Cardiac MR perfusion

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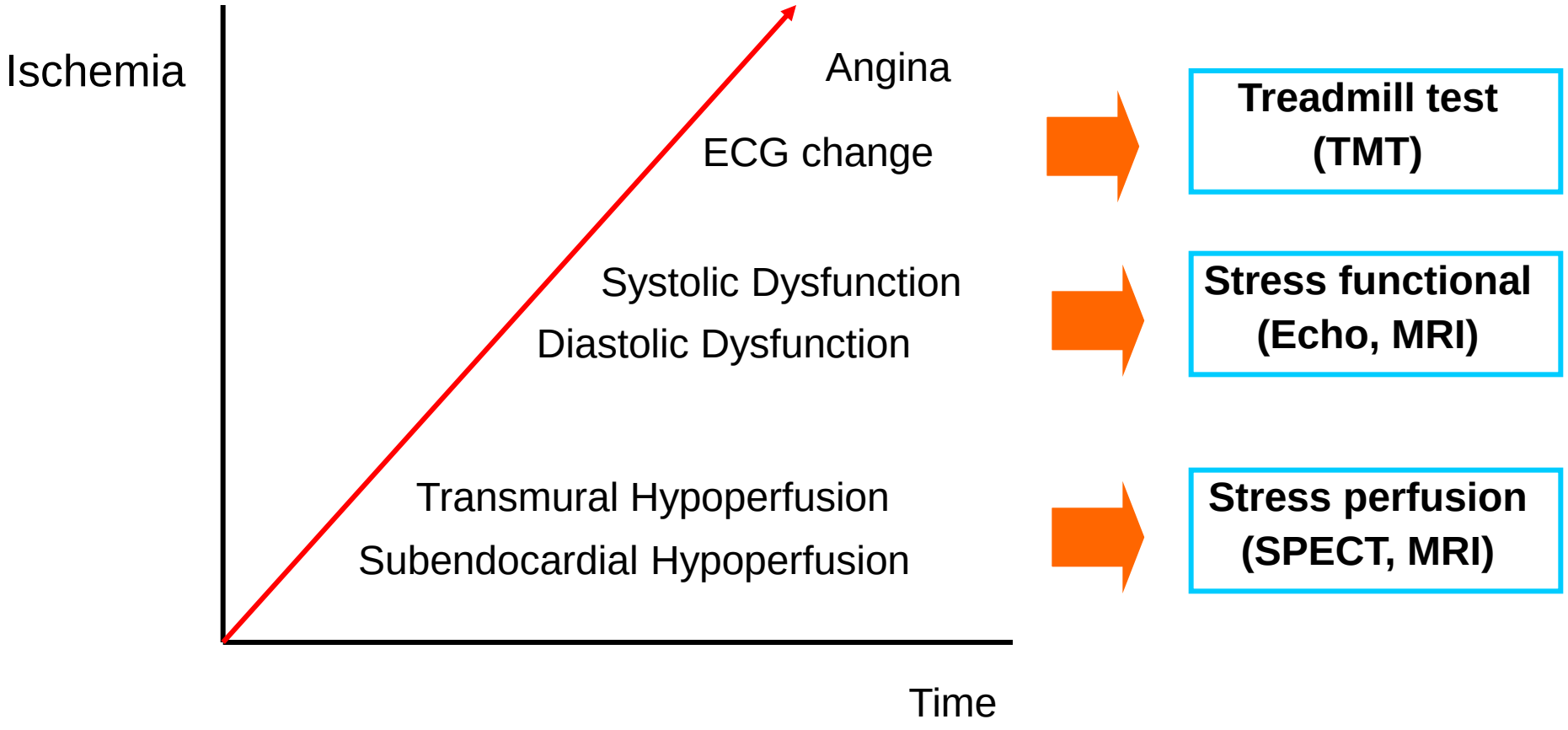
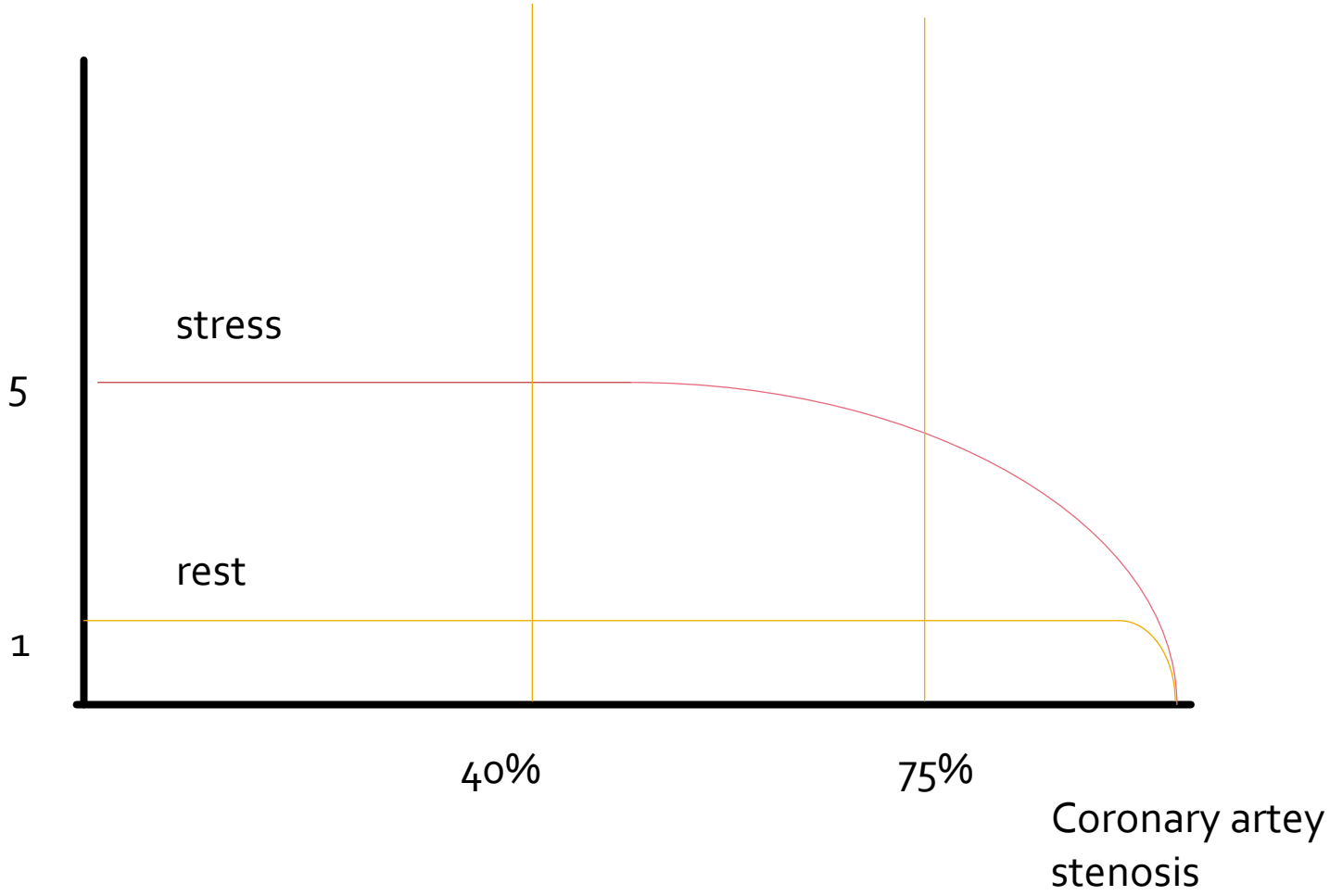
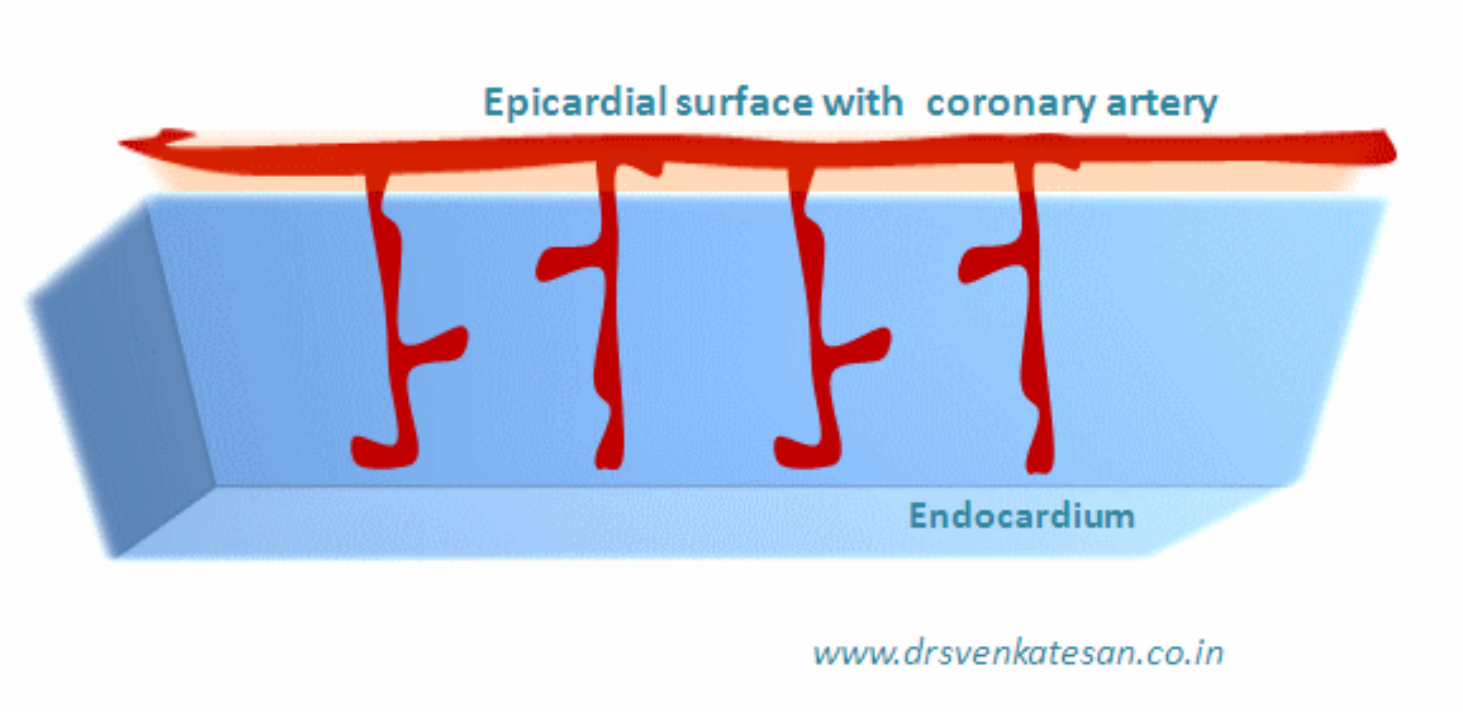
- Introduction
- Contrast and stress agents injection protocol
- MR protocol
- Dark rim artifact
- Functional analysis

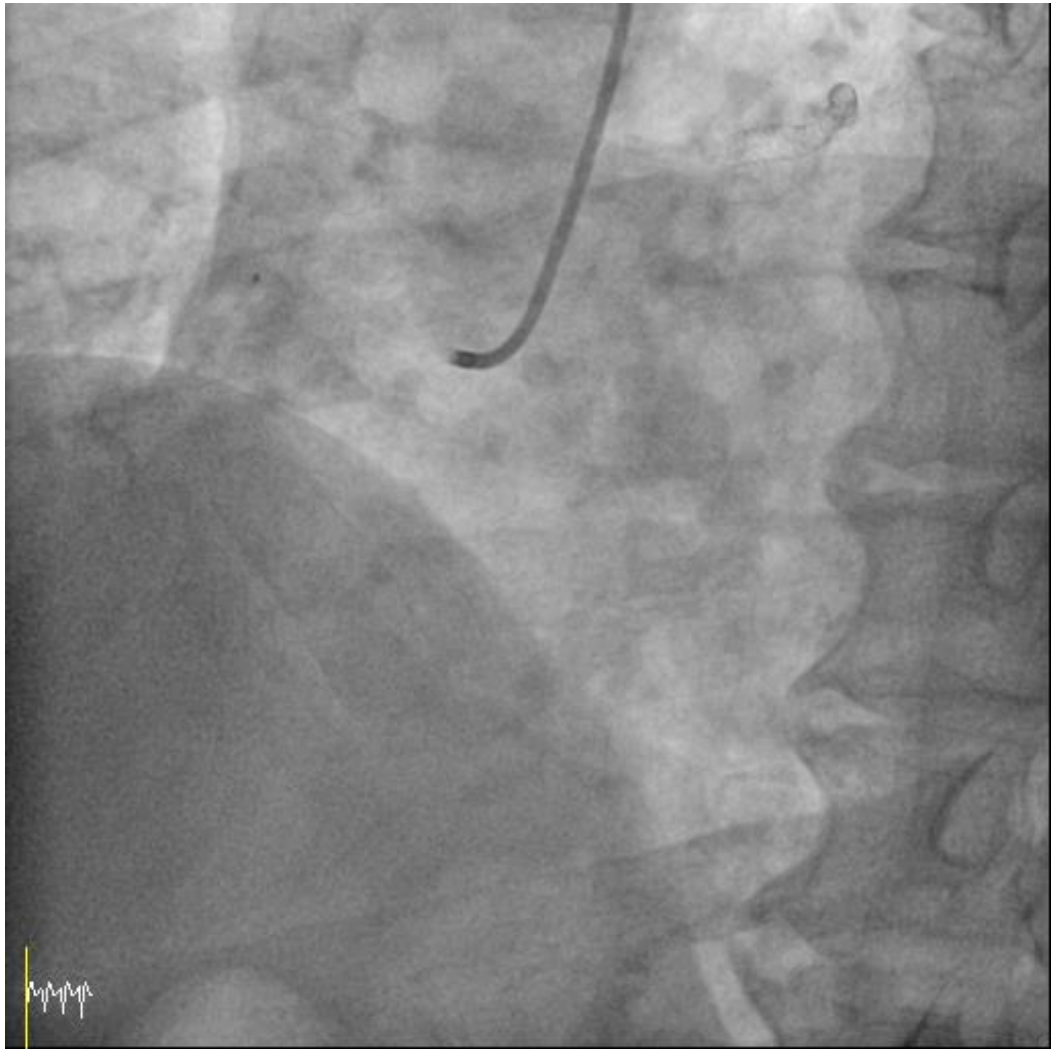
Ischemic Cascade

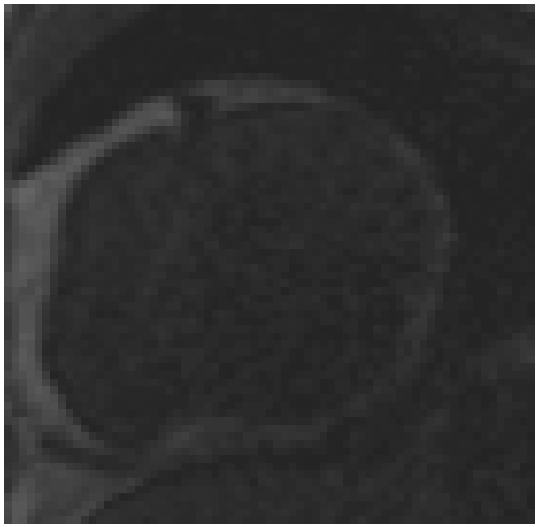


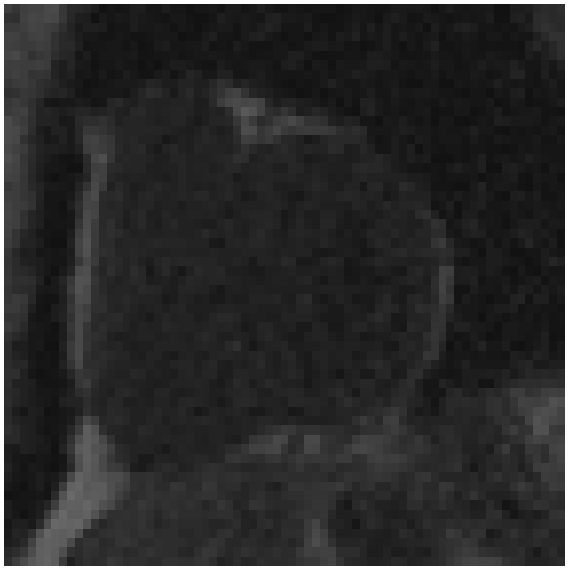

stress
5
rest
1
40%
75%
Coronary artey stenosis


Epicardial surface with coronary artery
Endocardium
www.drsvenkatesan.co.in

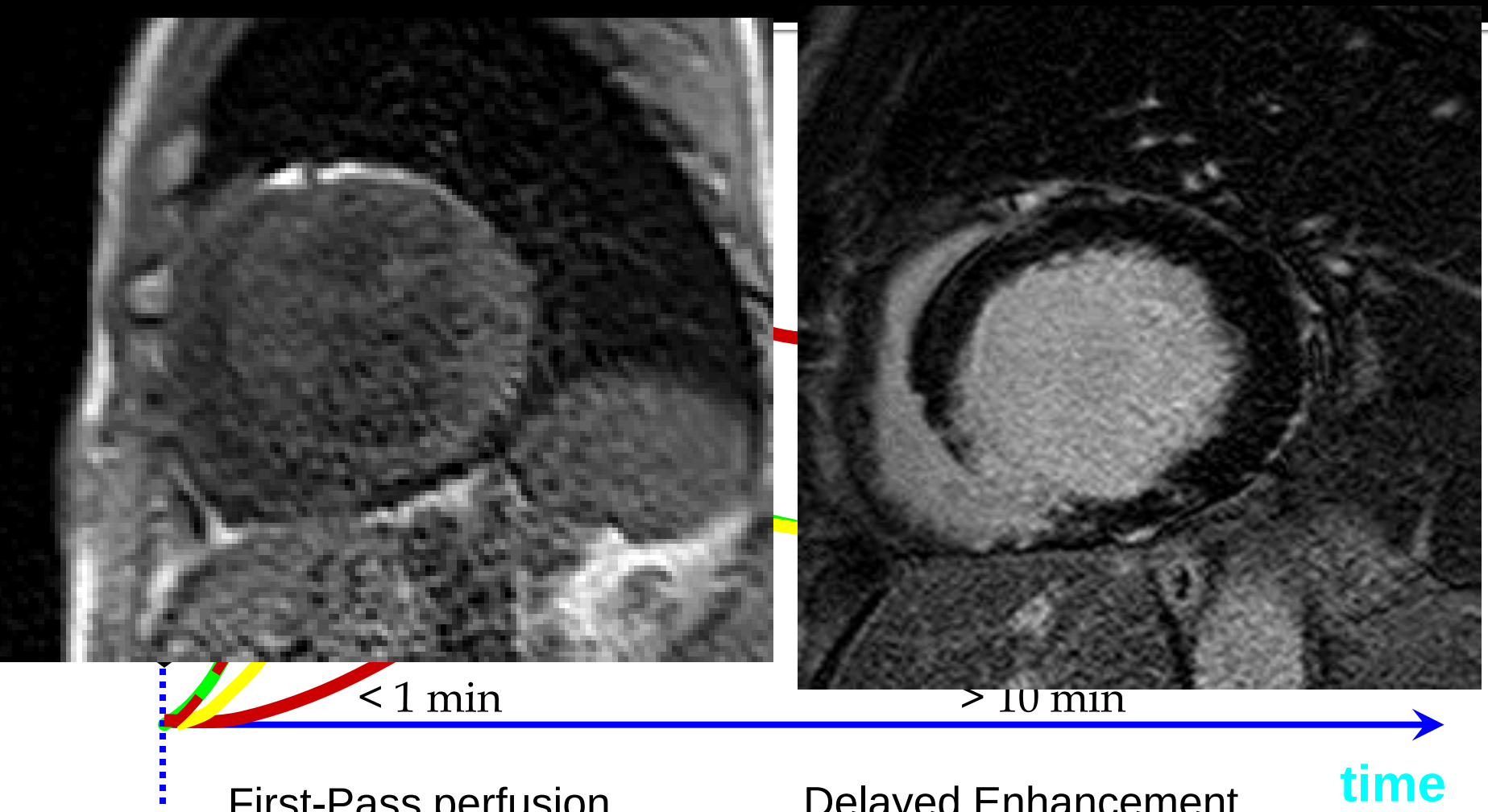
Severe stenosis in proximal RCA







Time Intensity Curve



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], ansson[6]

European Heart Journal (2013) 34, 775–781
doi:10.1093/eurheartj/ehs022

CLINICAL RESEARCH
Imaging

MR-IMPACT II: Magnetic Resonance Imaging for Myocardial Perfusion Assessment in Coronary artery disease Trial: perfusion-cardiac magnetic resonance vs. single-photon emission computed tomography for the detection of coronary artery disease: a comparative multicentre, multivendor trial

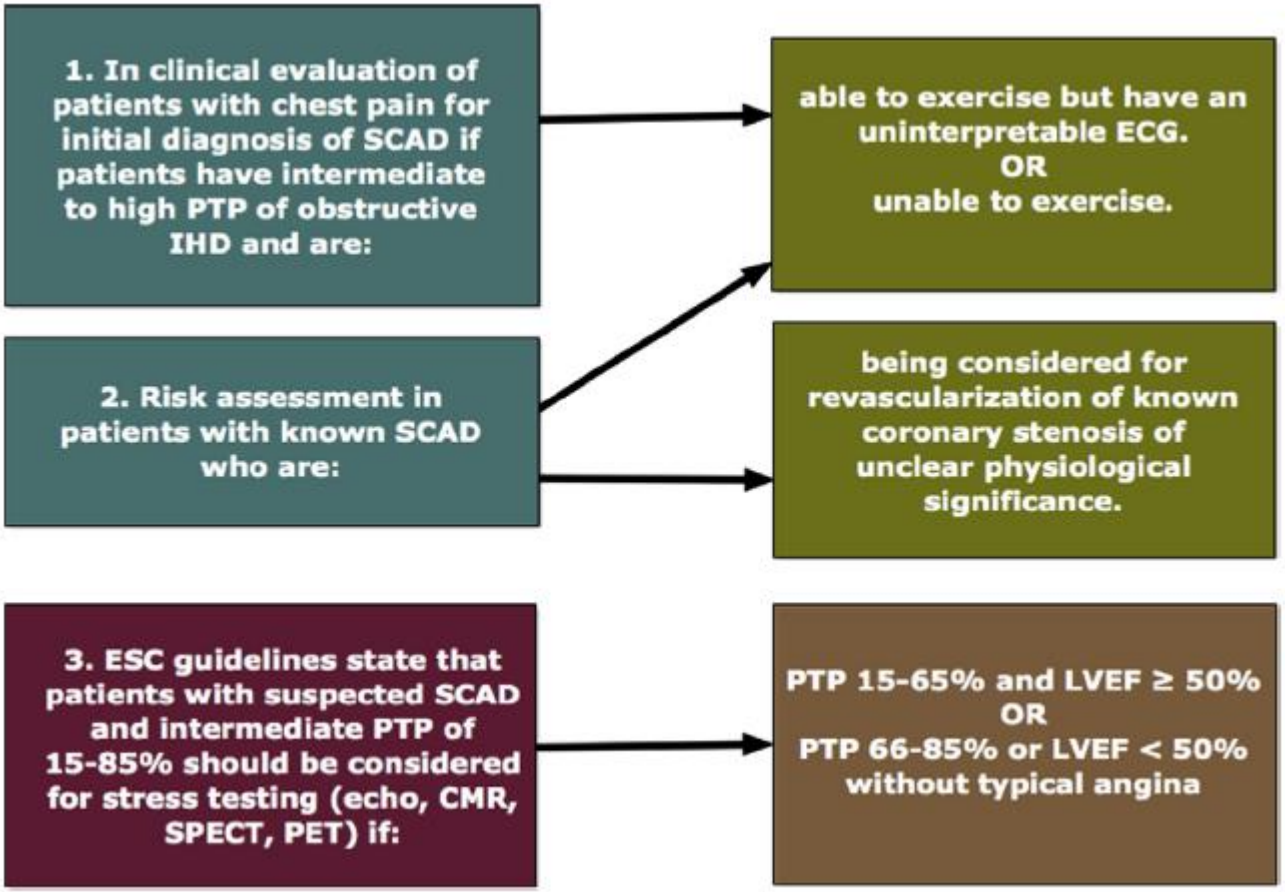
Juerg Schwitter[1]*, Christian M. Wacker[2], Norbert Wilke[3], Nidal Al-Saadi[4], Ekkehart Sauer[5], Kalman Huettle[6], Stefan O. Schönberg[7], Andreas Luchner[8], Oliver Strohm[9], Hakan Ahlstrom[10], Thorsten Dill[11], Nadja Hoebel[12], and Tamas Simor[13], for the MR-IMPACT Investigators

MR-IMPACT II
eart Journal (2008) 29, 480–489
MR-IMPACT II
Heart Journal (2013) 34, 775–781

Diagnostic Performance

Author and Year	No	Criterion for Significant CAD	Stress Agent	Sensitivity	Specificity
Thomas et al, 2008	60	Stenosis > 50%	Adenosine	0.93	0.84
Burgstahler et al, 2008	23	Stenosis > 70%	Adenosine	1.0	0.80
Arnold et al, 2010	65	Stenosis > 50%	Adenosine	0.90	0.81
Manka et al, 2010	41	Stenosis > 50%	Adenosine	0.92	0.75
Lockie et al, 2011	42	Fractional flow reserve < 0.75	Adenosine	0.82	0.94
Schwitter et al, 2008	225	Stenosis > 50%	Adenosine	0.85	0.67
Merkle et al, 2007	228	Stenosis > 50%	Adenosine	0.96	0.72

When do you perform stress MR in IHD?

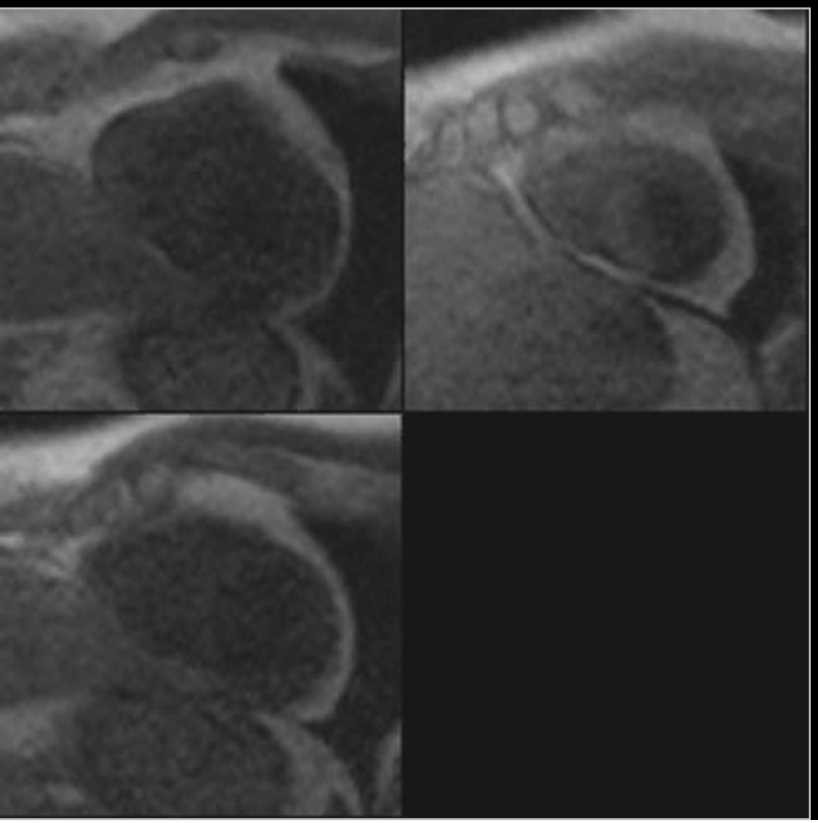


2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guidelines

2013 ESC guidelines

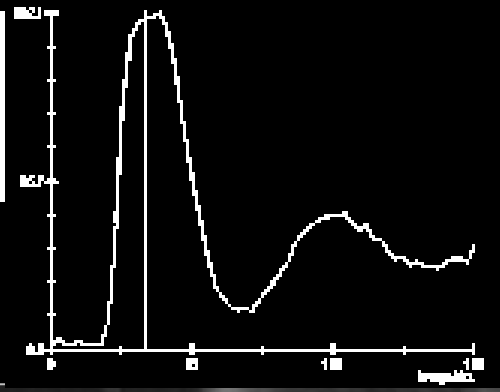
Contrast Agents and Injection Scheme

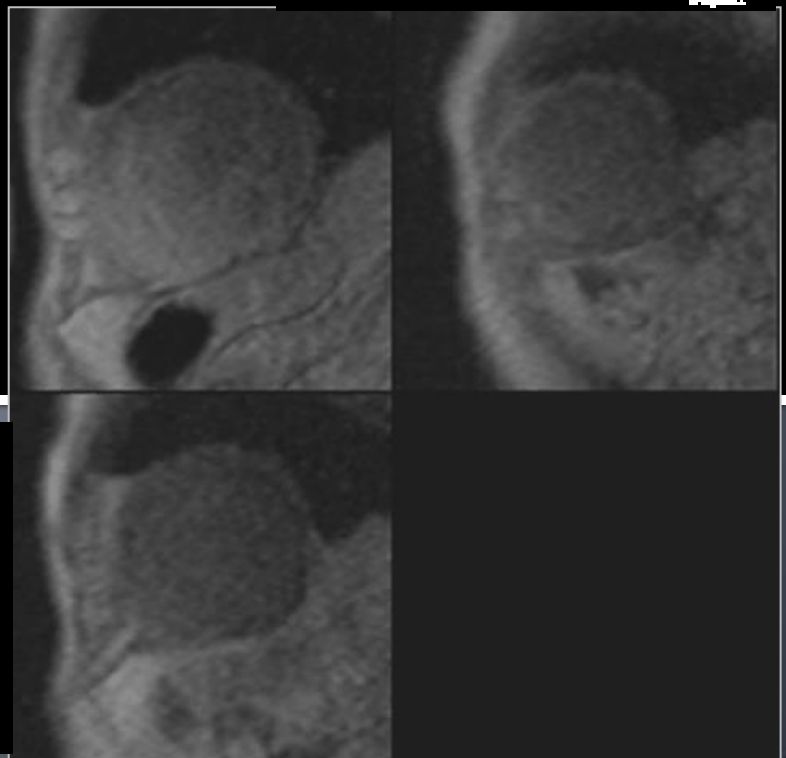
- Bolus with a dosage of 0.05 mmol/kg bw of an extra cellular Gd-based contrast agent
- 4 ml/s is used
- The bolus is followed by a 20 ml saline flush using the same injection rate to facilitate a compact bolus passage
- We recommend the use of an automatic infusion system
- Two 18 gauge venflons for separate administration of the stress agent and contrast agent



Good Bolus:

- Mean Curve ROI in LV
- Peaks in 5-10 sec
- Recirculation

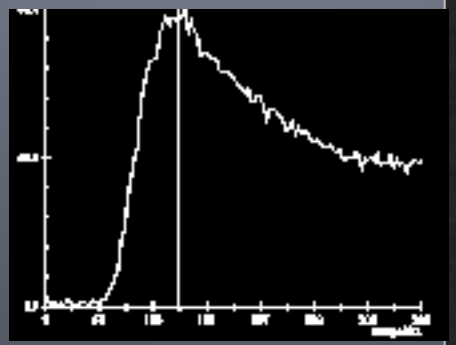




Bad Bolus:

Mean Curve ROI in LV

- Peaks in 20-30 sec
- No recirculation



Stress type

- Exercise vs pharmacologic agent
- Pharmacological stress will be more easily
- Myocardial blood flow will increase 4 times to 5 times downstream of normal coronary arteries
- not increase downstream of stenosed arteries because the related arteriolar beds have already vasodilated maximally

Stress type (exercise)

- Physical stress may not be feasible within the MRI environment

Stress agents

- Dipyridamole
  - Indirect vasodilator through its inhibition of adenosine reuptake, which increases endogenous adenosine
- Adenosine
  - a nonselective vasodilator that activates adenosine A1 receptors.
  - also activates adenosine A3 receptors, which causes bronchospasm

Stress agents

- Regadenoson
  - a newly approved vasodilator that selectively activates the adenosine A2 receptors
  - because of its selectivity and ease of use, regadenoson is increasingly being used
  - Rapid injection by 0.4mg/5mL for all weight

Adenosine

- Short half life (<10 secs)
- Better patient tolerence
- Side effects of Adenosine
  - Mild decrease in systemic blood pressure
  - Mild increase in heart rate
  - Increase respiratory rate
  - Headache
  - Dizziness
  - Shortness of breath
  - Nausea
  - flushing

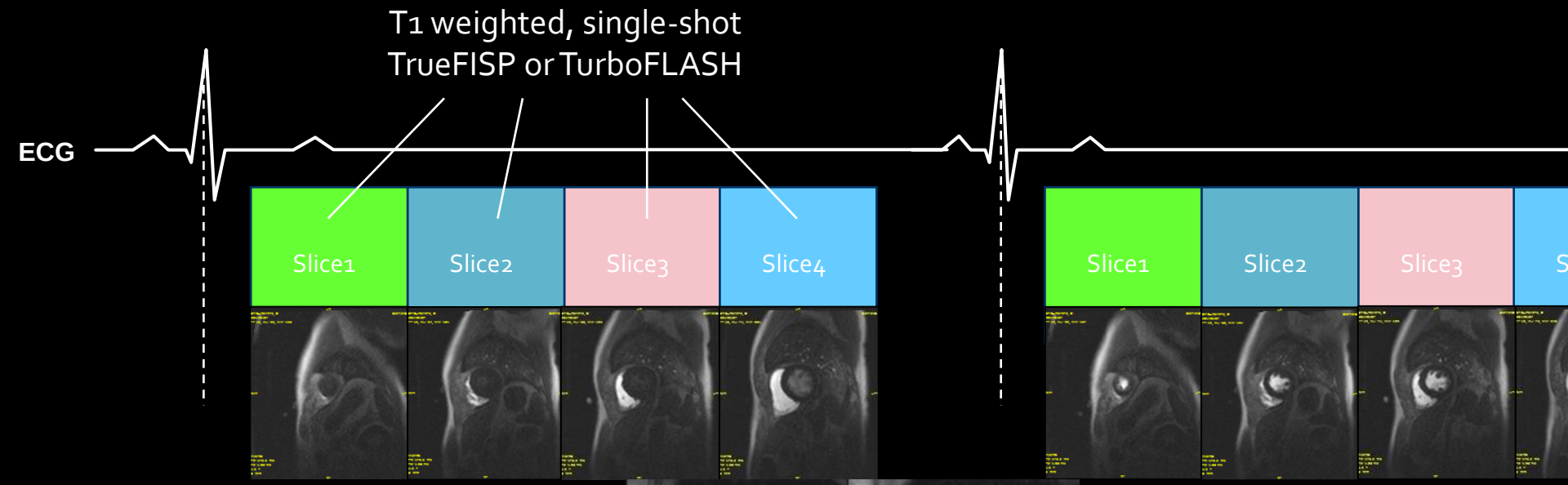
Contraindications of Adenosine

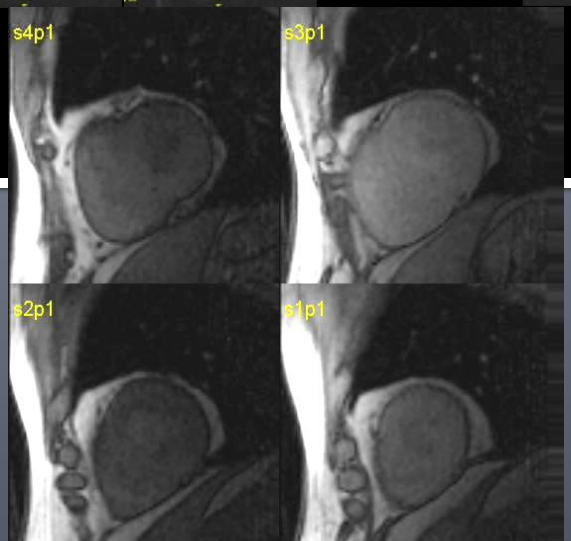
- Acute Myocardial infarction within few days
- Asthma
- Second- or third-degree atrio-ventricular block
- Sick sinus syndrome
- Symptomatic bradycardia

Patient Preparation for Adenosine Stress MRI Exam.

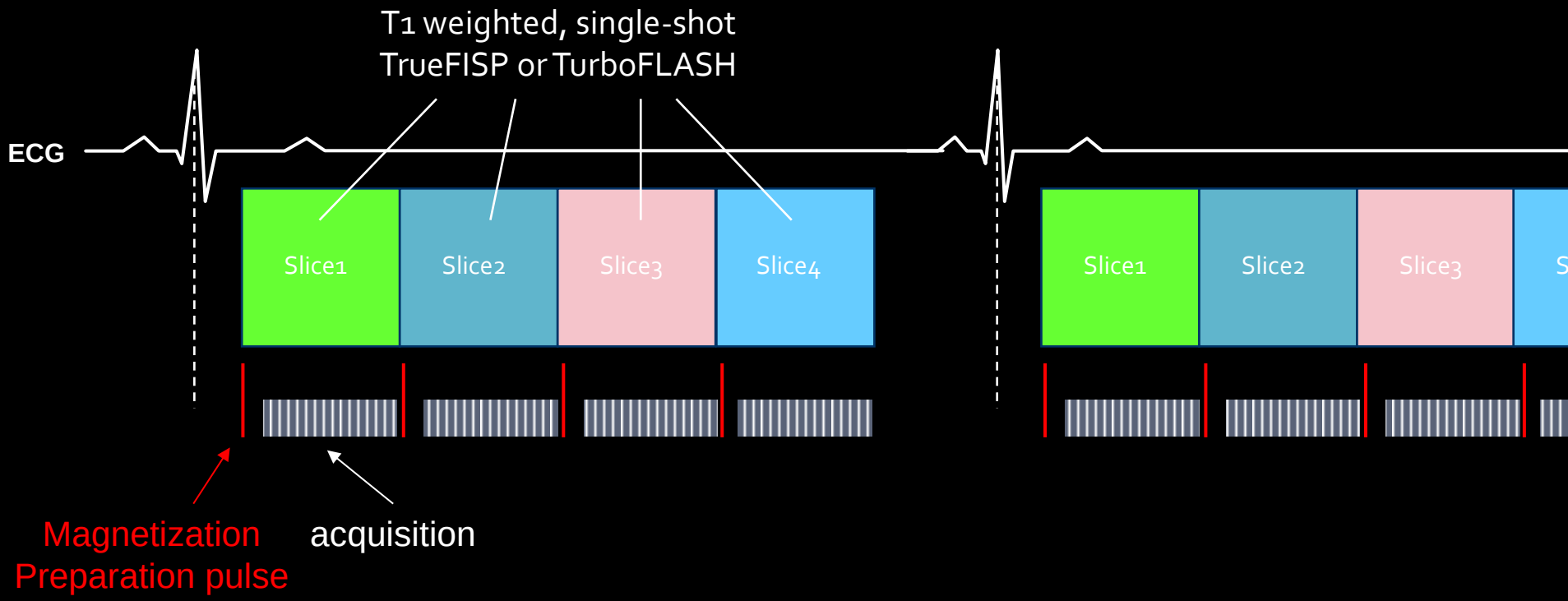
- Refrain from caffeinated food and drink for 24 hours
  - Such as coffee, tea, coke and chocolate
    - Adenosine antagonist
    - Interfere with the ability of Adenosine to dilate arteries
    - False negative examination result
    - Adenosine at 140μg/kg/min intravenously for at least 3 mins

MR Cardiac Perfusion Sequence
ECG-gated single shot imaging



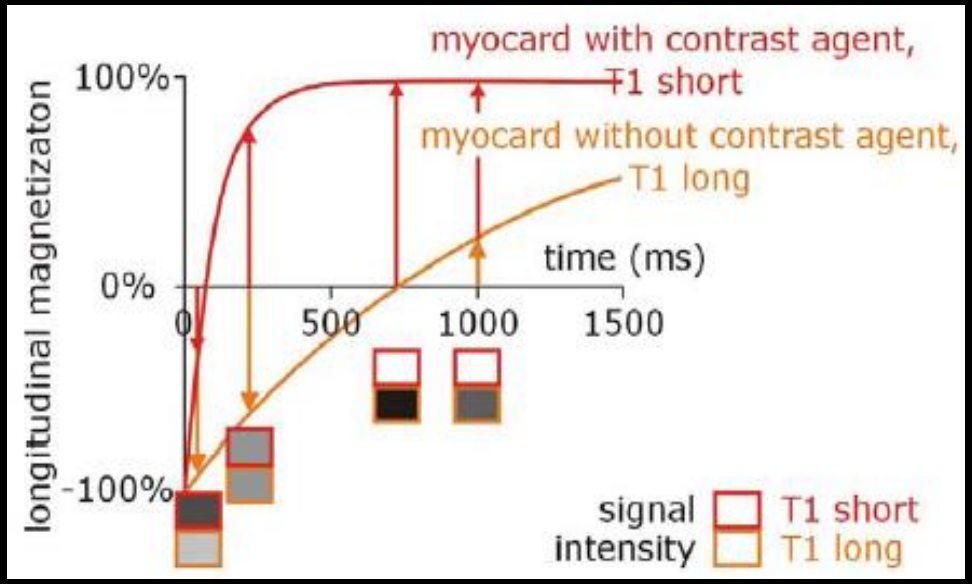


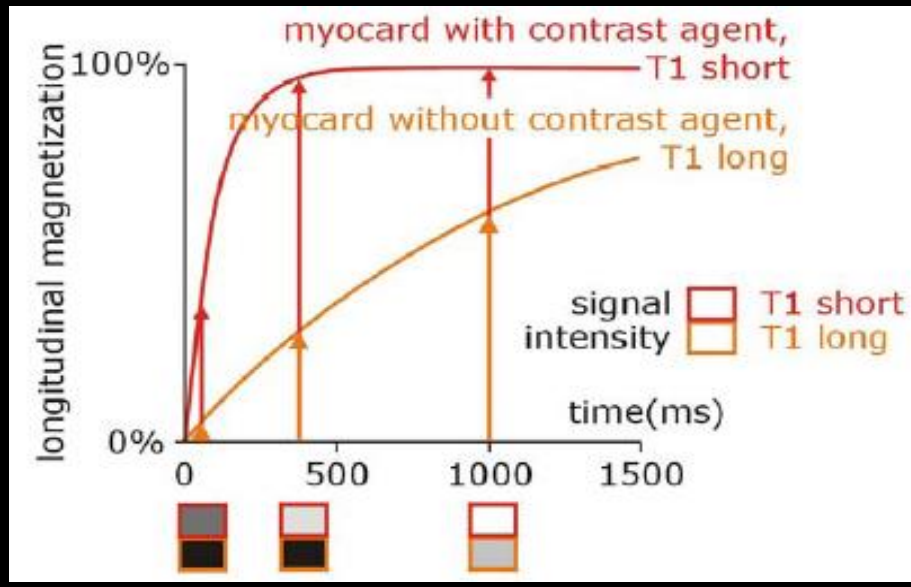
MR Cardiac Perfusion Sequence
Preparation Pulse for T1 contrast



To achieve suitable **T1 contrast** in gradient echo single shot techniques **preparatory pulse** must be used.

MR Cardiac Perfusion Sequence
Inversion Recovery Preparation Pulses





With 180⁰ Inversion Recovery pulse

+ Strong T1 contrast

- Multi-slice imaging difficult due to long waiting period

- Heart-rate dependent relaxation

(Sensitive to arrhythmia)

With 90⁰ saturation pulse

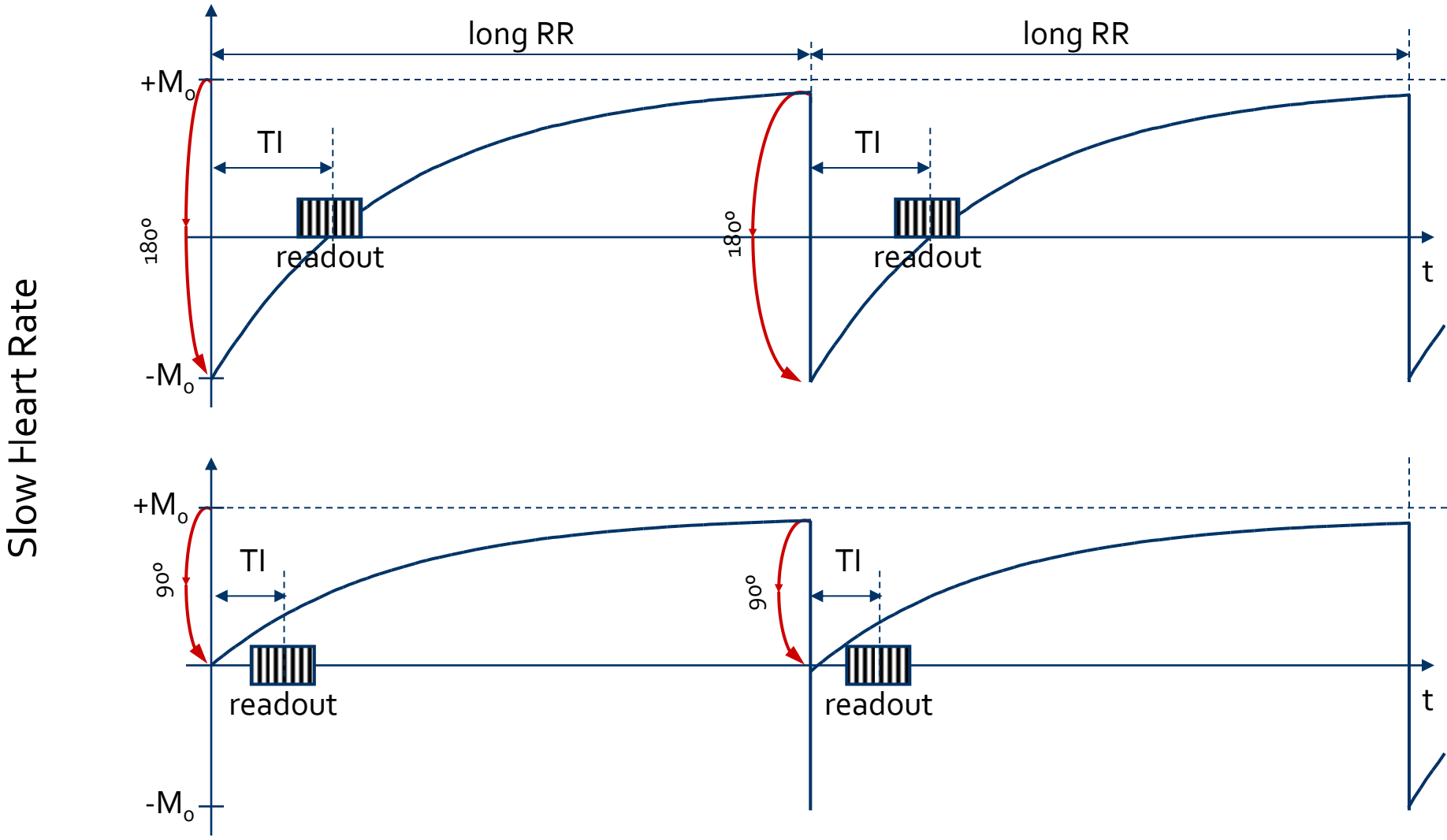
- Weak T1 contrast

+ Multi-slice capabilities

+ Heart rate independence

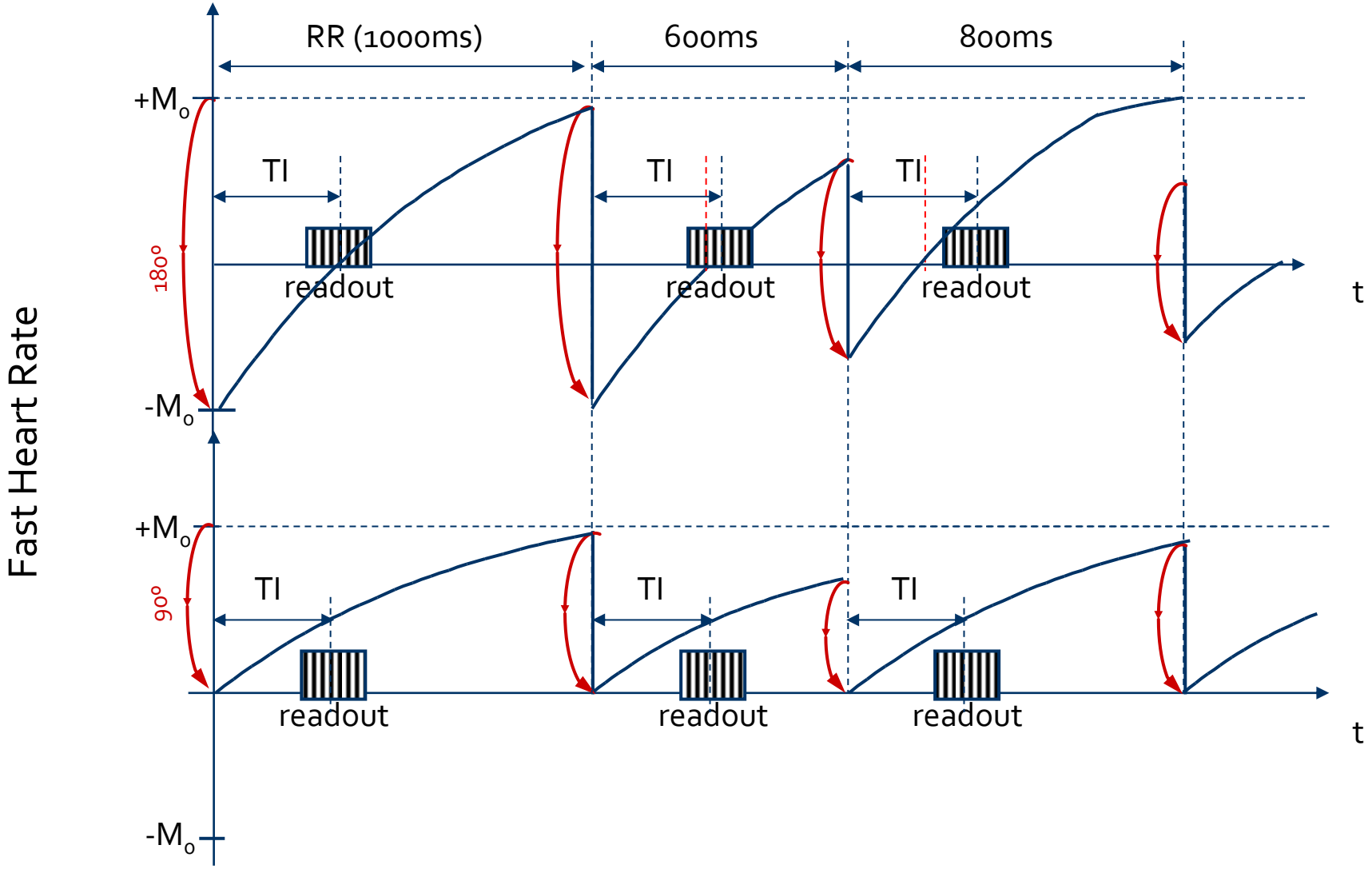
(Insensitive to arrhythmia)

MR Cardiac Perfusion Sequence
Preparation Pulse: 180° vs. 90°

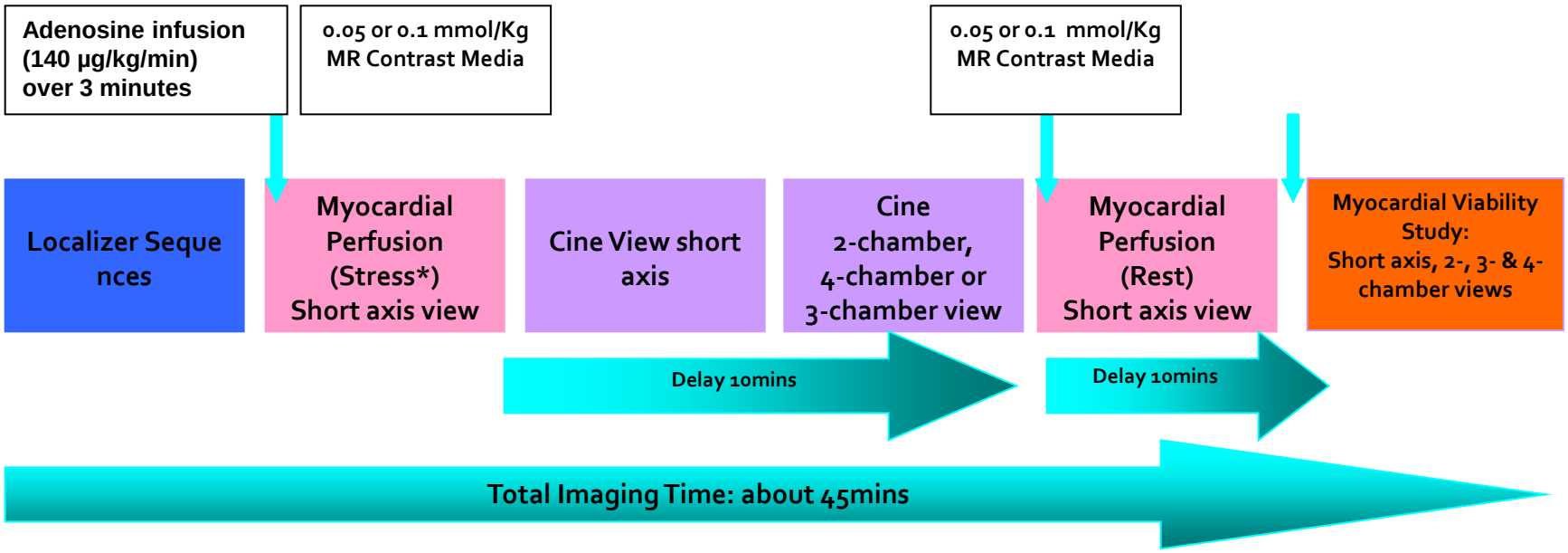


MR Cardiac Perfusion Sequence

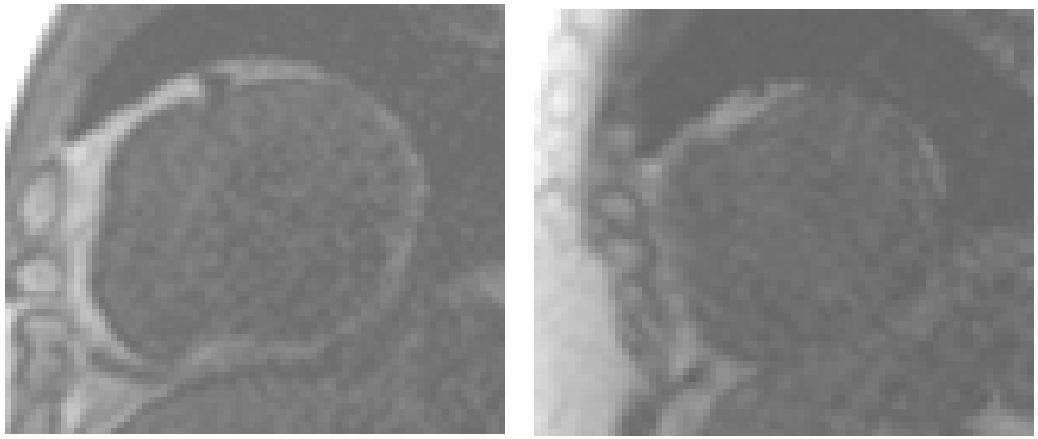
Preparation Pulse: 180° vs. 90°



Protocols Stress MRI Exam



Dark rim artifact vs true perfusion defect



Dark rim artifact

- 1. Gibbs Ringing at border dark-bright (low spatial resolution)
- 2. Direction of phase en-coding
- 3. Systolic motion (low temporal resolution)
- 4. Bo inhomogeneity

Analysis of MR Perfusion Studies

- ***Visual Analysis***
- ***Quantification***
  - Fullyquantification (absolute tissue perfusion)
    - Myocardial blood flow (MBF)
    - (Unit: ml/g/min) (requires mathematical modeling)
  - Semiquantification
    - stress induced change of upslope
    - Myocardial perfusion reserve (MPR)
    - Perfusion Index (stress upslope/rest upslope)
      - Under stress the slope should normally become steeper
      - The index should be > 1.5 to be considered normal

Quantification

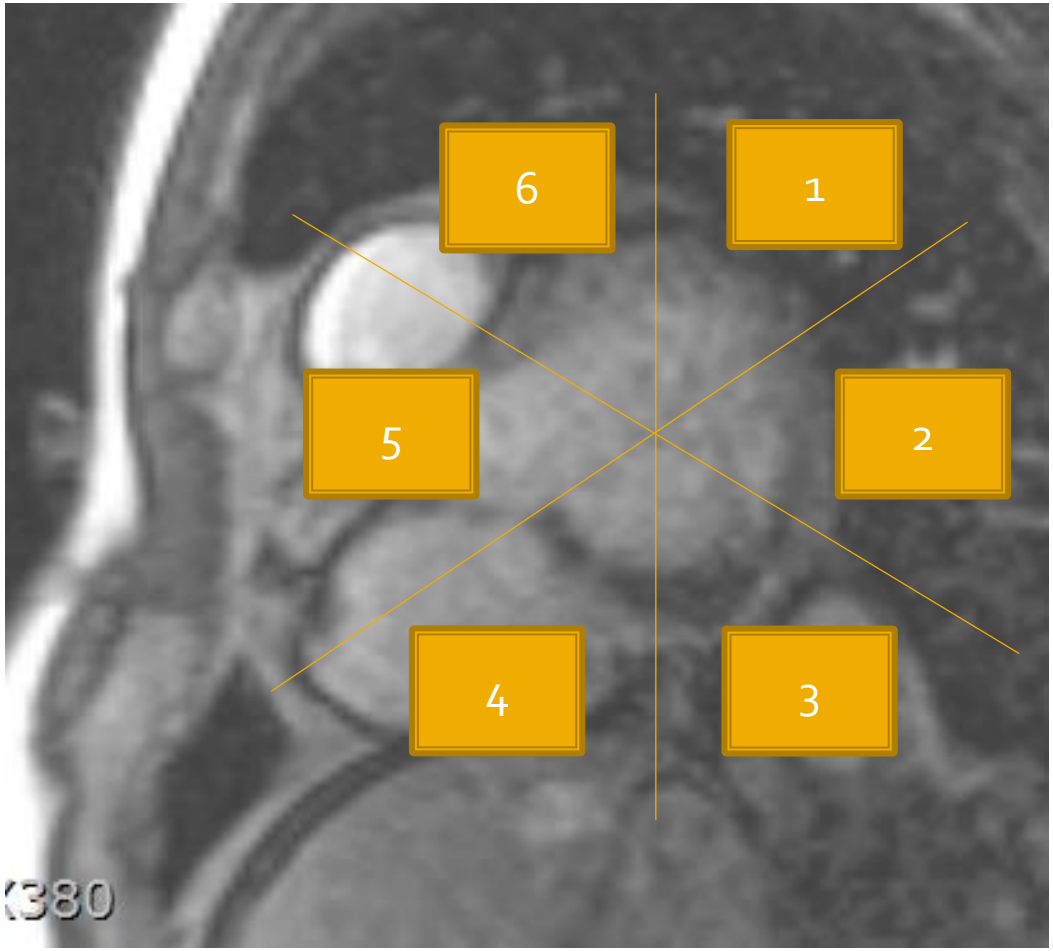
- Four established methods (tracer kinetic analysis methods)
  - Fermi-constrained deconvolution
  - model-independent deconvolution
  - a one-compartment model
  - an uptake model

Comparison of the Diagnostic Performance of Four Quantitative Myocardial Perfusion Estimation Methods Used in Cardiac MR Imaging: CE-MARC Substudy[1]

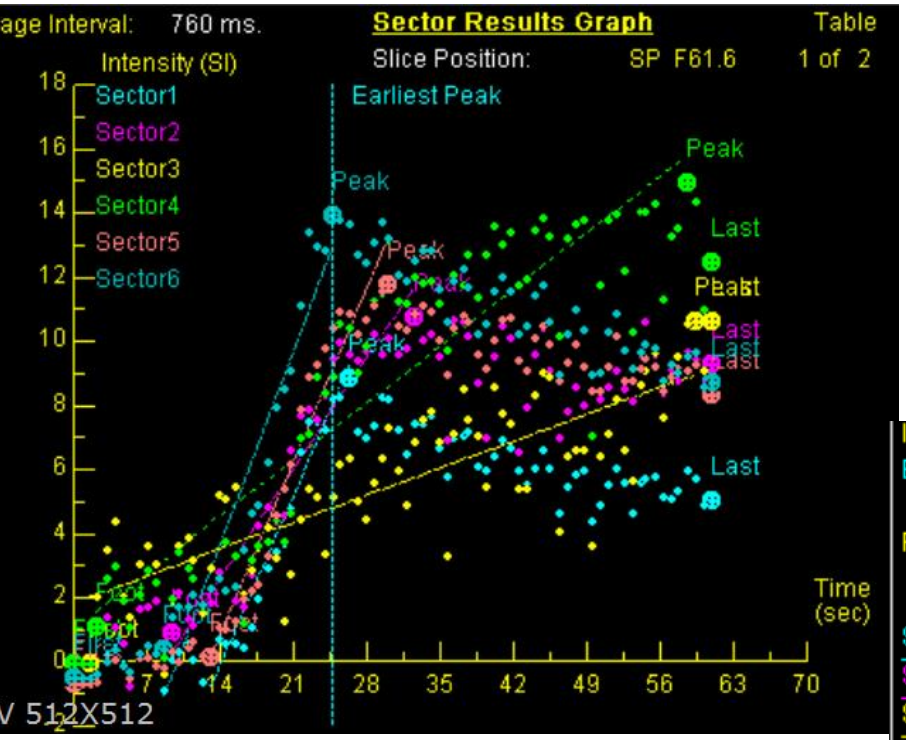
Conclusion : Diagnostic performance of quantitative myocardial perfusion estimates is not affected by the tracer kinetic analysis method used.

Radiology. 2014 Dec 18:140433. [Epub ahead of print]

Semiquantification



Sector analysis



- Time to peak
- Peak signal intensity
- Area under the curve from foot to earliest peak
- Slope (signal intensity per time)

Image Interval: 760 ms. **Sector Results Table** Table

Earliest Peak: 24.72 sec Slice Position: SP F61.6 1 of 1

Region	Foot Time sec	TTP sec	Peak Value SI	AUC Ft-Peak SI*sec	Slope SI/sec
Sector1	13.11	13.14	8.9	42.06	0.76
Sector2	9.29	23.13	10.7	62.78	0.49
Sector3	1.54	57.69	10.6	79.38	0.12
Sector4	2.13	56.33	15.0	99.45	0.25
Sector5	13.11	16.82	11.8	53.88	0.77
Sector6	8.51	16.21	13.9	95.67	0.87
InpRgn	13.11	5.36	50.4	---	10.12

Region analysis

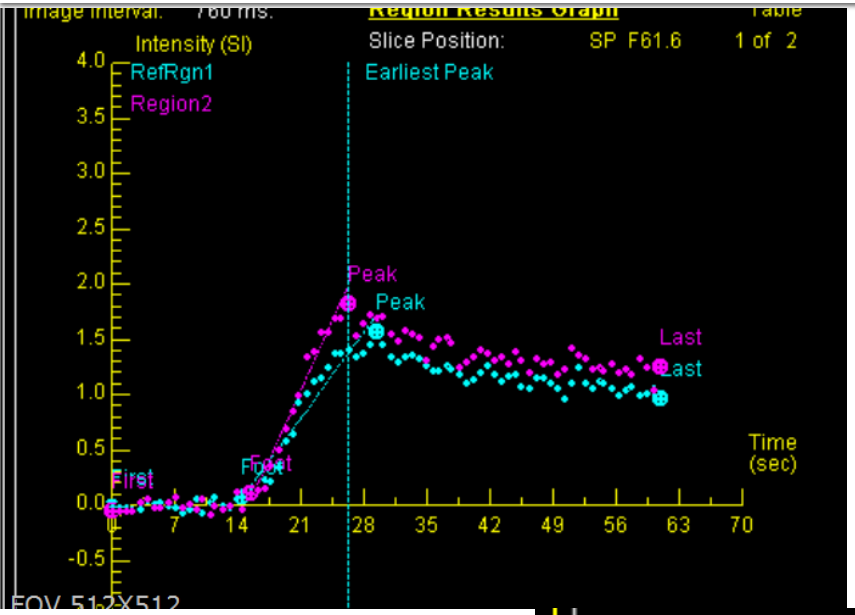
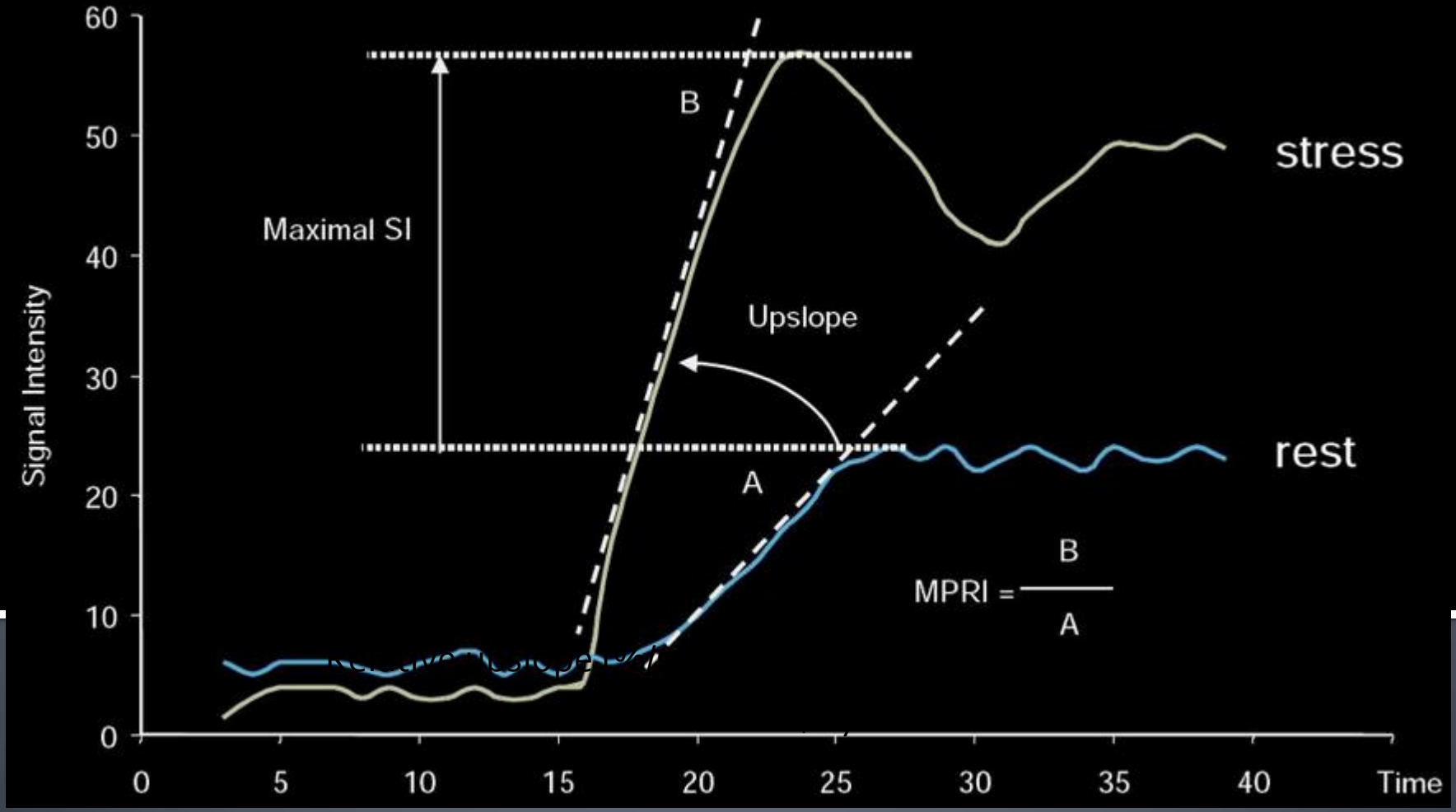


Image Interval:	760 ms.	Region Results Table		Table
Earliest Peak:	26.25 sec	Slice Position:	SP F61.6	1 of 1

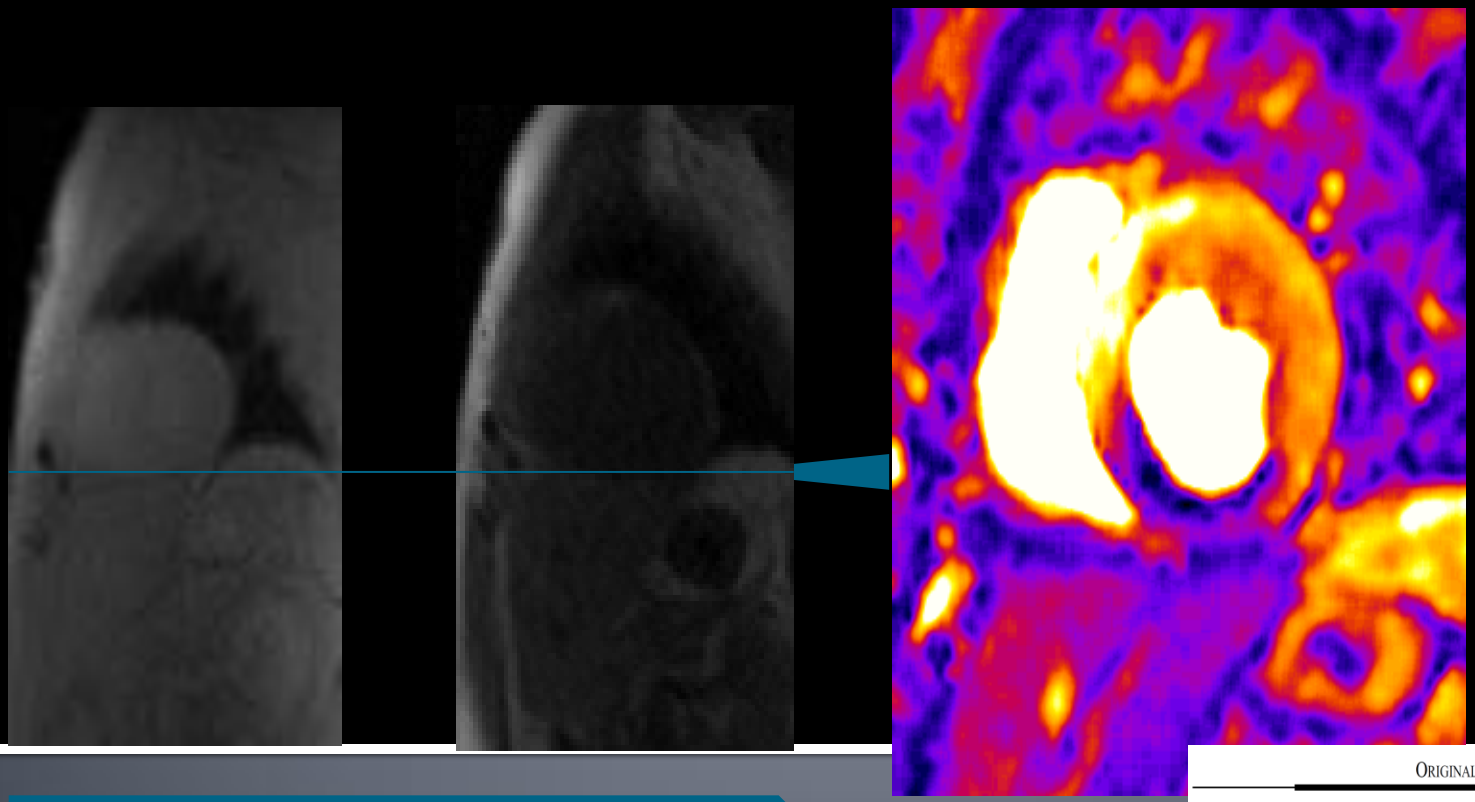
Region	Foot Time sec	TTP sec	Peak Value SI	AUC Ft-Peak SI*sec	Slope SI/sec
RefRgn1	14.44	14.94	1.6	8.43	0.11
Region2	15.39	10.85	1.8	10.93	0.18
InpRgn	13.11	5.36	6.2	---	1.23

Perfusion Evaluation
Semi-quantitative Analysis



"Heart Freeze" - Inline Motion Correction

Basis for clinically proven semi-quantitative Inline analysis



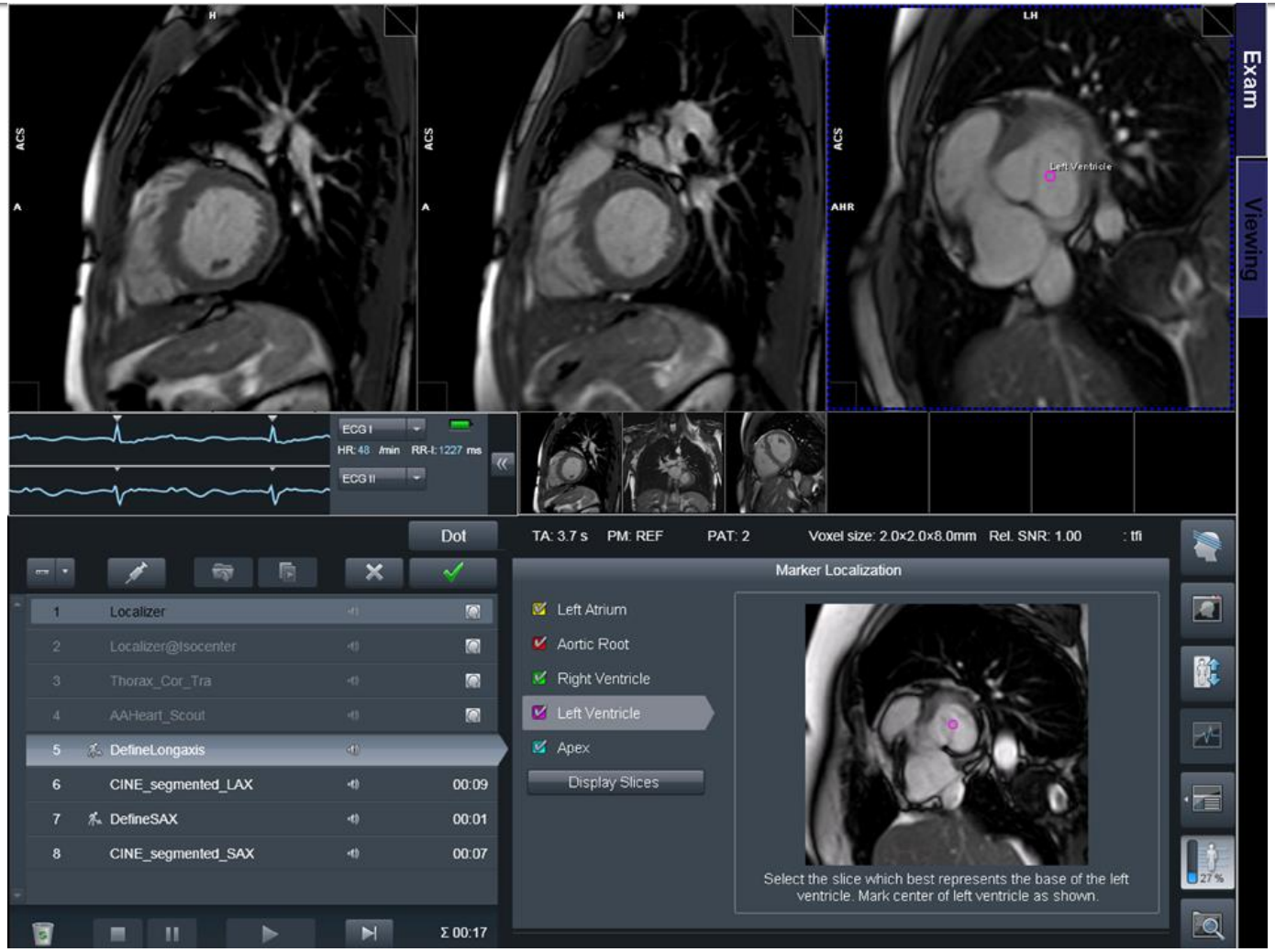
Fully System Guided – Siemens unique

ORIGINAL ARTICLE

Detection of Myocardial Ischemia by Automated, Motion-Corrected, Color-Encoded Perfusion Maps Compared With Visual Analysis of Adenosine Stress Cardiovascular Magnetic Resonance Imaging at 3 T

Doesch et al.; Invest Radiol-48(9):678

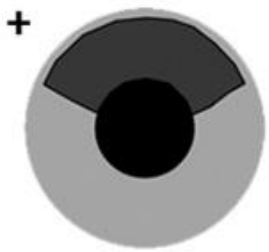
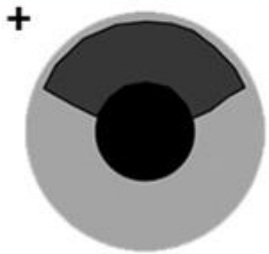
Auto localization



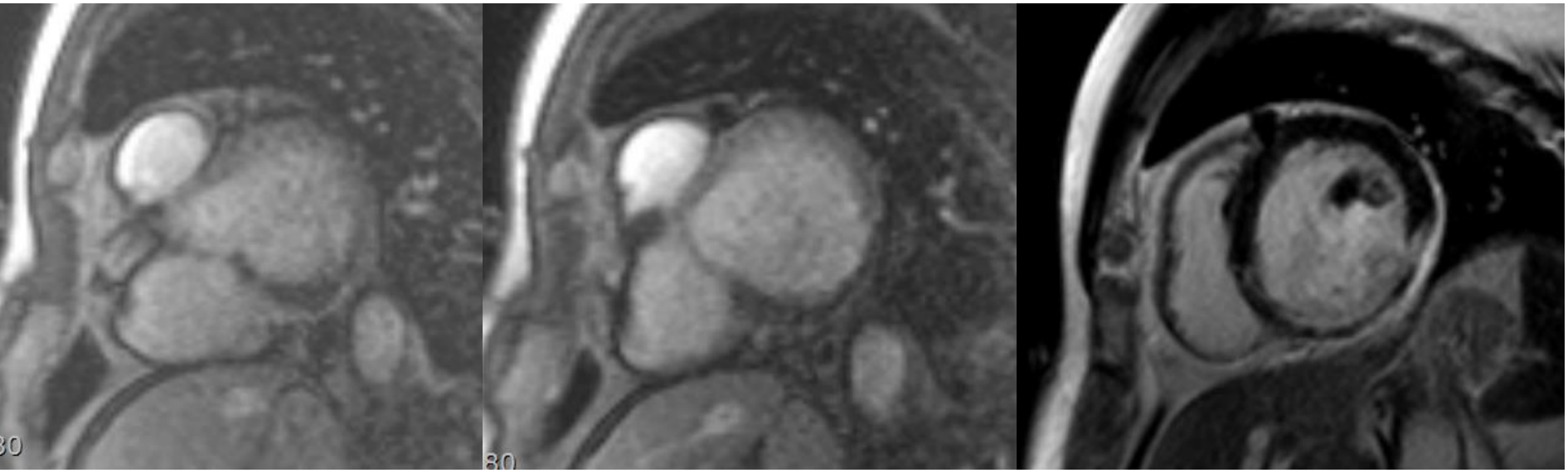
Courtesy of Siemens medical solution

Image interpretation

- Similar to the interpretation of nuclear MPI
- Reversibility; key distinguishing feature

Stress Acquisition	Rest Acquisition	Delayed Acquisition	Interpretation
			Reversible Defect Stress-induced Ischemia
			Fixed Defect Myocardial Infarct

Subendocardial infarction



Conclusion

- Stress MR can be useful tool for evaluation of CAD and IHD in some indication
- Should be familiar with how to perform this
- Dark rim artifact can be caused by various condition
- Visual analysis was preferred and semi and fully quantification will be popular

JACC: CARDIOVASCULAR IMAGING
VOL. 7, NO. 3, 2014

PUBLISHED BY ELSEVIER INC.
ISSN 1936-878X/$36.00
http://dx.doi.org/10.1016/j.jcmg.2013.06.008

Dynamic Myocardial CT Perfusion Imaging for Evaluation of Myocardial Ischemia as Determined by MR Imaging

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Munich, Germany

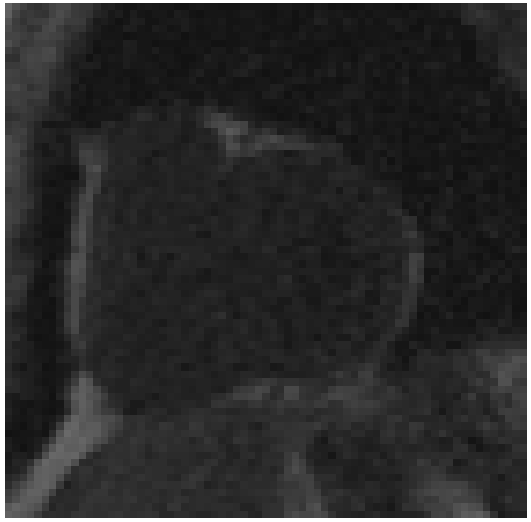
JACC Cardiovasc Imaging. 2014 Mar;7(3):267-77.

Table 3. Diagnostic Accuracy of Dynamic CT-Based Perfusion Imaging for the Detection of Any Ischemia and/or Infarction on Cardiac MR Stratified by Myocardial Segment, Per Vessel, and Per Subject

	Sensitivity	Specificity	PPV	NPV	Accuracy
Per segment	77.8 (91/117)	75.4 (273/362)	50.6 (91/180)	91.3 (273/299)	76.0 (364/479)
MBF positive	69.2–84.9	70.6–79.8	43.0–58.1	87.5–94.2	0.71–0.80
Per vessel territory	100.0 (23/23)	75.0 (6/8)	92.0 (23/25)	100.0 (6/6)	93.5 (29/31)
MBF positive	84.6–100.0	34.9–96.8	73–99.0	54.1–100.0	78.5–99.2
Per subject	100.0 (23/23)	75.0 (6/8)	92.0 (23/25)	100.0 (6/6)	93.5 (29/31)
MBF positive	85.2–100	34.9–96.8	74.0–99.0	54.1–100.0	78.5–99.2

Values are % (n/N) and 95% confidence interval. Numbers in parentheses indicate number of segments, vessels, and subjects, respectively.
MBF = myocardial blood flow; NPV = negative predictive value; PPV = positive predictive value; other abbreviations as in Table 2.


H
MPR Thin
LAO/RAO 47
CRAN/CAUD -27
A
P
F



Acknowlegement

- Mun Young Paek: Siemens Medical solutions