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DEGLI STUDI
DI PADOVA

**Master di 1° livello
Risonanza magnetica cardiaca per tecnici sanitari
di radiologia medica**

STRESS CMR

Annagrazia Cecere, MD, PhD student, Level 3 CMR EACVI Certified
Dipartimento di Scienze Cardio-Toraco-Vascolari e Sanità Pubblica
Università degli Studi di Padova



SCMR Position Paper (2020) on clinical indications for cardiovascular magnetic resonance

Tim Leiner^{1*}, Jan Bogaert^{2,3}, Matthias G. Friedrich⁴, Raad Mohiaddin^{5,6}, Vivek Muthurangu⁷, Saul Myerson⁸, Andrew J. Powell^{9,10}, Subha V. Raman¹¹ and Dudley J. Pennell^{12,13}

Leiner et al. *J Cardiovasc Magn Reson* (2020) 22:76
<https://doi.org/10.1186/s12968-020-00682-4>

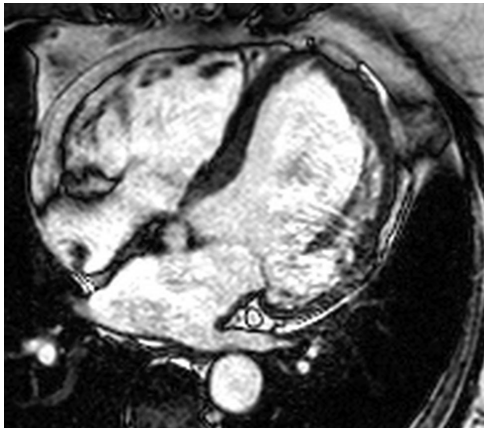
Clinical indication	Condition	Evidence
Cardiomyopathy	DCM	I
	HCM	I
	Myocarditis	I
	Arrhythmogenic cardiomyopathy	I
	Cardiac amyloidosis	I
	Iron overload	I
	Fabry's disease	I
	LV non compaction	I
	Cardiac sarcoidosis	I
	Takotsubo cardiomyopathy	I
	Endomyocardial fibrosis	I
	Restrictive cardiomyopathy/ chemotherapy induced CMP/ athlete's heart	II
	Coronary artery disease	Acute coronary syndromes/ MINOCA
Chronic coronary artery disease		I
Vascular assessment	Diagnosis and follow up of thoracic aortic aneurysm/ chronic dissection/ ulcers	I
Congenital Heart Disease	Volumes, flows, shunts, complex disease	I
Pericardial disease	Pericardial inflammation / constriction	I
Cardiac masses	Diagnosis, tissue characterization., guide surgery, follow up	I
Valvular heart disease	Sub and supra valvular stenosis/ pulmonary valve disease	I
	Aortic stenosis/ AR/ MR/ TR/ prosthetic valves	II



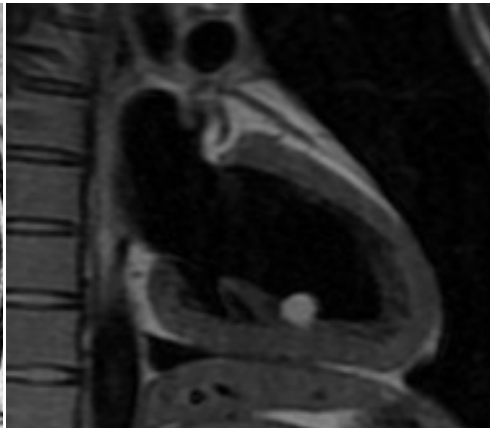


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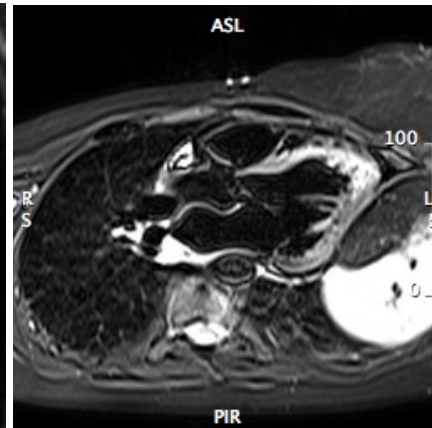
Cardiac magnetic resonance sequences



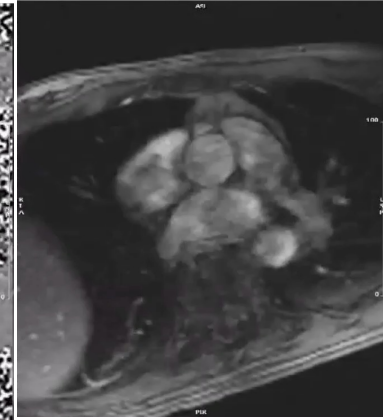
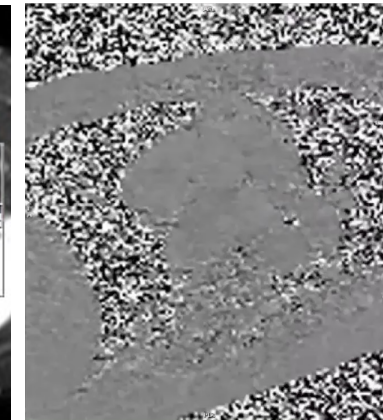
b-SSFP sequence



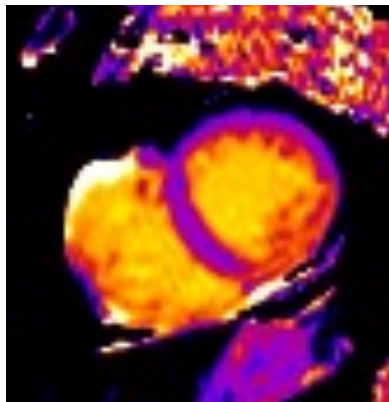
T1-weighted sequence



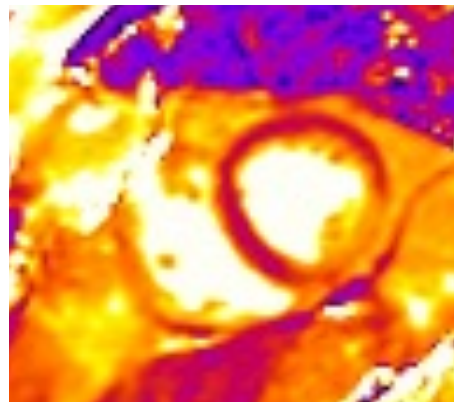
T2-weighted sequence



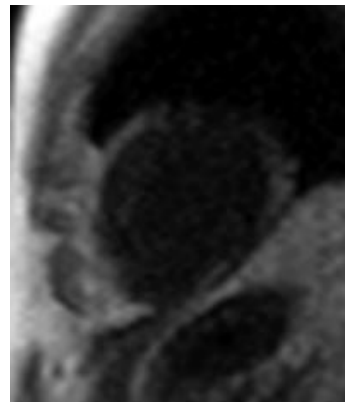
Phase-contrast sequences



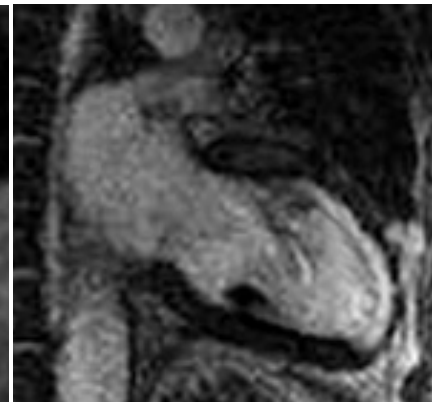
Native T1 mapping



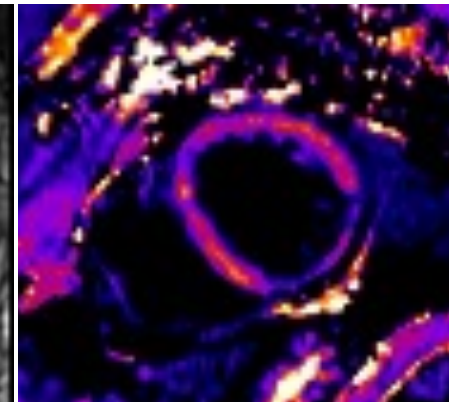
T2 mapping



First pass perfusion



Post-contrast image



ECV

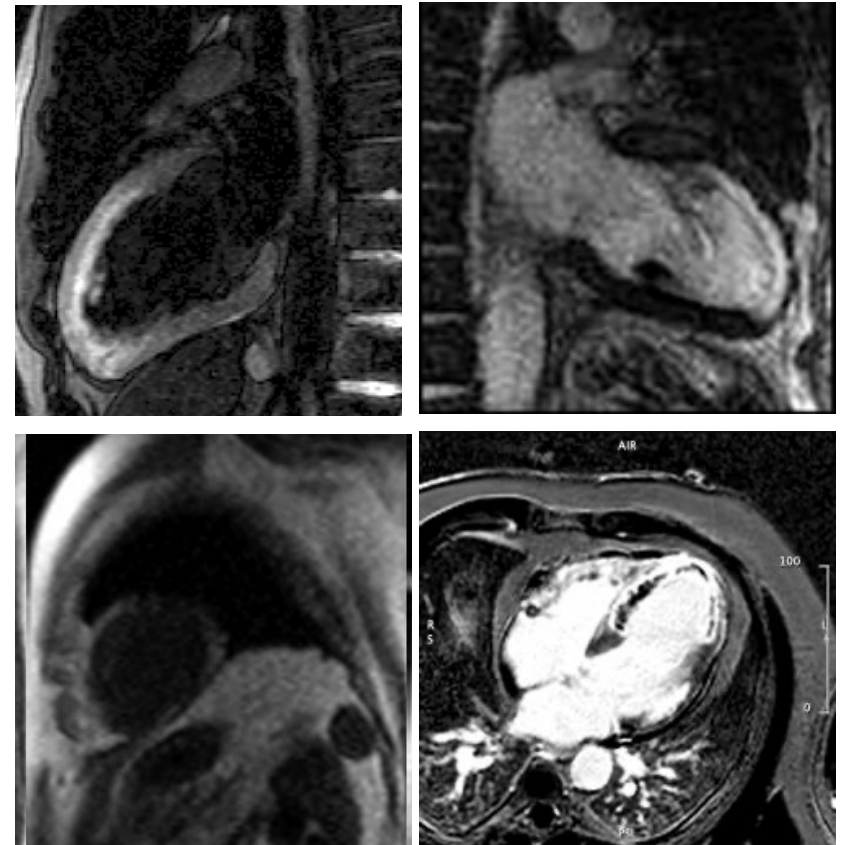


CMR role in acute coronary syndromes

CMR has emerging role in the assessment and management of patients with proven or suspected coronary artery disease.

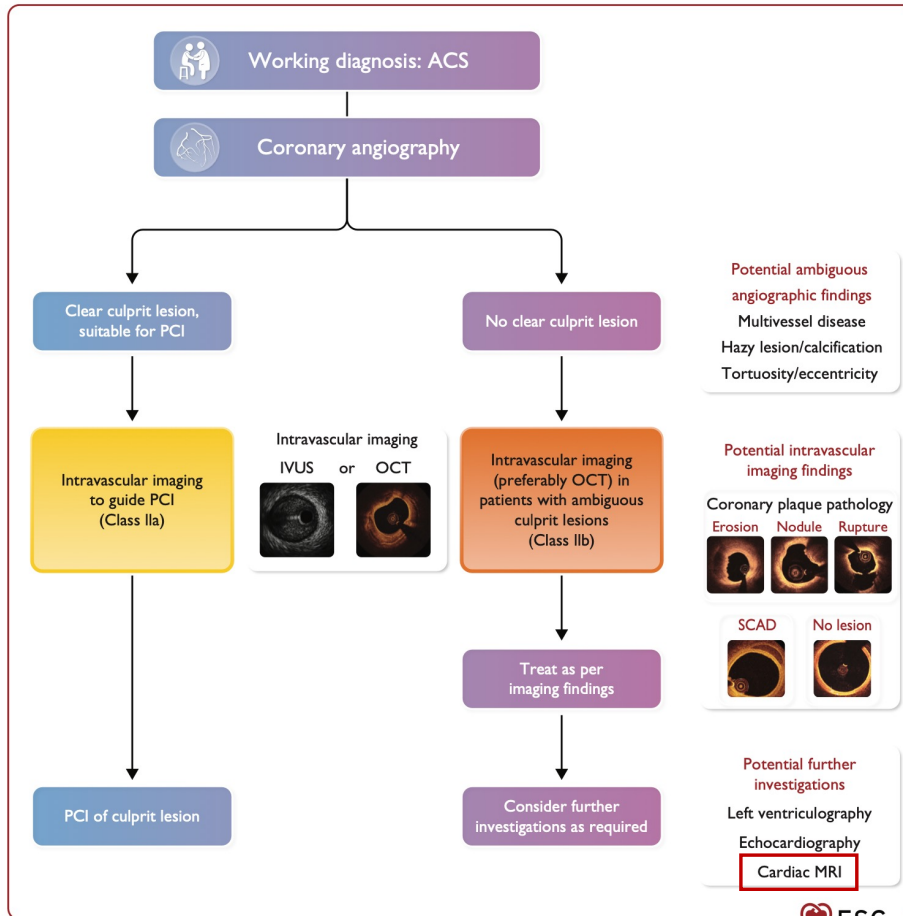


- myocardial oedema
- scar formation
- myocardial perfusion with myocardial motion and thickening at rest and stress perfusion
- microvascular obstruction and intramyocardial haemorrhage





CMR role in acute coronary syndromes



2023 ESC Guidelines for the management of acute coronary syndromes.



— Recommendations for in-hospital management

Recommendations	Class ^a	Level ^b
Logistical issues for hospital stay		
It is recommended that all hospitals participating in the care of high-risk patients have an ICCU/CCU equipped to provide all required aspects of care, including treatment of ischaemia, severe heart failure, arrhythmias, and common comorbidities.	I	C
It is recommended that high-risk patients (including all STEMI patients and very high-risk NSTEMI-ACS patients) have ECG monitoring for a minimum of 24 h.	I	C
It is recommended that high-risk patients with successful reperfusion therapy and an uncomplicated clinical course (including all STEMI patients and very high-risk NSTEMI-ACS patients) are kept in the CCU/ICCU for a minimum of 24 h whenever possible, after which they may be moved to a step-down monitored bed for an additional 24–48 h.	I	C
Discharge of selected high-risk patients within 48–72 h should be considered if early rehabilitation and adequate follow-up are arranged. ^{411,413,415,447}	IIa	A
Same-day transfer in selected stable patients after successful and uneventful PCI should be considered. ⁴¹⁹	IIa	C
Imaging		
Routine echocardiography is recommended during hospitalization to assess regional and global LV function, detect mechanical complications, and exclude LV thrombus.	I	C
When echocardiography is suboptimal/inconclusive, CMR imaging may be considered.	IIb	C



CMR role in chronic coronary syndromes

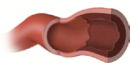
Main mechanisms of myocardial ischaemia
in chronic coronary syndromes

Epicardial

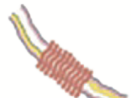
Structural



Atherosclerosis
(focal or diffuse)



Stabilized
intramural
haematoma



Myocardial
bridge



Coronary
aneurysm

Functional

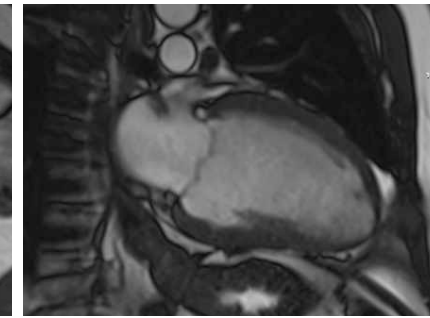
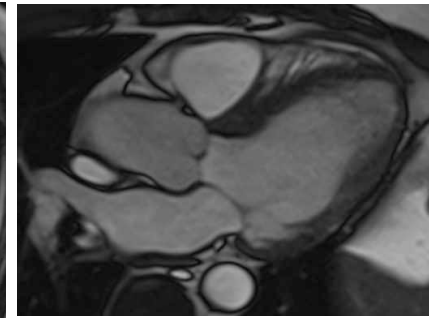
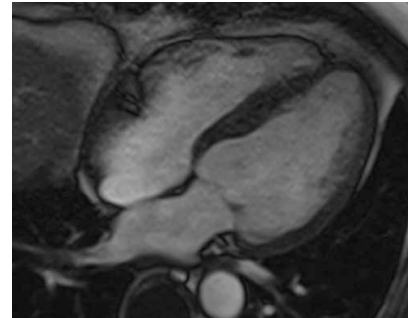


Epicardial
vasospasm

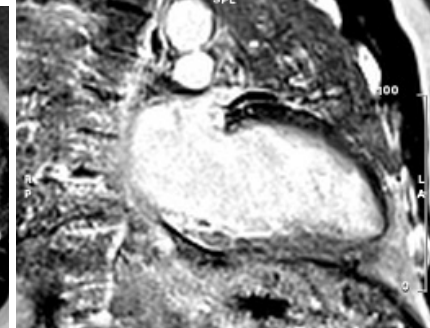
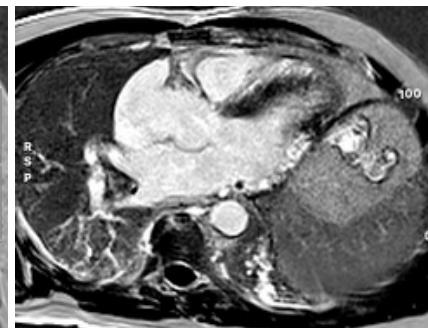
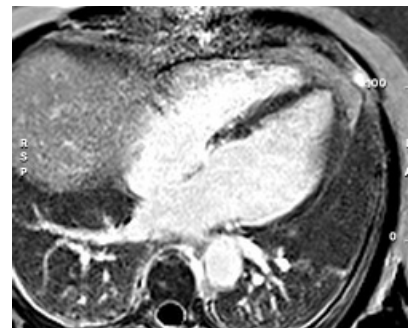
Endothelial
dysfunction and/or
VSMC hyperreactivity

Autonomic
dysregulation

FUNCTION



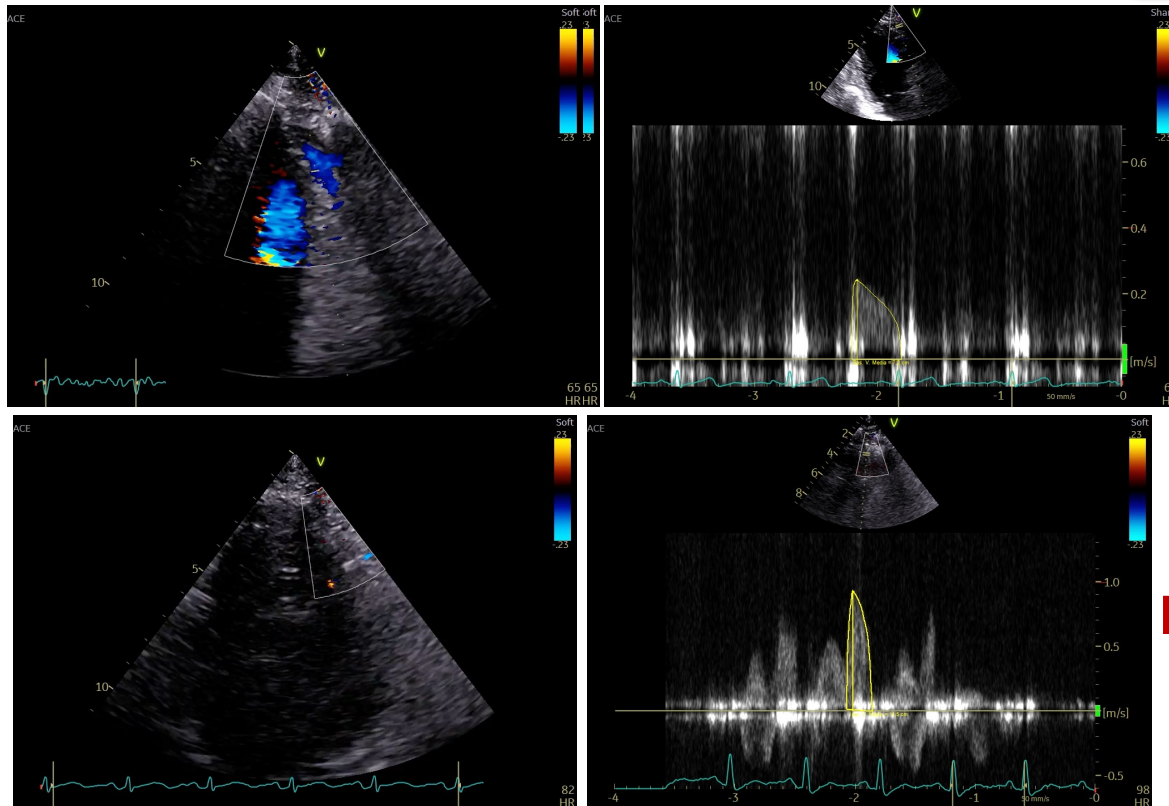
VIABILITY





CMR role in chronic coronary syndromes

Main mechanisms of myocardial ischaemia
in chronic coronary syndromes



BASAL

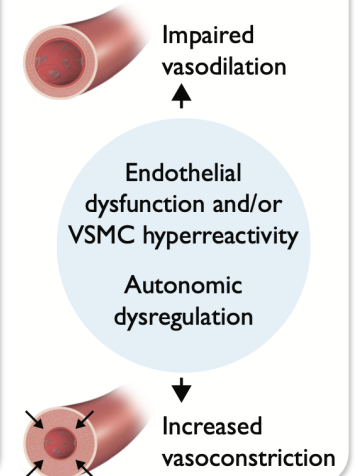
HYPEREMIC

Microvascular

Structural

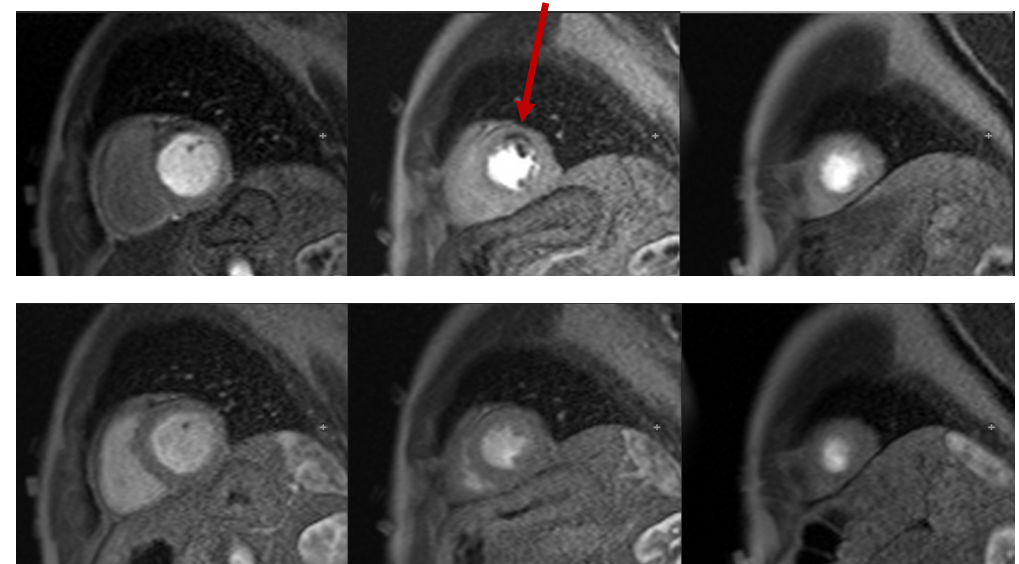
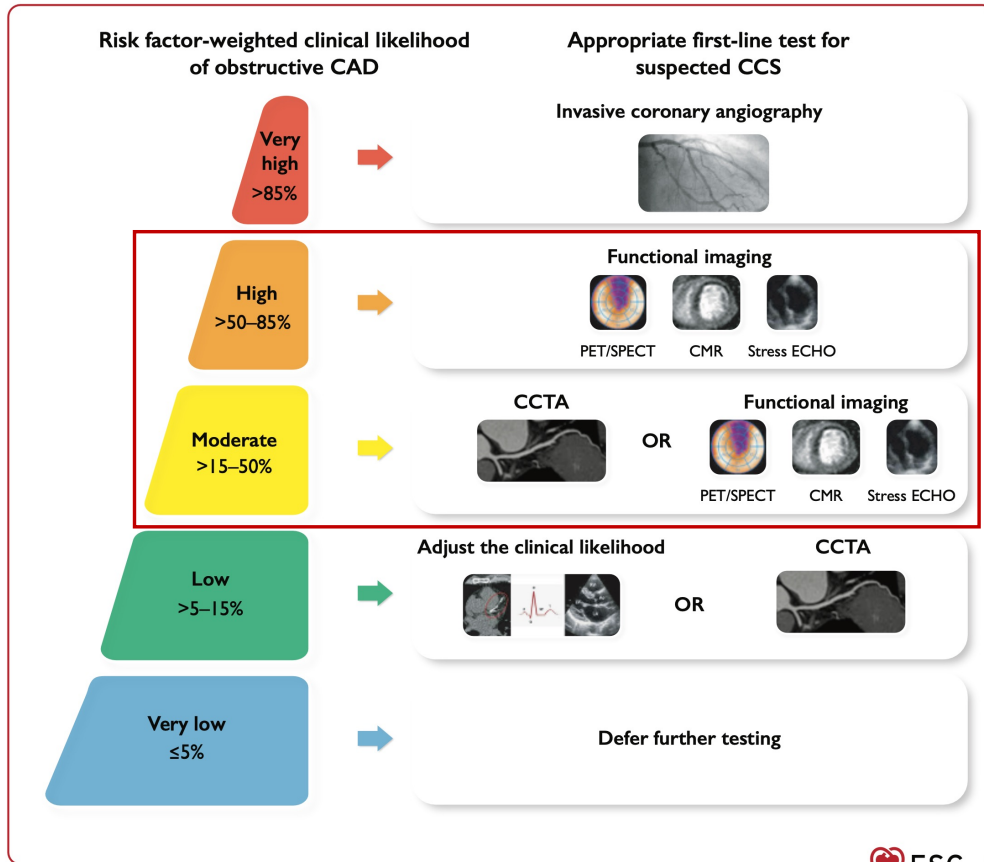
- Inward arteriolar remodelling
- Capillary rarefaction
- Intravascular plugging
- Perivascular fibrosis or infiltration
- Extramural compression (myocardial hypertrophy, increased LVEDP)

Functional





CMR role in chronic coronary syndromes



Non-invasive functional myocardial imaging tests in the initial diagnostic management of individuals with suspected chronic coronary syndrome—resting and stress single-photon emission computed tomography/positron emission tomography—cardiac magnetic resonance imaging, if available and supported by local expertise—Section 3

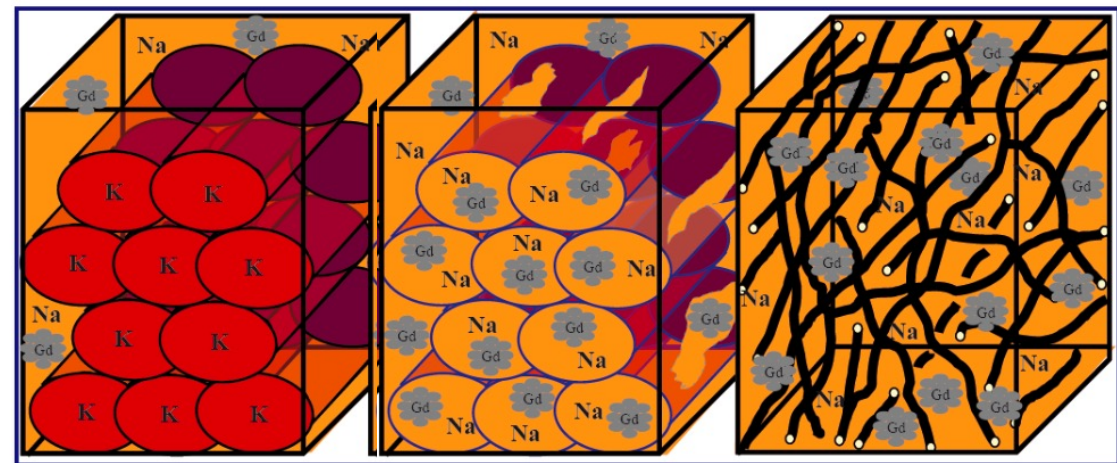
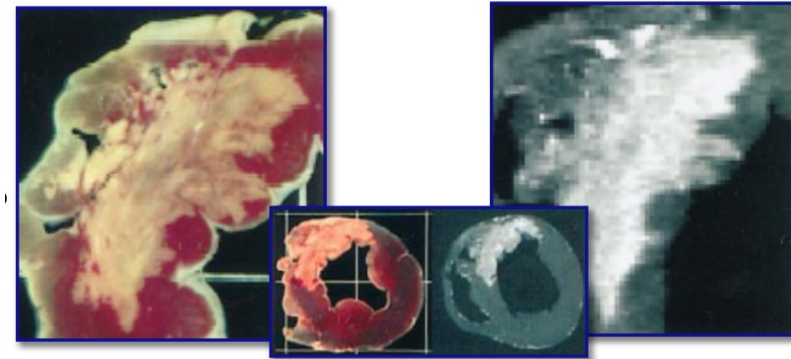
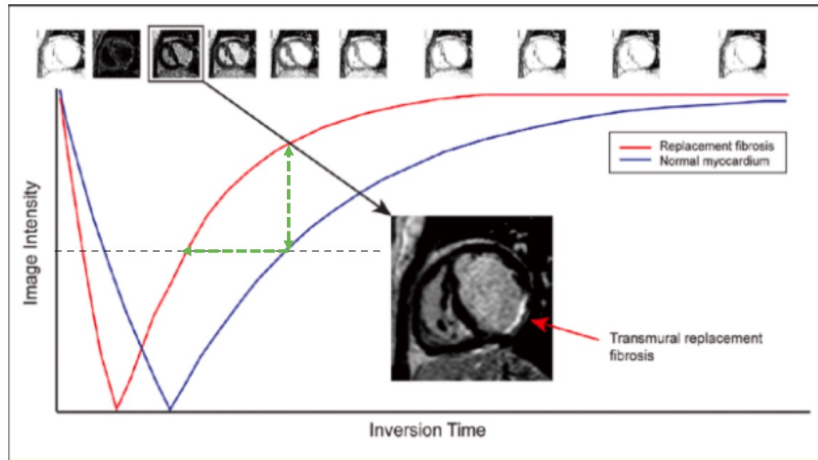
In individuals with suspected CCS and moderate or high (>15%–85%) pre-test likelihood of obstructive CAD, SPECT or, preferably, PET myocardial perfusion imaging is recommended to:

- diagnose and quantify myocardial ischaemia and/or scar;
- estimate the risk of MACE;
- quantify myocardial blood flow (PET).

I	B
I	B
I	B

In patients selected for PET or SPECT myocardial perfusion imaging, it is recommended to measure CACS from unenhanced chest CT imaging (used for attenuation correction) to improve detection of both non-obstructive and obstructive CAD.

In individuals with suspected CCS and moderate or high (>15%–85%) pre-test likelihood of obstructive CAD, CMR perfusion imaging is recommended to diagnose and quantify myocardial ischaemia and/or scar and estimate the risk of MACE.



Intact cell membrane

Damaged cell membrane

Increased interstitial space

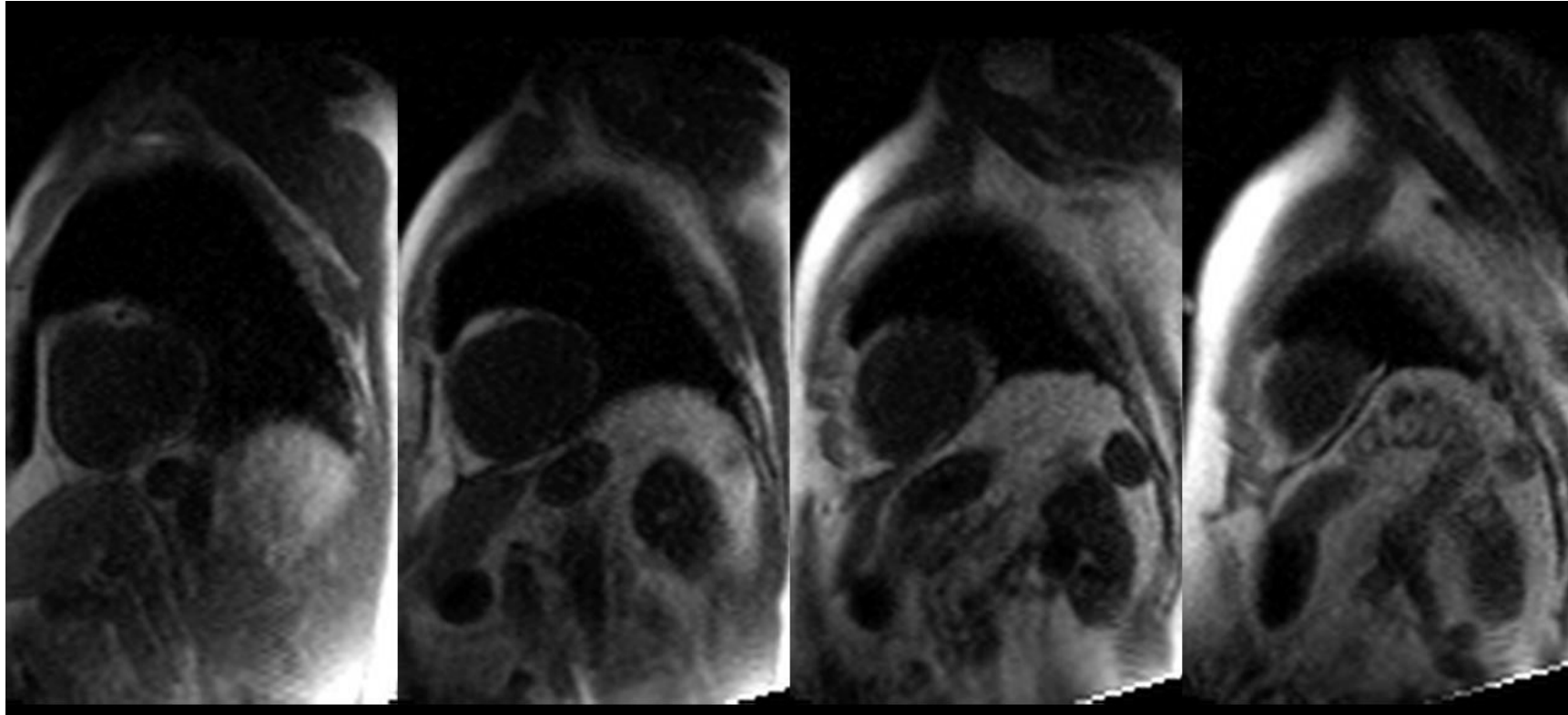
Wash-out

Gadolinium accumulation

Kim RJ et al. *Circulation* 1999; 100:1992-2002.
Mahrholdt H et al. *Eur Heart J* 2005; 26:1461-1474.



First pass perfusion

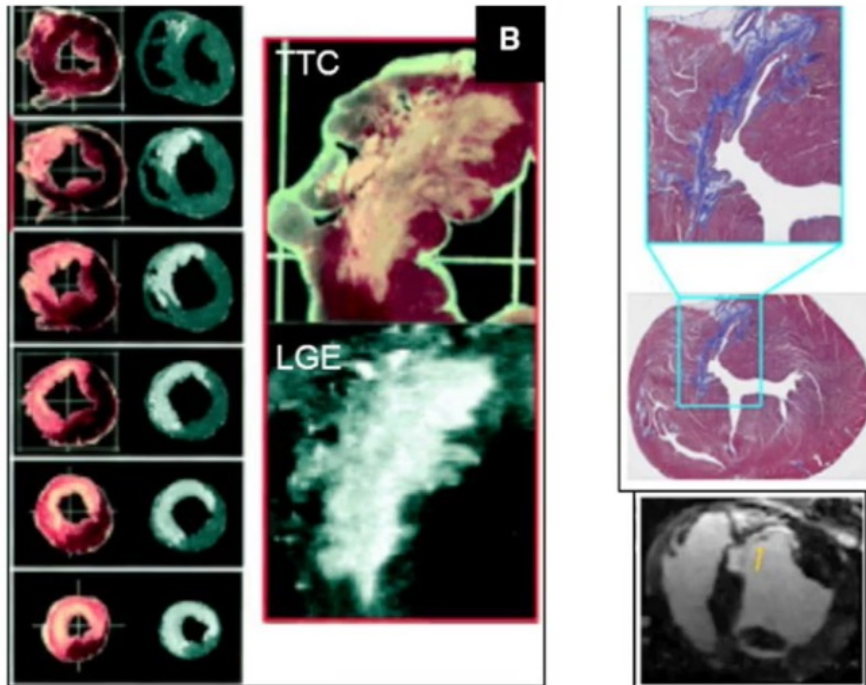


Myocardial first-pass perfusion evaluates the microvascular perfusion of the myocardium.

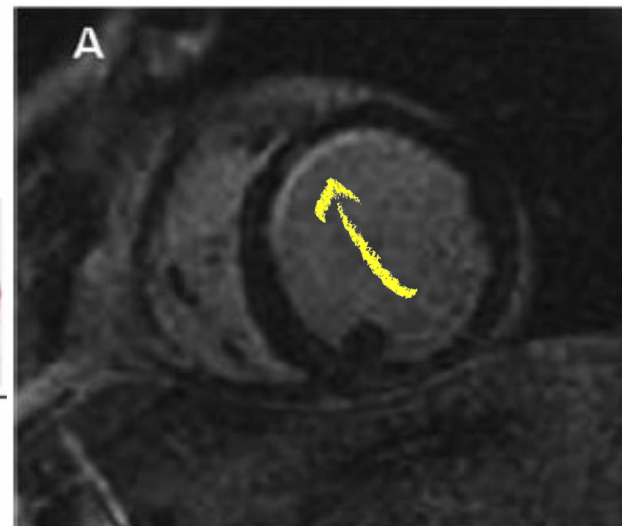


CMR LGE equals histological visualization of LV scar.

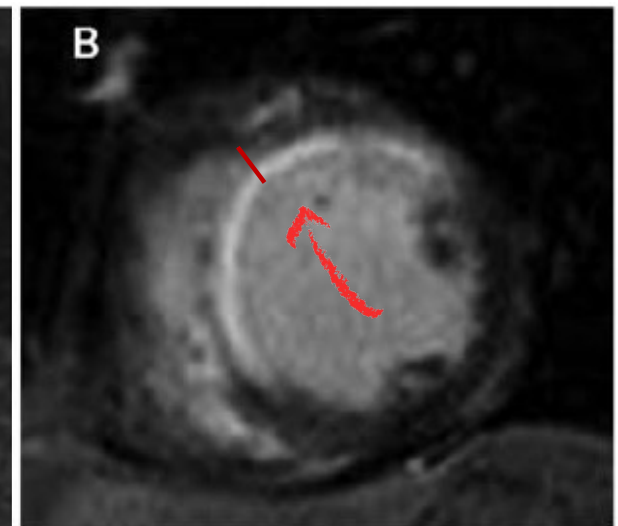
ISCHEMIC



SUBENDOCARDIAL LGE



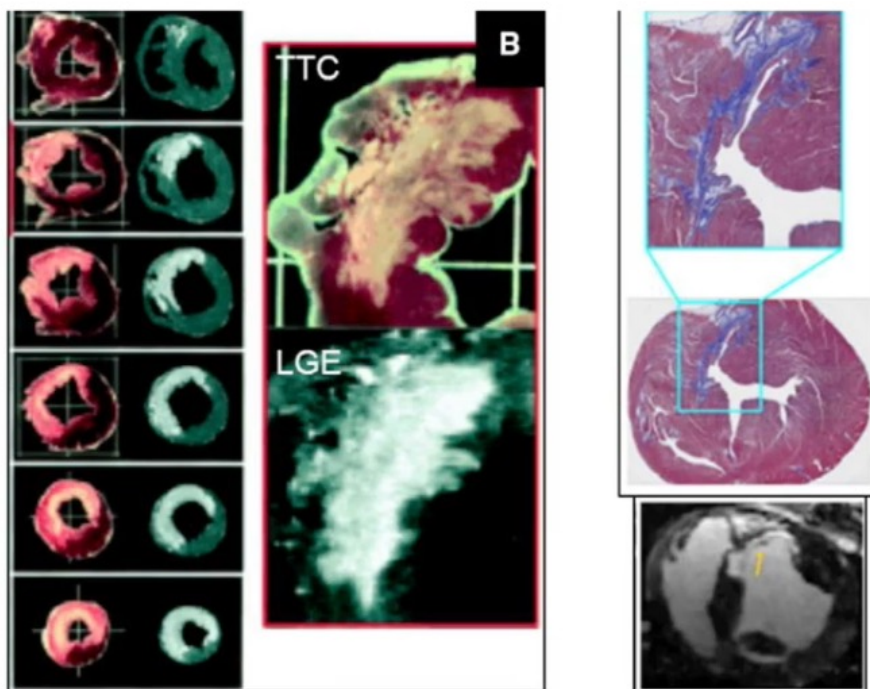
TRANSMURAL LGE





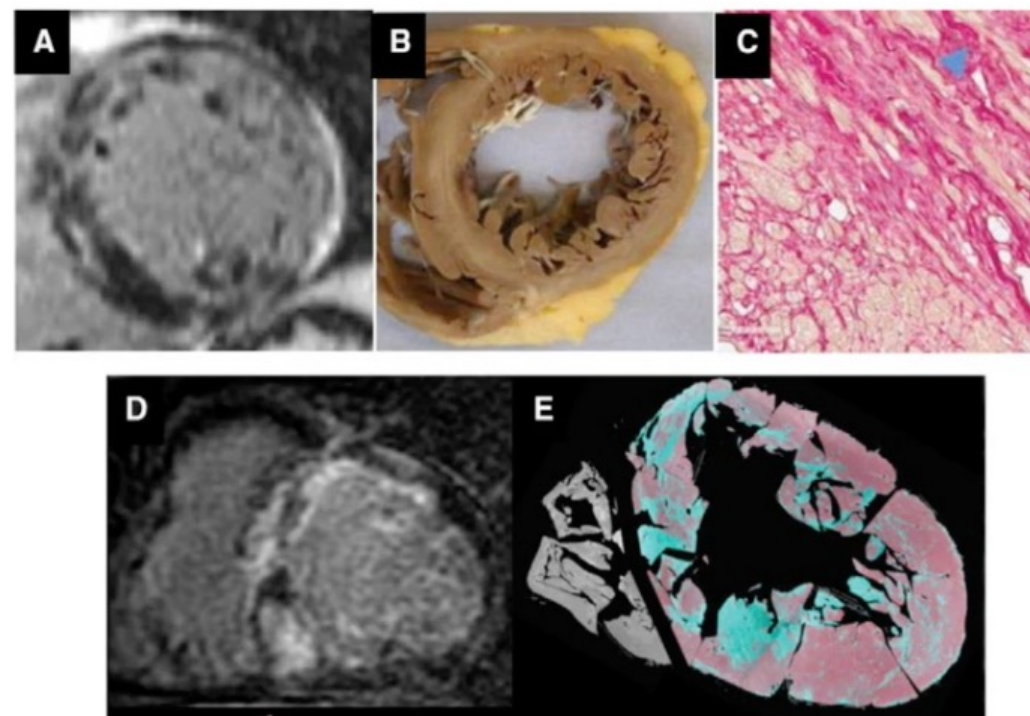
CMR LGE equals histological visualization of LV scar.

ISCHEMIC



Wu KC. *Circ Cardiovasc Imaging* 2017; 10:e005461.

NON ISCHEMIC

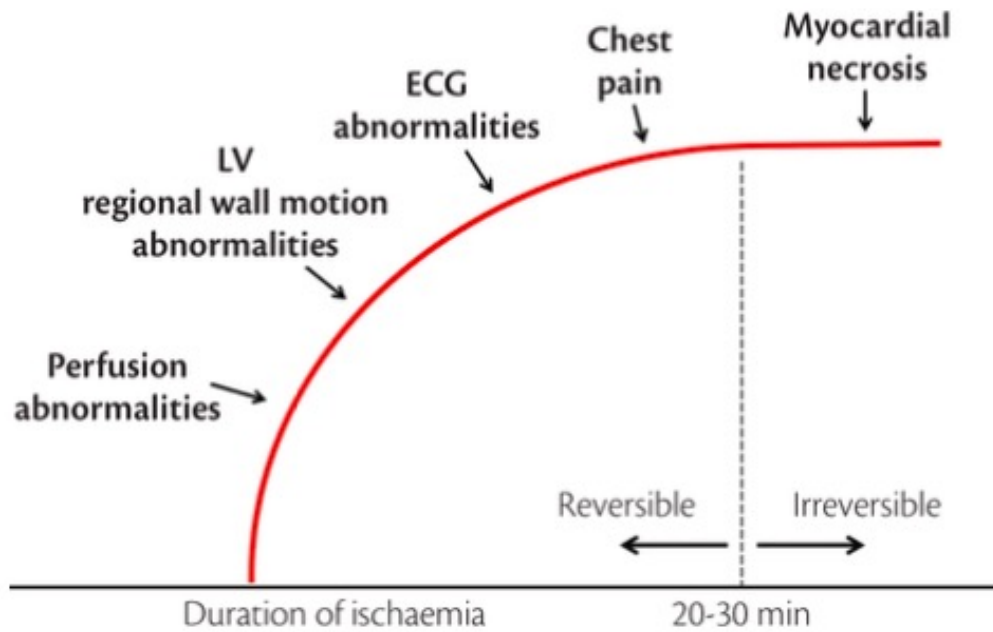


Halliday BP et al. *Circulation* 2017; 136:215-231.

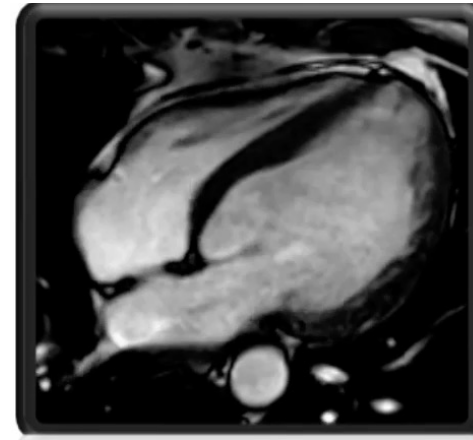
Iles LM et al. *Eur Heart J Cardiovasc Imaging* 2015; 16:14-22.



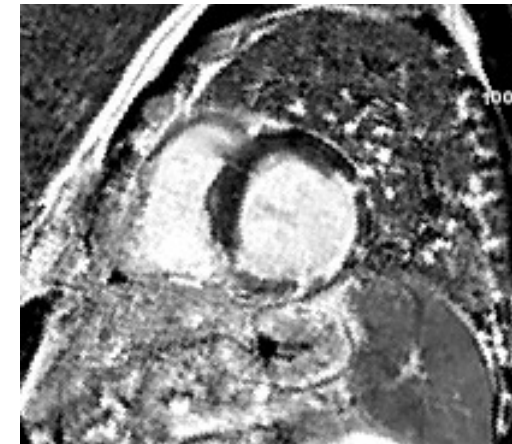
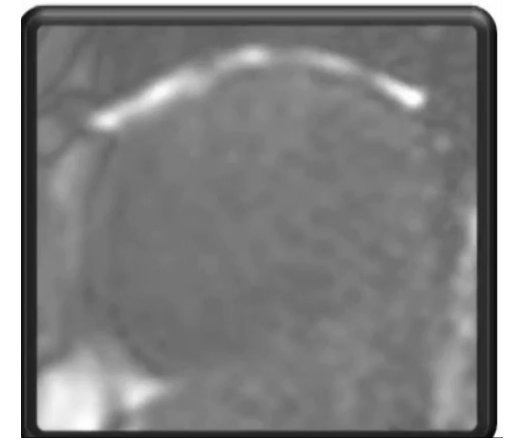
ISCHEMIC CASCADE



CINE



PERFUSION



LGE



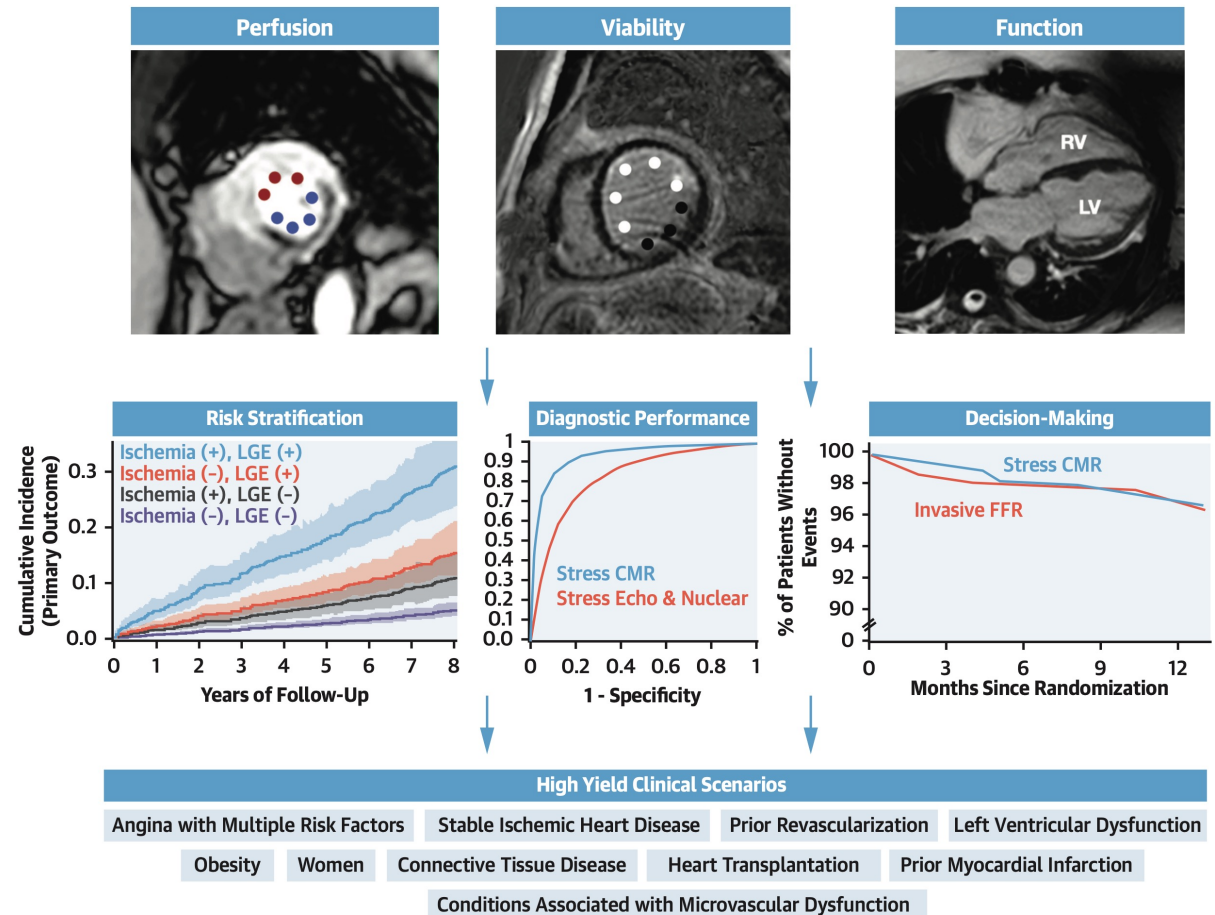
Stress CMR: ischemia, viability and function

CMR can accurately:

- detect hemodynamically significant CAD,
- assess microvascular function,
- predict myocardial viability,
- guide the need for revascularization,
- provide clinical risk stratification safely and effectively.

It has shown superiority to SPECT and equivalence to an FFR-guided invasive angiographic approach to patient evaluation.

**COST-EFFECTIVE
MODALITY**

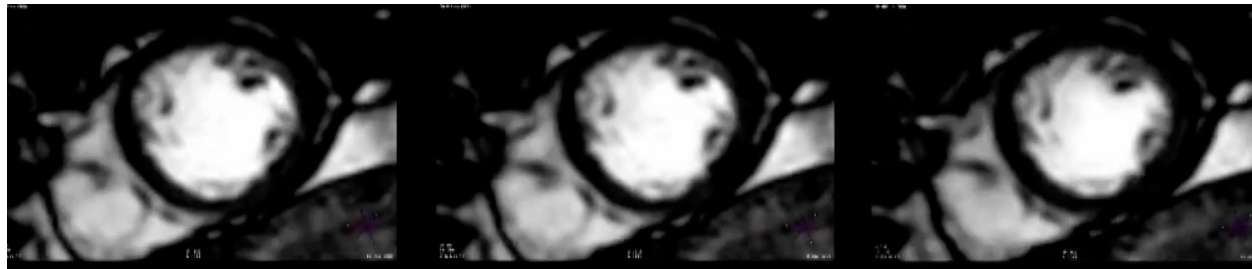




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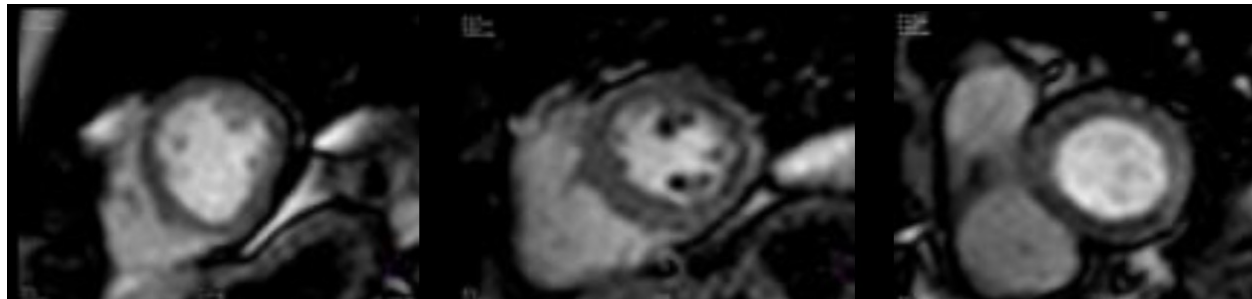
Stress CMR – Essential dataset

CINE



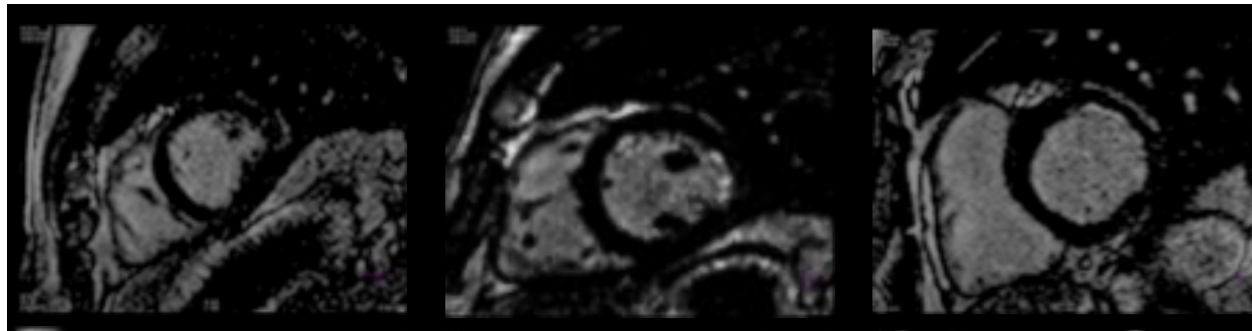
FUNCTION

PERFUSION

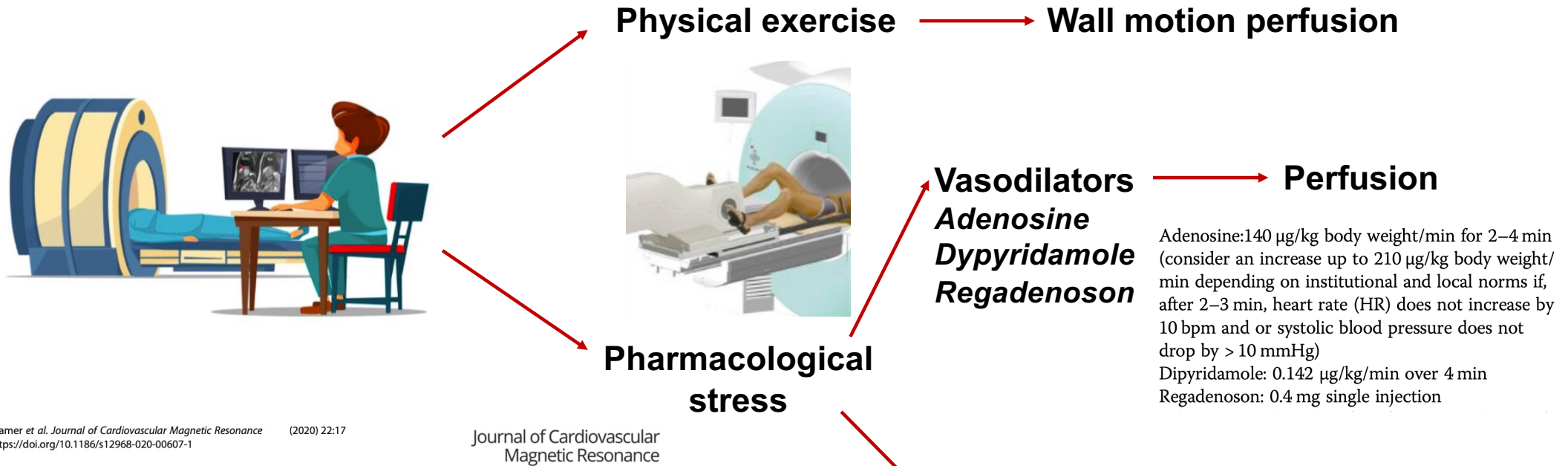


ISCHEMIA

LGE



VIABILITY



RESEARCH

Open Access

Standardized cardiovascular magnetic resonance imaging (CMR) protocols: 2020 update



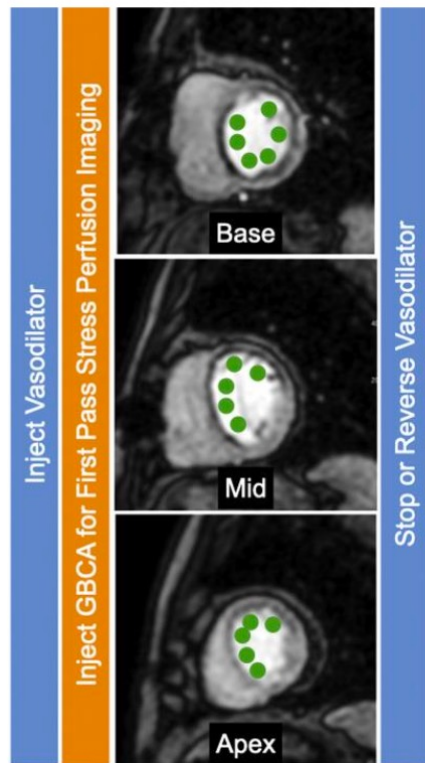
Christopher M. Kramer^{1*}, Jörg Barkhausen², Chiara Bucciarelli-Ducci³, Scott D. Flamm⁴, Raymond J. Kim⁵ and Eike Nagel⁶



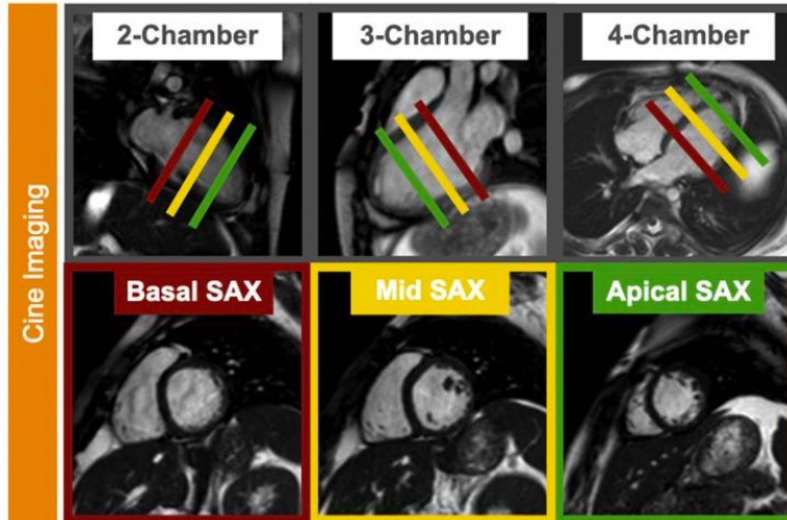
Stress CMR – Typical vasodilator stress CMR perfusion protocol

Patel AR, et al. JACC 2021; 78:1655-1668.

STRESS

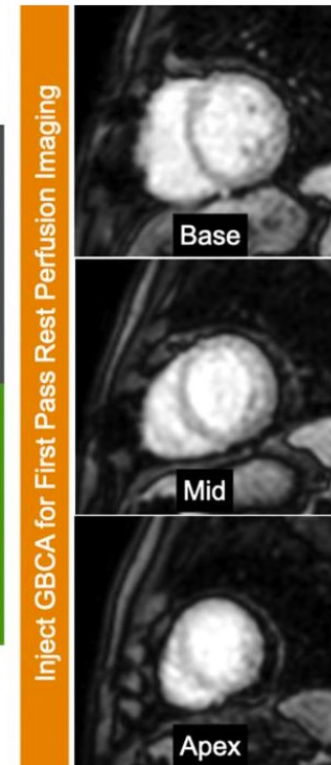


2 minutes



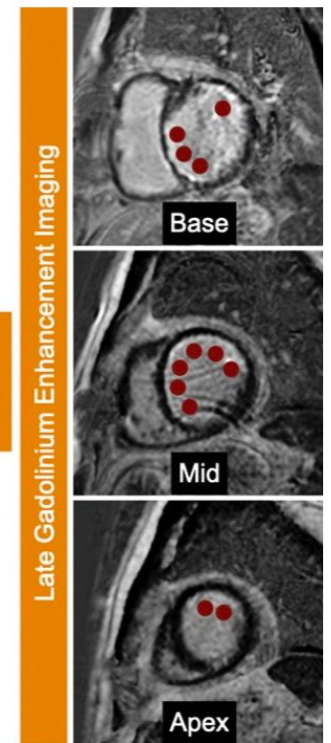
15 minutes

REST



2 minutes

Additional Sequences As Needed



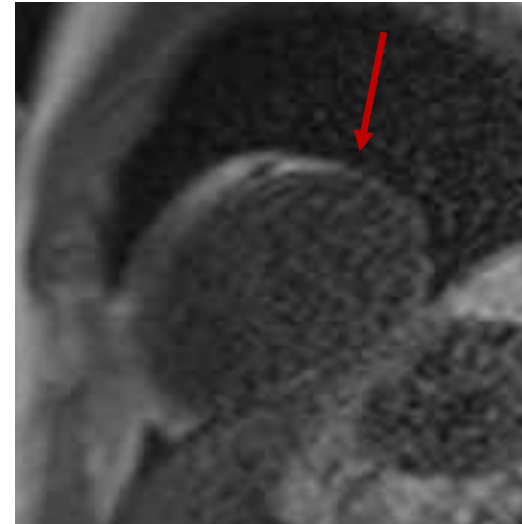
5 minutes

5-10 minutes

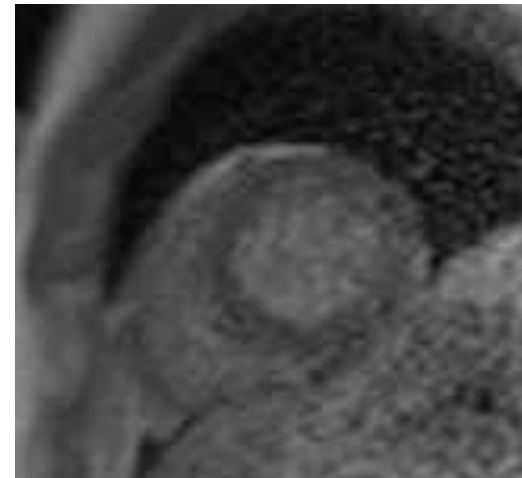


INDUCIBLE PERFUSION DEFECT:

- occurs first when contrast arrives in LV myocardium
- persists beyond peak myocardial enhancement and for several RR intervals
- is usually most prominent in the subendocardial portion of the myocardium
- is present at stress but non at rest
- conforms to the distribution territory of coronaries



STRESS

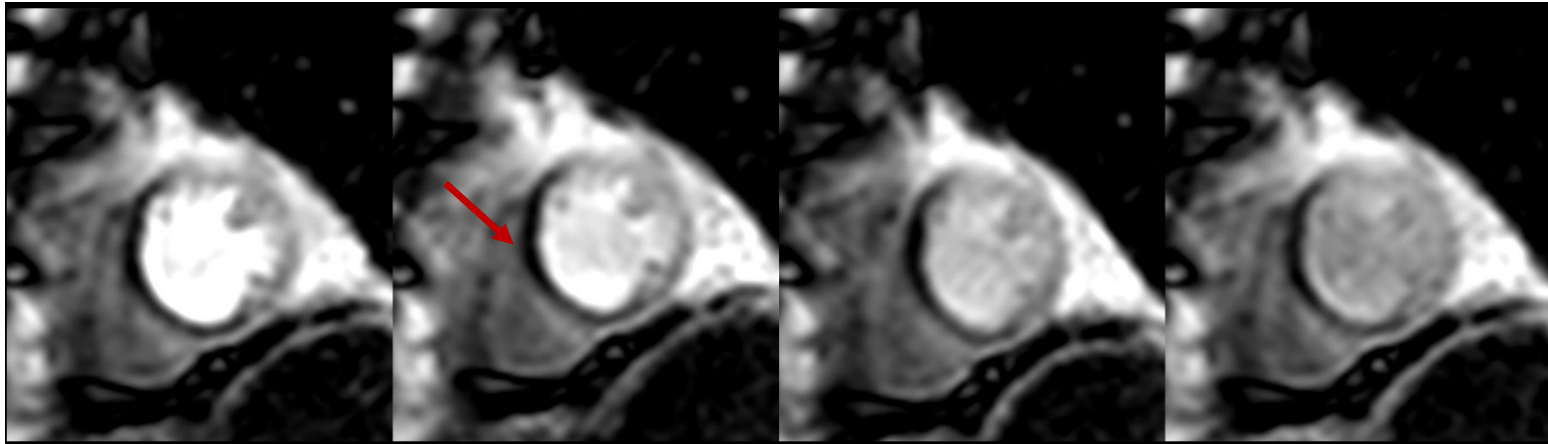


REST

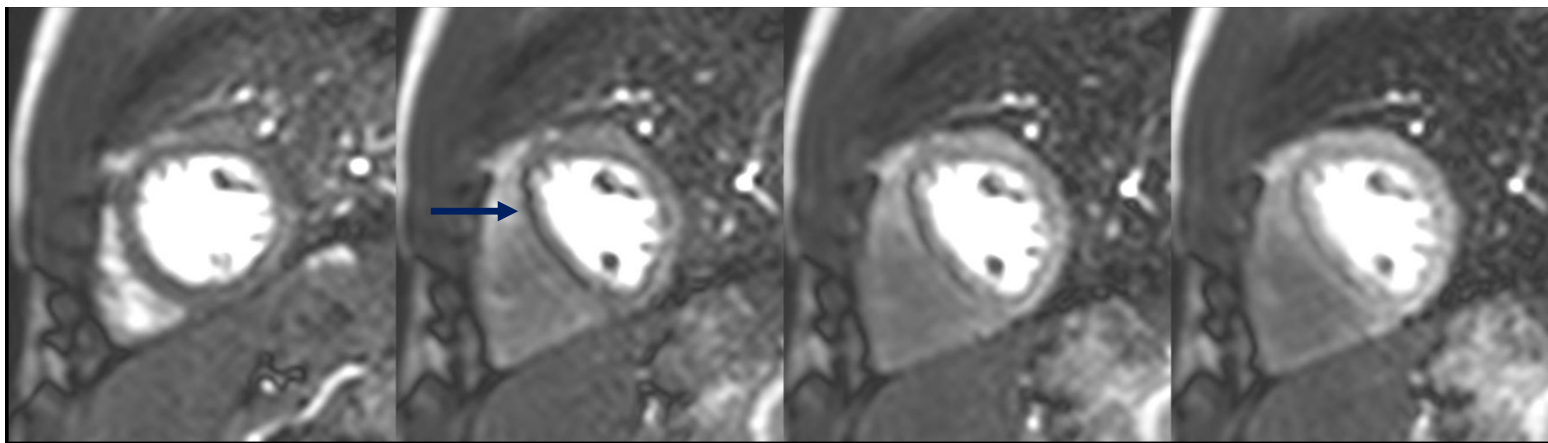


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Stress CMR – First pass perfusion



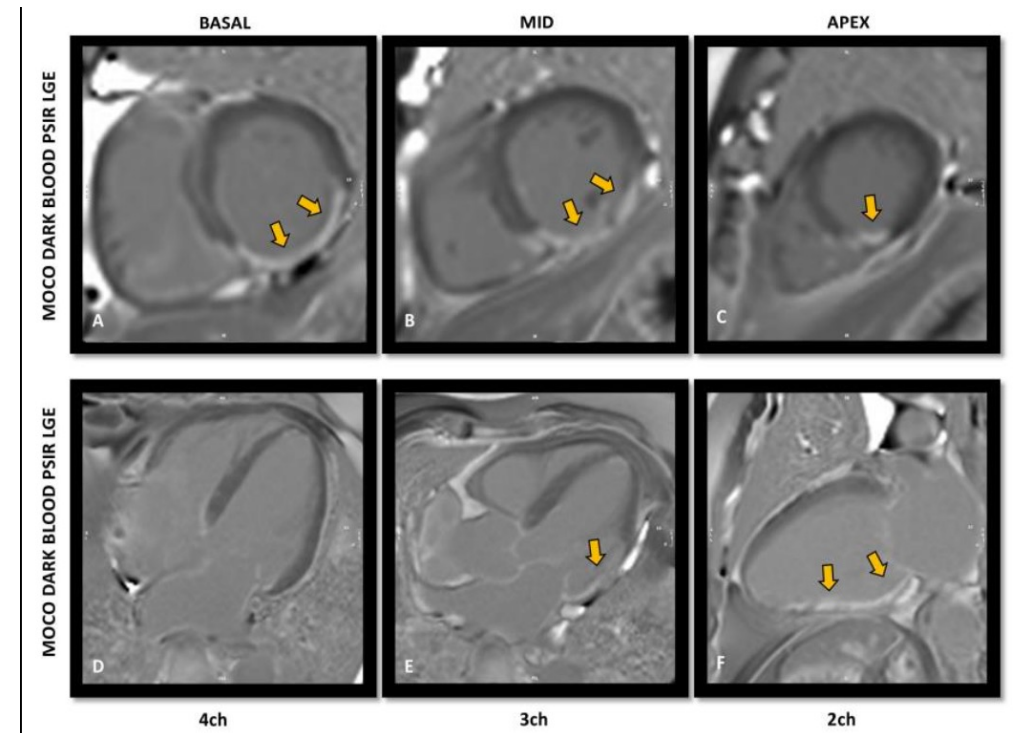
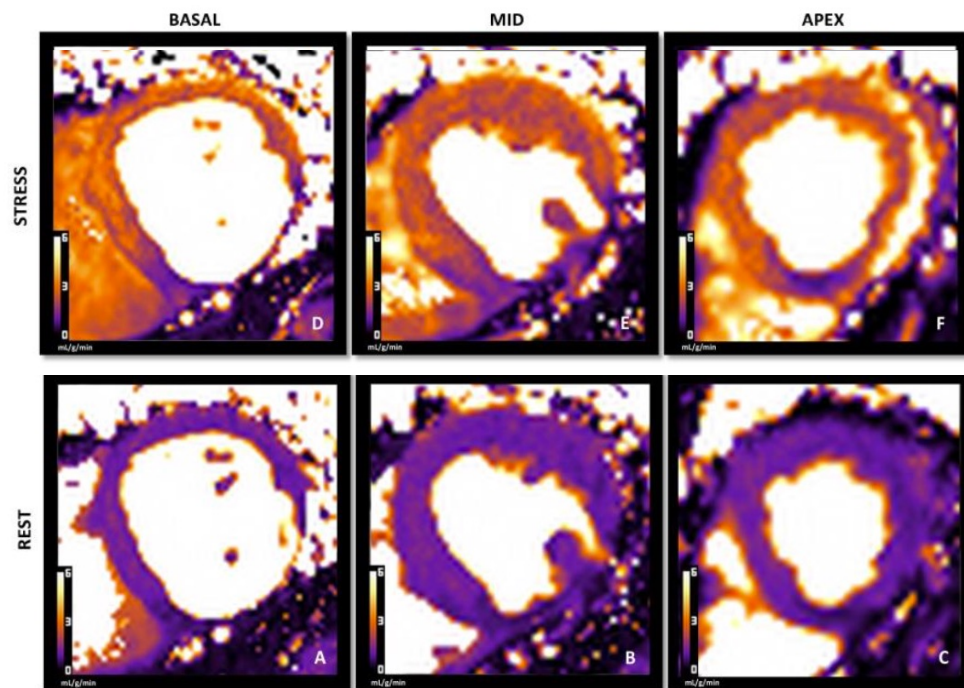
**TRUE INDUCIBLE
PERFUSION
DEFECT**



**DARK RIM
ARTIFACT**



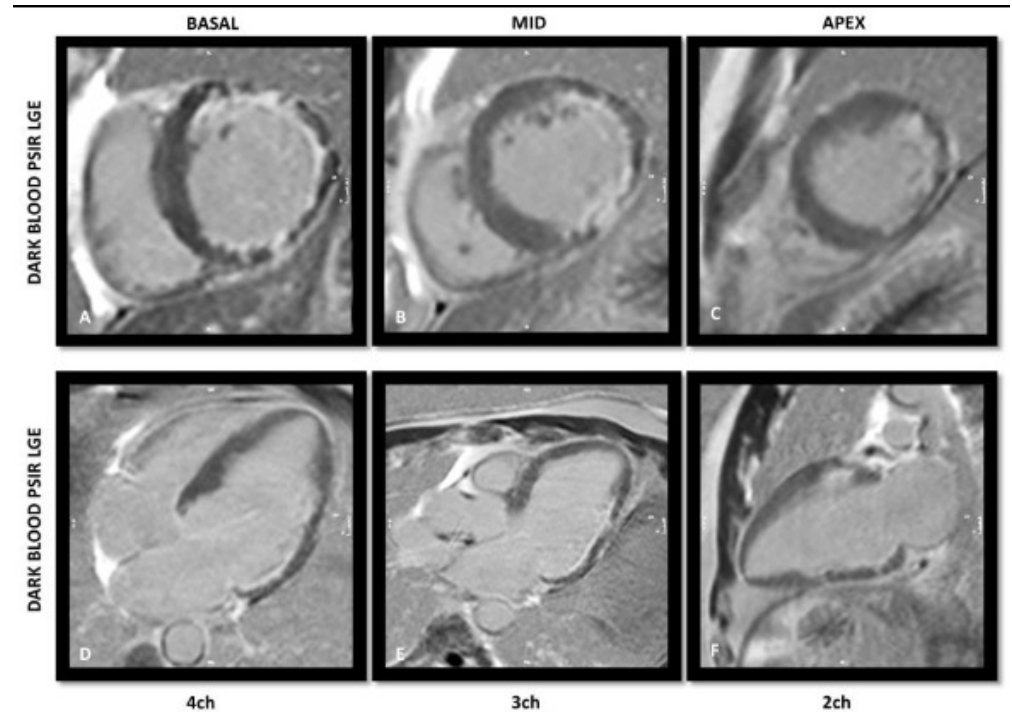
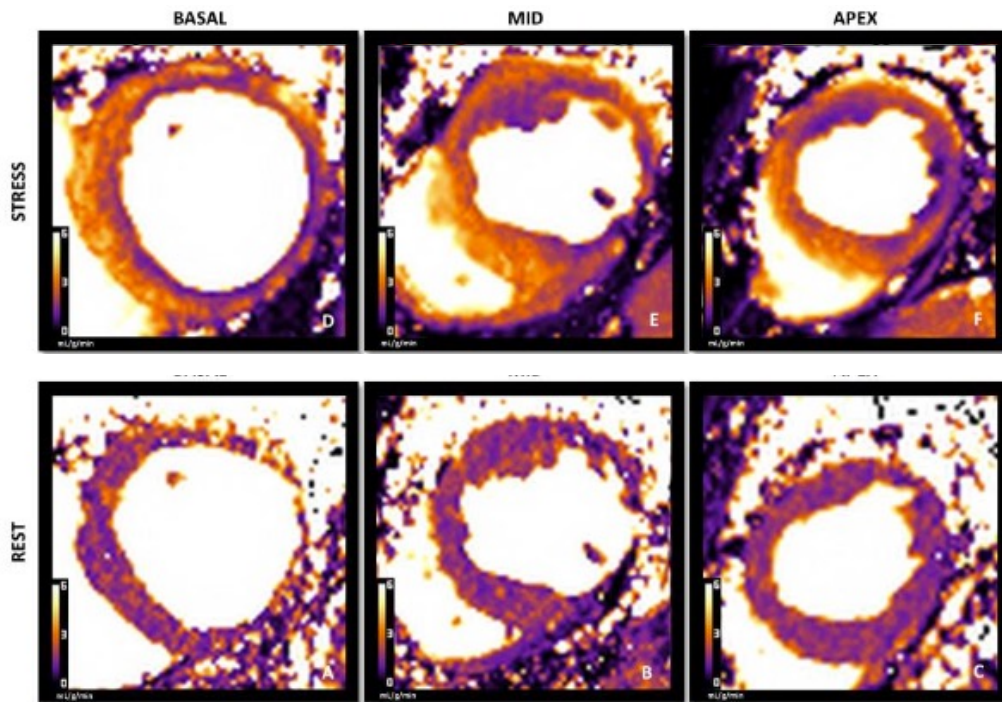
MATCHED PERFUSION DEFECT (no inducible ischemia)



Courtesy of Prof. Fabrizio Ricci, University of Chieti



UNMATCHED PERFUSION DEFECT (inducible ischemia)



Courtesy of Prof. Fabrizio Ricci, University of Chieti



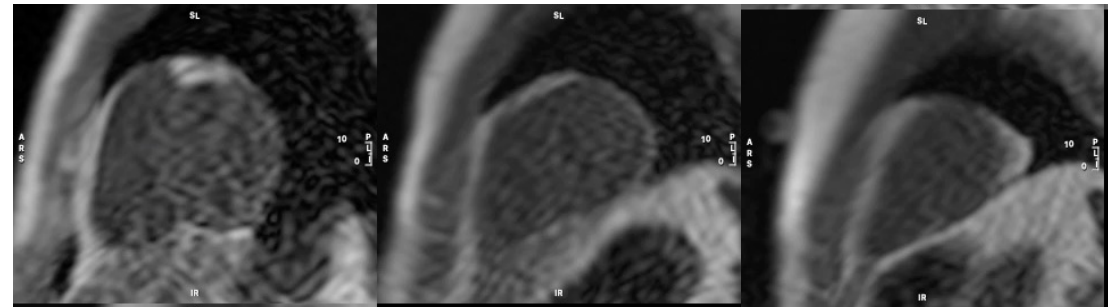
VISUAL ASSESSMENT

The key diagnostic feature for identifying a perfusion defect is the arrival and first passage of the contrast bolus through the LV myocardium.

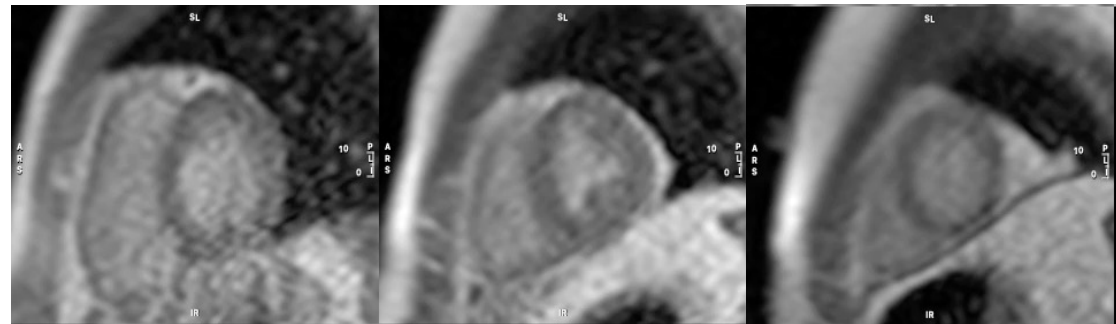
Based on comparison between endocardium vs epicardium, segments and slices to identify **relative hypoperfusion**.

Artifacts may be less pronounced or absent at rest compared with stress images due to differences in hemodynamics and contrast kinetics between stress and rest.

STRESS



REST





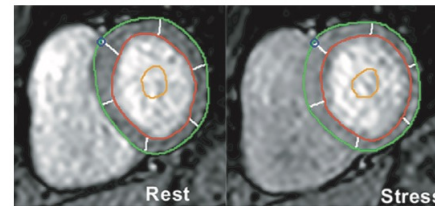
Stress CMR – Myocardial Perfusion Reserve Index (MPRI)

Long-Term Prognosis of Patients With Coronary Microvascular Disease Using Stress Perfusion Cardiac Magnetic Resonance

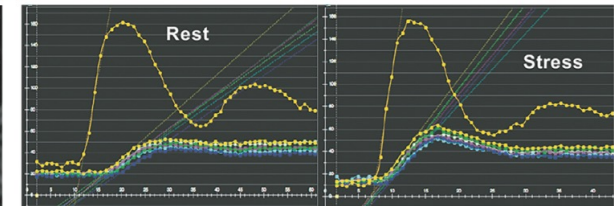
- 218 chest pain patients (mean age 59 ± 12 years; 49.5% male) without epicardial CAD
- Median follow-up of 5.5 years
- Average MPRI of that cohort was 1.56 ± 0.33
- Females and a history of hyperlipidemia were predictors of lower MPRI

A global MPRI ≥ 2.0 is considered normal.

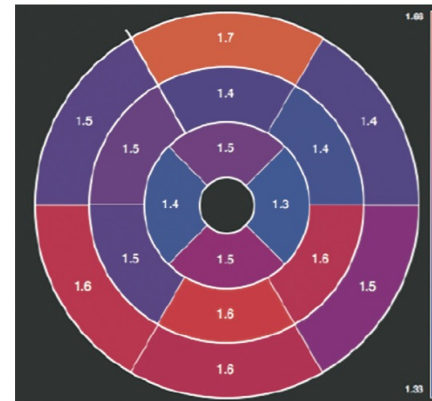
1. Contour Stress & Rest Perfusion Images



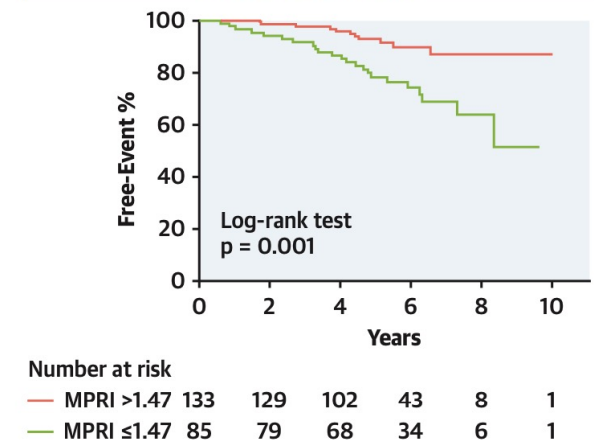
2. Signal Intensity Curve Generation



3. Global Myocardial Perfusion Reserve Index (MPRI) Calculated from 16 Segments



4. Survival Analysis of Patients According to MPRI Cut-Off Value



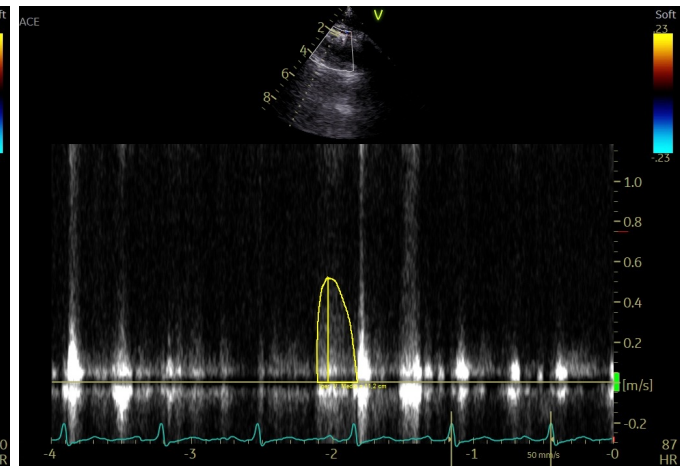
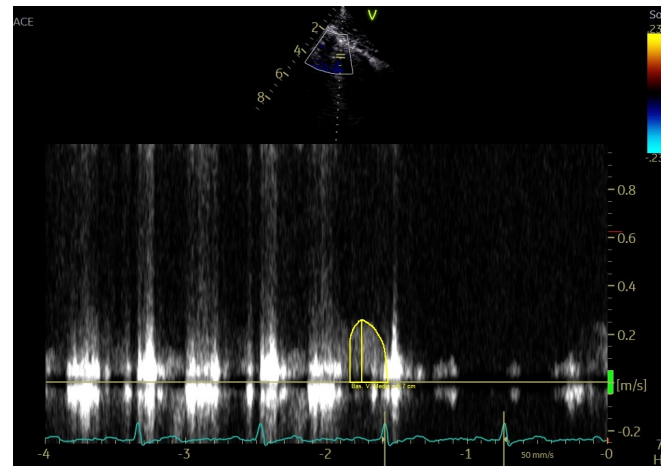
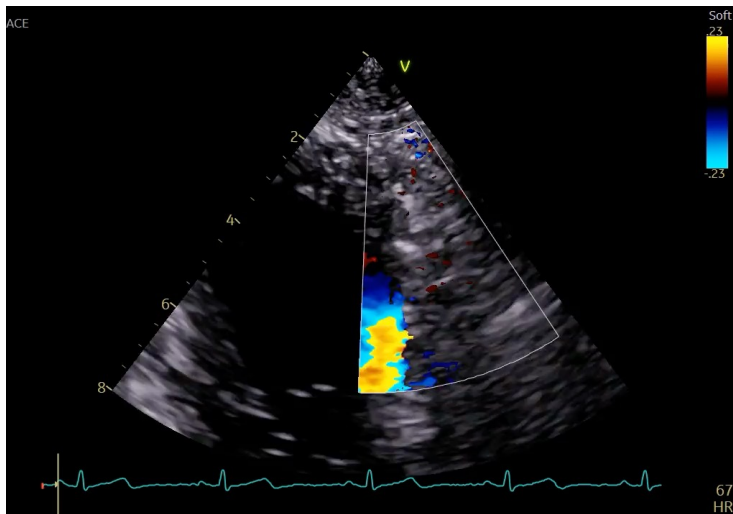
- Patients with MPRI ≤ 1.47 had three-fold increased risk of MACE compared with those with MPRI >1.47 ($p = 0.001$).
- MPRI was an independent predictor of MACE ($p < 0.001$).



A 27-year-old psoriatic patient without known CV disease

Basal coronary diastolic
velocity: 26/18 cm/sec

Hyperemic coronary diastolic
velocity: 54/22 cm/sec

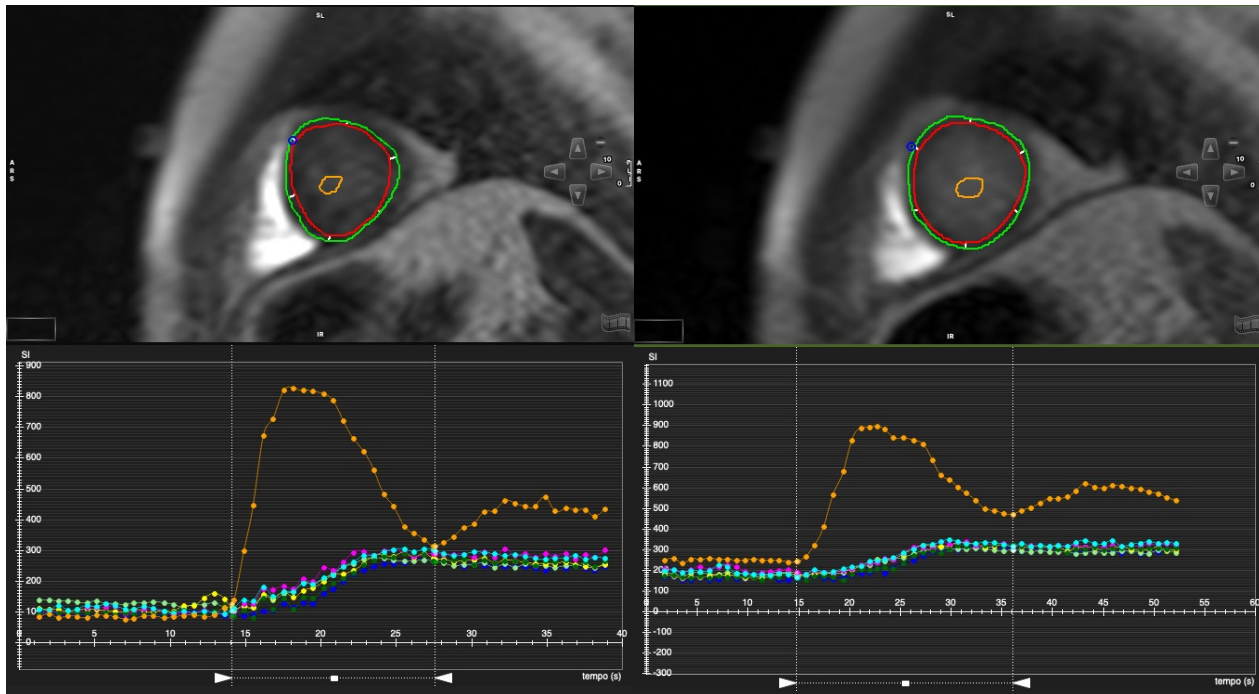


CFR: 2



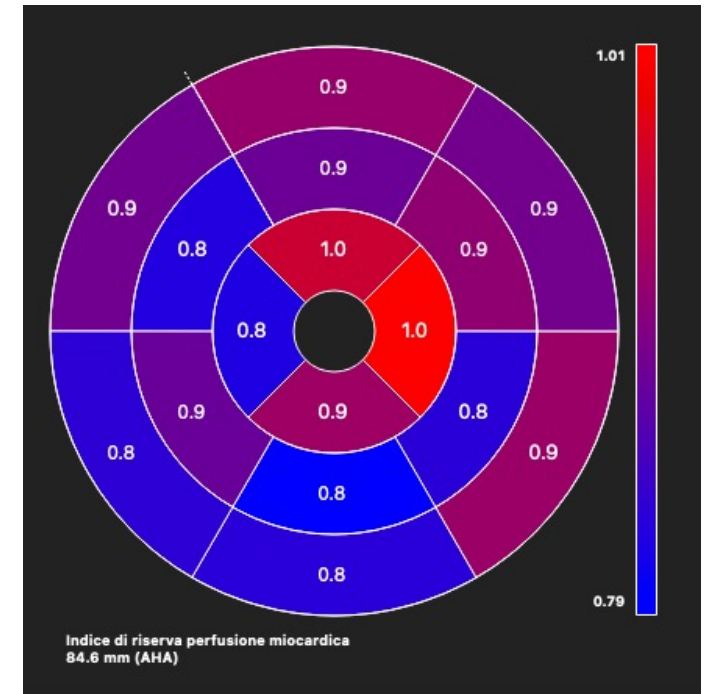
A 27-year-old psoriatic patient without known CV disease

STRESS



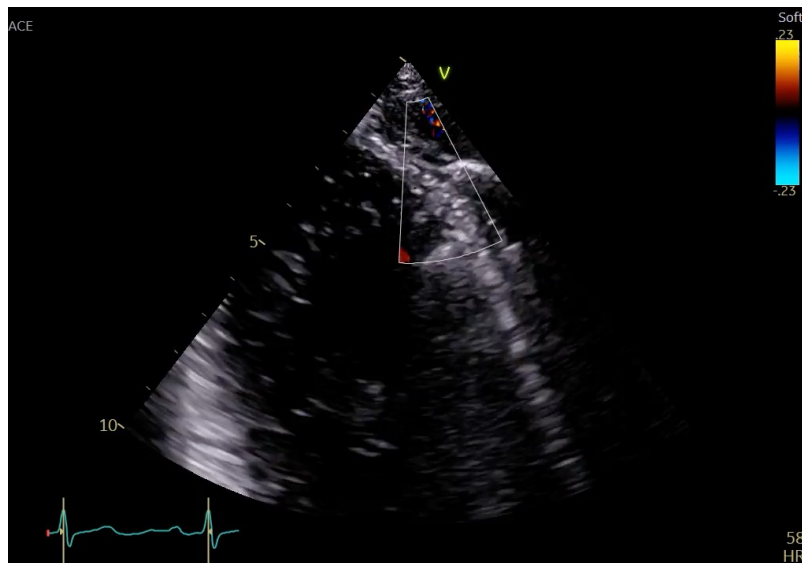
REST

REDUCED MPRI: 0.9

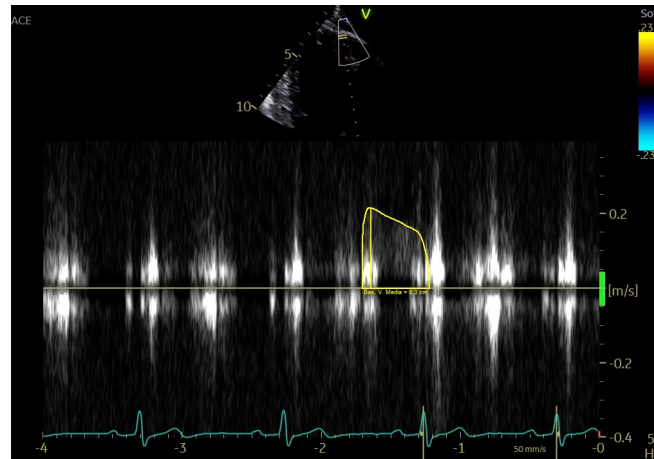




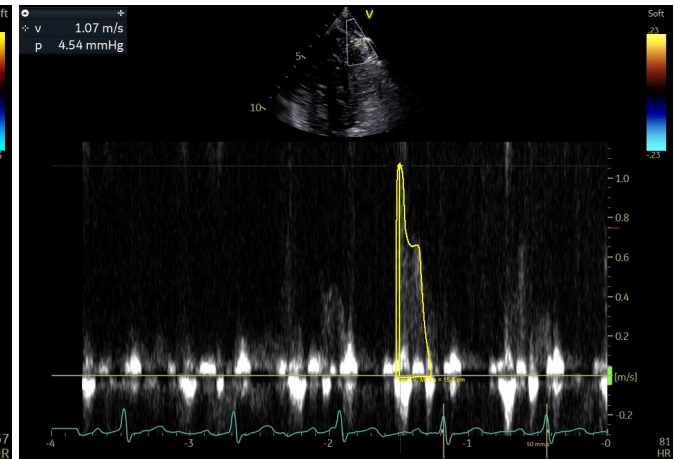
A 27-year-old psoriatic patient without known CV disease
Biological therapy started 6 months before



Basal coronary diastolic
velocity: 22/17 cm/sec



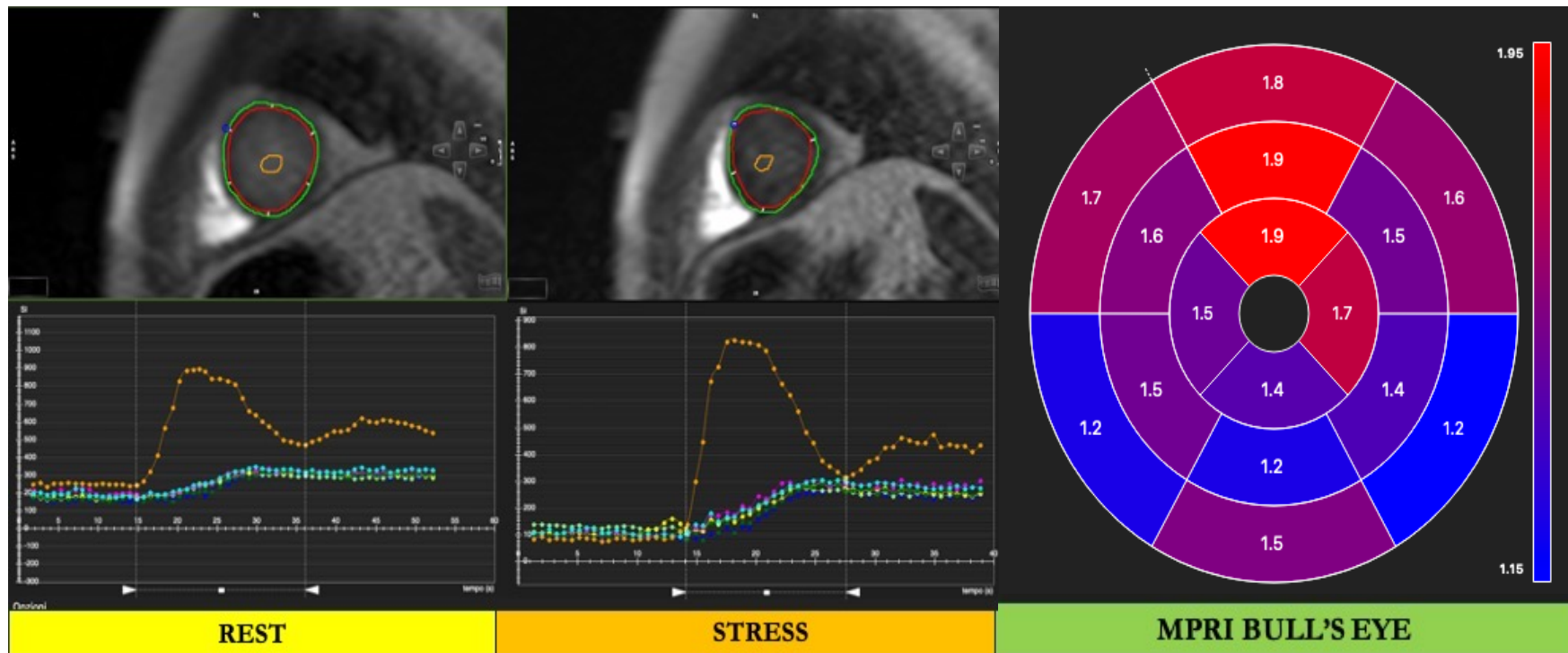
Hyperemic coronary diastolic
velocity: 107/63 cm/sec



CFR: 5



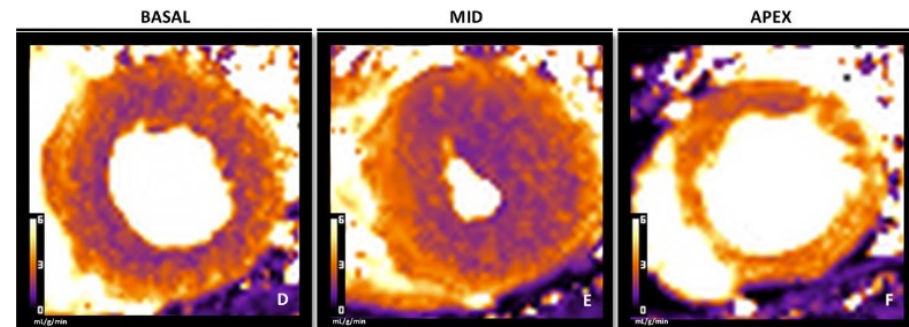
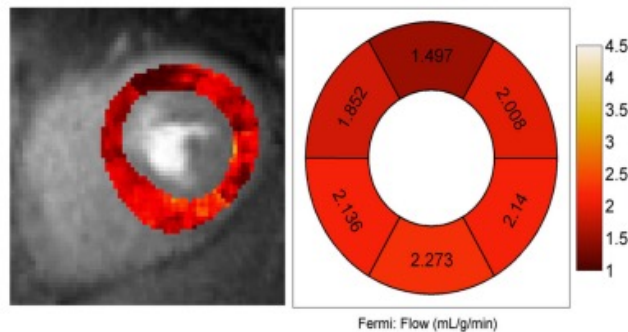
A 27-year-old psoriatic patient without known CV disease
Biological therapy started 6 months before



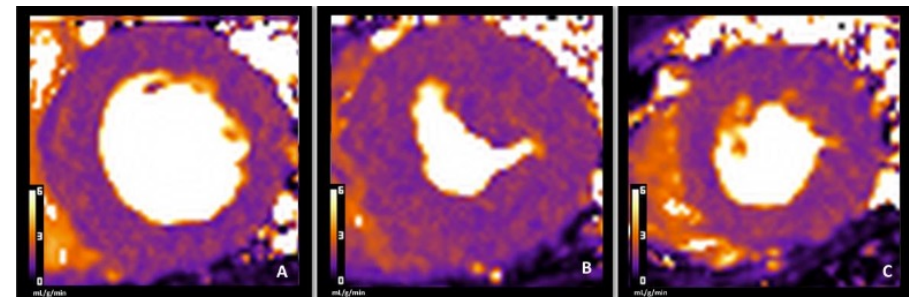
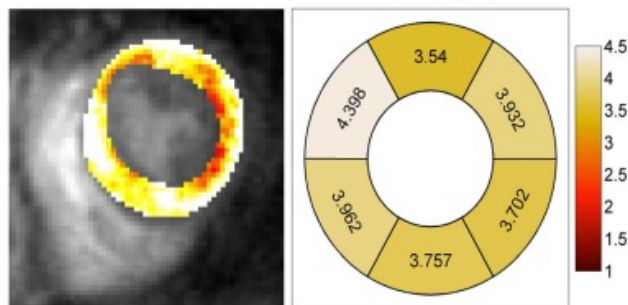


MYOCARDIAL BLOOD FLOW (nv > 2.25 ml/min/g)

STRESS



REST



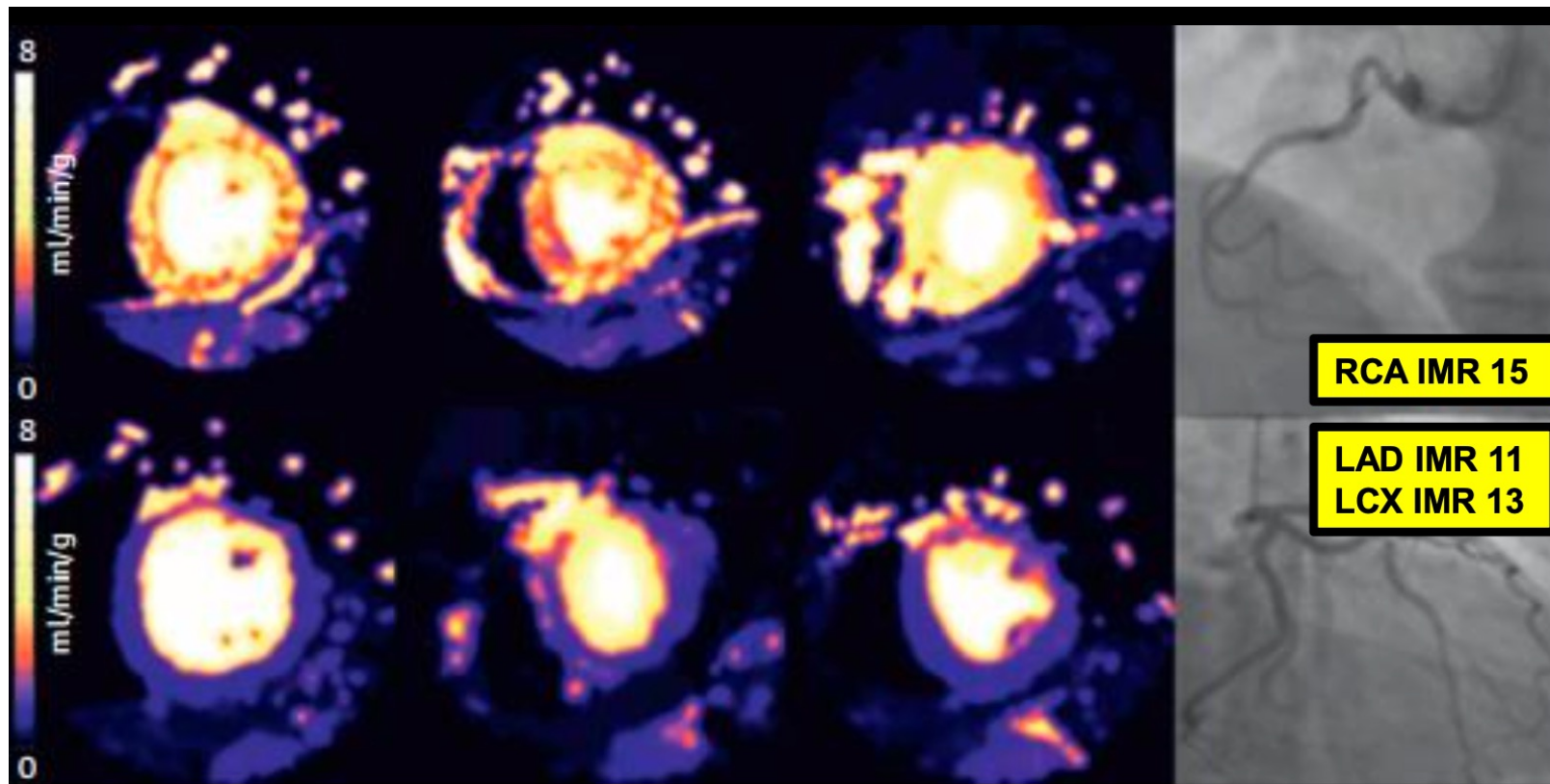
Reduction of MBF in microvascular disease.



NORMAL CORONARY PHYSIOLOGY

STRESS

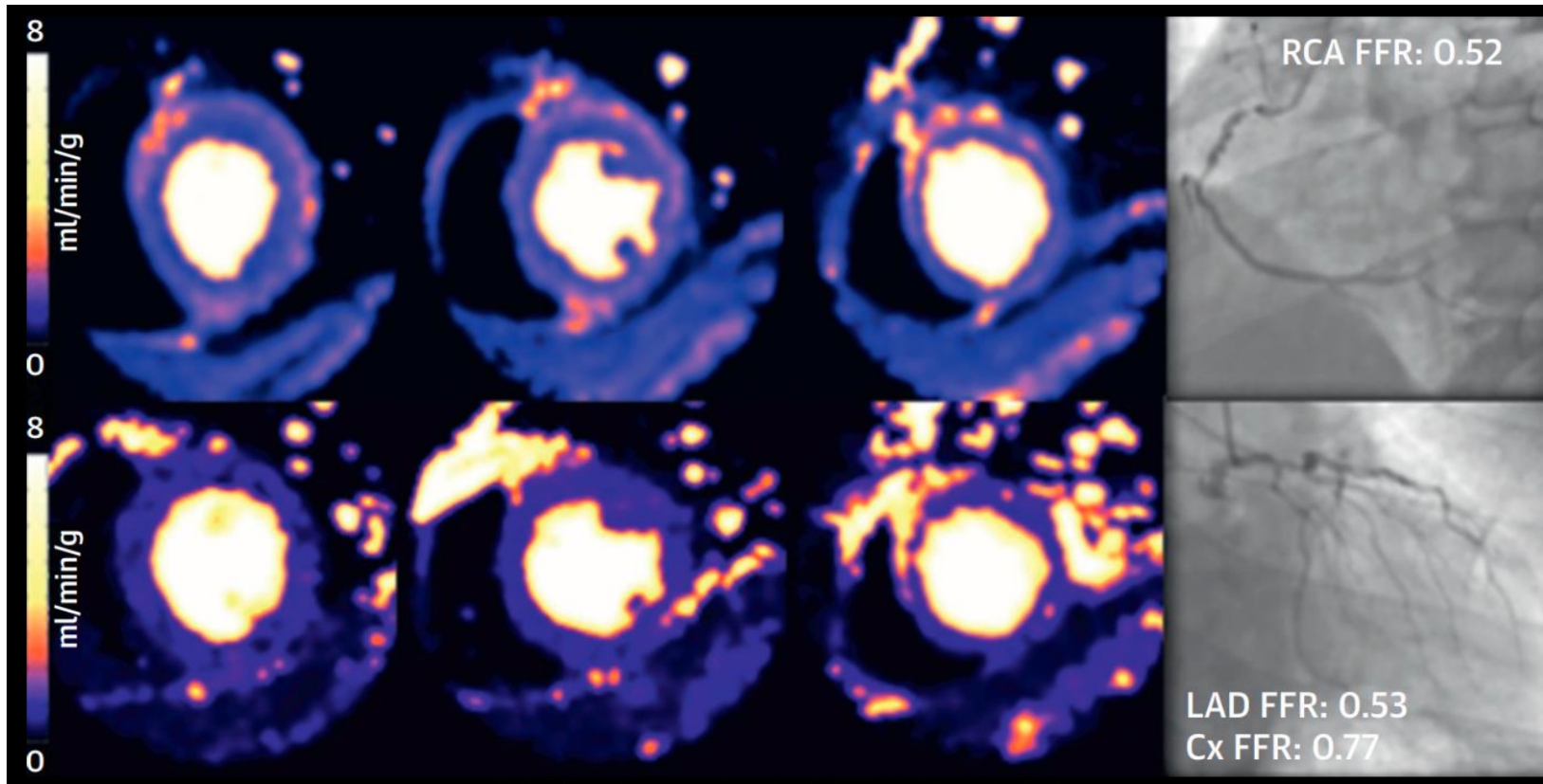
REST





THREE-VESSEL CORONARY DISEASE

STRESS



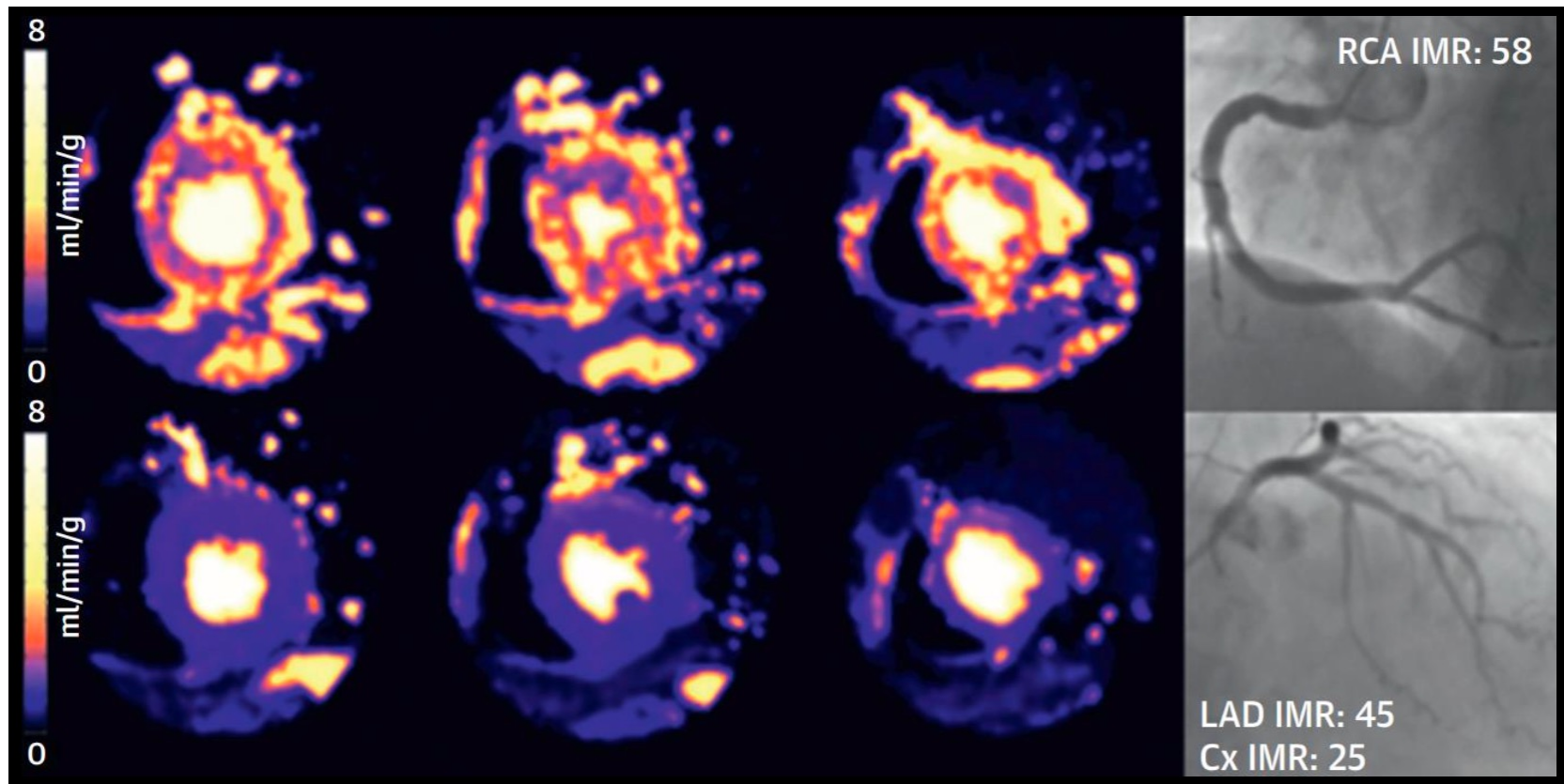
REST



CORONARY MICROVASCULAR DYSFUNCTION

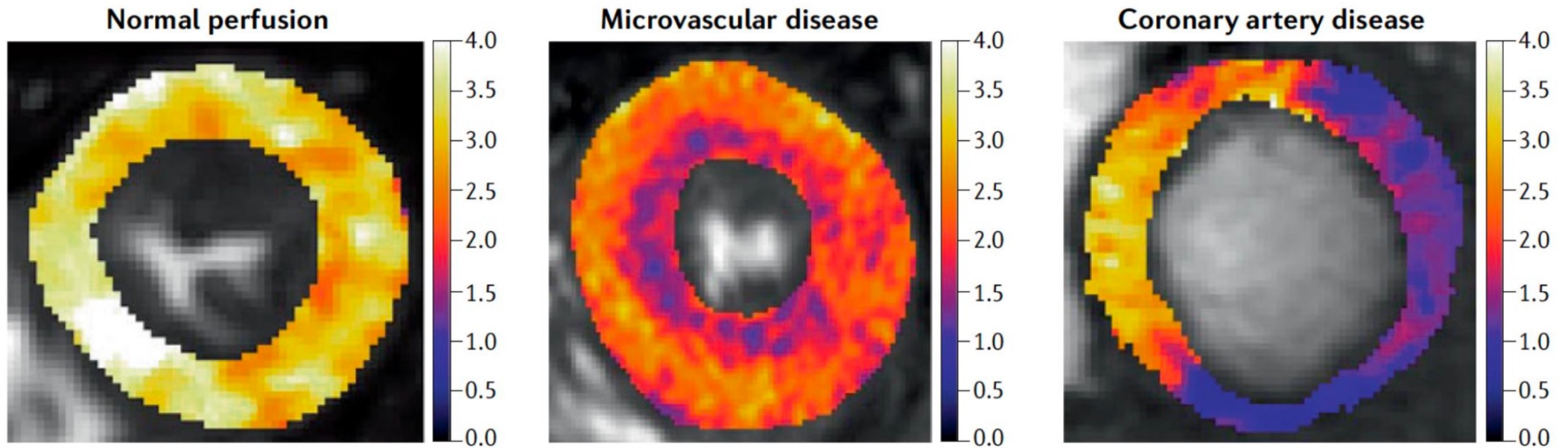
STRESS

REST





Stress CMR – Coronary microvascular dysfunction assessment



Courtesy of Prof. Fabrizio Ricci, University of Chieti



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Stress CMR – Semi-quantitative & Quantitative assessment



At the Heart of
IMAGING

Quantitative Perfusion Protocol Builder

Customize your acquisition protocol for Cardiac MRI Absolute Quantitation of Myocardial Blood Flow using Circle CVI's printable form

PATIENT WEIGHT

70 kg

SITE PROTOCOL

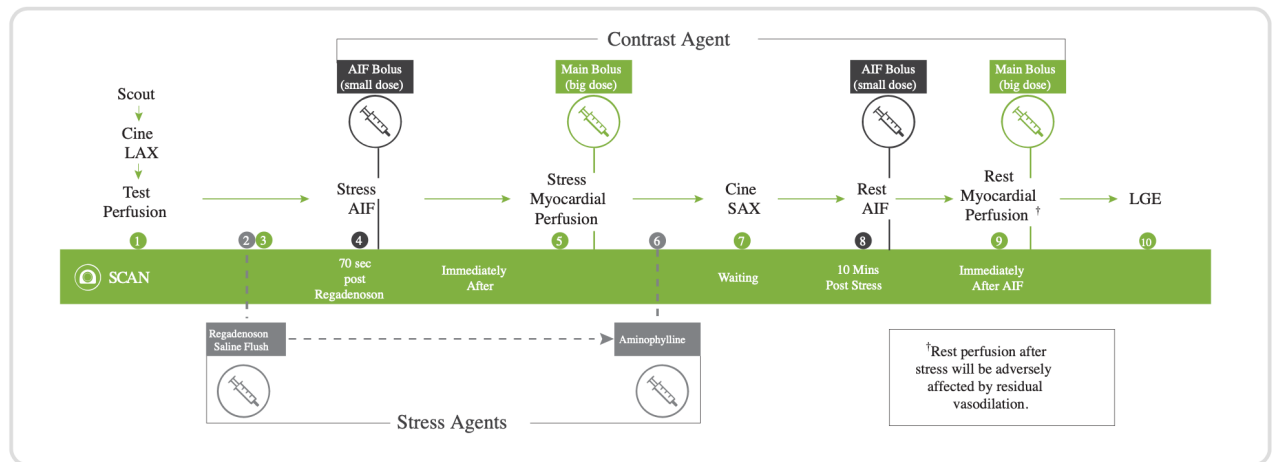
Acquisition Type	Stress/Rest
Pre-Bolus	Stress & Rest
Stress Agent	Contrast Agent
Regadenoson/Lexiscan	Gadovist Gadobutrol
Scanner Manufacturer	Sequence
Siemens	FLASH

AIF Bolus

Contrast Agent	Injection Rate	Flash Dose Volume
Gadovist 1ml/mmol 0.0075mmol/kg	2 ml/sec	0.53 ml

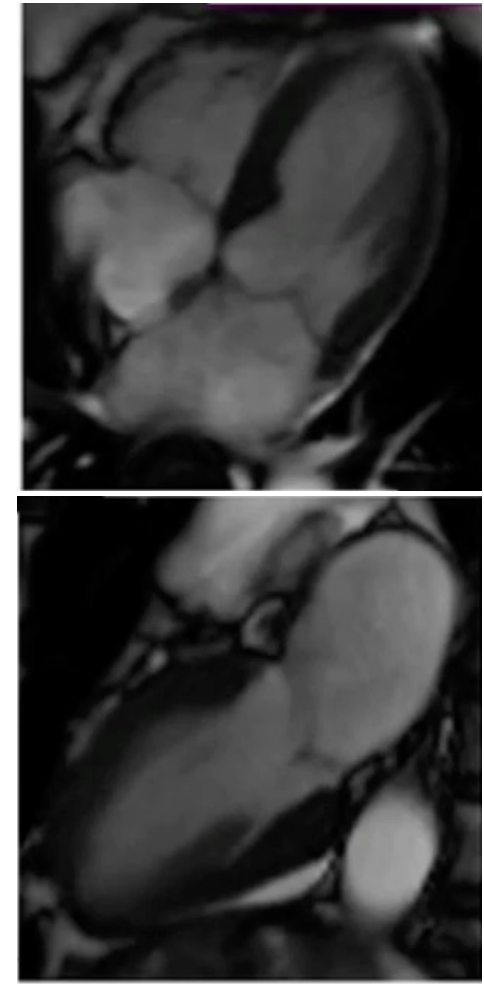
Myocardial Perfusion Bolus

Contrast Agent	Injection Rate	Flash Dose Volume
Gadovist 1ml/mmol 0.075mmol/kg	2 ml/sec	5.25 ml





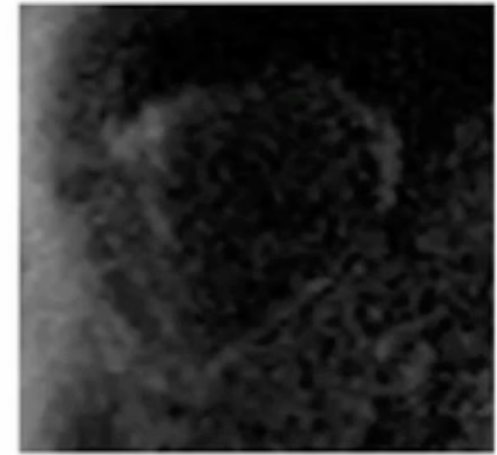
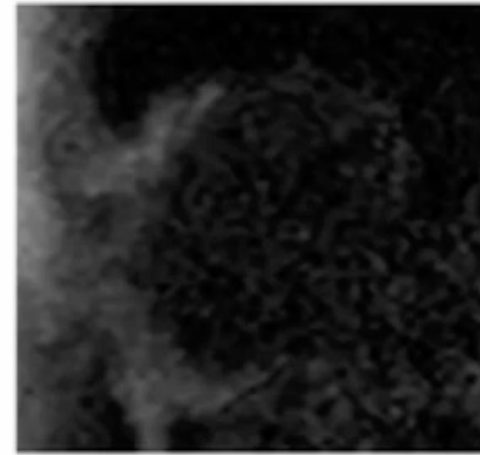
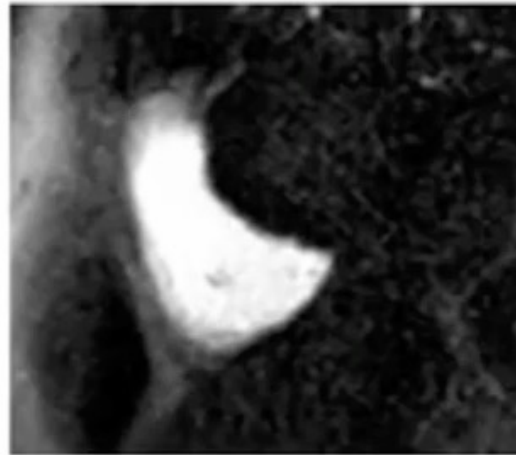
- 55-year-old man
- CV risk factors
- Atypical chest pain



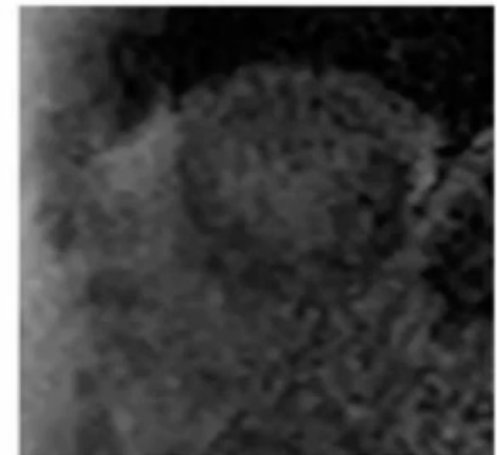
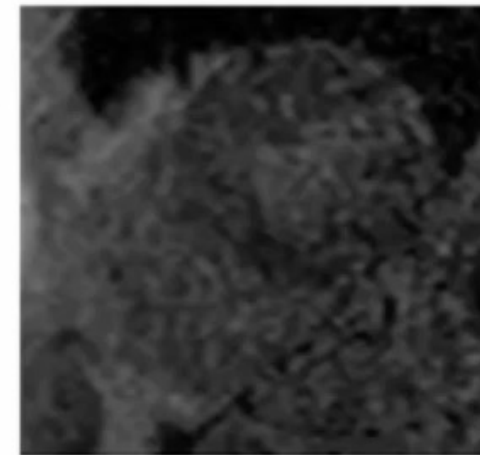
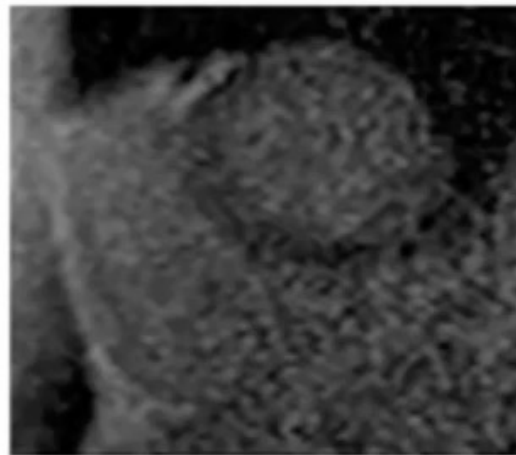


- 55-year-old man
- CV risk factors
- Atypical chest pain

STRESS

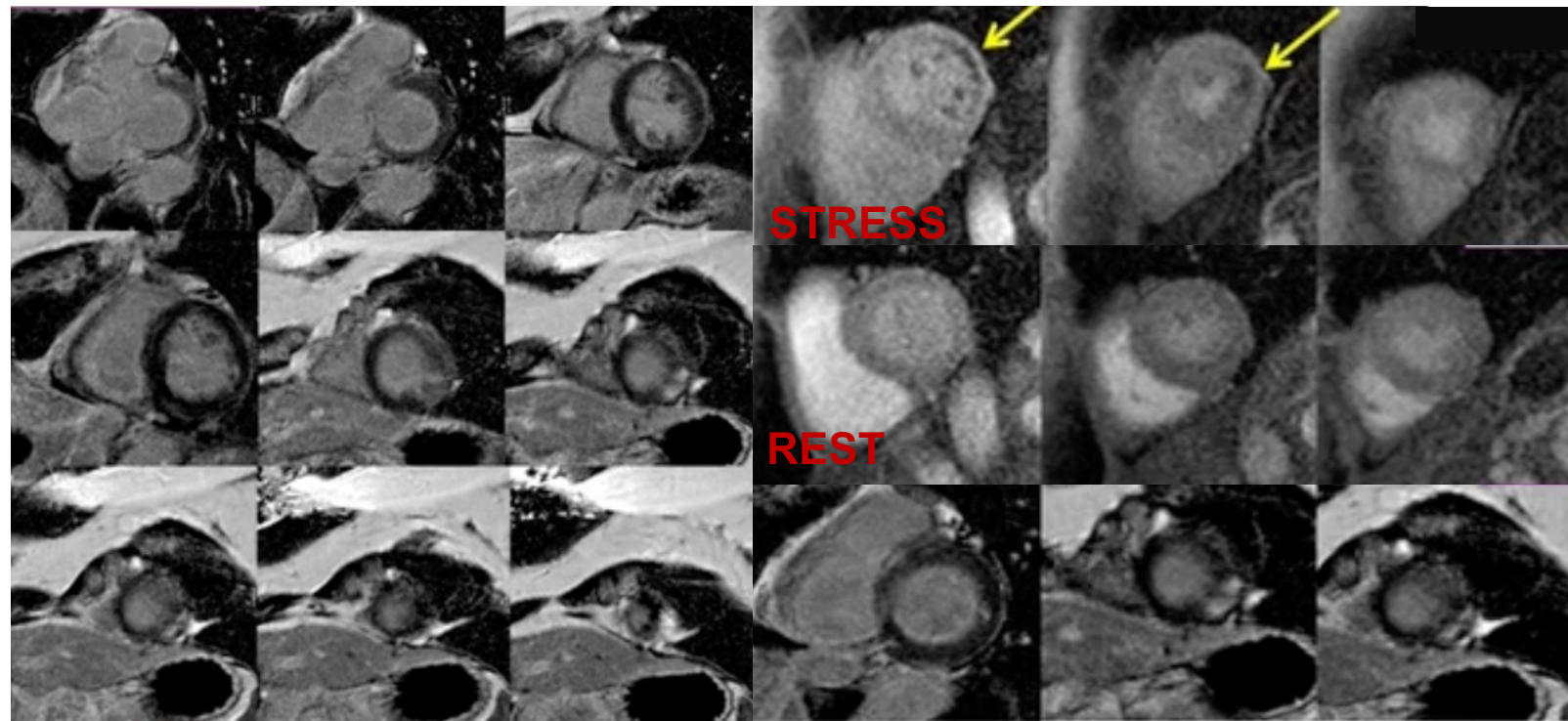


REST





- 55-year-old man
- CV risk factors
- Atypical chest pain



- Normal LV systolic function
- Inducible ischemia in the LCx territory
- Myocardial infarction in the distal LCx



- Stress CMR is a valuable non-invasive test imaging useful to assess inducible ischemia in patients with moderate or high pre-test likelihood risk of obstructive CAD, as well as microvascular dysfunction
- An integration of cine sequences, perfusion and LGE sequences are mandatory
- Stress CMR demonstrated to be a cost-effective tool to guide appropriate treatment
- Quantitative perfusion mapping is rapidly transitioning into clinical practice to assess both epicardial CAD and microvascular dysfunction

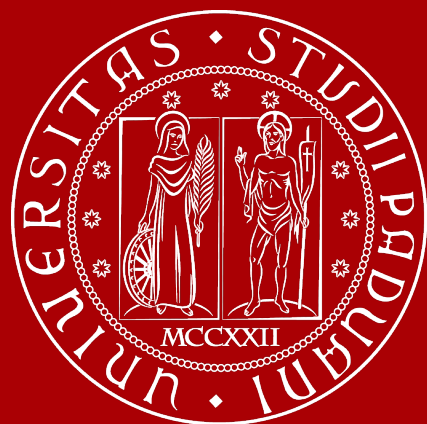


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Thanks for your attention

**Compio
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E ancora
imparo.**





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