When is Multimodality Assessment of Cardiac Function Needed?

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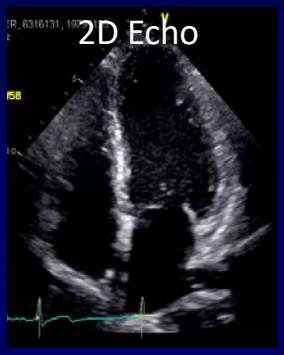
No Disclosures
Gadolinium is off-label for cardiac MR

1

Multimodality methods at our disposal



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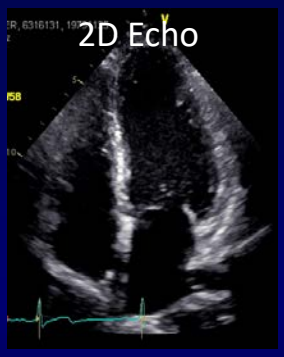
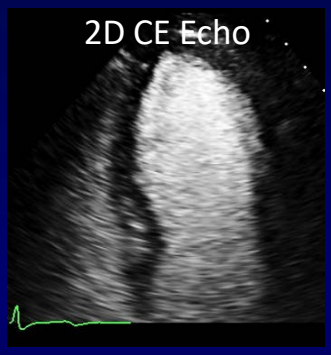
Multimodality methods at our disposal





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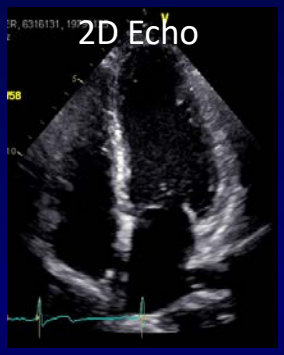
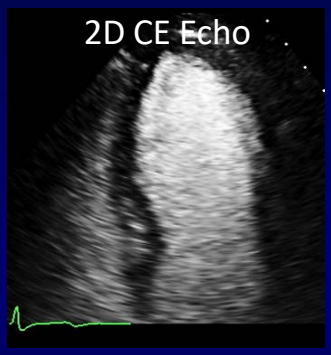
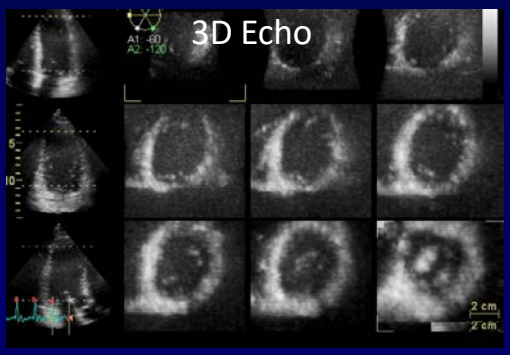
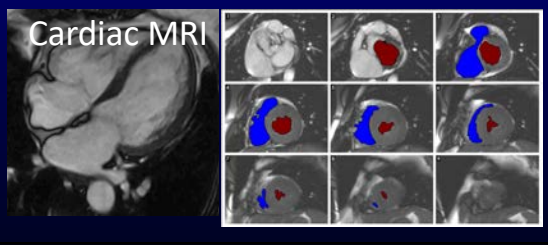
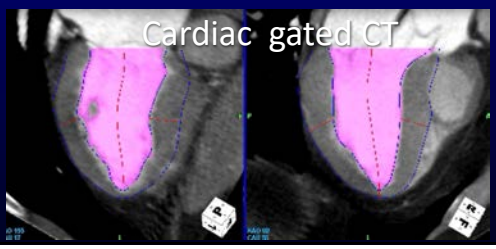
Multimodality methods at our disposal











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Multimodality Comparisons

Metanalysis involving 65 studies, mostly echo compared to CMR

Only structurally normal LVs included (ie no congenital)

Rigolli M. Open Heart 2016;3:e000388

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Multimodality Comparisons

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Only structurally normal LVs included (ie no congenital)

Difference vs. CMR	N	LVEDV	LVESV
2D Echo	**1683**	-33	-16

Rigolli M. Open Heart 2016;3:e000388

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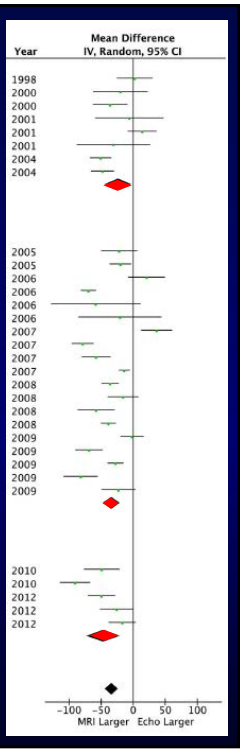
Multimodality Comparisons

Metanalysis involving 65 studies, mostly echo compared to CMR

Only structurally normal LVs included (ie no congenital)

Era didn't matter (<2005 vs. after 2009)

Difference vs. CMR	N	LVEDV	LVESV
2D Echo	**1683**	-33	-16
2D CE Echo	**283**	-18	-8
3D Echo	**1159**	-14	-6



Rigolli M. Open Heart 2016;3:e000388

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Sources of Error

ECHO

Apex foreshortening

Endocardial dropout

Lower spatial resolution

CMR

Basal plane interpretation

CT

Beta blocker/NTG

Fluid bolus

Lower temporal resolution

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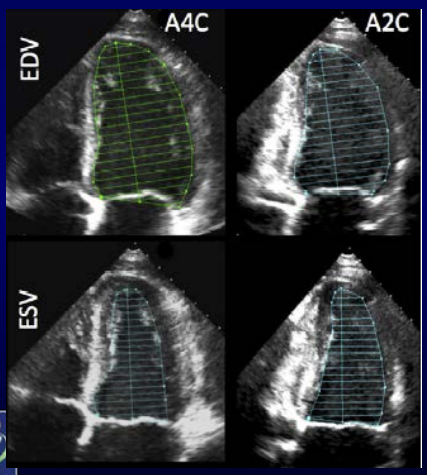
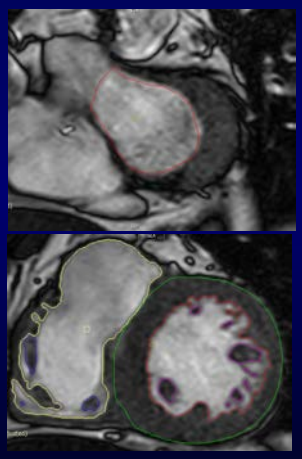
Methodologic Differences

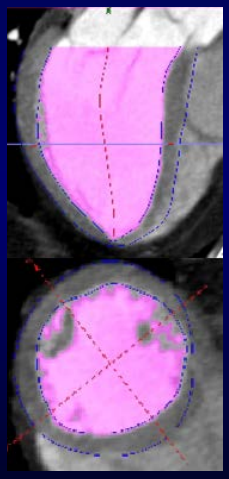
ECHO



CMR



CT



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Methodologic Differences

ECHO
Long axis

CMR
Short axis*

CT
Long/short axis*

* Variable use

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Methodologic Differences

ECHO	CMR	CT
Long axis	Short axis*	Long/short axis*
Papillaries and trabeculations excluded	Papillaries and trabeculations included*	Papillaries and trabeculations included

* Variable use

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Methodologic Differences

ECHO	CMR	CT
Long axis	Short axis*	Long/short axis*
Papillaries and trabeculations excluded	Papillaries and trabeculations included*	Papillaries and trabeculations included
Outflow tract excluded	Outflow tract included	Outflow tract included*

* Variable use

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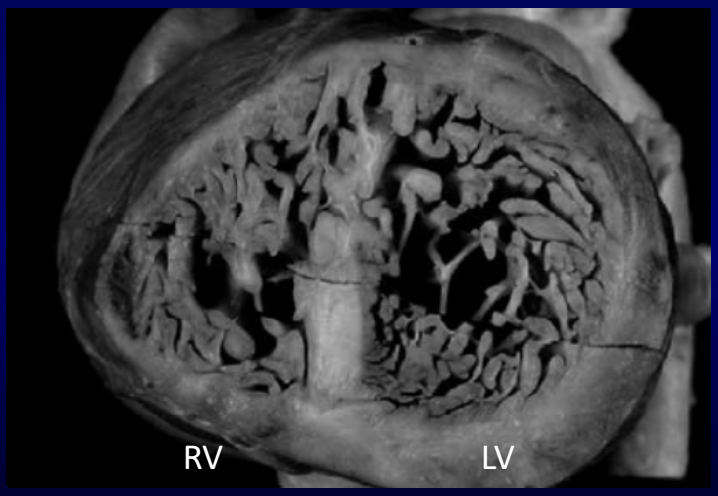
Papillaries and Trabeculations

Sometimes the differences can be extensive



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Temporal Resolution: Frame count

Echo = 60 frames, CMR = 30 frames, CT = 10 frames

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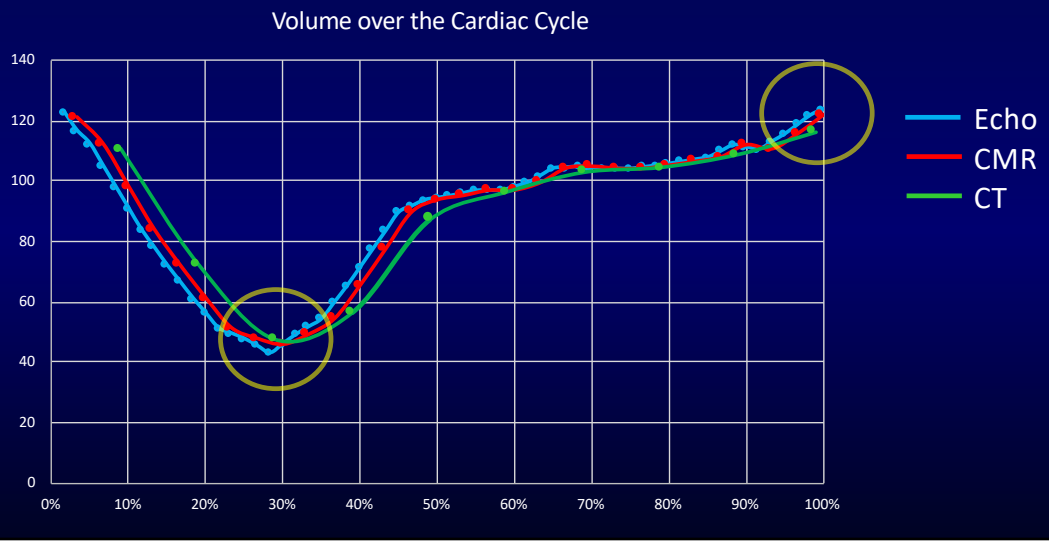
Temporal Resolution: Frame count

Echo = 60 frames, CMR = 30 frames, CT = 10 frames



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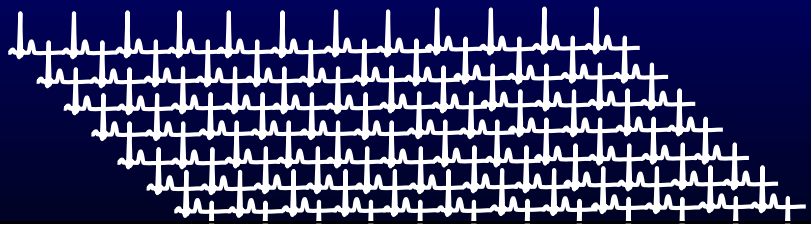
Temporal Resolution: Acquisition Time

Echo Single heart beat per image

CT 1-5 heart beats per image

CMR 8-10 heart beats/breath hold (~12 breath holds)



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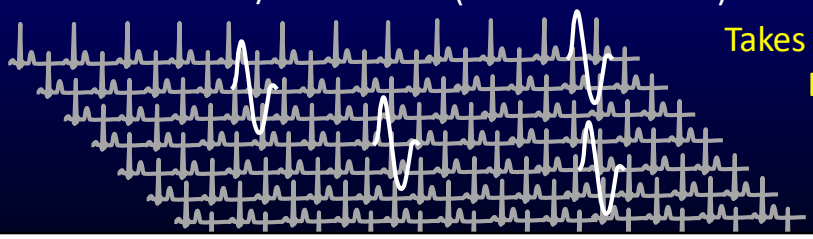
Temporal Resolution: Acquisition Time

Echo Single heart beat per image

CT 1-5 heart beats per image

Dependent on respiratory motion

CMR 8-10 heart beats/breath hold (~12 breath holds)



Takes longer, but less Dependent on respiratory motion

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CMR Sensitive to Volumetric Change

MERIT-HF: Metoprolol vs. Placebo (randomized, double-blind) for 6 months

CMR pre and post treatment

	Baseline	6 months	
LVEDVI	150 ml/m^2	126 ml/m^2	(p = 0.01)
LVEF	29%	37%	(p = 0.005)
	(no change with placebo)		

Groenning BA, J Am Coll Cardiol. 2000 Dec;36(7):2072-80

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CMR Sensitive to Volumetric Change

MERIT-HF: Metoprolol vs. Placebo (randomized, double-blind) for 6 months

CMR pre and post treatment

	Baseline	6 months		
LVEDVI	150 ml/m^2	126 ml/m^2	(p = 0.01)	**N = 22**
LVEF	29%	37%	(p = 0.005)	
	(no change with placebo)			**N = 19**

Groenning BA, J Am Coll Cardiol. 2000 Dec;36(7):2072-80

ANZ HF Trial (ECHO) N= 415 Circ 1995;92:212-218

MERIT-HF (Clinical End Points) N= 3,998

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When is functional assessment relevant?

Clinical Decisions that may depend on volume/function

- Timing of valve surgery
- Device implantation (ICD)
- Determining need for medical therapy (is this heart “normal”)
- Prognosis

These can all be addressed with echocardiography

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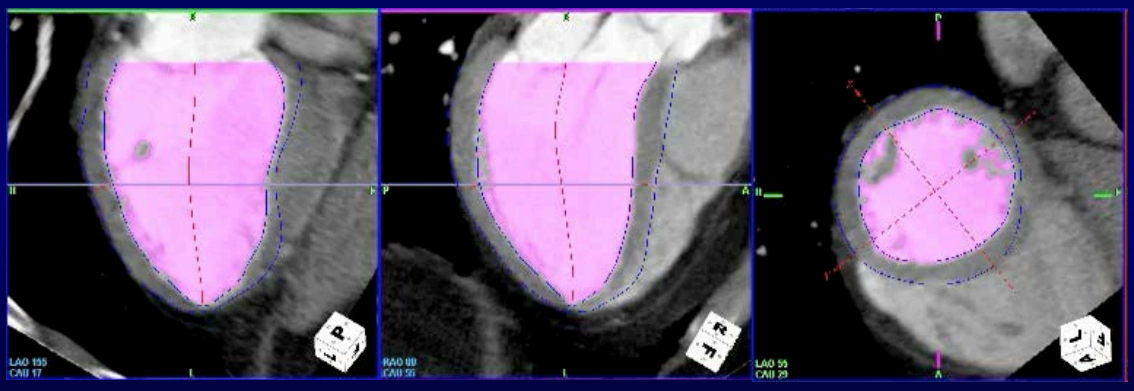
When CT?



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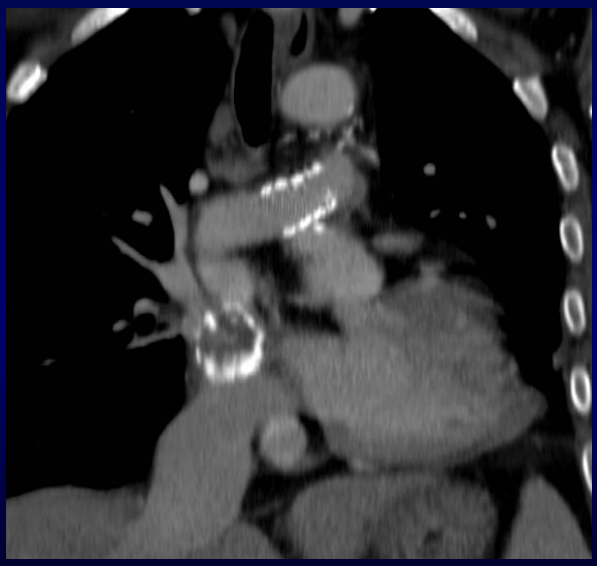
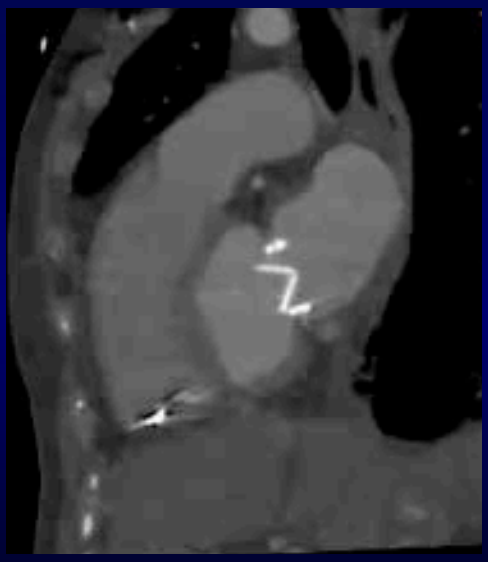
CT for valves





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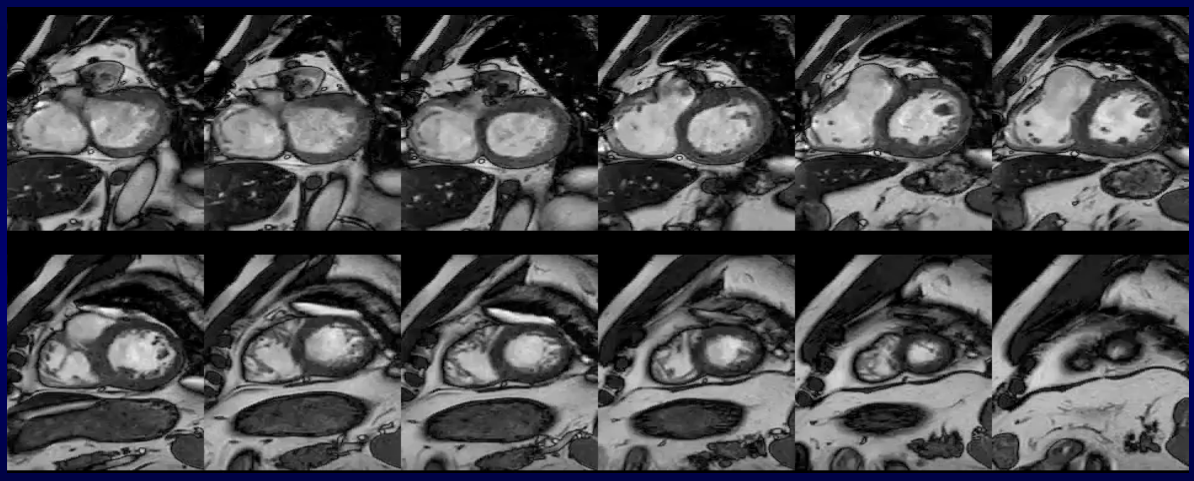
When CMR?



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CMR is an adjunct to Echo

From Guideline Statements: "CMR is useful when . . . .

"echocardiography is inconclusive ..."

"issues are not satisfactorily addressed ..."

"etiology is unclear ..."

"other means do not provide ..."

"risk remains borderline ..."

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Clinical Questions for which CMR is used

CMR functional assessment especially for

- Inadequate echo quality
- Quantification of valve regurgitation
- Myocardial tissue characterization
- RV quantification/Shunts

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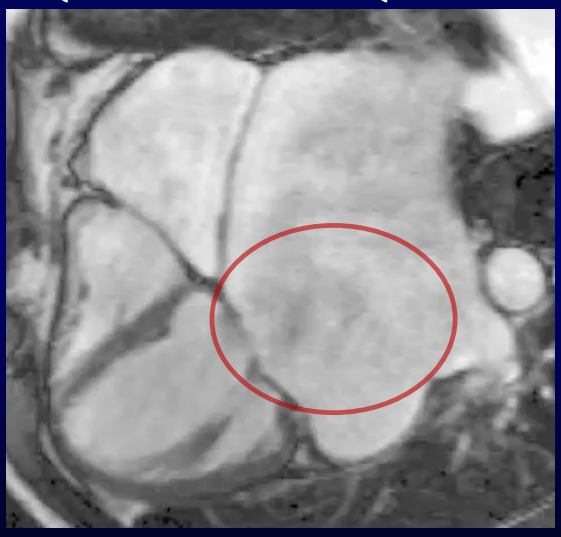
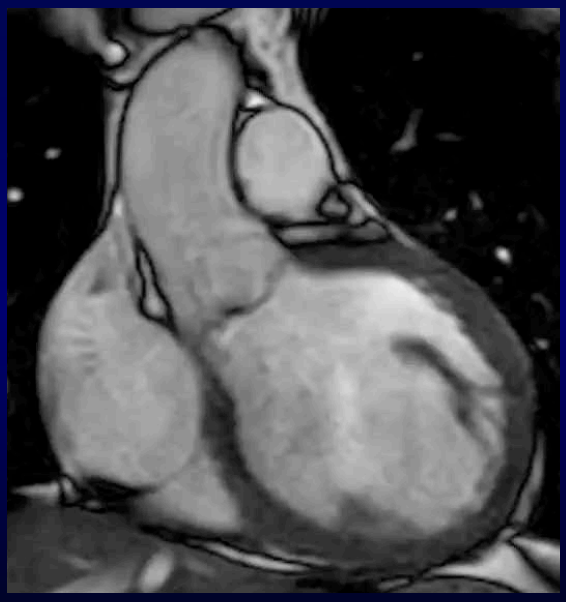
CMR Assessment of Valve Regurgitation

Less Qualitative but more Quantitative





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CMR Assessment of Valve Regurgitation

"The most challenging aspect in the management of MR is accurate quantification of severity and consequent decision regarding timing of intervention"

Kar S, Sharma R, JACC 2015 MAR 24:65(11):1089

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CMR Assessment of Valve Regurgitation

CMR vs. Echo done in 103 patients with mitral regurgitation,

- MR severity agreement between the methods was weak
- Only 22% of those with severe MR by echo had severe MR by CMR
- CMR had better reproducibility (90% vs. 61%)

Uretsky S, JACC 2015 65(11):1078-88

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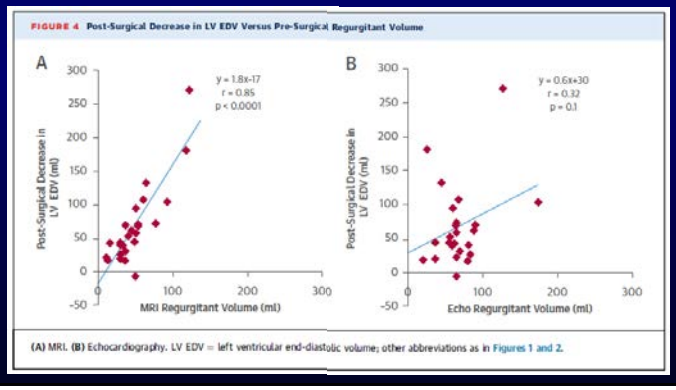
CMR Assessment of Valve Regurgitation

CMR vs. Echo done in 103 patients with mitral regurgitation,

- 38 underwent surgery
- LV remodeling was assessed ~6 months later ("gold standard")
- Degree of remodeling more predictive by CMR, not by echo



Uretsky S, JACC 2015 65(11):1078-88

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Valve Guidelines

1B "CMR is indicated in patients with . . . suboptimal echo images for the assessment of LV function and measurement of AR severity."

1B "CMR is indicated in patients with chronic primary MR to assess . . . MR severity and when not satisfactorily addressed by TTE."

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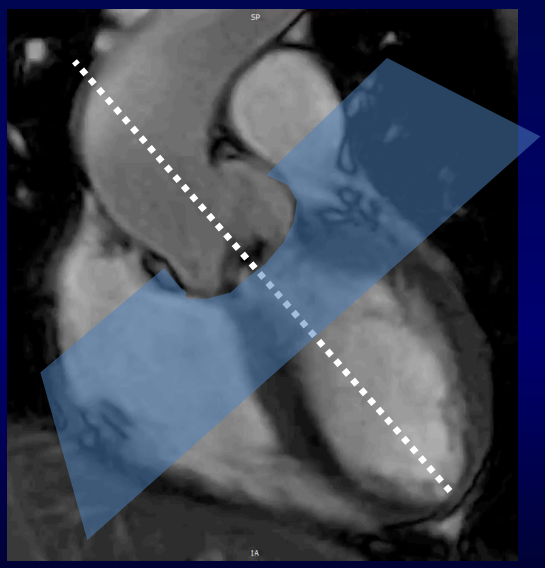
Valve Stenosis

CMR less advantageous than echo

Velocity can be measured

Less sensitive to finding peak gradient



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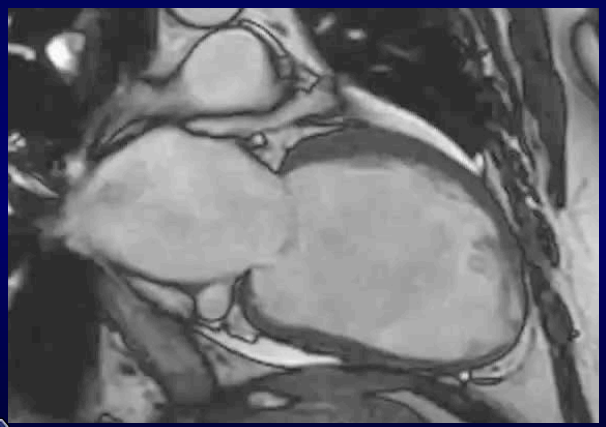
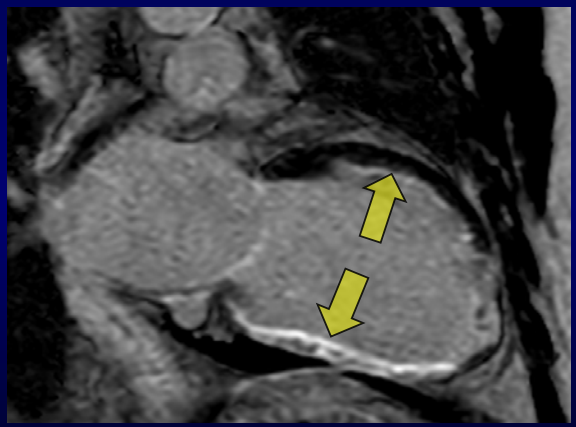
Myocardial Imaging (not just function)





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Cardiomyopathy Assessment with CMR

Etiology of myocardial change

Overall Prognostication

Arrhythmia prediction

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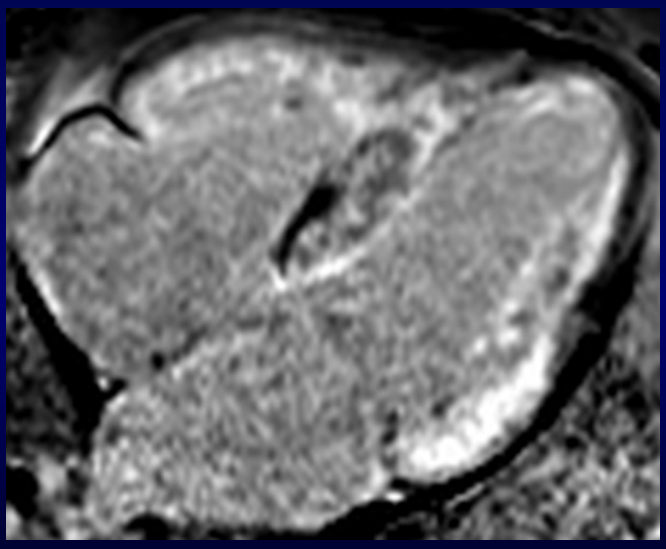
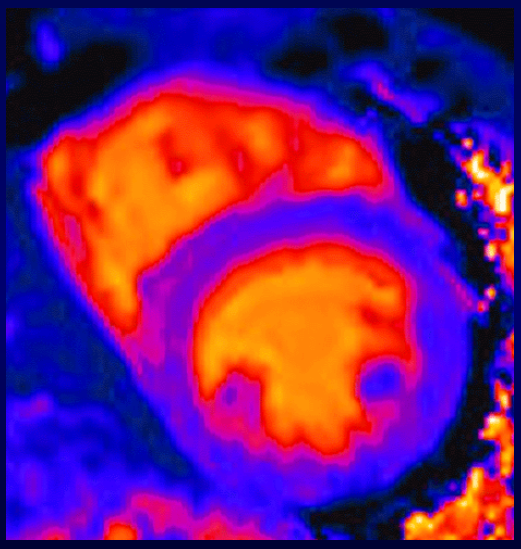
LGE and T1 mapping





T1 is an independent predictor of events in CAD

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Extracellular Volume Fraction

ECV detects fibrosis burden in the setting of:

- dilated cardiomyopathy
- atrial fibrillation
- hypertrophic cardiomyopathy
- muscular dystrophy
- aortic stenosis
- amyloidosis
- mitral valve prolapse

Iles L, J Am Coll Cardiol. 2008;52:1574-1580
Ling LH,J Am Coll Cardiol. 2012;60:2402-2408
Brouwer WP, J Cardiovasc Magn Reson. 2014;16:28
Florian A, J Cardiovasc Magn Reson. 2014;16:81
Aus dem Siepen F, European heart journal cardiovascular Imaging. 2014
de Meester de Ravenstein C, J Cardiovasc Magn Reson. 2015;17:015-0150
Iles L, J Am Coll Cardiol. 2011;57:821-828

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"Parametric mapping should be considered in the diagnostic evaluation of all patients with heart failure and unexplained troponin elevation."

Messroghli D, J CMR (2017) 19:75

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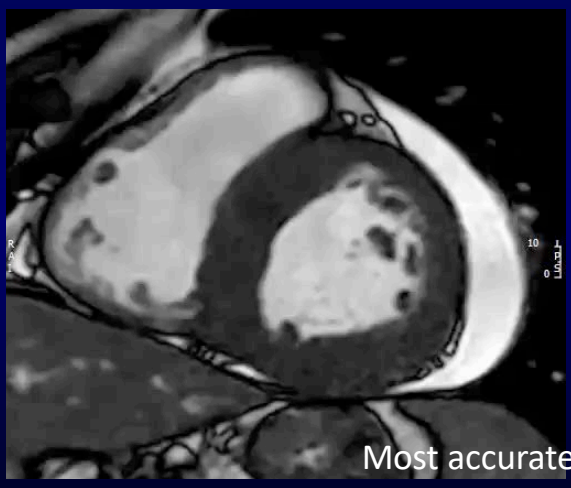
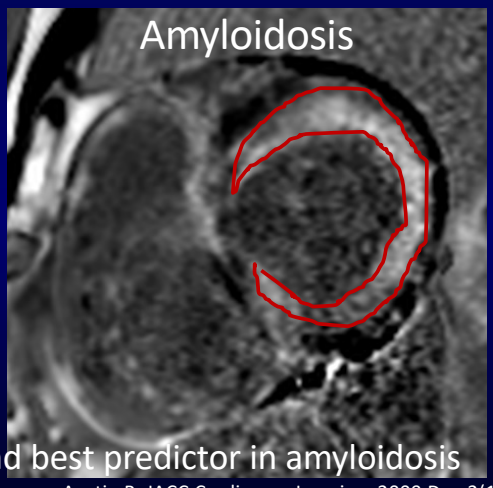
"Parametric Mapping" for Myocardium

Not just seeing the function, but seeing what's in the tissue





Most accurate and best predictor in amyloidosis

Austin B, JACC Cardiovasc Imaging. 2009 Dec;2(12):1369-77.

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"Parametric Mapping" for Myocardium

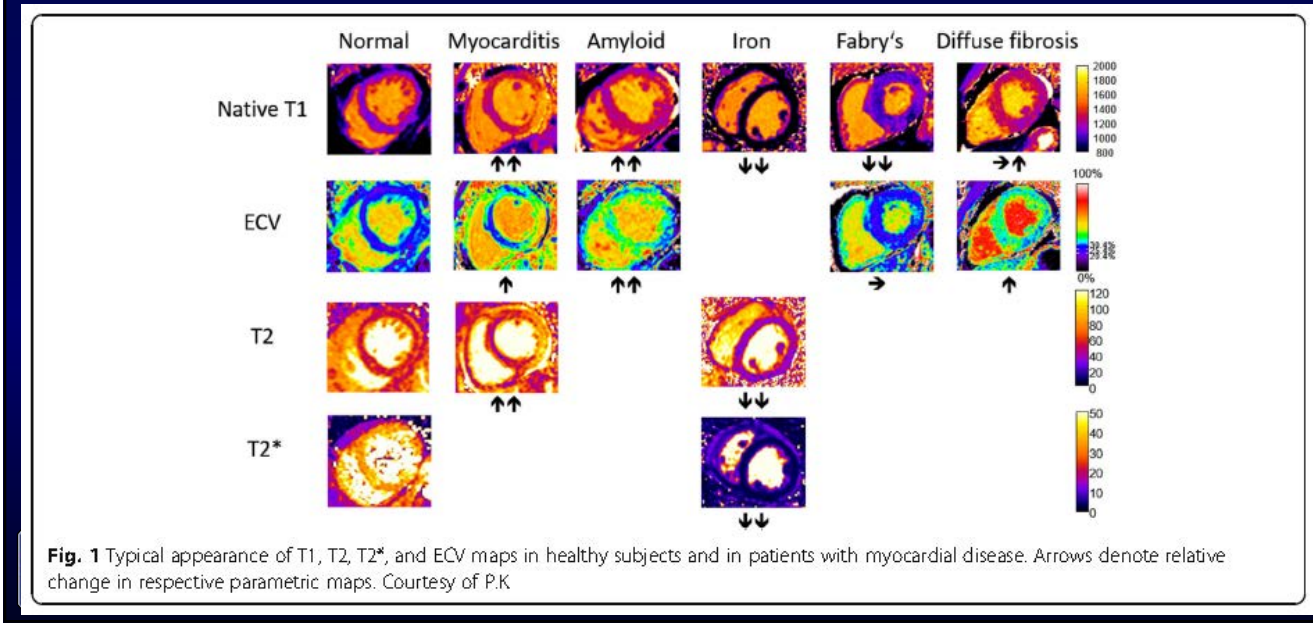

Fig. 1 Typical appearance of T1, T2, T2*, and ECV maps in healthy subjects and in patients with myocardial disease. Arrows denote relative change in respective parametric maps. Courtesy of P.K

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Arrhythmia Prediction (VT/SCD/ICD shock)

Metanalysis of thousands of patients:

DCM	LGE present in 44%, mean follow up 3 years		
	Any ventricular arrhythmia		
	with LGE	21%	6.5%/year
	without LGE	4.7%	1.6%/year
		HR=6.7; $p < 0.001$	

Di Marco A, JACC Heart Fail 2017;5:28-38

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DCM LGE present in 44%, mean follow up 3 years

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without LGE	4.7%	1.6%/year
	HR=6.7; p < 0.001	

Di Marco A, JACC Heart Fail 2017;5:28-38

HCM LGE present in 60% , mean follow up 3.1 years

Cardiac death

with LGE	4.9%
without LGE	1.2%
	OR=2.9; p = 0.047

Green JJ, JACC: CVI Apr 2012, 5 (4) 370-377

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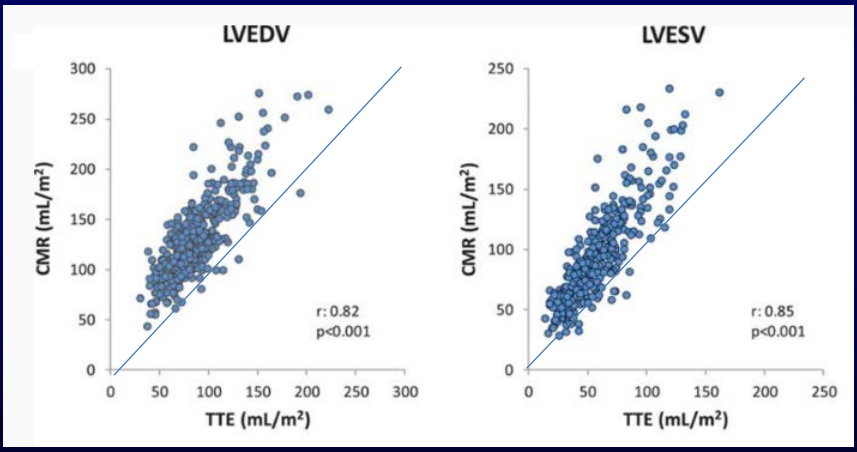
Echo vs. CMR in risk prediction

409 Italians with cardiomyopathy (52% ischemic, 48% non-ischemic)

CMR and Echo done at baseline. CMR volumes were bigger



Pontone G, Circ Cardiovasc Imaging. 2016 Oct;9(10). pii: e004956

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Echo vs. CMR in risk prediction

409 Italians with cardiomyopathy (52% ischemic, 48% non-ischemic)

Followed for ~1.5 years

- 25% had MACE (19% ventricular arrhythmias)
- Higher LVEDV (both echo and CMR) was a significant predictor
- Strongest prediction was based on CMR volume + LGE

Pontone G, Circ Cardiovasc Imaging. 2016 Oct;9(10). pii: e004956

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Guidelines

DCM

I (C) "CMR imaging is recommended to . . . characterize cardiac tissue in subjects with inadequate echocardiographic images or where the echocardiographic findings are inconclusive or incomplete."

IIA (B) "CMR should be considered in patients with ventricular arrhythmias when echocardiography does not provide accurate assessment of LV and RV function and/or evaluation of structural changes."

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Guidelines

DCM

I (C) "CMR imaging is recommended to . . . characterize cardiac tissue in subjects with inadequate echocardiographic images or where the echocardiographic findings are inconclusive or incomplete."

IIA (B) "CMR should be considered in patients with ventricular arrhythmias when echocardiography does not provide accurate assessment of LV and RV function and/or evaluation of structural changes."

HCM

IIB (C) "When SCD risk stratification is inconclusive after documentation of the conventional risk factors, CMR imaging with assessment of LGE may be considered in resolving clinical decision making."

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RV Visualization

CMR is well suited for RV

- Not limited by acoustic windows
- No assumptions needed about geometry

Useful for

- RV cardiomyopathies
- Pulmonic and tricuspid valves
- Pulmonary hypertension
- Congenital heart disease

Intervention guidelines are mostly based on CMR based assessment

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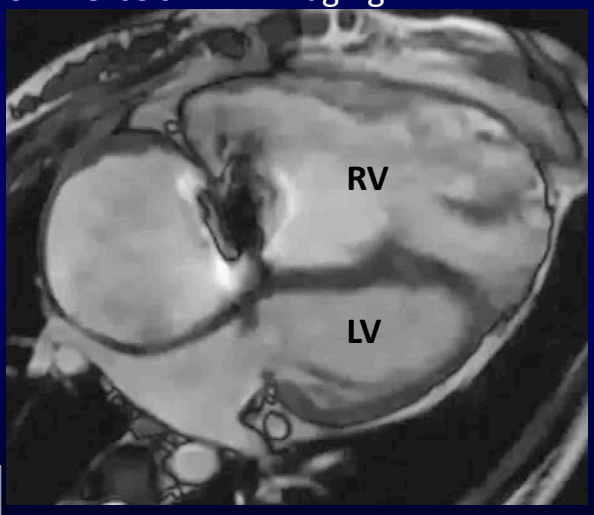
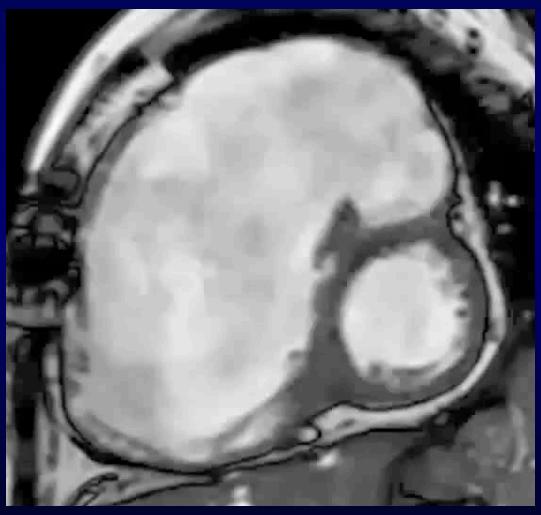
Right Ventricular Volume and Function

CMR excels in RV imaging





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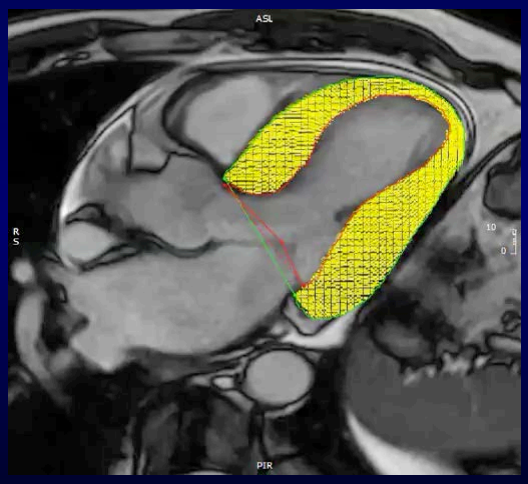
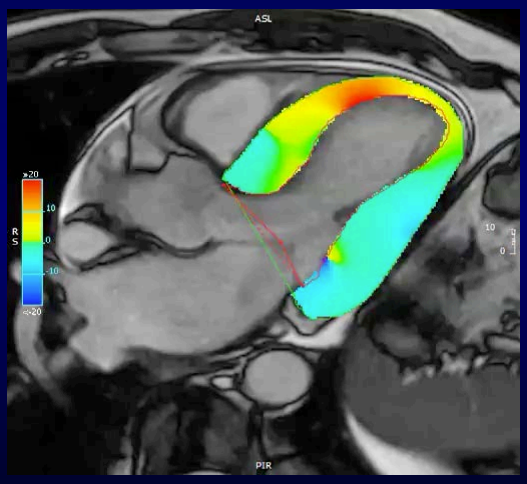
Strain by CMR?

Feature tracking algorithms. Temporal resolution is different than echo





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Take Home Points on Multimodality Imaging

Echo for all, CMR and CT for specific circumstances

Echo will typically underestimate the ventricular volumes relative to CMR

CMR is more reproducible and quantitative volumes and valve regurgitation

CMR provides assessment of myocardial tissue which can be prognostic

Functional CT is especially useful for metal valves, metal implants and when CMR is unusable

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