Sistema Socio Sanitario
Ospedale Niguarda
Regione Lombardia

Cardiac magnetic resonance Clinical applications

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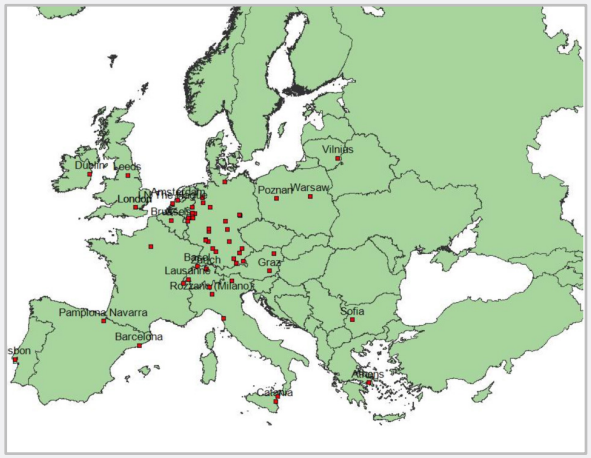
Cardiac magnetic resonance – Clinical applications

Journal of Cardiovascular Magnetic Resonance

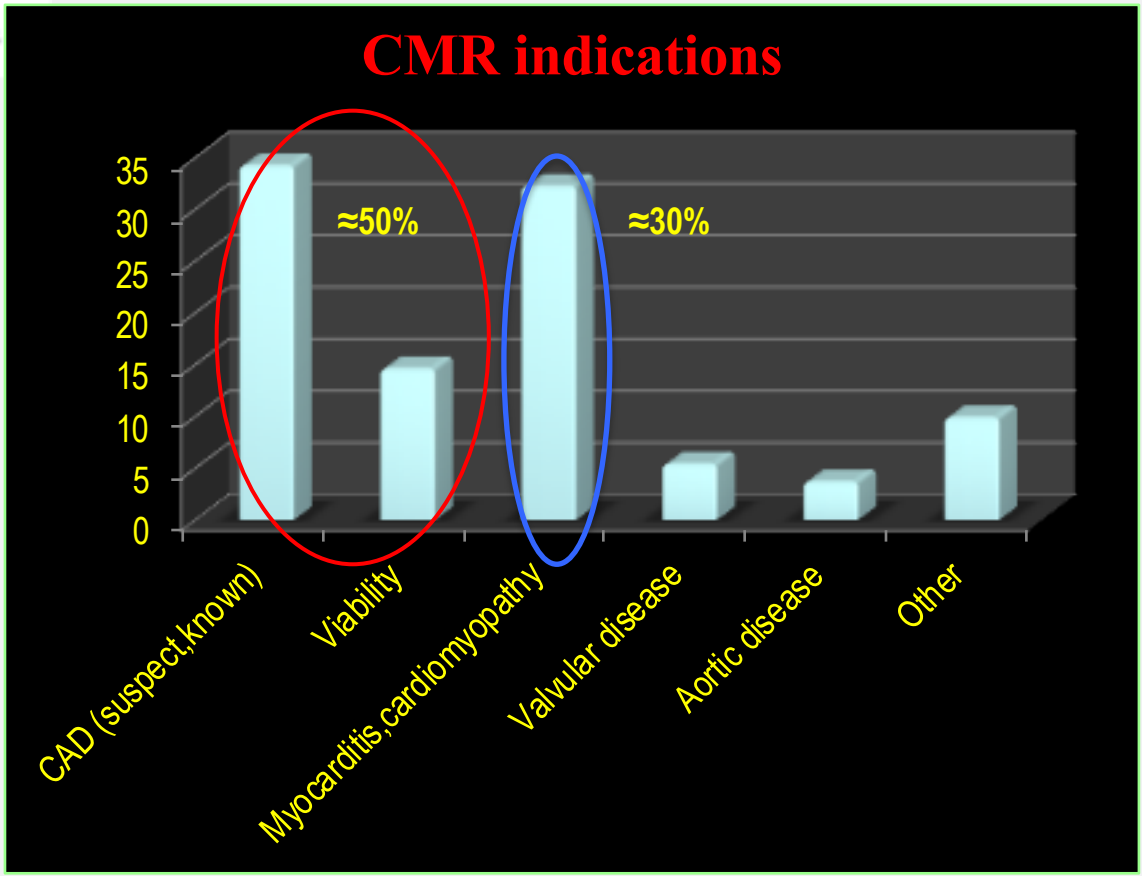
RESEARCH Open Access

European cardiovascular magnetic resonance (EuroCMR) registry – multi national results from 57 centers in 15 countries

Oliver Bruder[1], Anja Wagner[2], Massimo Lombardi[3], Jörg Schwitter[4], Albert van Rossum[5], Günter Pilz[6], Detlev Nothnagel[7], Henning Steen[8], Steffen Petersen[9], Eike Nagel[10], Sanjay Prasad[11], Julia Schumm[12], Simon Greulich[13], Alessandro Cagnolo[3], Pierre Monney[14], Christina C Deluigi[15], Thorsten Dill[16], Herbert Frank[16], Georg Sabin[1], Steffen Schneider[17] and Heiko Mahrholdt[17*]



EuroCMR Registry



Bruder et Al, JCMR 2013

EuroCMR Registry

Impact of CMR on patient management

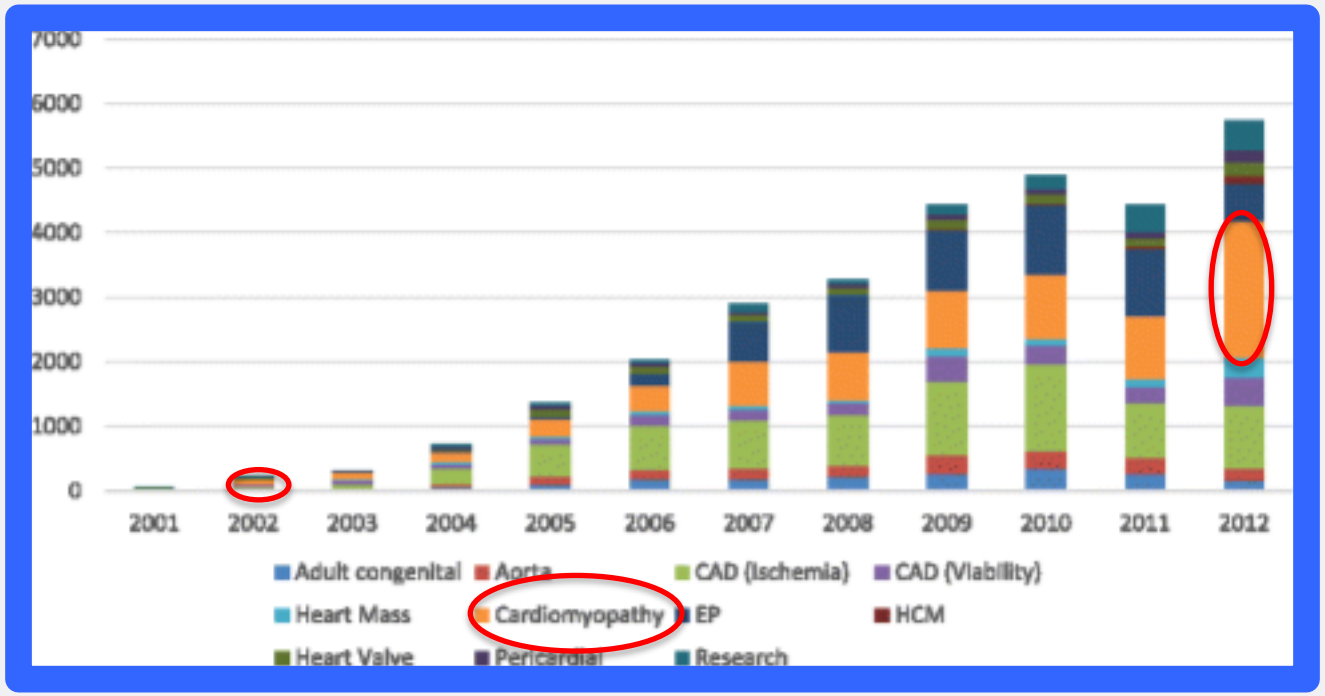
		N or quartiles
All	100%	27781
Completely new diagnosis not suspected before	8.7%	2354/27006
Therapeutic consequences		
Change in medication	25.0%	6689/26743
Invasive procedure	16.8%	4510/26778
Hospital discharge	10.2%	2738/26771
Hospital admission	1.4%	386/26780
Impact on patient management (new diagnosis and/or therapeutic consequence)	61.8%	16677/27006

Values are % (n).

Bruder O, JCMR 2013

The global cardiac magnetic resonance registry (GCMR) of the Society for Cardiovascular Magnetic Resonance (63% USA Centres)

Growth of CMR indications in the GCMR cohort, 2001–2012

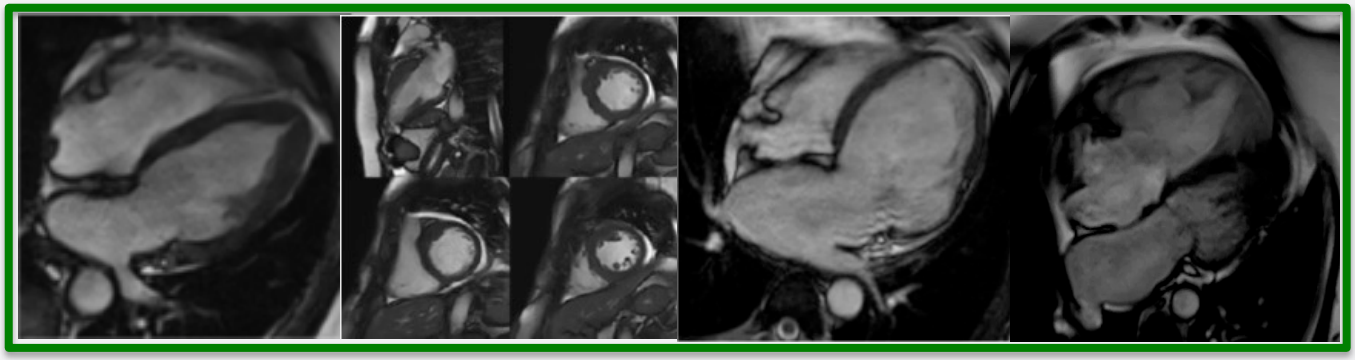


Kwong RY, JCMR 2017

CARDIOMYOPATHIES

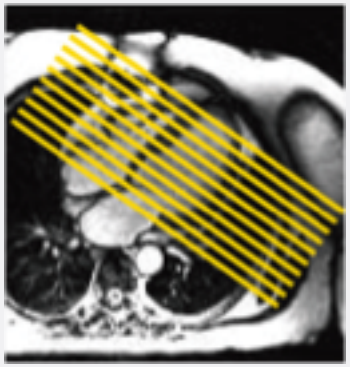
Cardiac magnetic resonance – Clinical applications

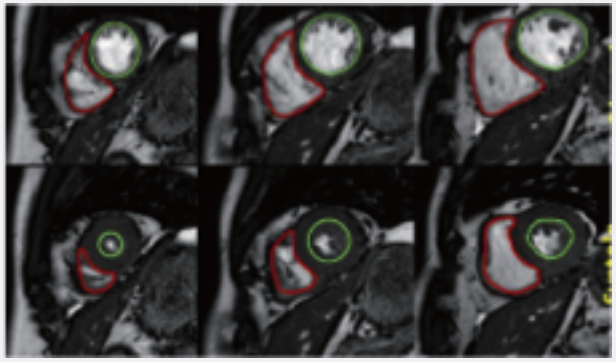
Advantages of CMR for the assessment of heart disease – **1) Cardiac morphology and function**



Specific advantages of CMR

LV apex	Basal anterior wall and septum	Lateral wall	Right ventricle
-Apical HCM -Apical aneurysm -Thrombus	-Asymmetric HCM -Cardiac masses	-Circumflex artery territory -Dystrophinopathies	-Cardiomyopathies -Congenital heart disease



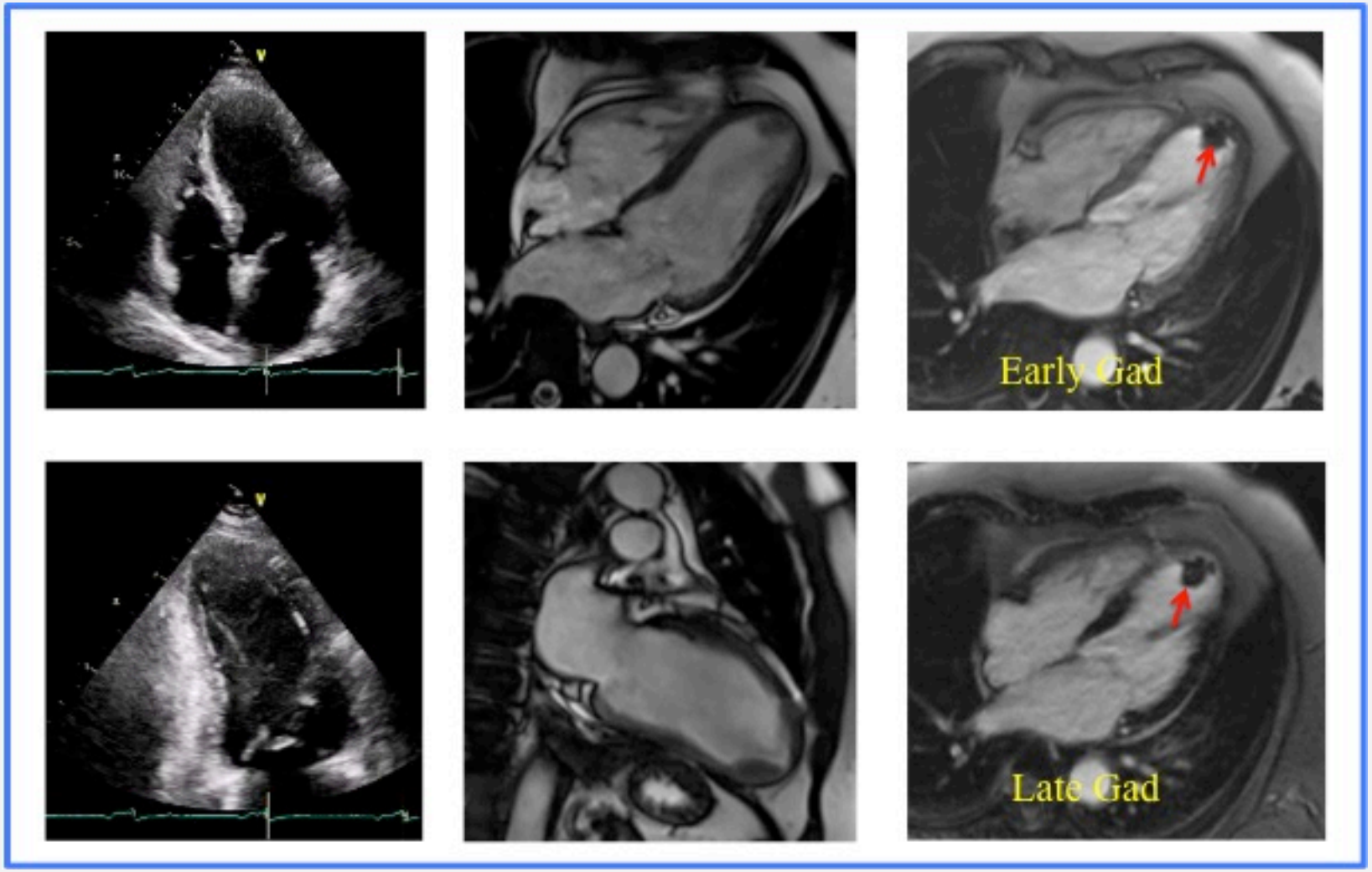


CMR is the **gold standard** to assess cardiac **volumes**, **mass** and **function**

Grothues F, Am J Cardiol, 2002; Grothues F, Am Heart J, 2004; Walsh TF, Cardiol Clin 2007

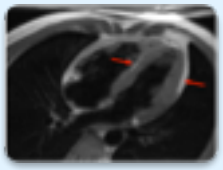
Cardiac magnetic resonance – Clinical applications

Specific advantages of CMR in the assessment of cardiac morphology – **Thrombus detection**



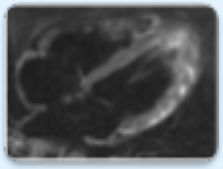
Srichai MB, Am Heart J, 2006; Weinsaft JV, JACC 2008; Delewi R, Eur J Radiol, 2012

Advantages of CMR for the assessment of heart disease –
2) Tissue characterization



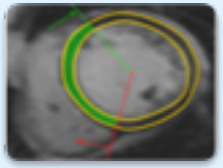
T1-weighted images (native myocardium)

- Fat



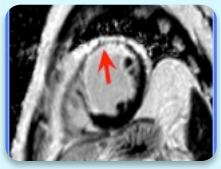
T2-weighted images (native myocardium)

- Edema



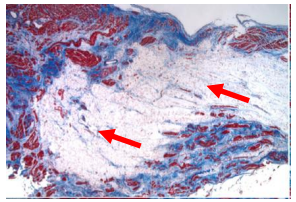
T2*-weighted images (native mayocardium)

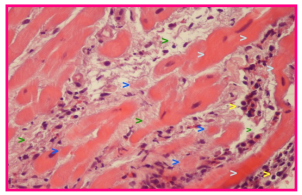
- Iron

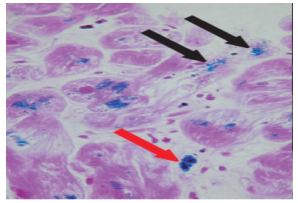


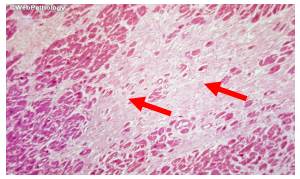
Late enhancement (post-contrast)

. Fibrosis (scar)

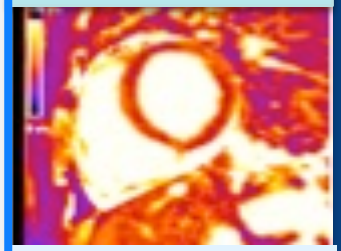
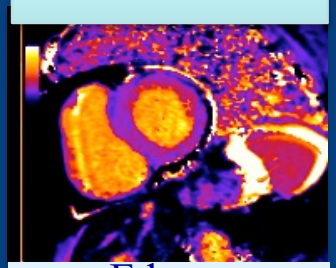
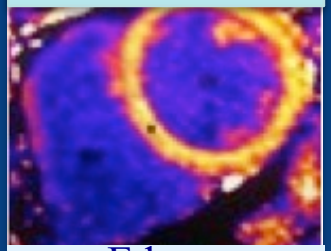
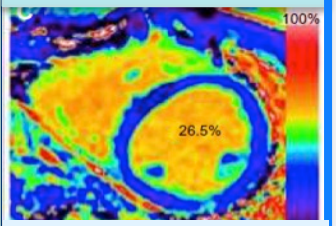








Advantages of CMR for the assessment of heart disease – 3) Quantitative tissue characterization – Parametric mapping

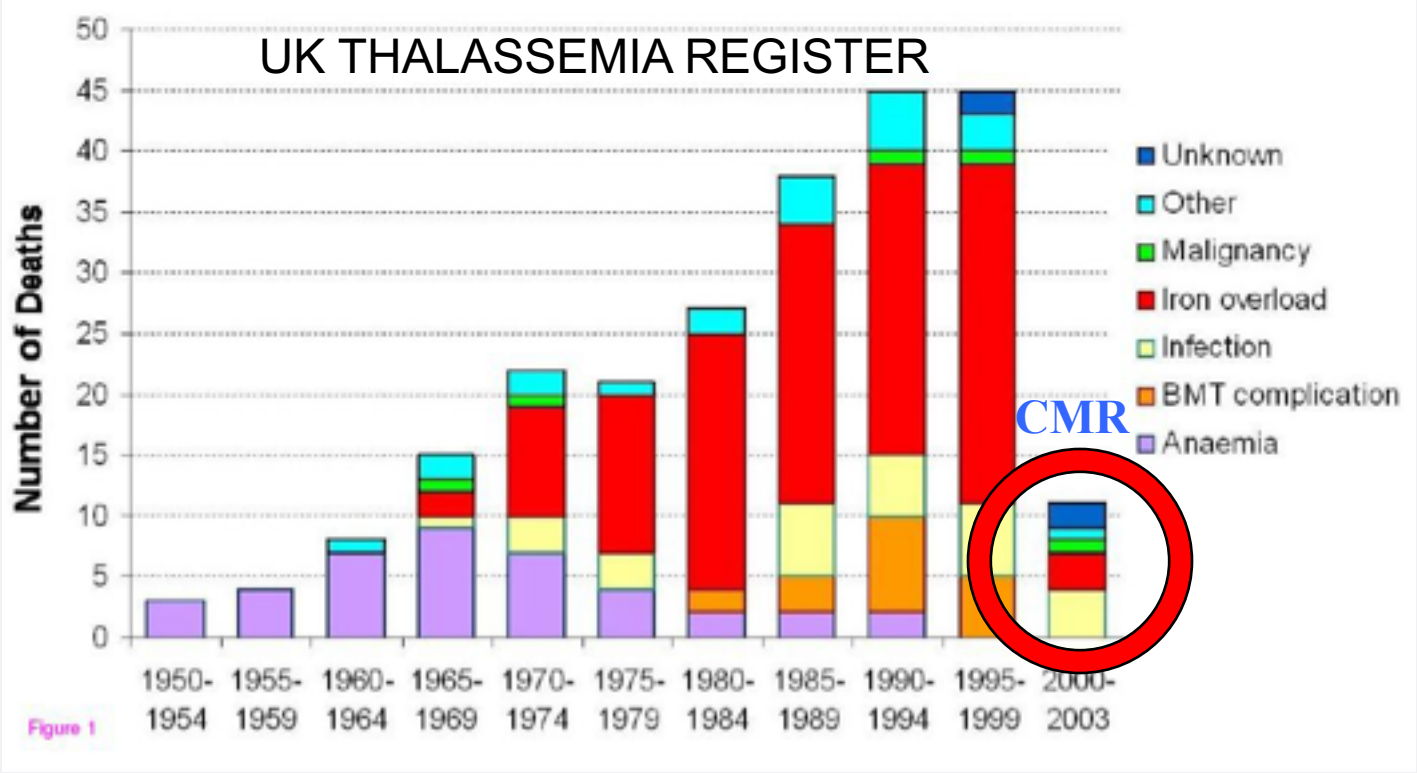
T2 mapping (native; ms)	T1 mapping (native; ms)	T1 mapping (post-gd; ms)	ECV (post-gd; %)
			
Edema	Edema Interstitial fibrosis Amyloid Fat Iron	Edema Interstitial fibrosis Amyloid	Edema Interstitial fibrosis Amyloid

- Quantification of myocardial signal
- Disease-specific alterations
- Native myocardium (no contrast)
- Early diagnosis
- Longitudinal follow up

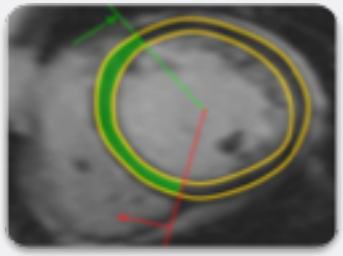
ECV= extracellular volume

1) Specific advantages of CMR in defining etiology

CMR to define etiology – Iron overload cardiomyopathy



Modell JCMR 2008

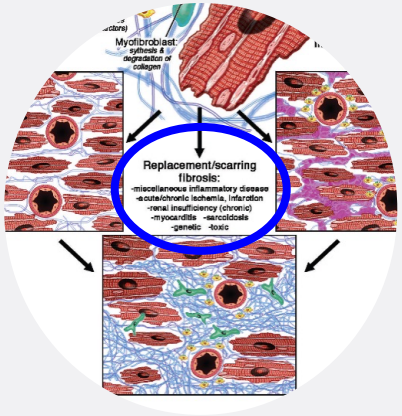


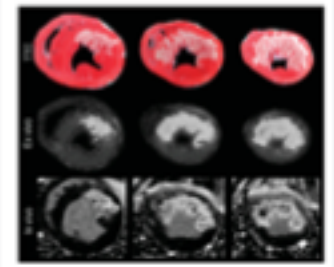
T2* to assess iron overload

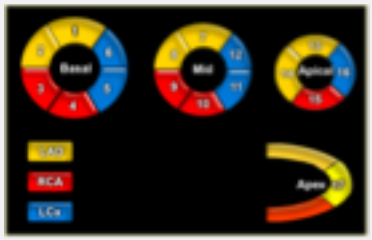
- Impact of CMR on chelation therapy titration
- Impact of CMR on prognosis
- Impact of CMR on general patient management

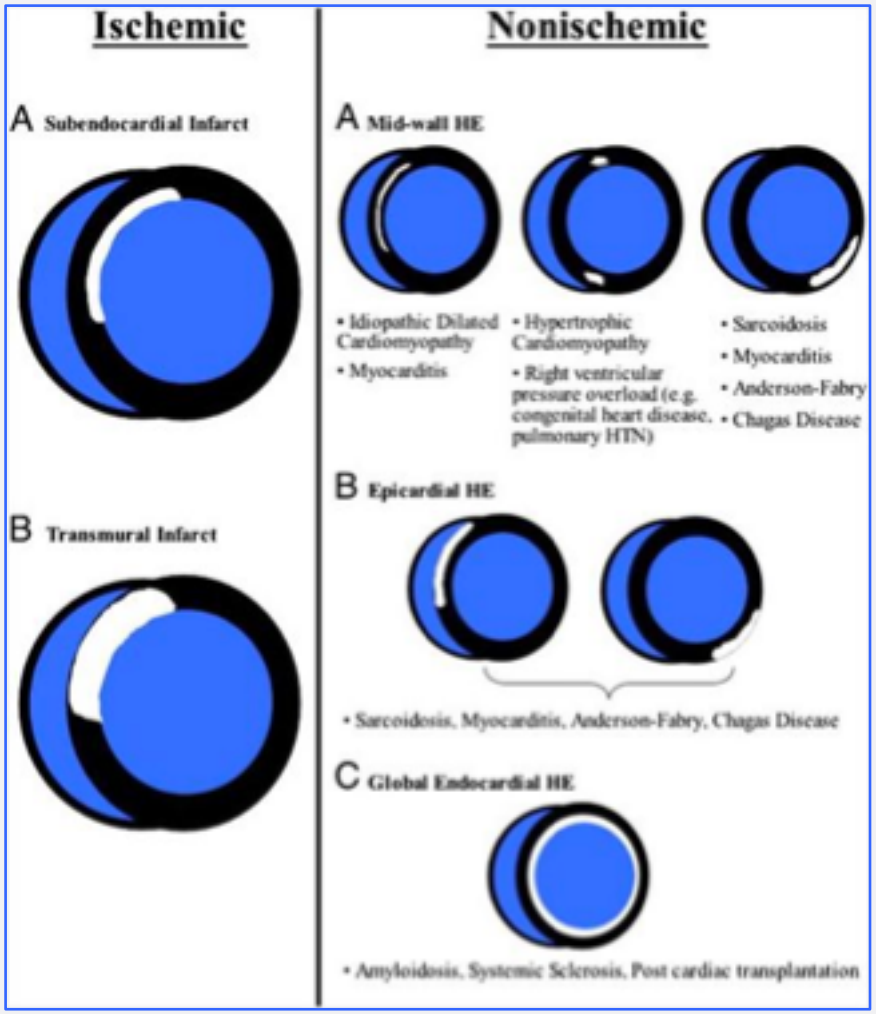
Cardiac magnetic resonance – Clinical applications

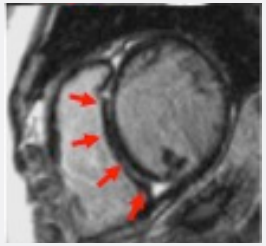
CMR to define etiology – Late enhancement patterns

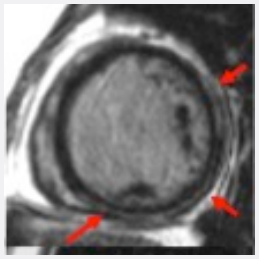


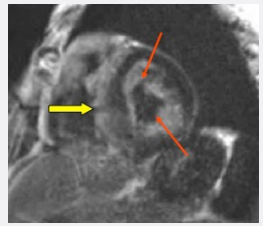






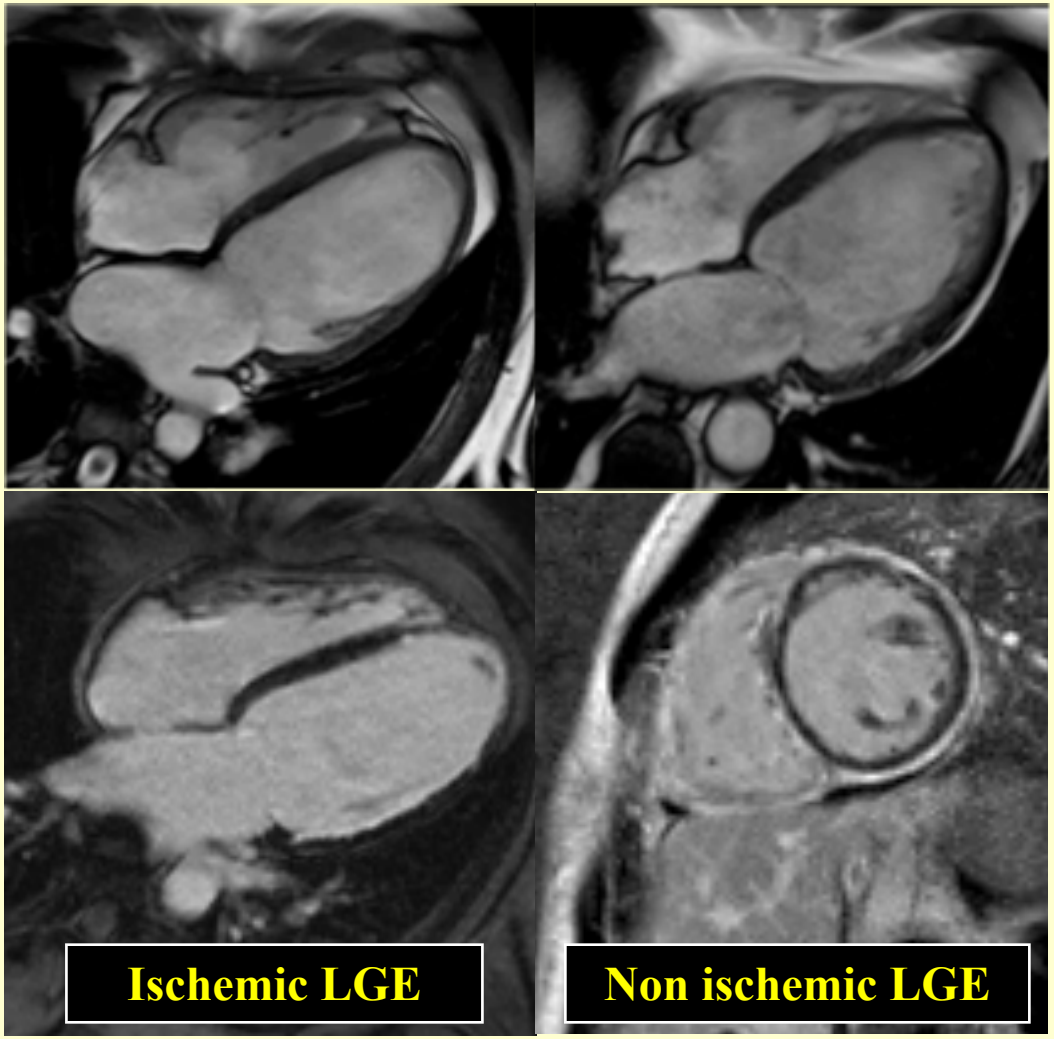






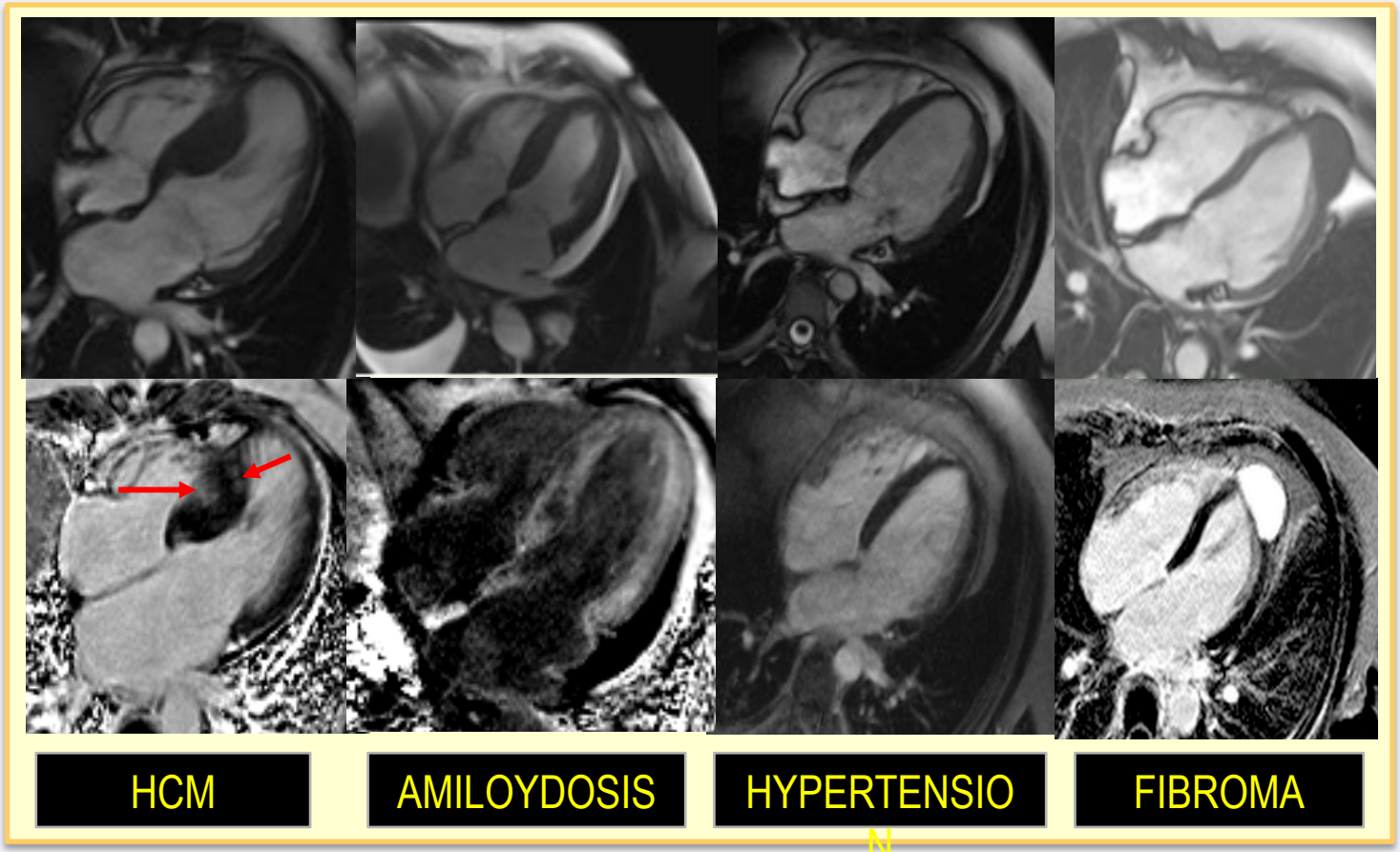
Dual pathology occurs!

Ischemic versus non ischemic cardiomyopathy



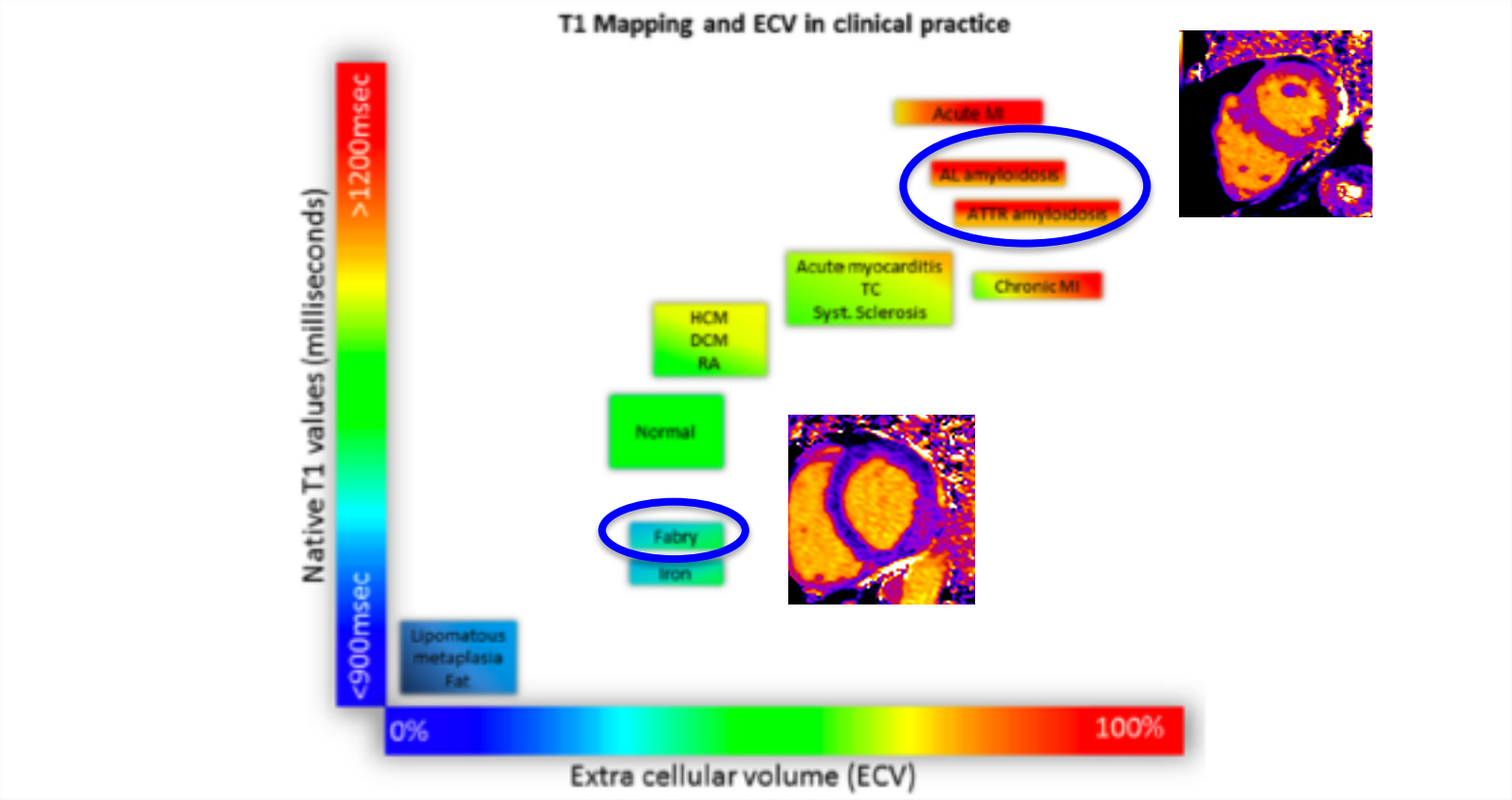
- Impact of CMR on diagnosis
- Impact of CMR on patient management

Differential diagnosis of myocardial hypertrophy



- Impact of CMR on diagnosis
- Impact of CMR on patient management

Parametric mapping for the differential diagnosis of cardiac hypertrophy



Haaf *et al. Journal of Cardiovascular Magnetic Resonance* (2016) 18:89

Cardiac magnetic resonance – Clinical applications

Recommendations for cardiac imaging in patients with suspected or established heart failure

Recommendations	Class	Level	Ref
TTE is recommended for the assessment of myocardial structure and function in subjects with suspected HF in order to establish a diagnosis of either HFrEF, HFmrEF or HFpEF.	I	C	
TTE is recommended to assess LVEF in order to identify patients with HF who would be suitable for evidence-based pharmacological and device (ICD, CRT) treatment recommended for HFrEF.	I	C	
TTE is recommended for the assessment of valve disease, right ventricular function and pulmonary arterial pressure in patients with an already established diagnosis of either HFrEF, HFmrEF or HFpEF in order to identify those suitable for correction of valve disease.	I	C	
TTE is recommended for the assessment of myocardial structure and function in subjects to be exposed to treatment which potentially can damage myocardium (e.g. chemotherapy).	I	C	
Other techniques (including systolic tissue Doppler velocities and deformation indices, i.e. strain and strain rate), should be considered in a TTE protocol in subjects at risk of developing HF in order to identify myocardial dysfunction at the preclinical stage.	IIa	C	
CMR is recommended for the assessment of myocardial structure and function (including right heart) in subjects with poor acoustic window and patients with complex congenital heart diseases (taking account of cautions/contra-indications to CMR).	I	C	
CMR with LGE should be considered in patients with dilated cardiomyopathy in order to distinguish between ischaemic and non-ischaemic myocardial damage in case of equivocal clinical and other imaging data (taking account of cautions/contra-indications to CMR).	IIa	C	
CMR is recommended for the characterization of myocardial tissue in case of suspected myocarditis, amyloidosis, sarcoidosis, Chagas disease, Fabry disease non-compaction cardiomyopathy, and haemochromatosis (taking account of cautions/contra-indications to CMR).	I	C	
Non-invasive stress imaging (CMR, stress echocardiography, SPECT, PET) may be considered for the assessment of myocardial ischaemia and viability in patients with HF and CAD (considered suitable for coronary revascularization) before the decision on revascularization.	IIb	B	116–118
Invasive coronary angiography is recommended in patients with HF and angina pectoris recalcitrant to pharmacological therapy or symptomatic ventricular arrhythmias or aborted cardiac arrest (who are considered suitable for potential coronary revascularization) in order to establish the diagnosis of CAD and its severity.	I	C	
Invasive coronary angiography should be considered in patients with HF and intermediate to high pre-test probability of CAD and the presence of ischaemia in non-invasive stress tests (who are considered suitable for potential coronary revascularization) in order to establish the diagnosis of CAD and its severity.	IIa	C	
Cardiac CT may be considered in patients with HF and low to intermediate pre-test probability of CAD or those with equivocal non-invasive stress tests in order to rule out coronary artery stenosis.	IIb	C	
Reassessment of myocardial structure and function is recommended using non-invasive imaging: - in patients presenting with worsening HF symptoms (including episodes of AHF) or experiencing any other important cardiovascular event; - in patients with HF who have received evidence-based pharmacotherapy in maximal tolerated doses, before the decision on device implantation (ICD, CRT); - in patients exposed to therapies which may damage the myocardium (e.g. chemotherapy) (serial assessments).	I	C	

CMR in ESC Guidelines on heart failure

- cardiac function
- tissue characterization
- stress (ischemia detection)

2016 ESC Guidelines – Heart failure

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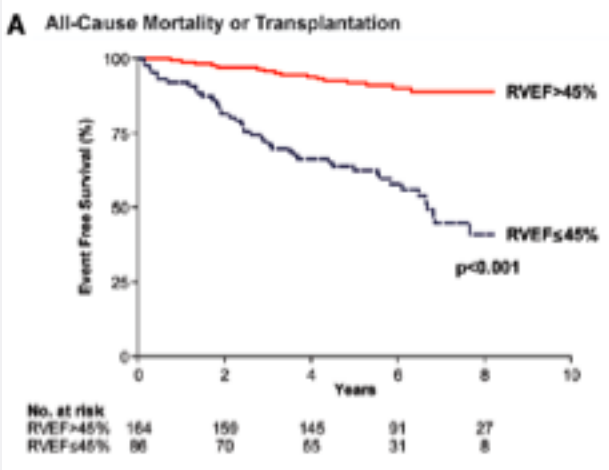


2) Specific advantages of CMR in defining prognosis

Right ventricular function

Table 2. Study Outcome Data According to Presence (RVSD+) or Absence (RVSD–) of Right Ventricular Systolic Dysfunction.

Outcome	RVSD– (n=164)	RVSD + (n=86)	Hazard Ratio (95% CI)	*P* Value
Primary end point, No. of patients (%)				
All-cause mortality or cardiac transplantation	17 (10.4)	42 (48.8)	5.90 (3.35–10.37)	<0.001
All-cause mortality	16 (9.8)	36 (41.9)	5.51 (3.06–9.94)	<0.001
Cardiac transplantation	1 (0.6)	6 (7.0)	13.01 (1.56–108.26)	0.018
Secondary end points, No. of patients (%)				
Cardiovascular mortality or cardiac transplantation	15 (9.2)	35 (40.7)	5.62 (3.07–10.30)	<0.001
Cardiovascular mortality	14 (8.5)	29 (33.7)	5.12 (2.70–9.70)	<0.001
Heart failure death, heart failure hospitalization, or cardiac transplantation*	13 (7.9)	32 (37.2)	6.13 (3.21–11.70)	<0.001
Heart failure death	3 (1.8)	17 (19.8)	14.19 (4.15–48.45)	<0.001
Heart failure hospitalization	12 (7.3)	27 (31.4)	5.61 (2.84–11.10)	<0.001

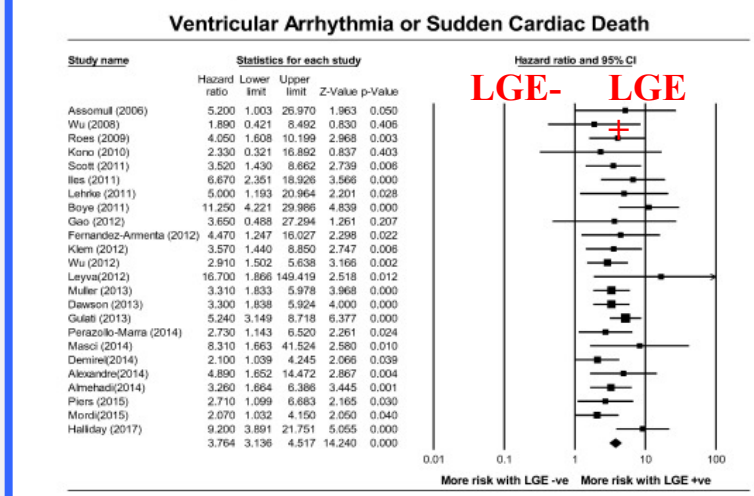
250 pts with DCM
RVEF < 45% in 86 pts (34%)
Primary end point (all cause mortality and HTx): 49% pts with RV dysfunction and 10% pts without RV dysfunction ($p < 0.001$)

Gulati A, Circulation 2013

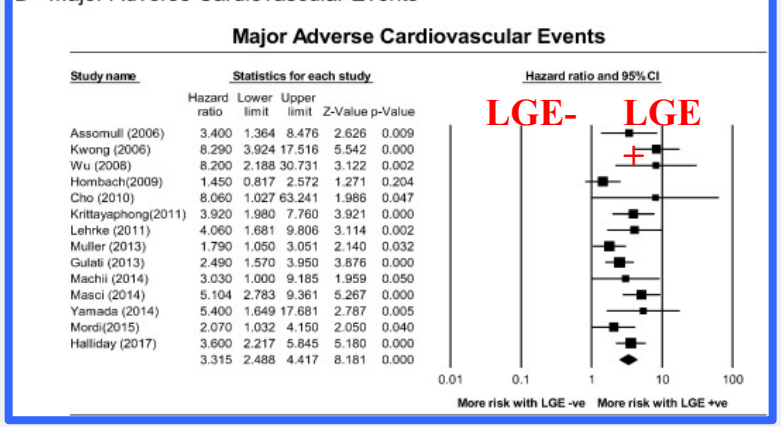
Cardiac magnetic resonance – Clinical applications

Late enhancement

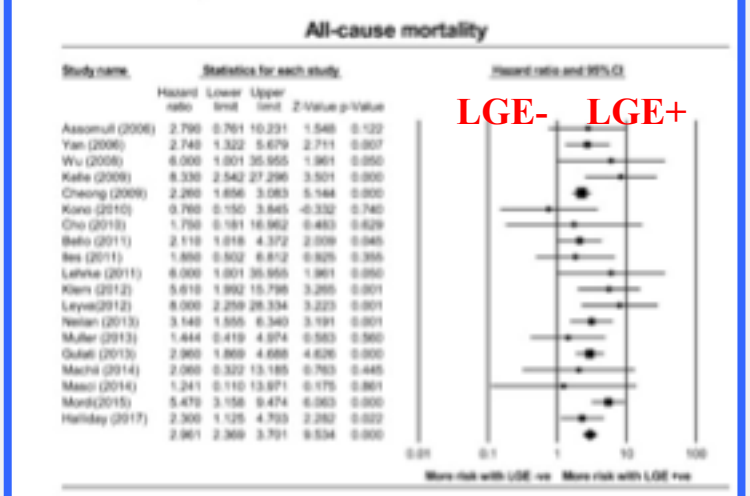
C-All-Ventricular Arrhythmia or Sudden Cardiac Death



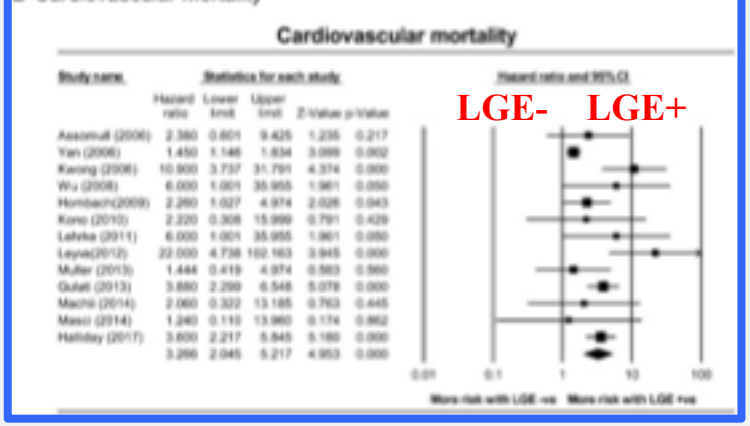
D –Major Adverse Cardiovascular Events



A-All-cause mortality



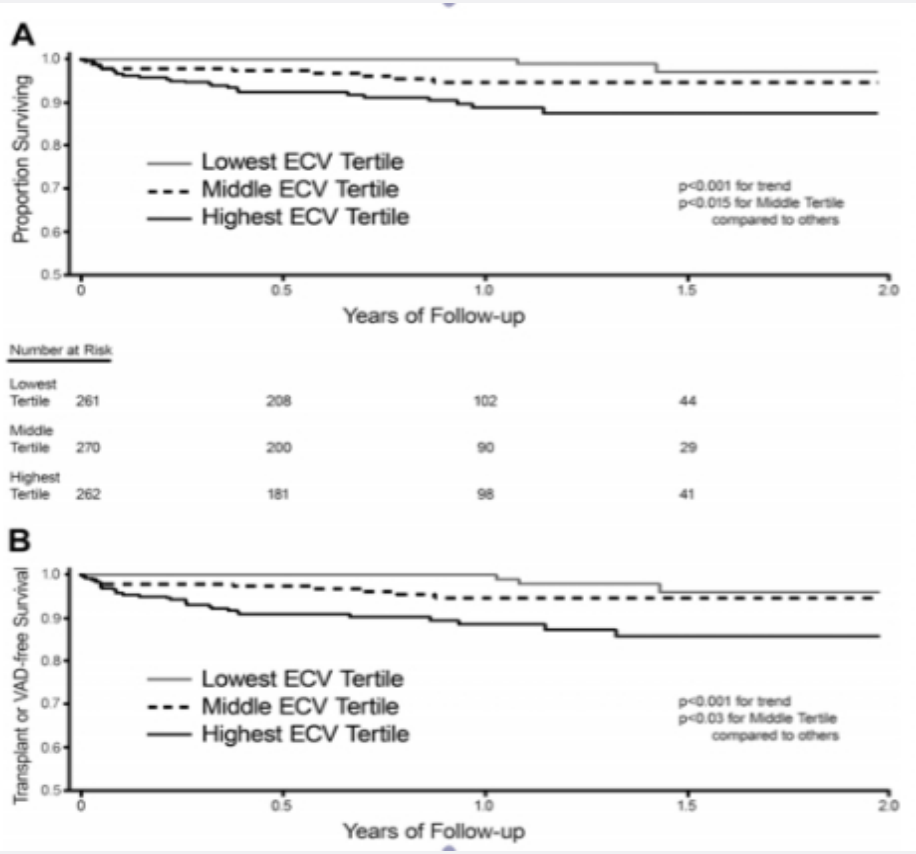
B-Cardiovascular Mortality



Impact of LGE on prognosis in ischemic and non-ischemic cardiomyopathy. A meta-analysis. Ganesan AN, Int J Cardiol, 2018

Future perspective - Parametric mapping

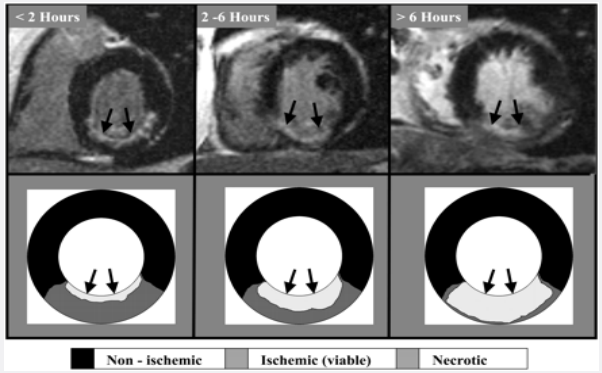
-793 pts
-HCM and amyloidosis excluded
-Worse prognosis in pts with higher ECV
-Preliminary data, further assessment warranted
-ECV expansion related to diastolic dysfunction in HFpEF (Su MM, Jacc Imaging 2014)



Wong T. et al. Circulation 2012

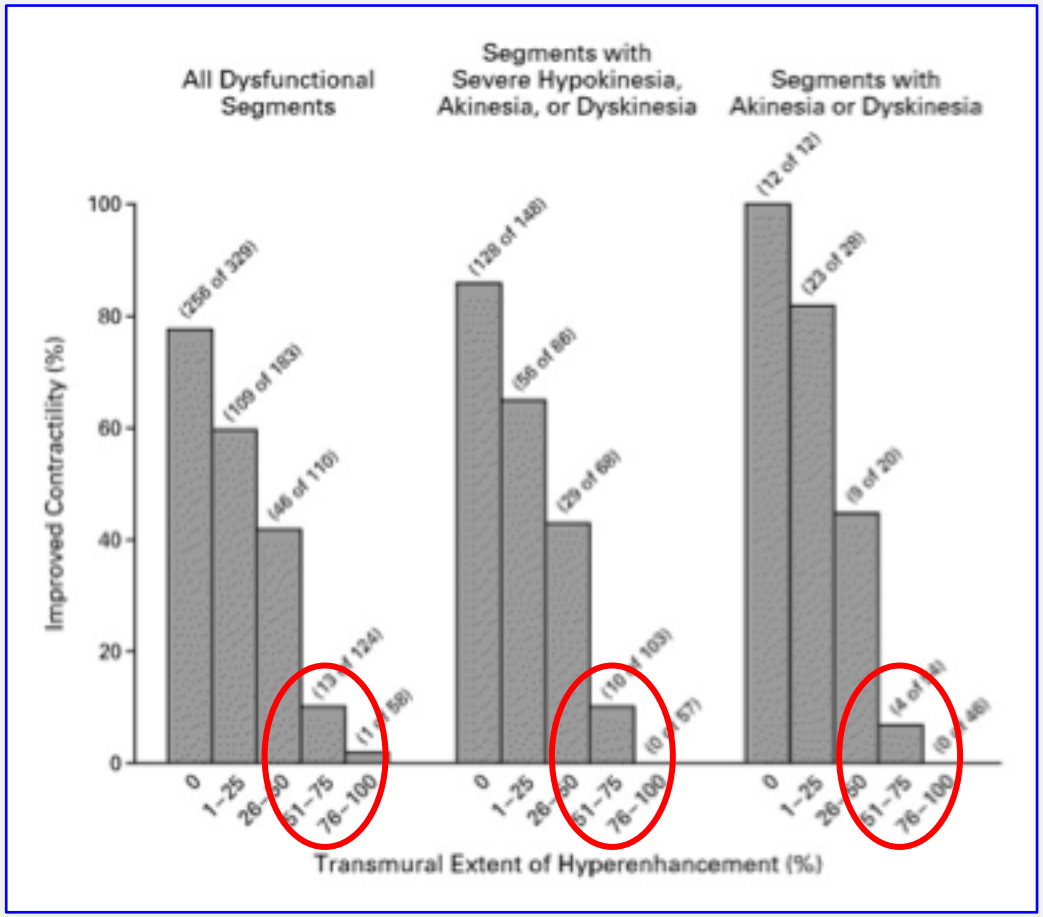
3)CMR to guide therapy

CMR to Identify Reversible Myocardial Dysfunction



Segments with LGE > 50% didn't show contractility improvement

Impact of CMR on patient management (revascularization)



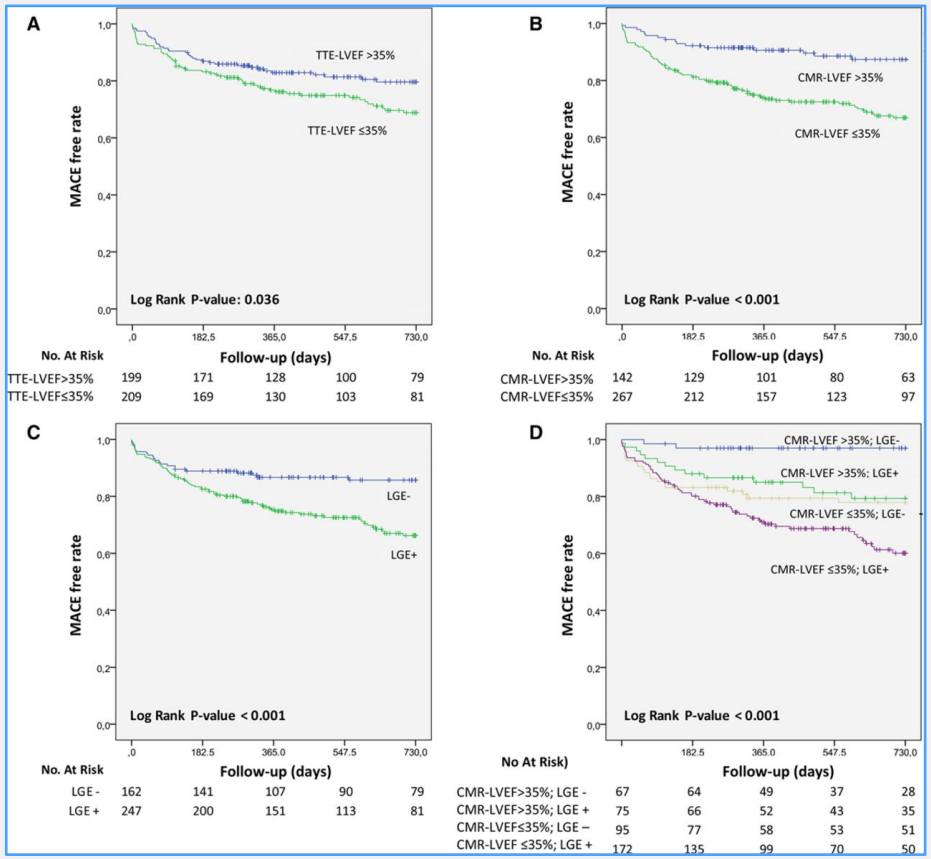
- Wall thickness < 4-5 mm: recovery unlikely
- Viability < 20-30% of LV: recovery unlikely
- Coronary anatomy, chronic ischemia duration, extent of revascularization, site of viable and non viable segments, comorbidities influence contractility recovery

Kim RJ New Engl J Med 2000

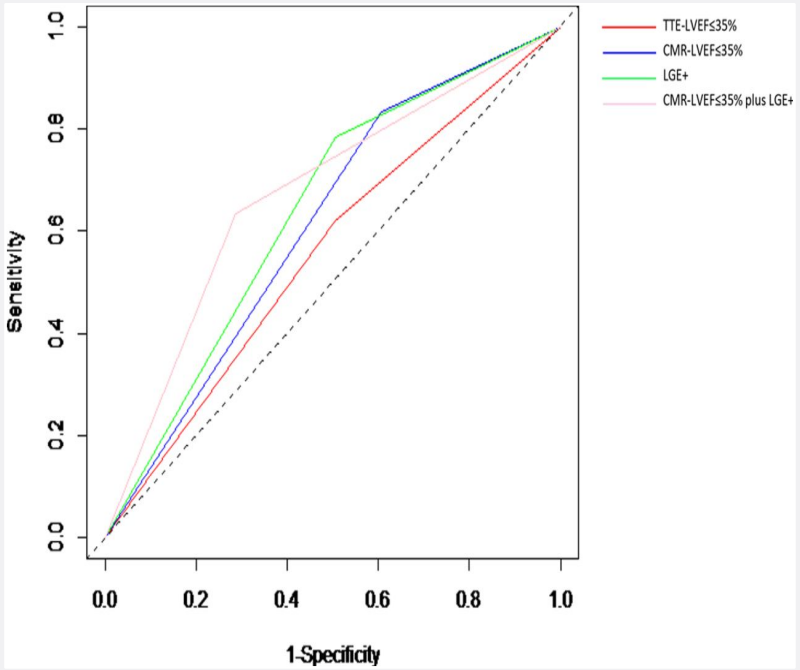
Cardiac magnetic resonance – Clinical applications

Preliminary data on CMR role in selection of pts for primary prevention ICD therapy

Kaplan–Meier curves for MACE based on TTE-LVEF; A), CMR-LVEF (B), late gadolinium enhancement (LGE) detection (C), and the combination of CMR-LVEF plus LGE detection (D)



-409 pts, NICM, ICM
-TTE; CMR
-Median f.u. 545 days



Gianluca Pontone et al. Circ Cardiovasc Imaging. 2016;9:e004956

Cardiac magnetic resonance – Clinical applications

Future perspective – CMR score for selection of pts with heart failure for primary prevention ICD therapy

CarDiac MagnEtic Resonance for Primary Prevention Implantable CardioVerter DebrillAtor ThErapy international registry: Design and rationale of the DERIVATE study

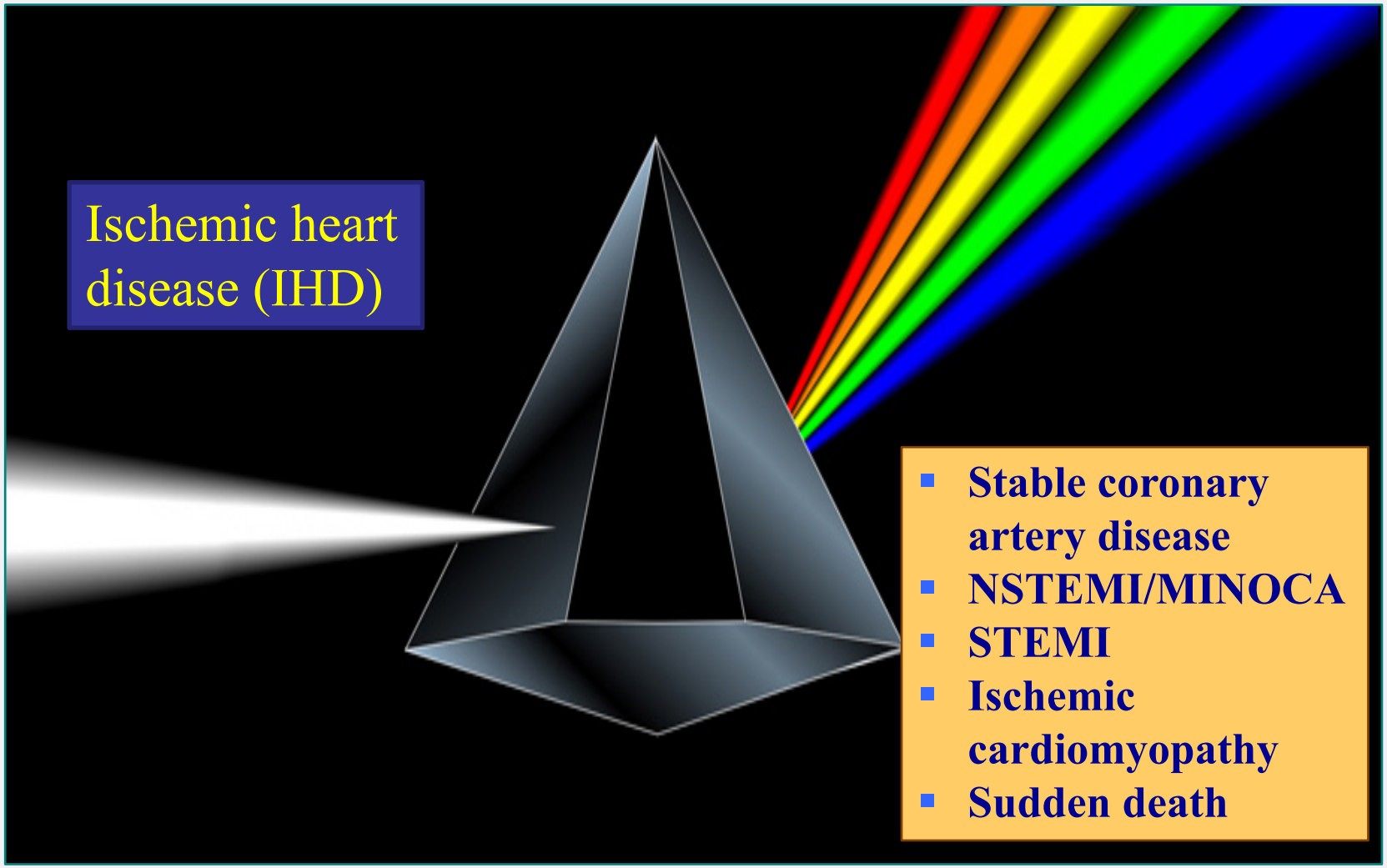
Andrea Igoren Guaricci [a,1], Pier Giorgio Masci [b,1], Valentina Lorenzoni [c], Jurg Schwitter [b,1], Gianluca Pontone [d,*,1]

-Prospective, international, multicenter, observational registry of NICM and ICM pts with chronic heart failure and reduced LVEF
-Clinical evaluation, TTE and CMR
-Identification of prognostic CMR parameters for a better selection of patients with heart failure being worthy of primary prevention ICD therapy

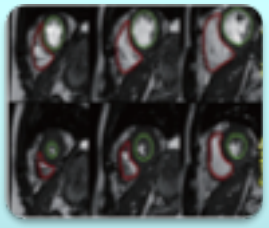
https://doi.org/10.1016/j.ijcard.2018.03.043; clinicaltrials.gov registration: RTT# NCT03352648).

ISCHEMIC HEART DISEASE

Cardiac magnetic resonance – Clinical applications

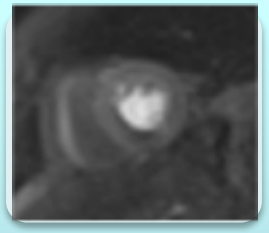


CMR in ischemic heart disease



Ventricular volumes and function

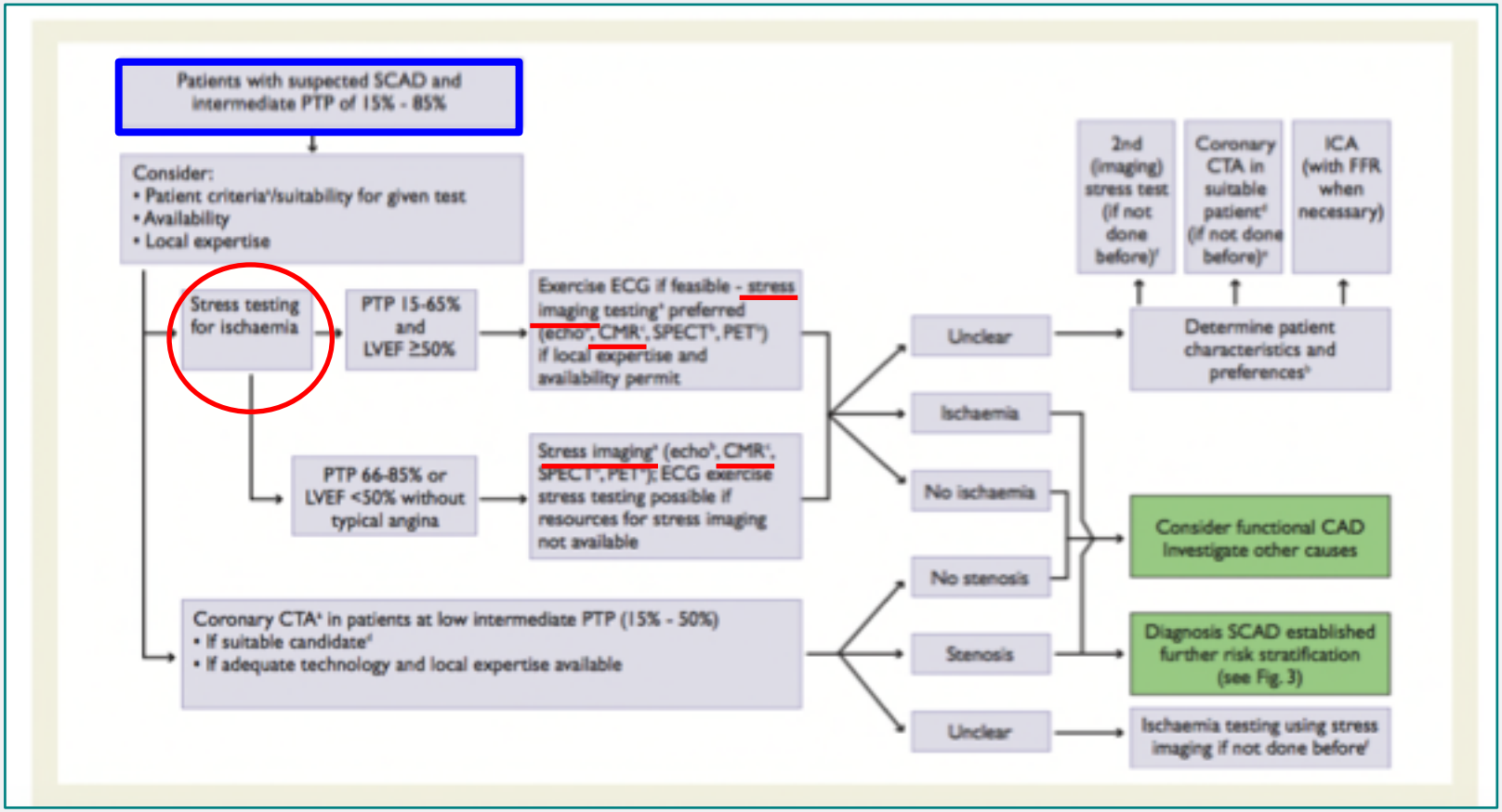
Tissue characterization



Stress perfusion

Cardiac magnetic resonance – Clinical applications

1) STABLE CORONARY ARTERY DISEASE – A) ASSESSMENT OF MYOCARDIAL ISCHEMIA



2013 ESC guidelines on the management of stable coronary artery disease

Diagnostic & prognostic performance of stress CMR

Table 1 Large scale clinical validation of stress perfusion CMR since 2008

Authors	Year	Study design	n	Results
Diagnostic accuracy				
Hamon *et al*[w11]	2010	Meta-analysis; 35 studies	2154	Sensitivity=89%, specificity=80%
Greenwood *et al*[8]	2011	Prospective; single centre	752	Sensitivity=87%, specificity=83%
Schwitter *et al*[9]	2012	Retrospective; multicentre	515	Sensitivity=67%, specificity=61%
Jaarsma *et al*[w12]	2012	Meta-analysis; 37 studies	2841	Sensitivity=89%, specificity=76%
Prognostic data				
Bingham *et al*[w4]	2011	Retrospective; single centre	908	AER for negative stress CMR <1%/year
Lipinski *et al*[w2]	2013	Meta-analysis; 19 studies*	11 636	AER for negative stress CMR <1%/year
Gargiulo *et al*[w3]	2013	Meta-analysis; 14 studies†	12 178	AER for negative stress CMR=1%/year

*Including 4 studies using dobutamine stress for inducible wall motion abnormality.
†Including 6 studies using dobutamine stress for inducible wall motion abnormality.
AER, combined annualised event rate (cardiac death or myocardial infarction); CMR, cardiovascular magnetic resonance.

Motwani M. et Al., Heart 2014

Ospedale Niguarda

Sistema Socio Sanitar
Regione Lombardi

Prognostic Value of Cardiovascular Magnetic Resonance and Single-Photon Emission Computed Tomography in Suspected Coronary Heart Disease: Long-Term Follow-up of a Prospective, Diagnostic Accuracy Cohort Study

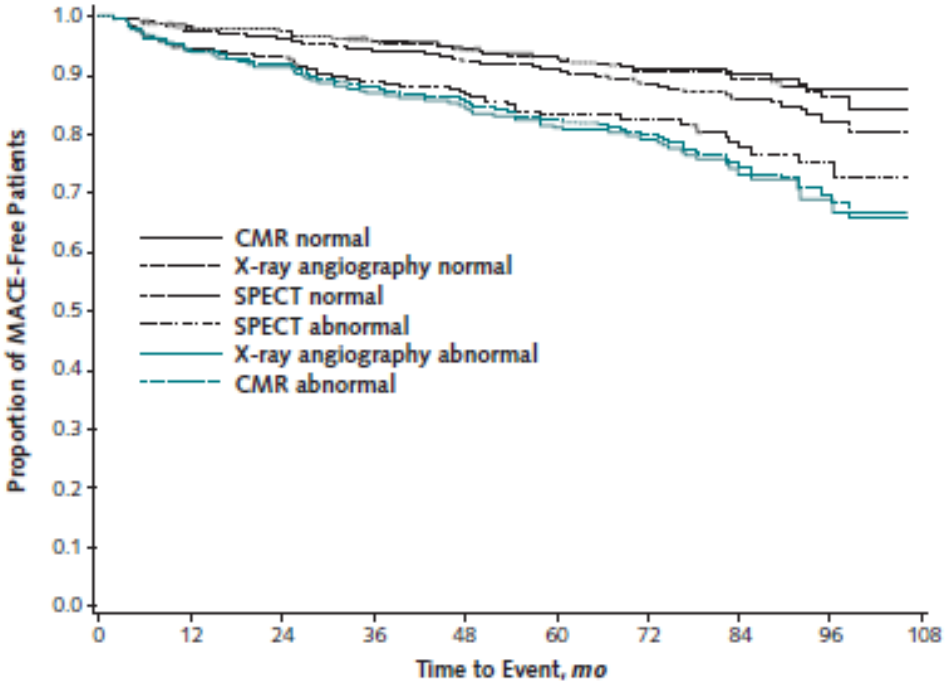
John P. Greenwood, MB ChB, PhD; Bernhard A. Herzog, MD; Julia M. Brown, MSc; Colin C. Everett, MSc; Jane Nixon, PhD; Petra Bijsterveld, MA; Neil Maredia, MB ChB, MD; Manish Motwani, MB ChB, PhD; Catherine J. Dickinson, BM BCh, MA, PhD; Stephen G. Ball, MB BChir, PhD; and Sven Plein, MD, PhD

2016

Table 4. Predictors of MACEs, by Multivariable Analysis

Predictor	Hazard Ratio (95% CI)	*P* Value
CMR		
Abnormal result	2.3 (1.5–3.6)	<0.001
Age	1.0 (1.0–1.1)	<0.001
Male sex	1.1 (0.71–1.7)	>0.20
Diabetes mellitus	1.1 (0.65–2.0)	>0.20
Current smoker	1.2 (0.67–2.0)	>0.20
Total cholesterol	0.99 (0.83–1.2)	>0.20
Hypertension	1.0 (0.70–1.5)	>0.20
Family history	0.86 (0.57–1.3)	>0.20
SPECT		
Abnormal result	1.41 (0.94–2.1)	0.10
Age	1.1 (1.0–1.1)	<0.001
Male sex	1.2 (0.79–1.9)	>0.20
Diabetes mellitus	1.2 (0.71–2.1)	>0.20
Current smoker	1.2 (0.7–2.1)	>0.20
Total cholesterol	1.0 (0.84–1.2)	>0.20
Hypertension	1.1 (0.72–1.6)	>0.20
Family history	0.95 (0.63–1.4)	>0.20

CMR = cardiovascular magnetic resonance; MACE = major cardiovascular event; SPECT = single-photon emission computed tomography.



Five-year follow-up of the CE-MARC study indicates that compared with SPECT, CMR is a stronger predictor of risk for MACEs, independent of cardiovascular risk factors, angiography result, or initial patient treatment.

Greenwood JP, Ann Internal Med 2016

2) MINOCA (Myocardial Infarction with NOrmal Coronary Arteries)

ESC working group position paper on myocardial infarction with non-obstructive coronary arteries

Stefan Agewall[1*], John F. Beltrame[2], Harmony R. Reynolds[3], Alexander Niessner[4], Giuseppe Rosano[5,6], Alida L. P. Caforio[7], Raffaele De Caterina[8], Marco Zimarino[8], Marco Roffi[9], Keld Kjeldsen[10], Dan Atar[1], Juan C. Kaski[6], Udo Sechtem[11], and Per Tornvall[12], on behalf of the WG on Cardiovascular Pharmacotherapy

1 AMI
2 Non-
angio
arteries
3 No c
cause for the acute presentation

1-13% of AMI

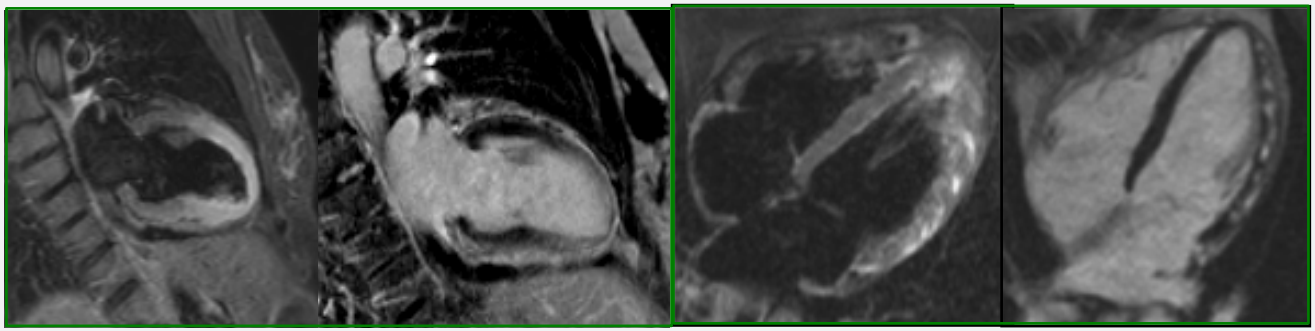
…cardiac magnetic resonance imaging is the key diagnostic tool to be employed in MINOCA patients...

Eur Heart J 2016

- Takotsubo cardiomyopathy
- Unrecognized myocarditis
- Other forms of type-2 myocardial infarction

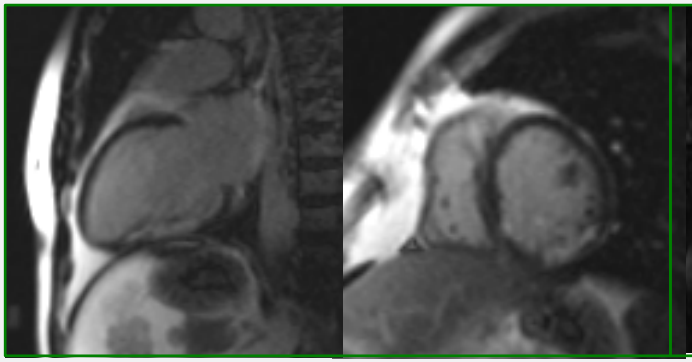
Eur Heart J 2016

2) MINOCA (Myocardial Infarction with NOrmal Coronary Arteries)

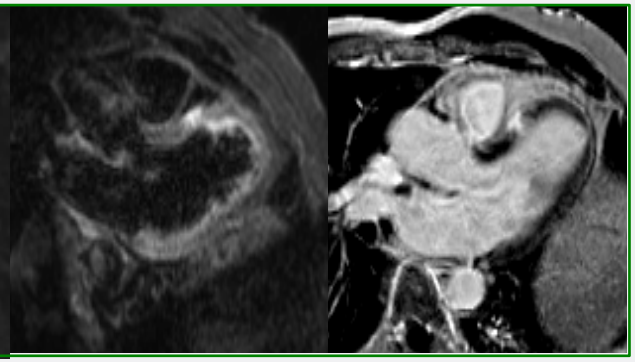


TAKOTSUBO

ACUTE MYOCARDITIS



PRINZMETAL

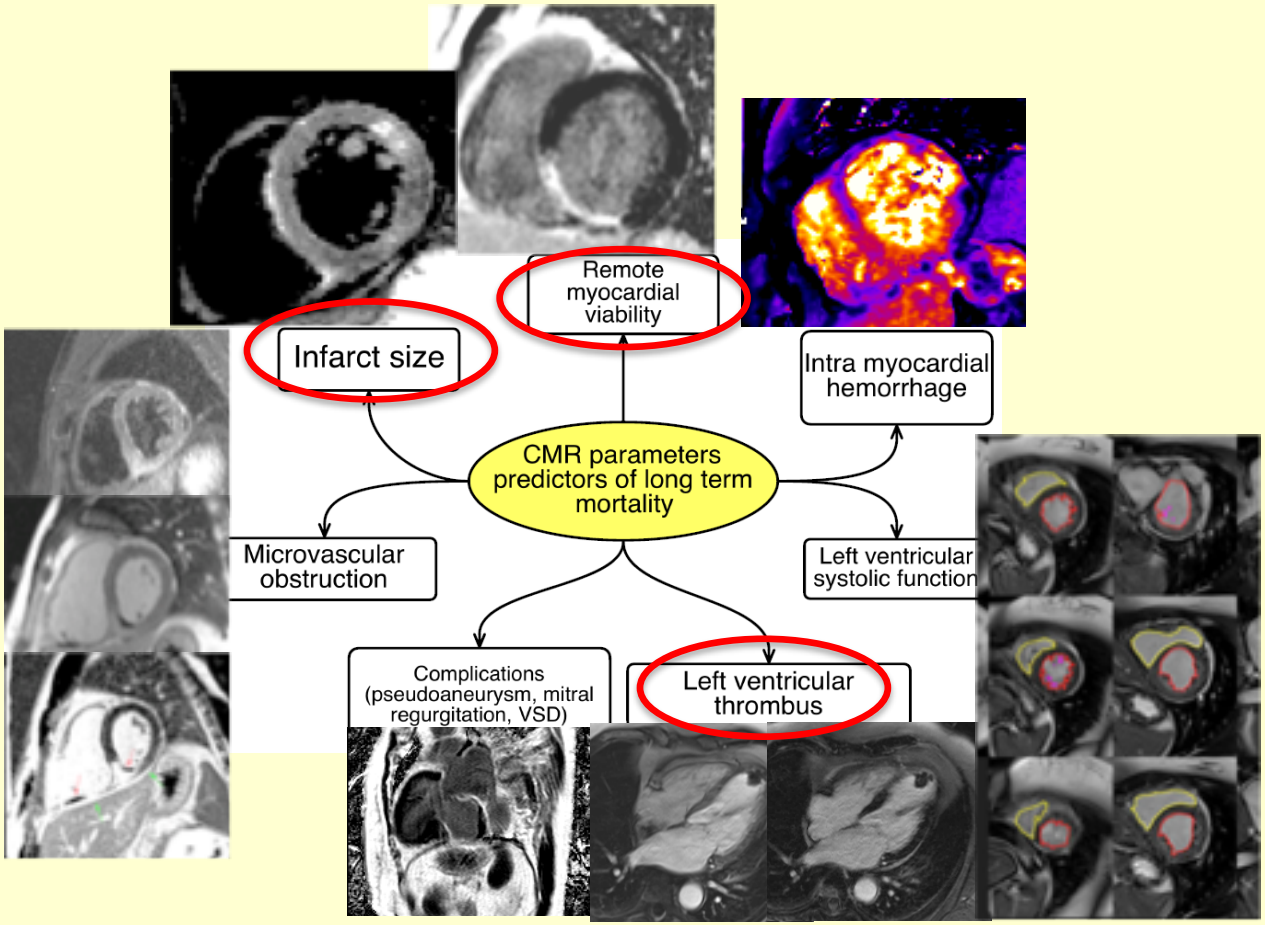


MYOCARDIAL INFARCTION

-Impact of CMR on diagnosis
-Impact of CMR on patient management

Cardiac magnetic resonance – Clinical applications

3) STEMI

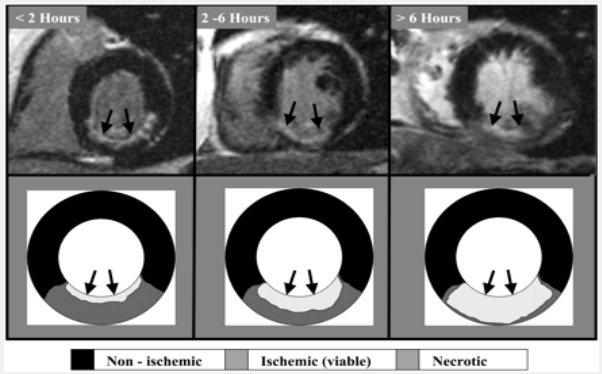


- Impact of CMR on patient management (anticoagulants, revascularization)
- Prognostic markers

Kidambi A, Eur Hear J 2016; Thygesen K, Eur Heart J 2018

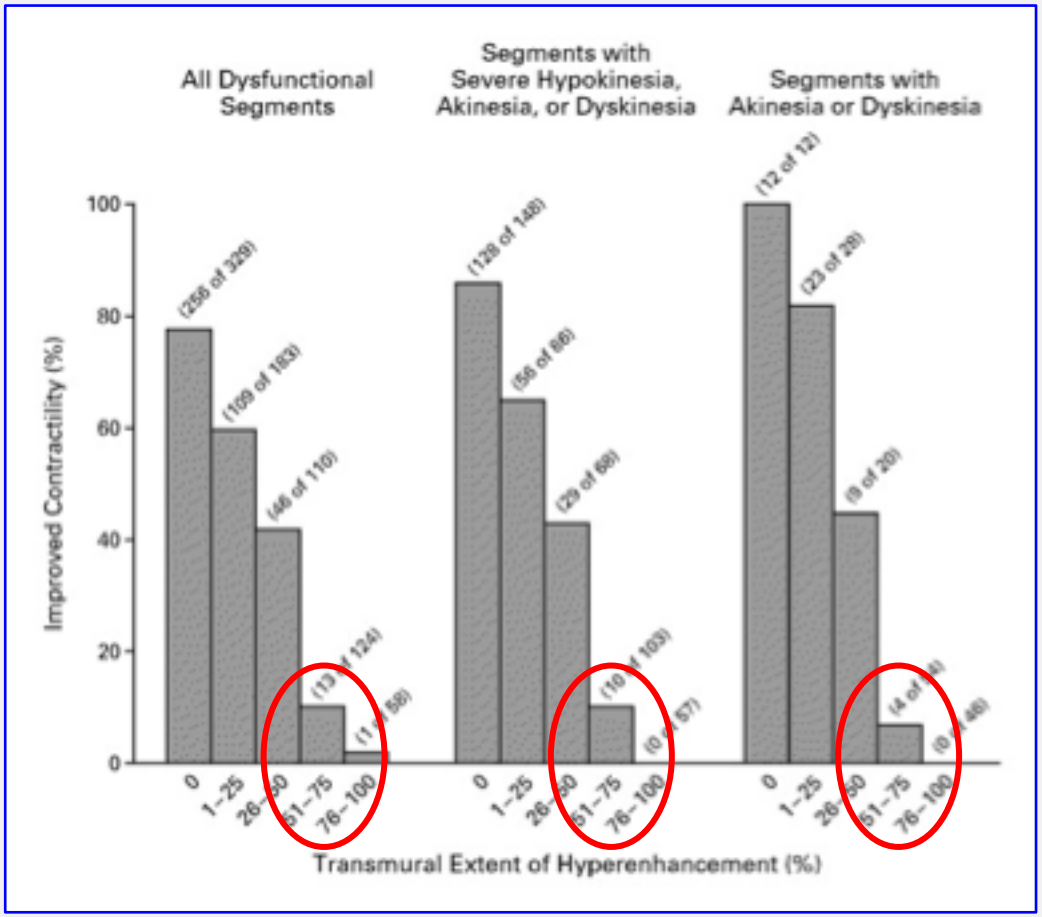
4) Ischemic cardiomyopathy

CMR to Identify Reversible Myocardial Dysfunction



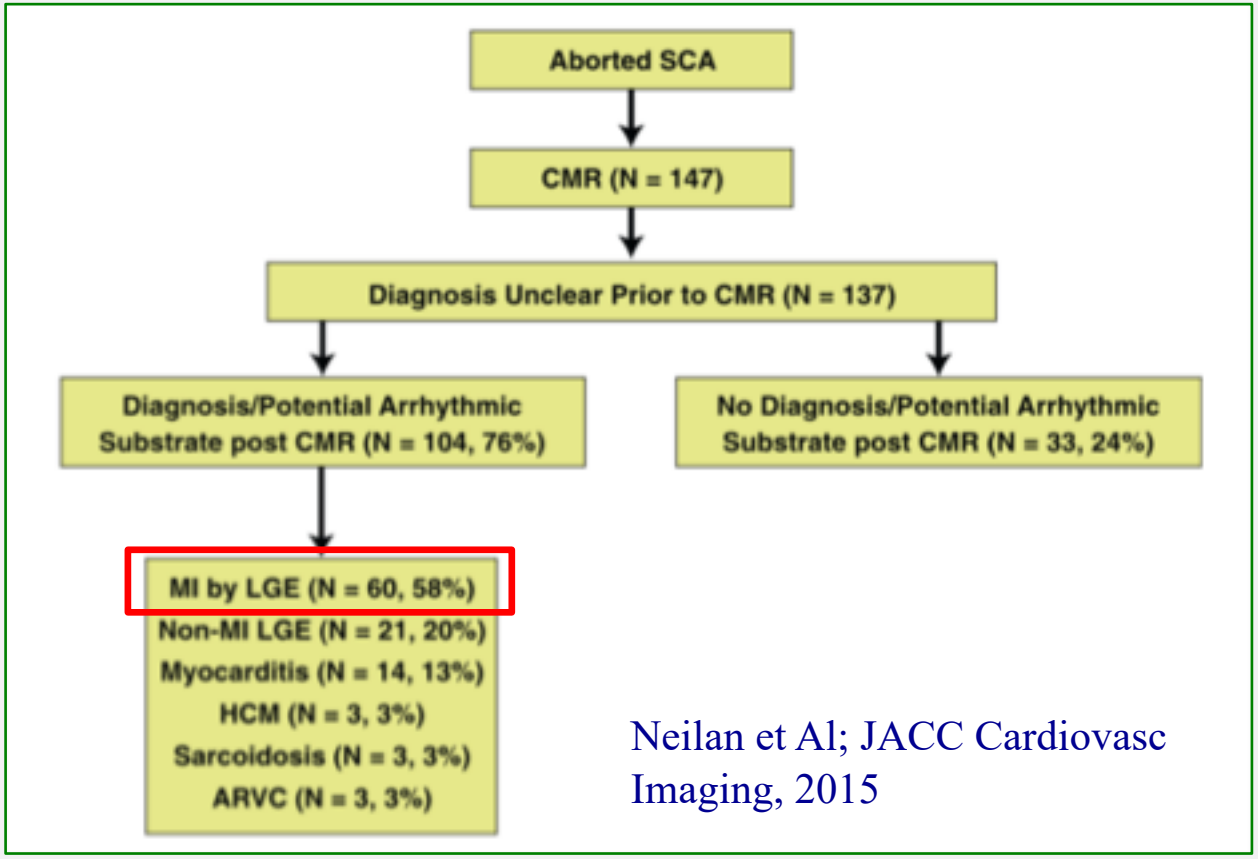
Segments with LGE > 50% didn't show contractility improvement

Impact of CMR on patient management (revascularization)



Kim RJ New Engl J Med 2000

4) CARDIAC ARREST



Neilan et Al; JACC Cardiovasc Imaging, 2015

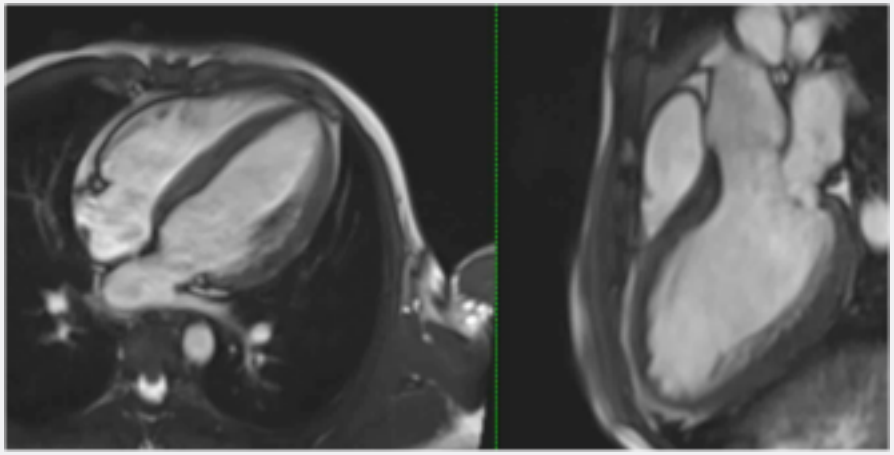
-Impact of CMR on diagnosis
-Impact of CMR on patient management

Whenever possible, perform CMR before ICD implantation if cause of aborted SCA is not clear

What about CMR…in the real world?

- 15 yo boy of Pakistani origin
- Worsening effort dyspnoea and fatigue in the last 2 yrs
- Visited by a cardiologist: no significant past medical history, no family history of heart disease, physical examination normal, abnormal EKG (not shown), mild LVH at echo, other parameters normal
- Referred for CMR in the suspect of HCM

CMR…in the real world



Long axis cines

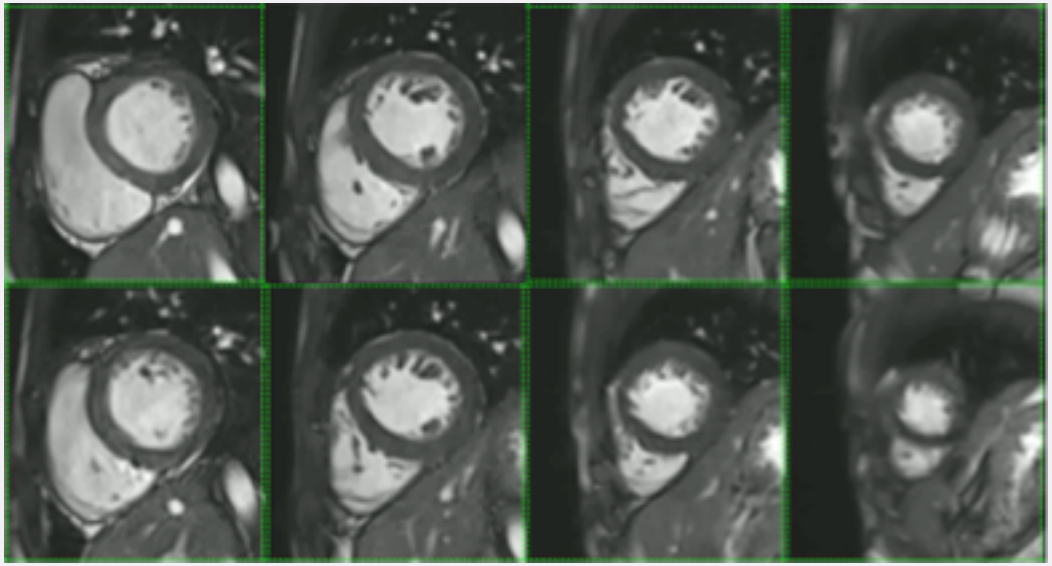
-Mild LVH

-Normal LV and RV function

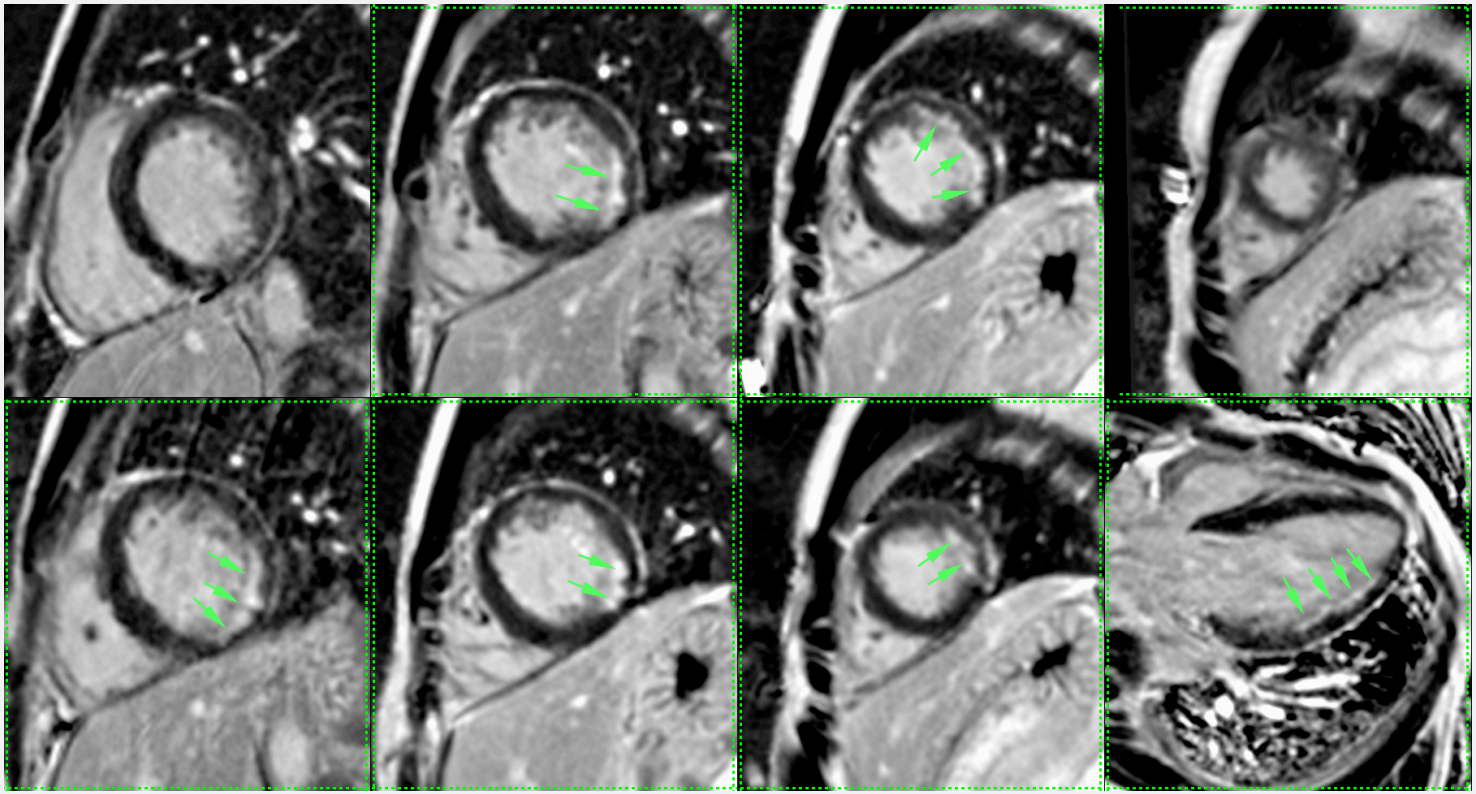
-No LVOT obstruction

Short axis cines

-Mild wall motion abnormality of the mid-apical inferolateral (IL) wall



CMR…in the real world

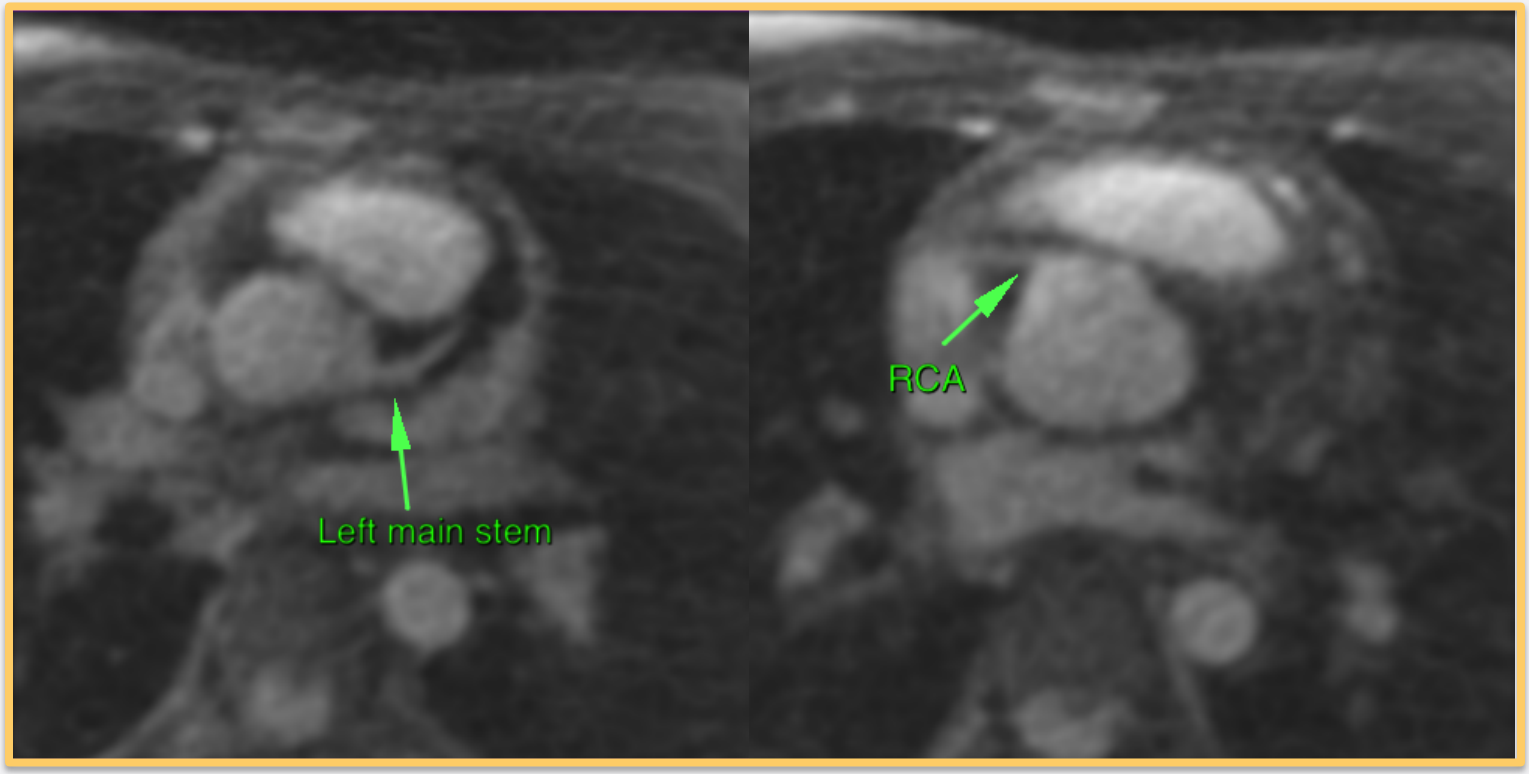


LGE images

-Subendocardial LGE in the mid-apical inferolateral wall

➢ **Ischemic pattern!**

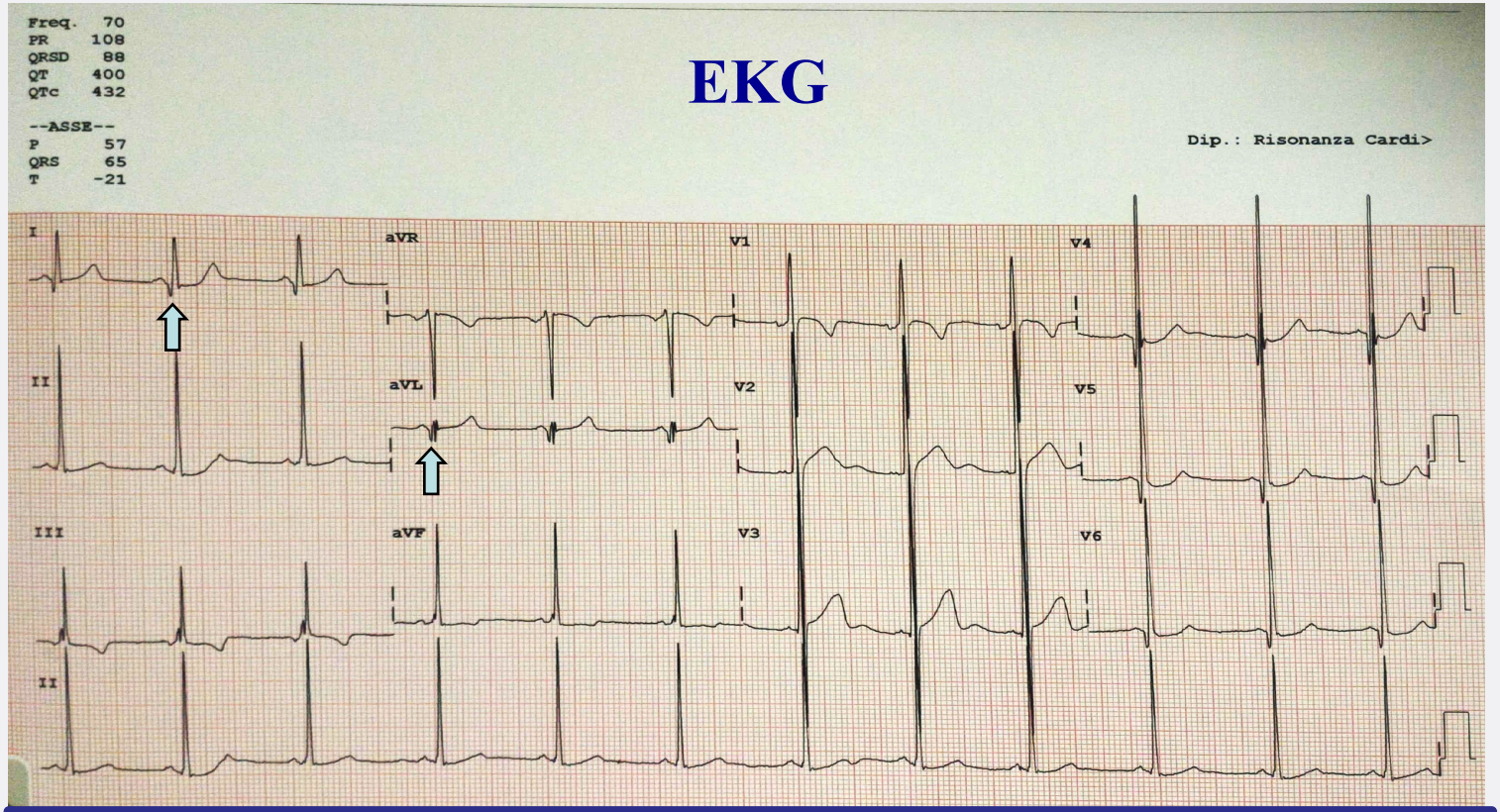
CMR…in the real world



3D free-breathing self navigated whole-heart acquisition

-Normal origin of coronary arteries

CMR…in the real world



EKG

- Pt referred to **paediatric emergency department**
- HsTn, NT pro-BNP, CRP, electrolytes, renal function and blood count normal
- Assessed by paediatric cardiologist; admitted to paediatric cardiology ward for further assessment

CMR…in the real world

Stress ergometry

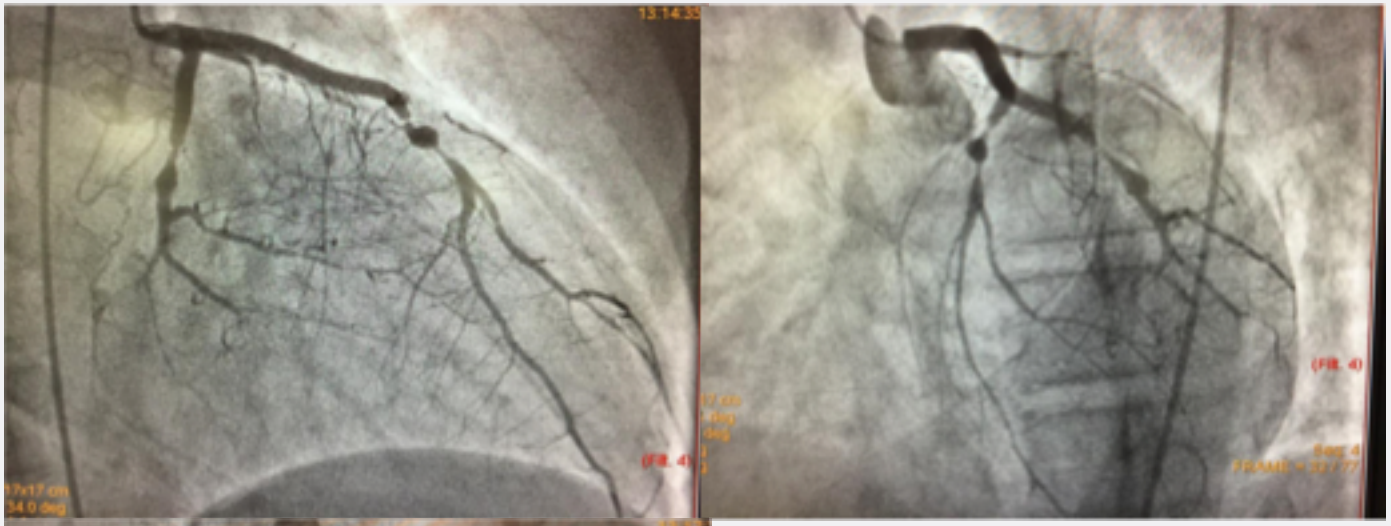
-Reduced effort tolerance

-Downsloping ST depression

-No arrhythmias

-No chest pain

CMR…in the real world



Left coronary artery

Right coronary artery

Coronary angiography

-Severe 3-vessel disease

-Aneurysms of LAD and CX

-Sub-occlusion of intermediate branch

-OCT showed alterations of coronary walls also in apparently normal segments

CMR…in the real world

- Lipid profile and coagulation normal (no mutations), LAC -
- Diagnosis: severe 3-vessel disease in likely Kawasaki disease (sub-clinical acute phase)
- PCI with multiple DES
- DAPT, beta-blockers, statins

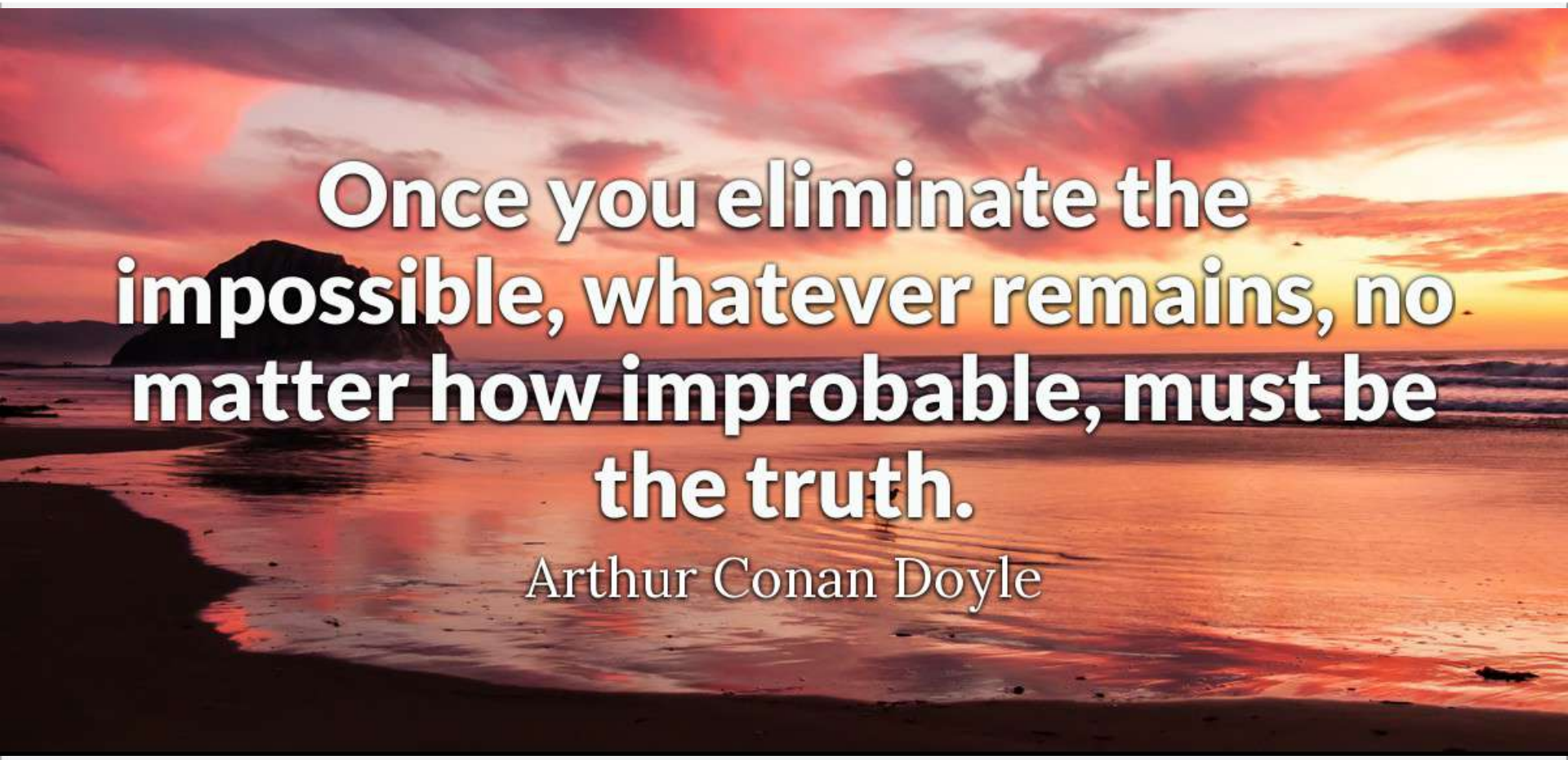
CMR supplied

- new diagnosis
- impact on patient management
- impact on prognosis (revealed unknown severe ischemic heart disease)

		N or quartiles
All	100%	27781
Completely new diagnosis not suspected before	8.7%	2354/27006
Therapeutic consequences		
Change in medication	25.0%	6689/26743
Invasive procedure	16.8%	4510/26778
Hospital discharge	10.2%	2738/26771
Hospital admission	1.4%	386/26780
Impact on patient management (new diagnosis and/or therapeutic consequence)	61.8%	16677/27006

Values are % (n).

EuroCMR Registry



…and this is CMR ! Thank you for your attention

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