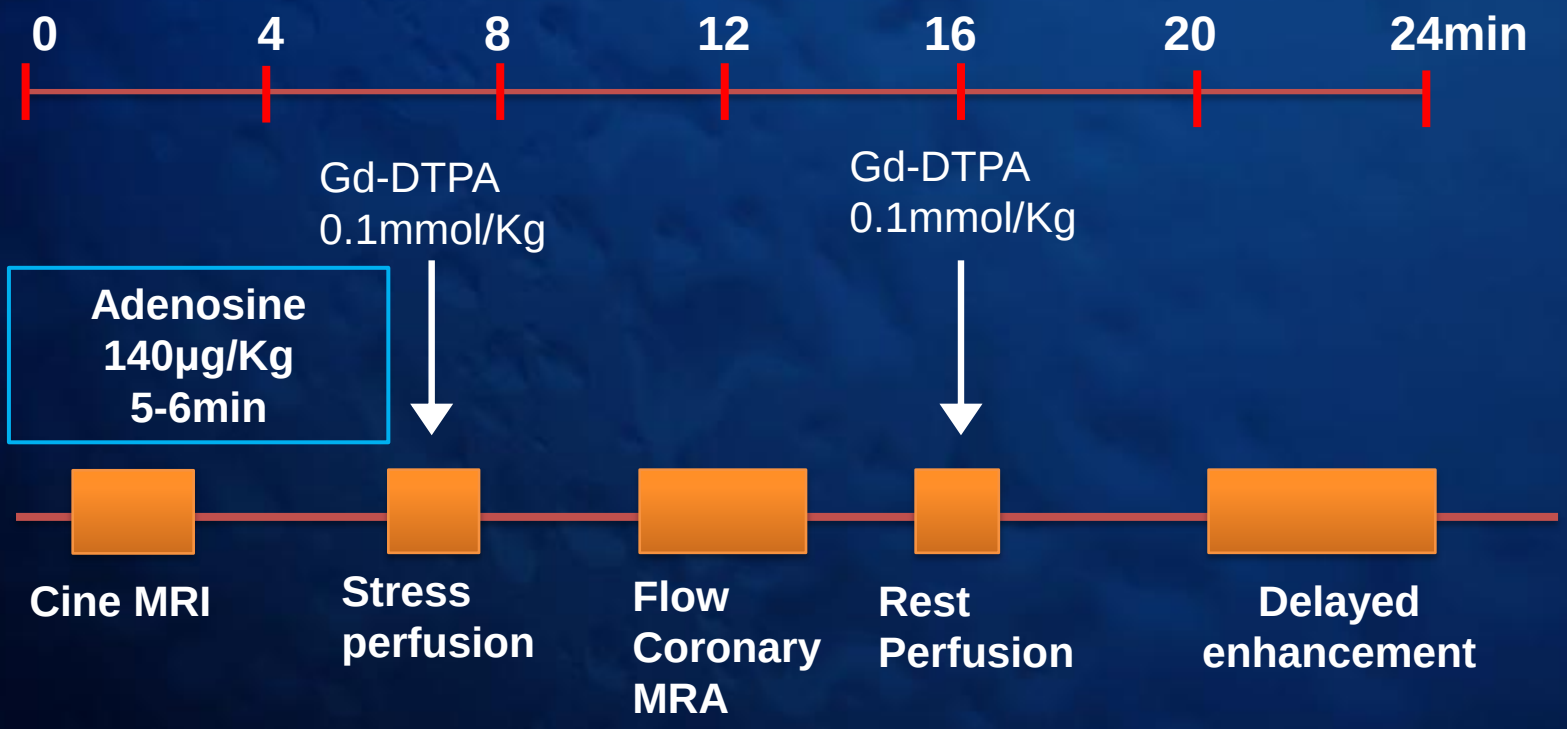
First pass perfusion CMR



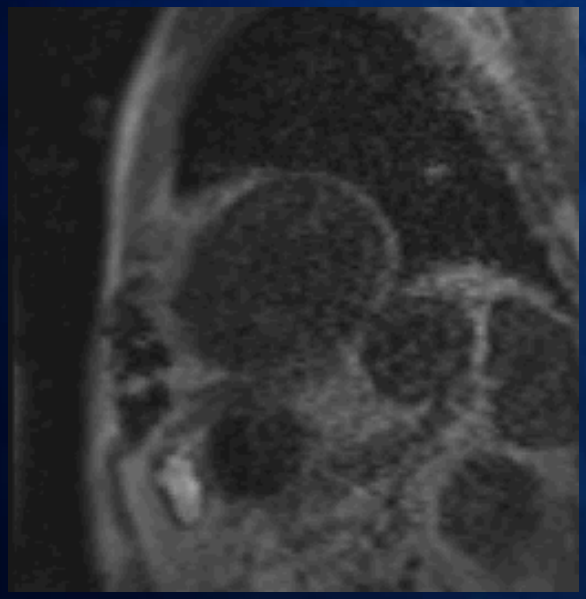
Time-intensity curve at normal and pathologic myocardium after administration of contrast media.

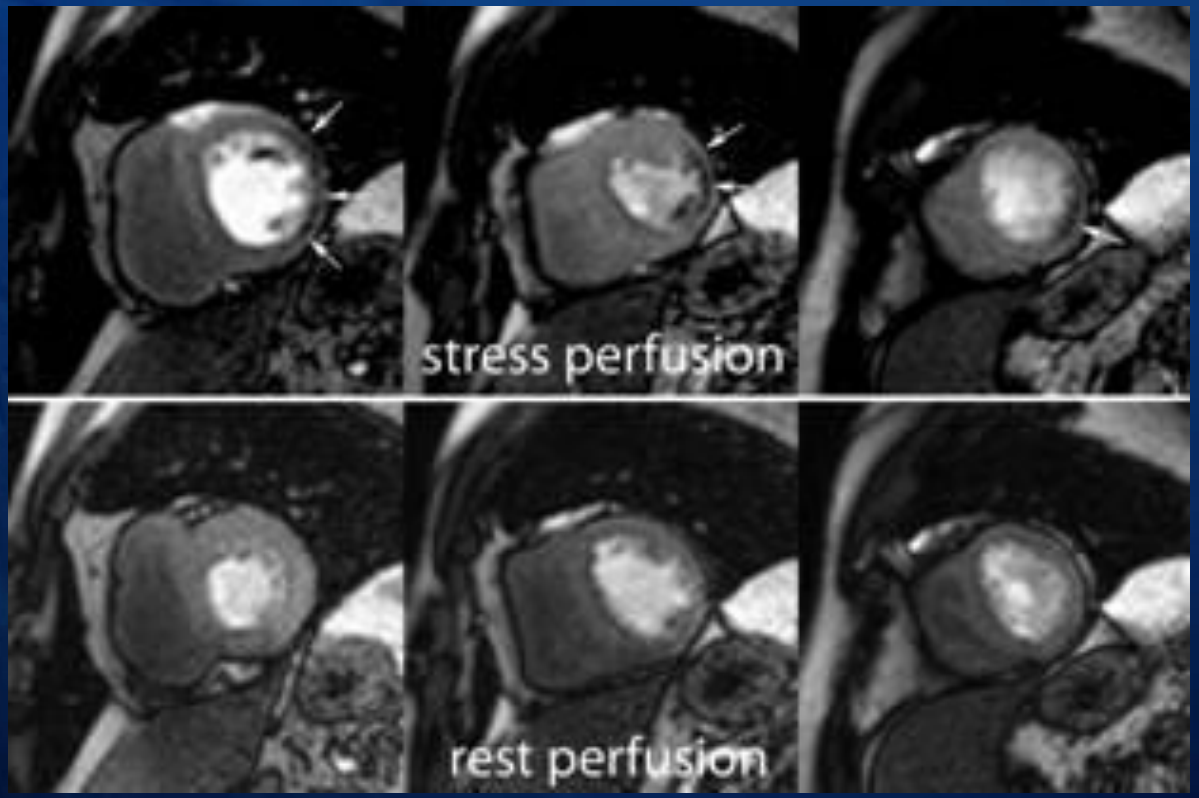

TIME
[minutes]
CMR TECHNIQUE
COMMENTS
0
5
13
16
17
25
32
33
38
45
Adenosine
3-4 minutes
contrast injection
contrast injection
CINE
MORPHOLOGY
STRESS PERFUSION
ADDITIONAL IMAGING
REST PERFUSION
5 minute delay
DELAYED ENHANCEMENT
Includes
- Cardiac function, volumes, mass
- Valvular morphology, stenosis, regurgitation
- Pericardium
Optional
- Dark and bright blood tomographic imaging of heart & great vessels
- T2 weighted imaging (or T1 or T2 mapping) of acute injury
Performed in appropriate patients
- Post MI risk stratification
- Ischemia evaluation
15 min interval between stress/rest perfusion
- Velocity/Flow imaging for valvular disease and cardiac output
- Whole heart coronary MRA (may be performed prior to contrast)
- Additional cine imaging
Performed in appropriate patients
- Improves specificity of stress perfusion imaging
- Quantification of myocardial blood flow reserve
Typical Sequence
- 2D or 3D, Segmented (high resolution and high SNR)
Useful Additional Sequences
- Single Shot (rapid, no breath hold required, resistant to arrhythmias)
- Long inversion time (~600 ms)
(useful for thrombus detection and “no-reflow” regions in acute MI)
- Post contrast T1 mapping for ECV measurement and serial quantification

Adenosine Stress Perfusion Protocol (SMC protocol)



Perfusion MRI

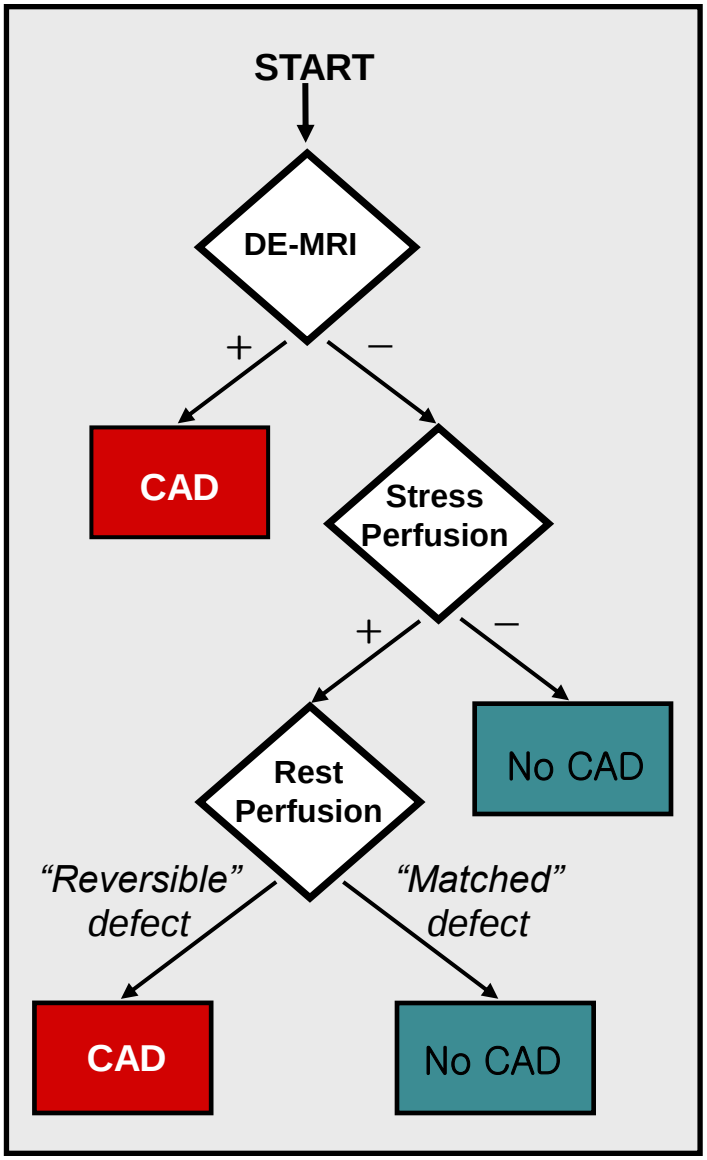




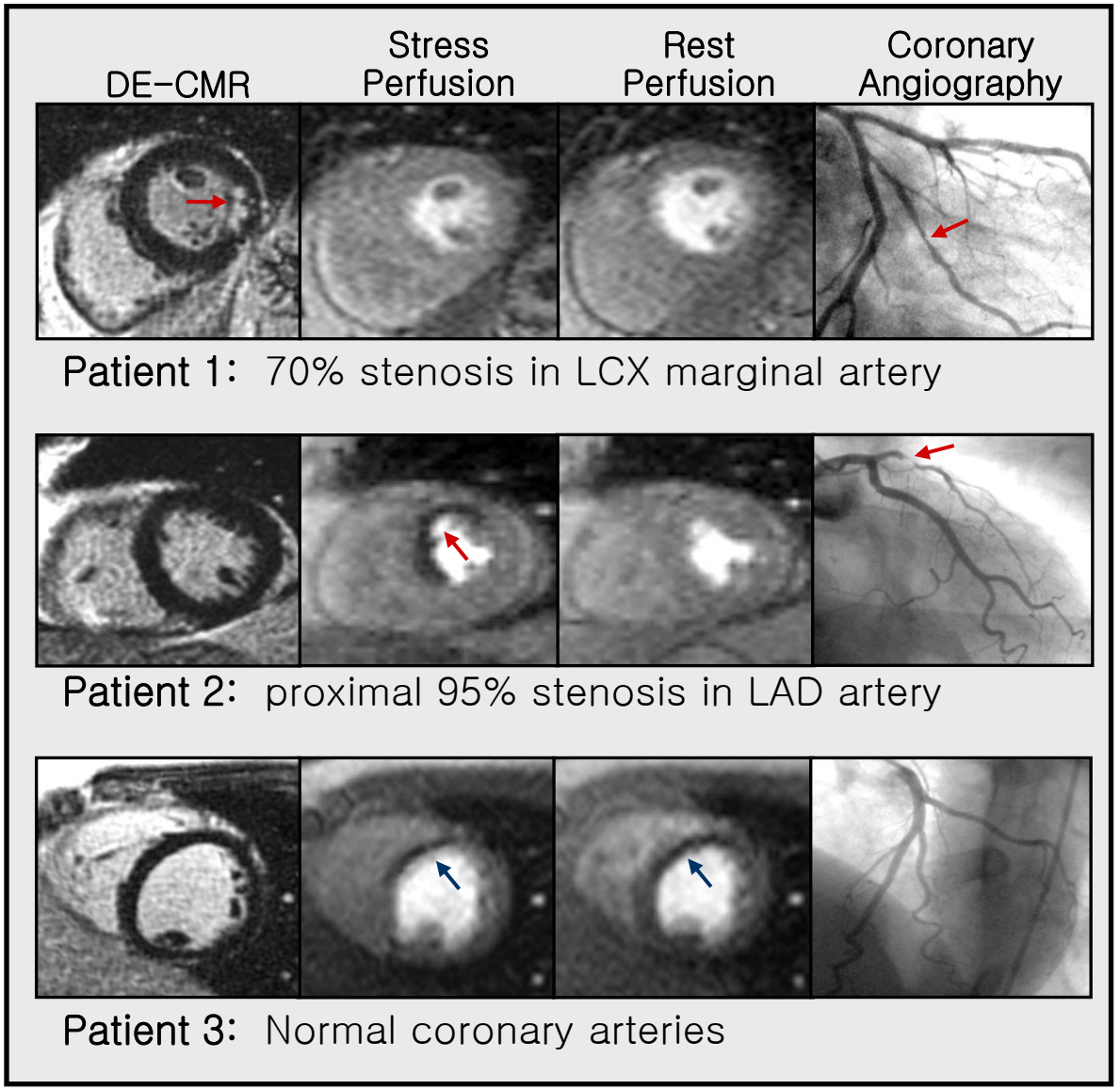
Scanning protocol and Interpretation of CMR

- Assessment of wall motion abnormality
- Adenosine Stress Perfusion image
- Viability image (visualization of dead tissue)

a. Interpretation Algorithm



b. Examples



European Heart Journal (2008) **29**, 480–489
doi:10.1093/eurheartj/ehm617

CLINICAL RESEARCH
Imaging

MR-IMPACT: comparison of perfusion-cardiac magnetic resonance with single-photon emission computed tomography for the detection of coronary artery disease in a multicentre, multivendor, randomized trial

Juerg Schwitter[1]*, Christian M. Wacker[2], Albert C. van Rossum[3], Massimo Lombardi[4], Nidal Al-Saadi[5], Hakan Ahlstrom[6], Thorsten Dill[7], Henrik B.W. Larsson[8], Scott D. Flamm[9], Moritz Marquardt[10], and Lars Johansson[6]

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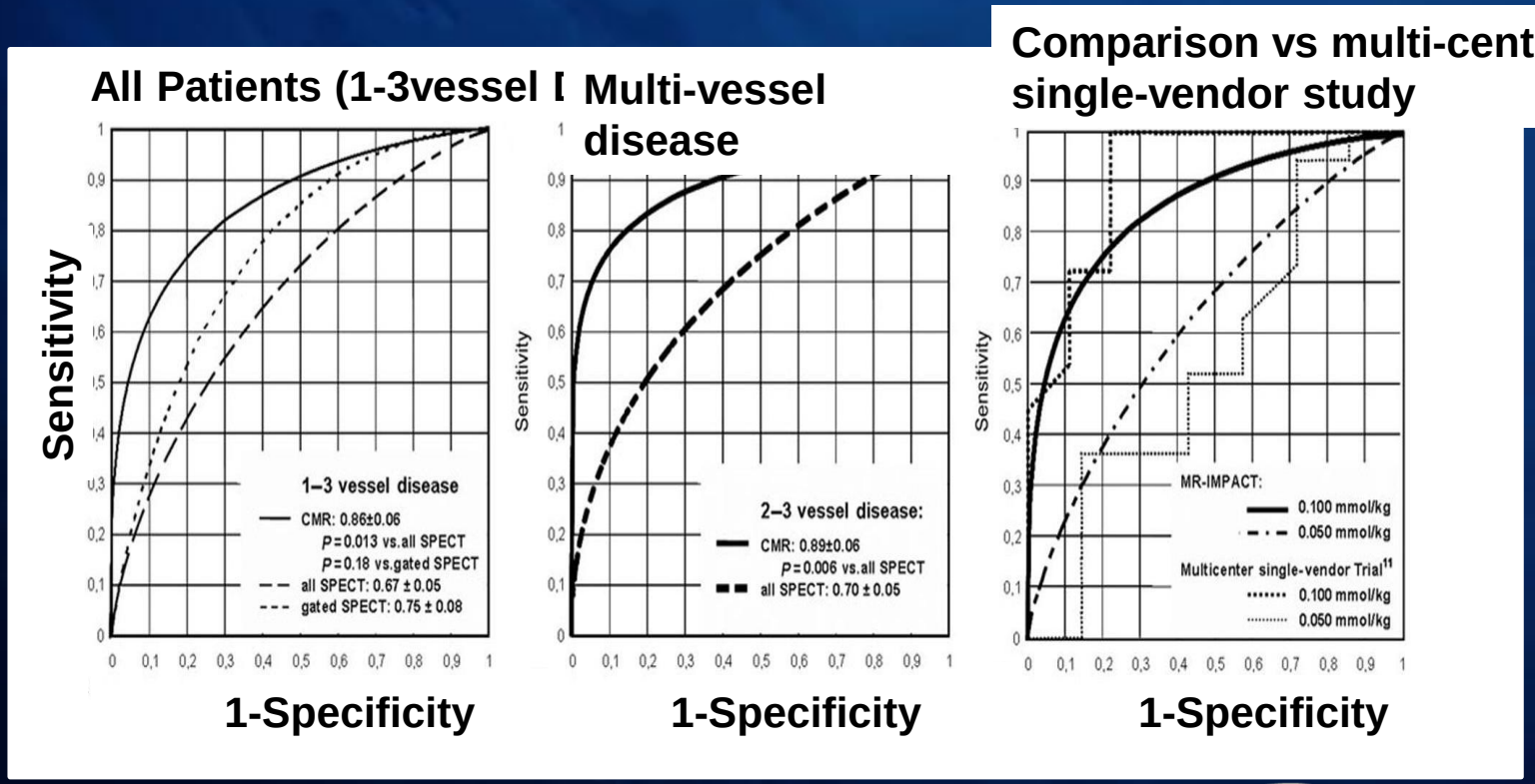
Received 22 April 2007; revised 11 November 2007; accepted 13 December 2007; Online publish-ahead-of-print 21 January 2008

MR-IMPACT

- 18-center multivendor study
- N = 234
- Comparison of Perfusion MR with SPECT and CAG



Schwitter, EHJ 2008

Cardiovascular magnetic resonance and single-photon emission computed tomography for diagnosis of coronary heart disease (CE-MARC): a prospective trial

John P Greenwood, Neil Maredia, John F Younger, Julia M Brown, Jane Nixon, Colin C Everett, Petra Bijsterveld, John P Ridgway, Aleksandra Radjenovic, Catherine J Dickinson, Stephen G Ball, Sven Plein

Summary

Background In patients with suspected coronary heart disease, single-photon emission computed tomography (SPECT) is the most widely used test for the assessment of myocardial ischaemia, but its diagnostic accuracy is reported to be variable and it exposes patients to ionising radiation. The aim of this study was to establish the diagnostic accuracy of a multiparametric cardiovascular magnetic resonance (CMR) protocol with x-ray coronary angiography as the reference standard, and to compare CMR with SPECT, in patients with suspected coronary heart disease.

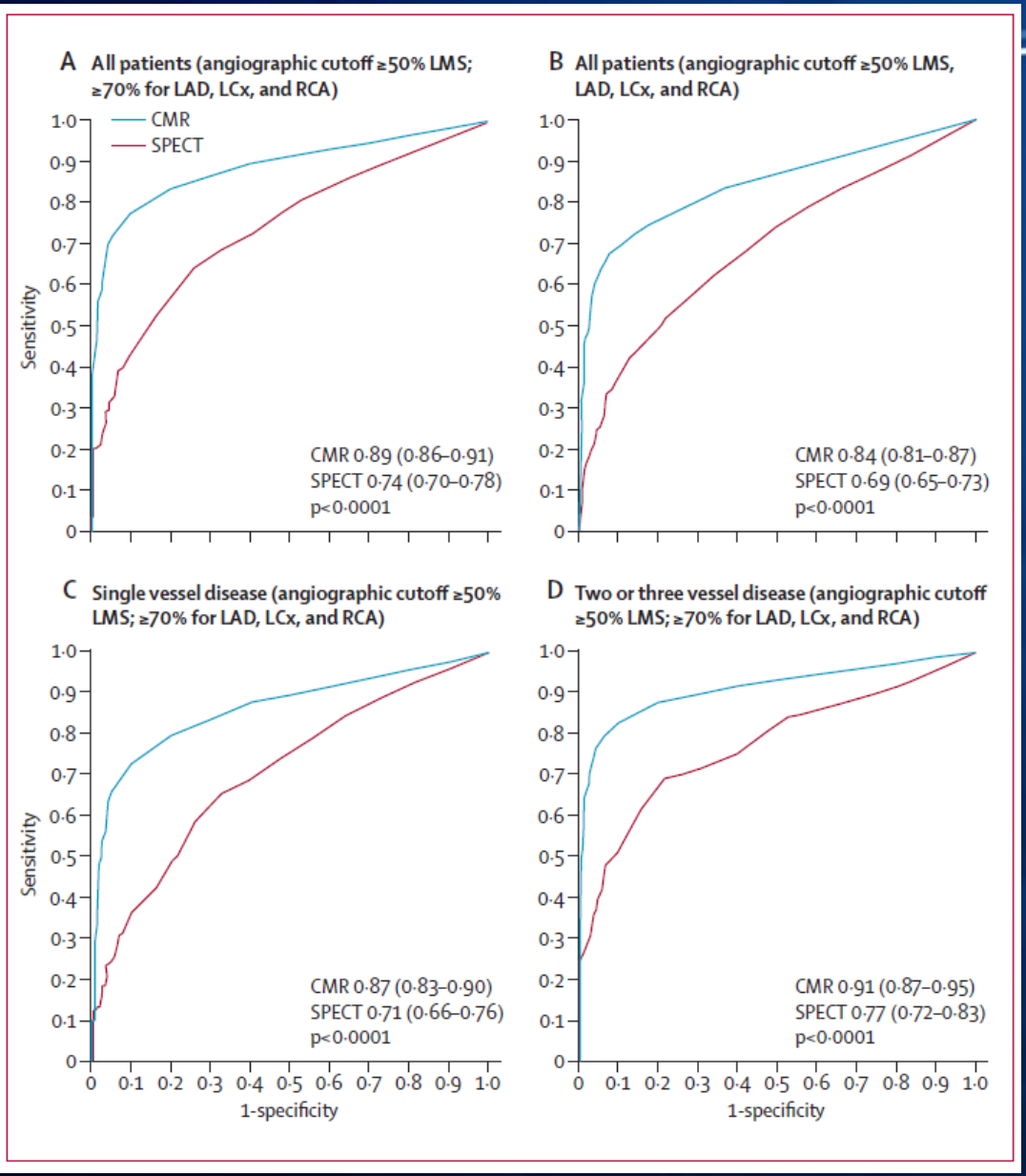
Methods In this prospective trial patients with suspected angina pectoris and at least one cardiovascular risk factor

Lancet 2012; 379: 453–60

Published Online December 23, 2011 DOI:10.1016/S0140-6736(11)61335-4

See Comment page 393

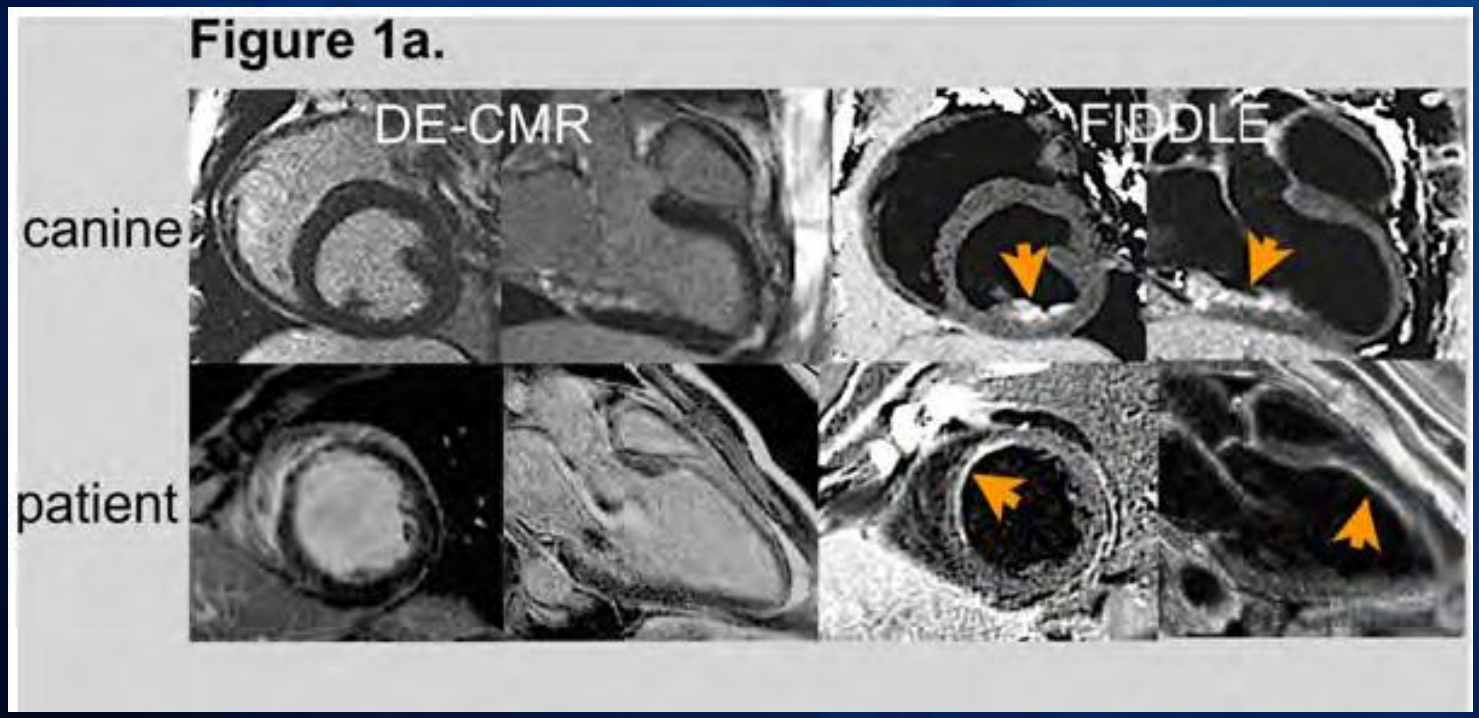
Multidisciplinary Cardiovascular Research Centre and Leeds Institute of Genetics, Health



Lancet 2012; 379: 453–60

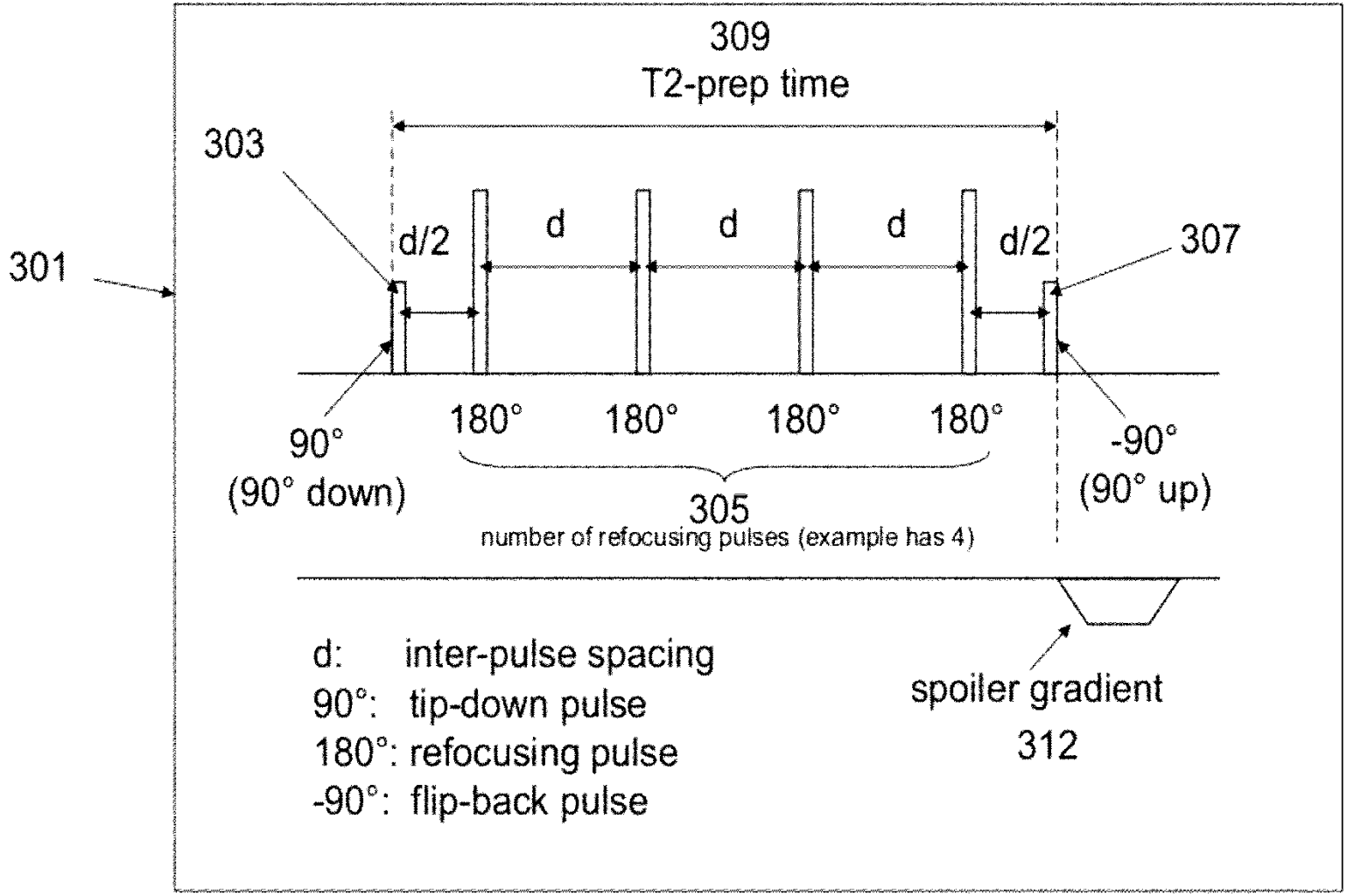
SAMSUNG MEDICAL CENTER

Flow-**I**ndependent **D**ark-blood **DeL**ayed **E**nhancement technique (FIDDLE)

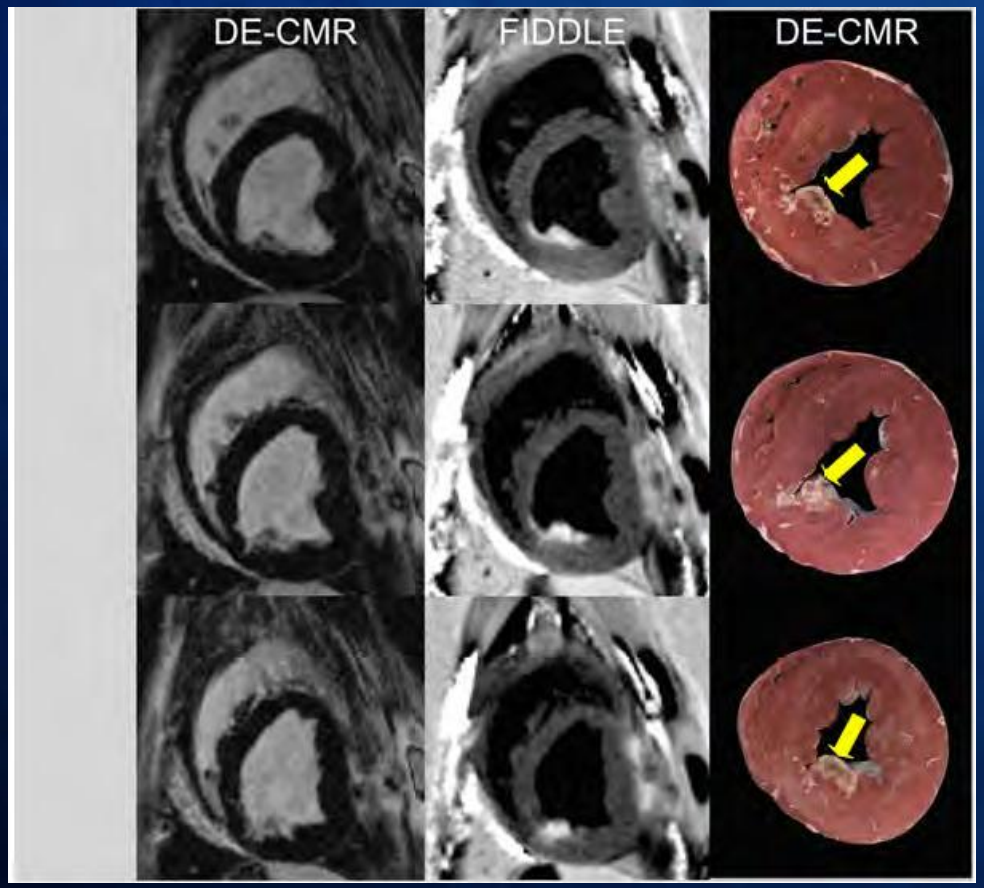


SCMR 2016 presented, from DCMRC

Figure 3



Flow-**I**ndependent **D**ark-blood **D**e**L**ayed **E**nhancement technique (FIDDLE)



SCMR 2016 presented, from DCMRC

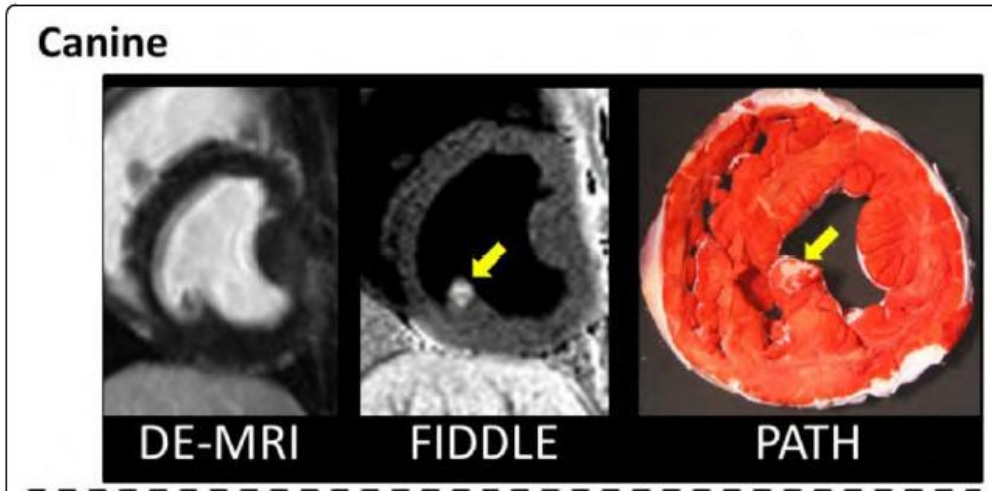


Figure 1(abstract Q6) DE-MRI (left), FIDDLE (center), and TTC (right) showing myocardial infarction of only the inferior paillary muscle (arrows). Bottom: patient example of left circumflex coronary artery infarction showng subendocardial hyperenhancement and papillary infarction

SCMR 2016 presented, from DCMRC

Table 1(abstract O55) Diagnostic Performance in Canines.

	Sensitivity	Specificity	Accuracy
Overall			
FIDDLE	97% (95/98)	92% (35/38)	96% (130/136)
DE-CMR	81% (79/98)	95% (36/38)	85% (115/136)
p-value	< 0.001	0.65	0.001
Subendocardial MI (transmurality < 25%)			
FIDDLE	98% (44/45)	92% (35/38)	95% (79/83)
DE-CMR	71% (32/45)	95% (36/38)	82% (68/83)
p-value	< 0.001	0.65	0.008

- CMR is the only cardiac imaging to visualize the viable and non-viable myocardium.
- Resolution of CMR stress imaging and viability imaging is better than nuclear imaging.
- CMR is not a single image - interpretation of CMR is more integrated and summation of multiple imaging technique.
- Viability imaging in CMR is progressing.