EACVI
European Association of Cardiovascular Imaging

DCM, LVNC and transplant

Preparatory course to certification in CMR

Steffen E Petersen, MSc MPH MD DPHIL SFHEA FSCMR FRCP FACC FEACVI FESC

29th September to 1st October 2022

ESC
European Society of Cardiology

Disclosures of interest

EACVI
European Association of
Cardiovascular Imaging

- **Consultancy, Circle Cardiovascular Imaging, Inc., Calgary, Alberta, Canad**

Syllabus

EACVI
European Association of Cardiovascular Imaging

- **3.2. Dilated cardiomyopathy (DCM)**
  - 3.2.1. LGE in DCM
    - 3.2.1.1. Frequency
    - 3.2.1.2. Typical spatial distribution
    - 3.2.1.3. Prognostic importance
  - 3.2.2. Relative diagnostic yields for DCM by echo and CMR
  - 3.2.3. Potential of CMR to reveal underlying cause of DCM
  - 3.2.4. Differential diagnosis in heart failure of unclear aetiology

Dilated cardiomyopathy: DCM

EACVI
European Association of Cardiovascular Imaging

- **LV dilatation and globally impaired systolic function**
- **Diagnosis by exclusion of secondary causes, e.g.**
  - Valvular disease
  - Ischaemic heart disease
  - Hypertension
- **20-50% familial**

DCM: CMR protocol

EACVI
European Association of Cardiovascular Imaging

- Anatomy
- LV function, RV function (Cine CMR)
- Oedema-sensivite CMR imaging
- Late gadolinium enhancement
- ± mapping techniques

DCM: CMR reporting

EACVI
European Association of Cardiovascular Imaging

- LV and RV volumes, function (global and regional), and mass/wall thickness
- Evidence of mitral regurgitation
- Presence and pattern of late gadolinium enhancement
- Evidence of LV thrombus

Frequency and typical spatial distribution of LGE in DCM

EACVI
European Association of Cardiovascular Imaging

TABLE 3. Findings of Contrast-Enhanced CMR

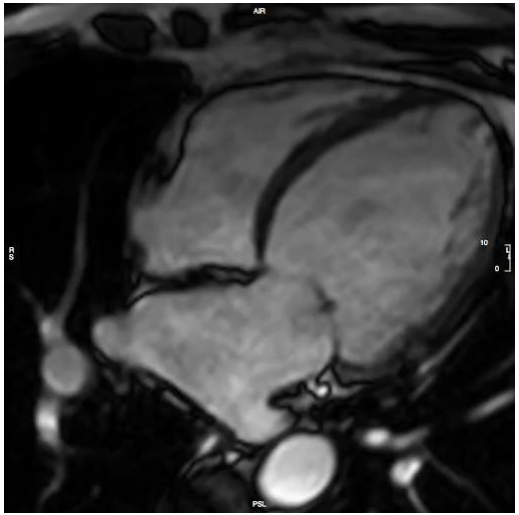
	DCM	Ischemic LV	*P*
Enhancement, n (%)	26 (41)	27 (100)	<0.001
Average gadolinium score	15±33	66±46	<0.001
Gadolinium score, % of patients			
0	59	0	
1–50	31	37	
50–100	8	39	
>100	2	24	
Enhancement location, n (%)			
Absent	37/63 (59)	0	
Endocardial	8/26 (13)	27/27 (100)	
Midwall	18/26 (28)	0	

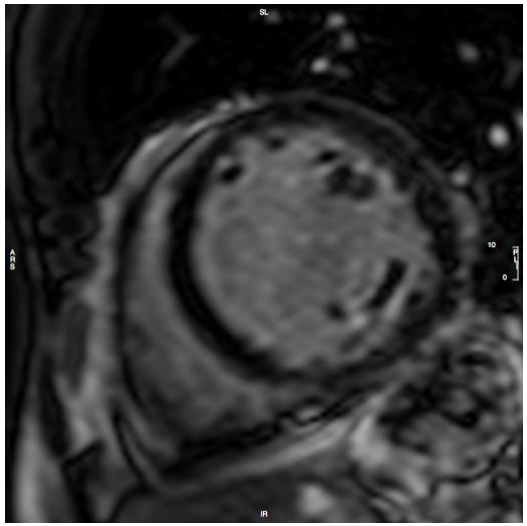
McCrohon JA et al. Circulation. 2003

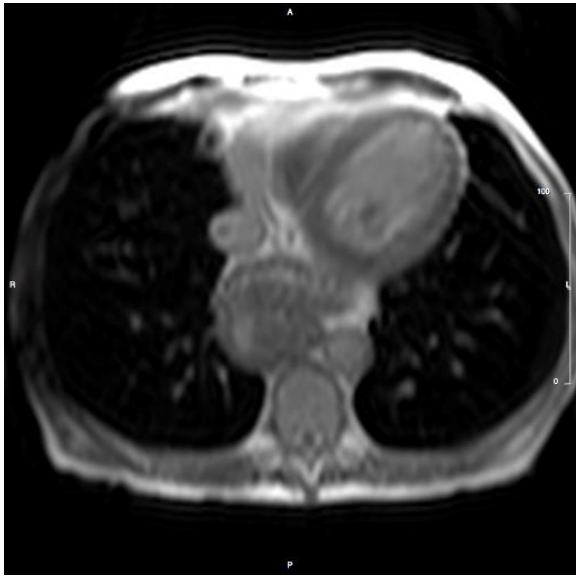
DCM: CMR and prognosis

EACVI
European Association of Cardiovascular Imaging

- LVEF <35%
- Presence and extent of mid-wall fibrosis





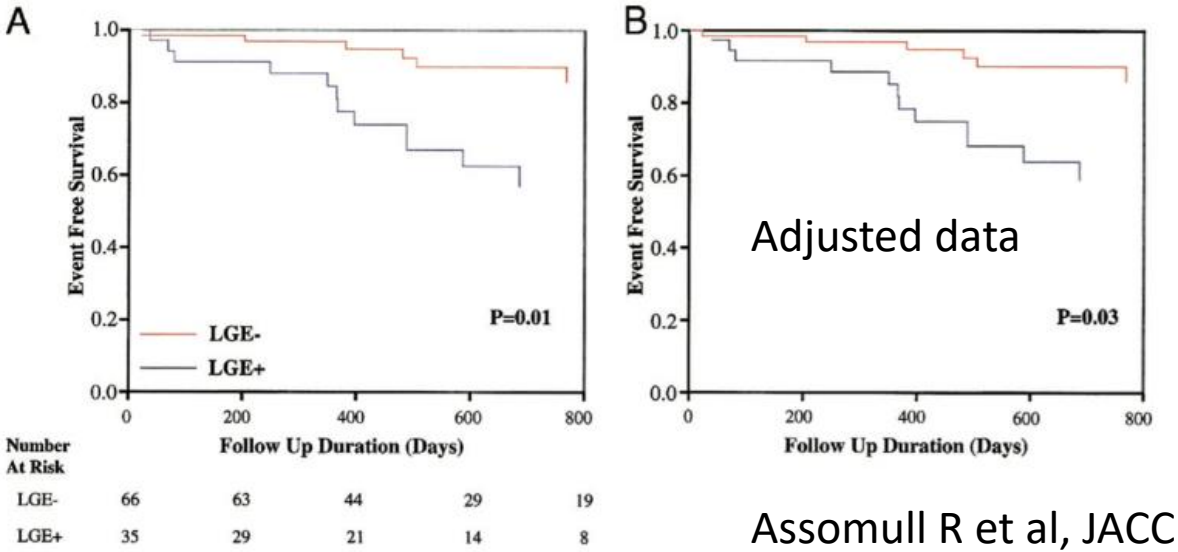


ESC

DCM: CMR and prognosis

EACVI
European Association of Cardiovascular Imaging

- **LVEF <35%**
- **Presence and extent of mid-wall fibrosis**



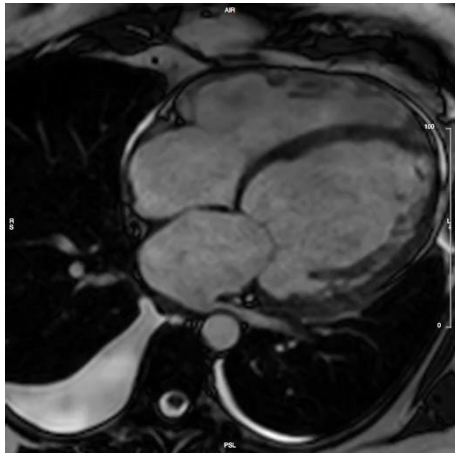
Assomull R et al, JACC 2006

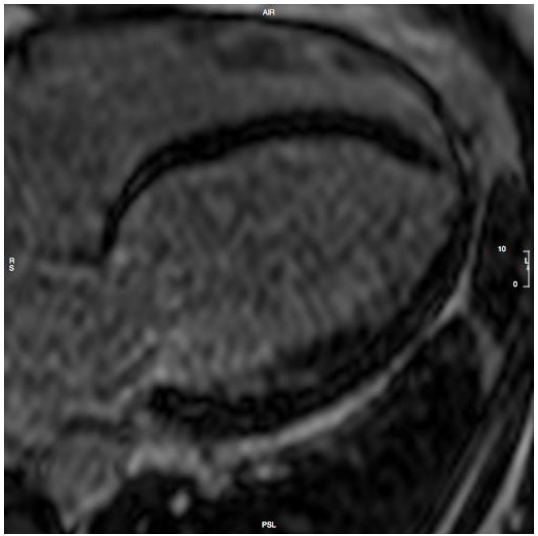
ESC

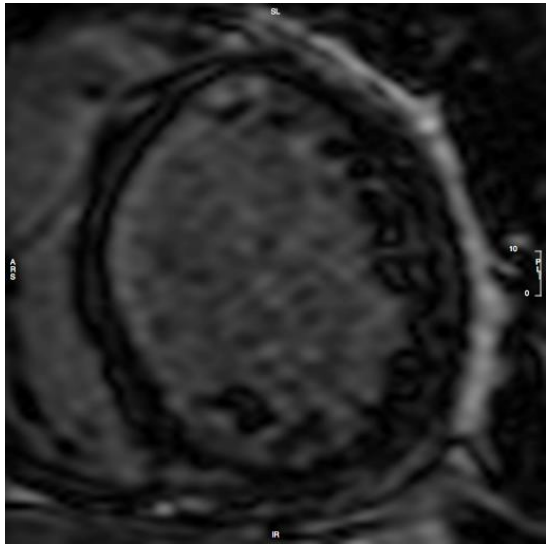
DCM: CMR and prognosis

EACVI
European Association of Cardiovascular Imaging

- LVEF <35%
- Presence and extent of mid-wall fibrosis







ESC

Potential of CMR to reveal underlying cause of DCM

EACVI
European Association of Cardiovascular Imaging

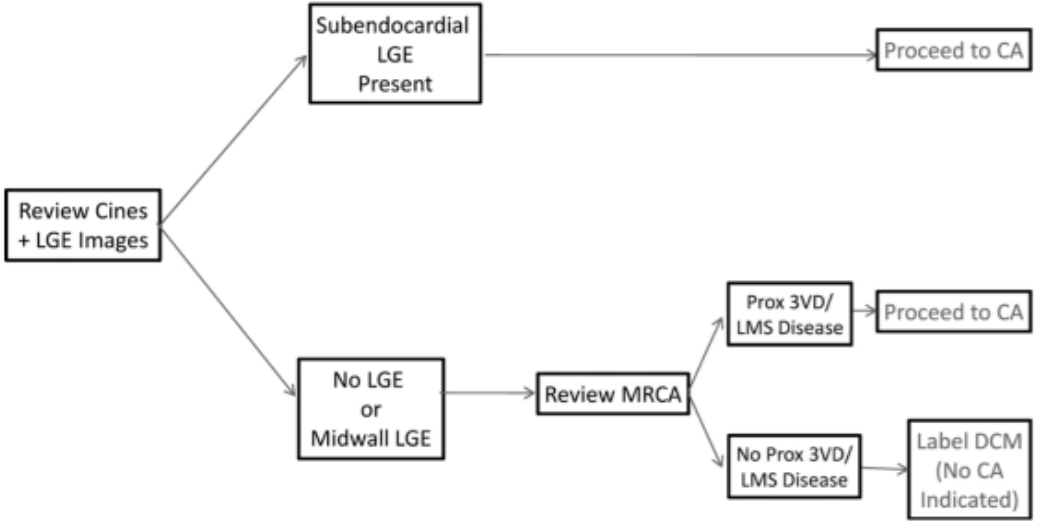


Figure 1. Predefined decision algorithm for the cardiac magnetic resonance consensus panel to decide whether to proceed to invasive x-ray coronary angiography (CA). The algorithm states that the presence of subendocardial late gadolinium enhancement (LGE) should trigger the decision to proceed to CA. In cases when subendocardial LGE is not present, magnetic resonance coronary angiography (MRCA) images should be reviewed before deciding whether CA is required. The review of MRCA should exclude proximal severe 3-vessel disease (Prox 3VD) or left main stem (LMS) disease before a scan be labeled dilated cardiomyopathy (DCM).

Assomull R et al. Circulation. 2011

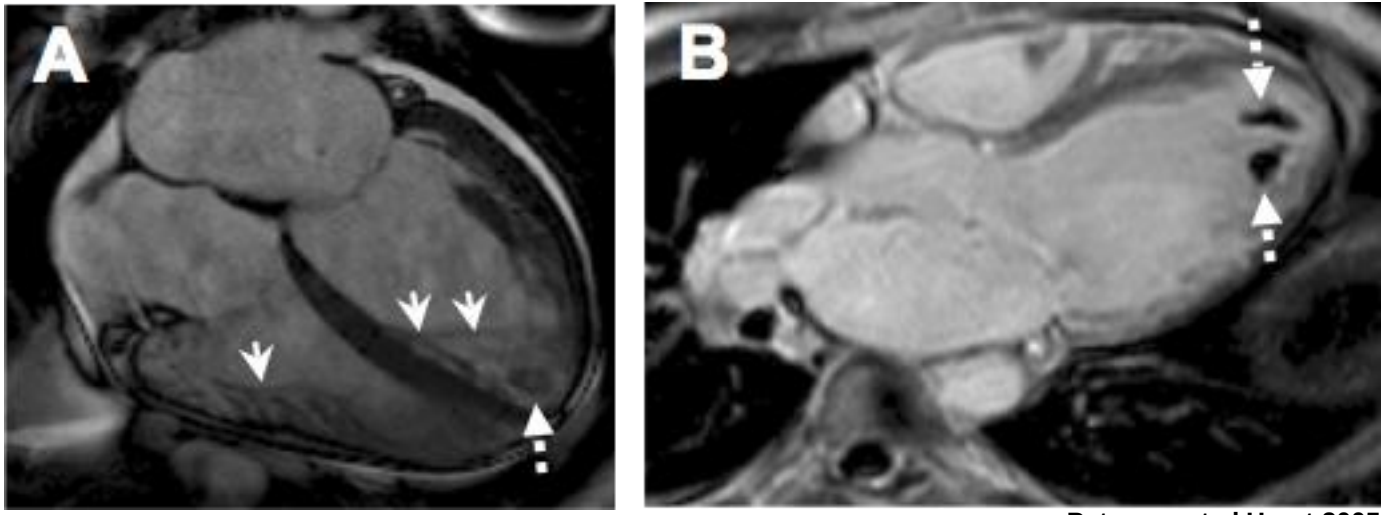
Syllabus

EACVI
European Association of Cardiovascular Imaging

- **3.5. Non-compaction cardiomyopathy (NCP)**
  - 3.5.1. Criteria for NCP (including differences in echo and CMR criteria)
  - 3.5.2. Relative diagnostic yields for NCP by echo and CMR
  - 3.5.3. LGE in NCP

LVNC: Left ventricular non-compaction

EACVI
European Association of Cardiovascular Imaging



Petersen et al Heart 2005

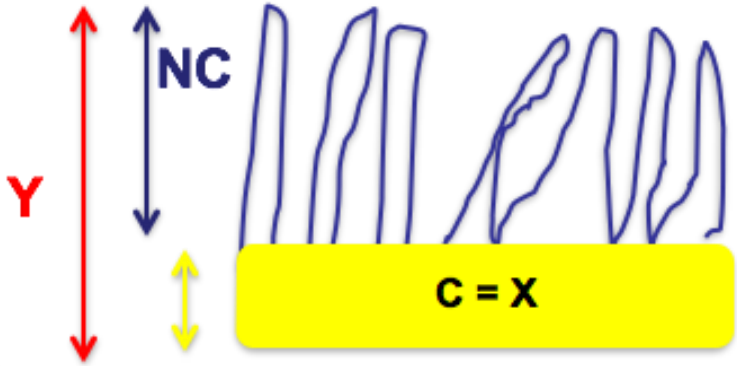
- **Characterised by prominent myocardial trabeculations and deep inter-trabecular recesses that communicate with the ventricular cavity**
- **Can lead to chronic cardiac failure, malignant arrhythmias and thromboembolic events**

ESC

Diagnostic echocardiography criteria: LVNC

EACVI
European Association of Cardiovascular Imaging

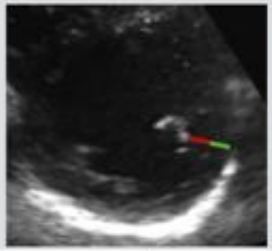
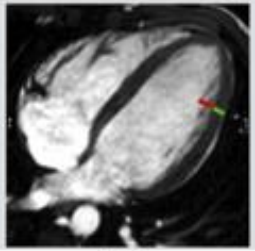
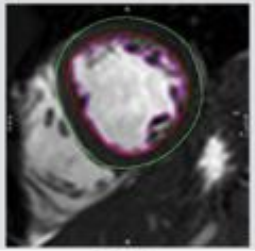
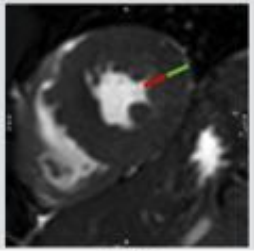
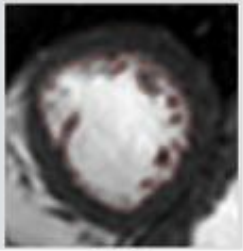
- Jenni criteria: NC/C>2 in systole
- Chin criteria: X/Y=C/(NC+C) ≤0.5
- Stollberger criteria: > 3 trabeculations protruding the left ventricular wall, apically to the papillary muscles, visible in a single image plane



Jenni R et al. Heart 2001
Chin TK et al. Circulation 1990
Stollberger C et al. AM J Cardiol 2002

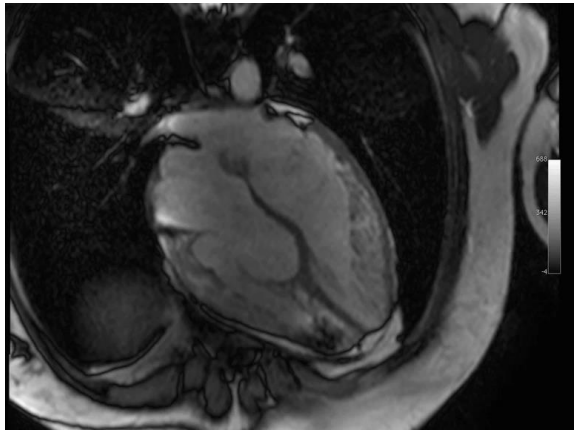
Diagnostic CMR criteria: LVNC

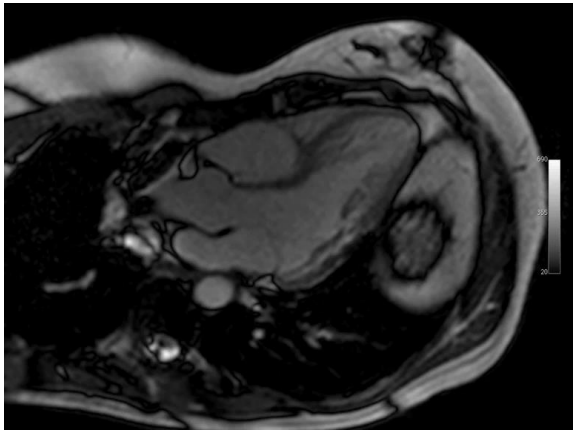
EACVI
European Association of Cardiovascular Imaging

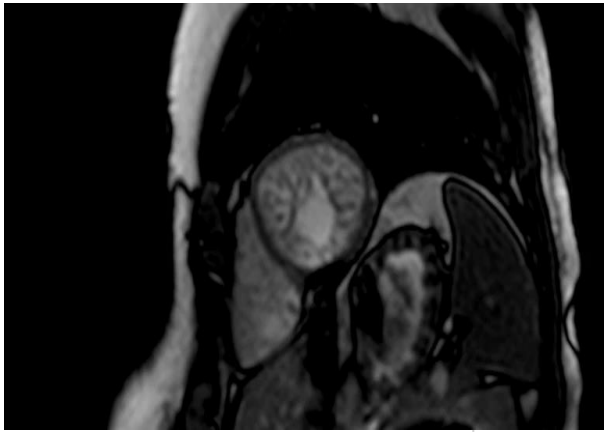
	Jenni	Petersen	Jacquier	Stacey	Captur
					
Modality	echo	CMR	CMR	CMR	CMR
Criteria	- N/C in parasternal short-axis views - Colour Doppler evidence of deep perfused intertrabecular recesses - Decreased thickening and hypokinesia present within, but not limited to, the non- compacted segments	- two layered myocardium - long axis SSFP cine - measured at the most pronounced trabeculations - measurement perpendicular to compacted myocardium	- short axis SSFP fines to obtain total LV mass - same used to obtain compacted myocardial mass - difference between first and second provides the trabecular mass - papilary muscles included in the myocardial mass	-apical short-axis views 16 to 24 mm from the true apical slice -region with the largest NC/C ratio	- short axis views - loss of base-to-apex FD gradient
Cardiac phase	End-systole	End-diastole	End-diastole	End-systole	End-diastole
Definition	NC/C ratio > 2	NC/C ratio > 2.3	Trabecular mass > 20%	NC/C ratio ≥ 2	FD ≥1.30

Steffen E Petersen

ESC

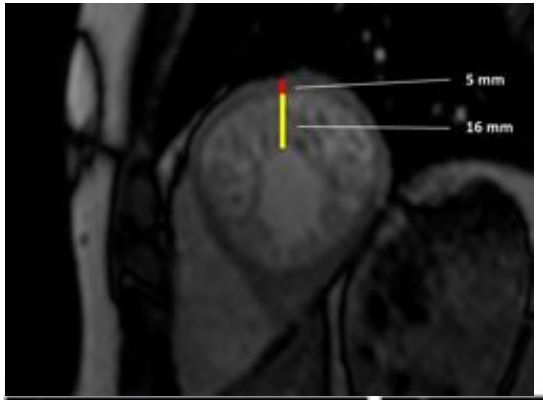




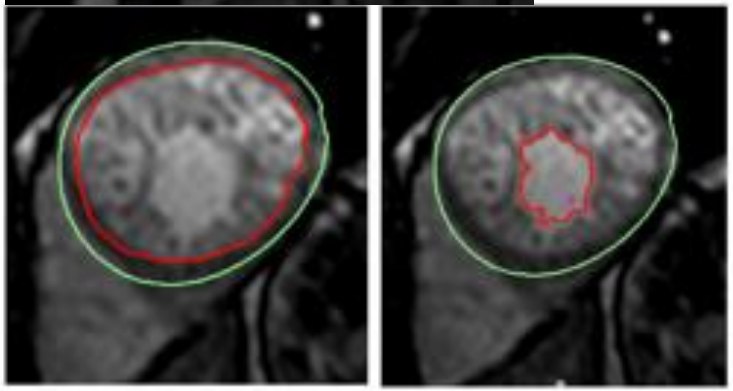


LVNC: CMR analysis approaches

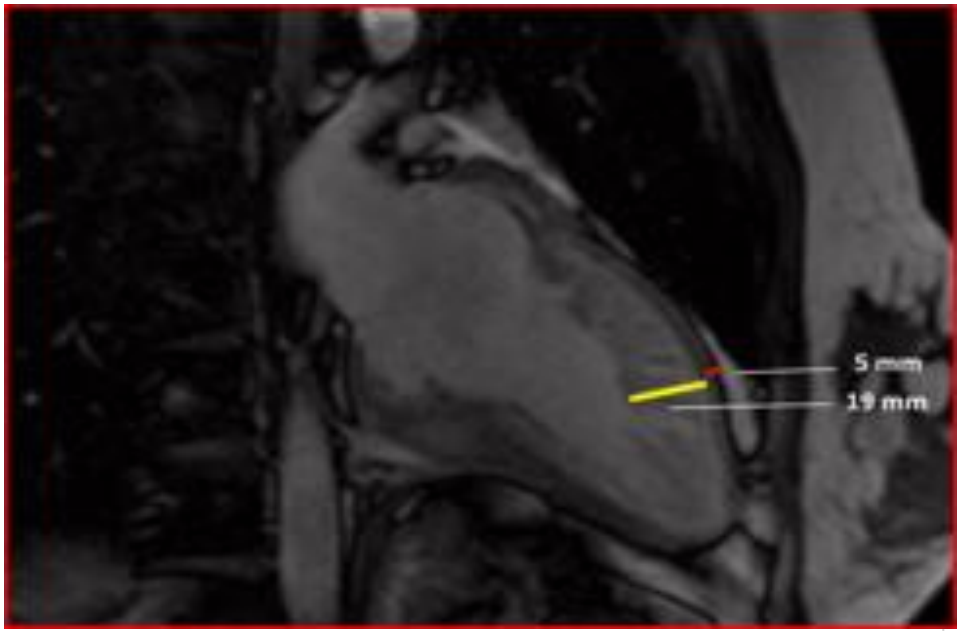
EACVI
European Association of Cardiovascular Imaging



?



?

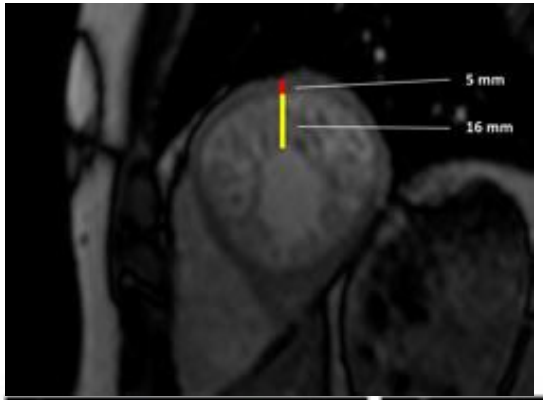


?

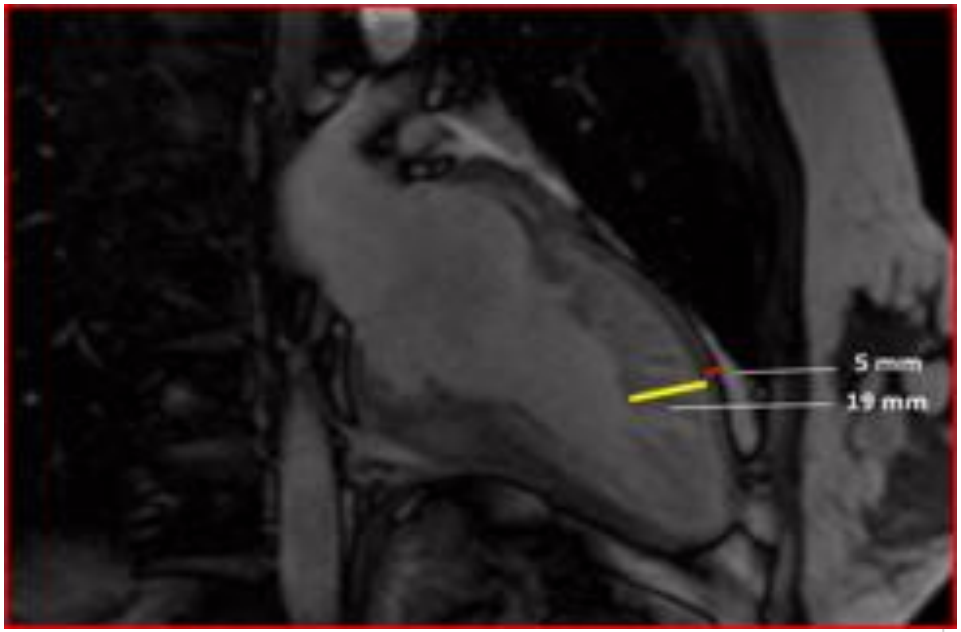
ESC

LVNC: CMR analysis approaches

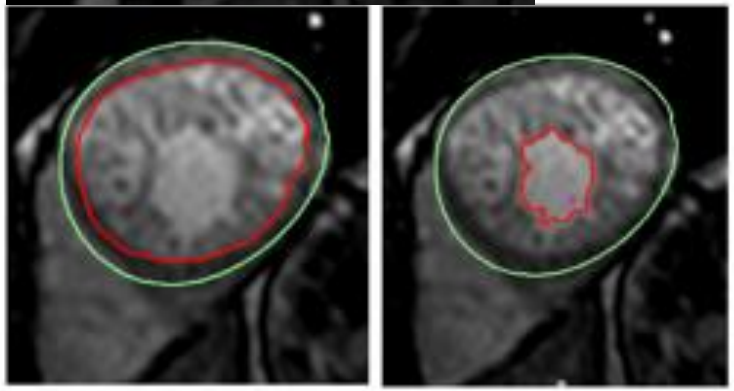
EACVI
European Association of Cardiovascular Imaging



Stacey



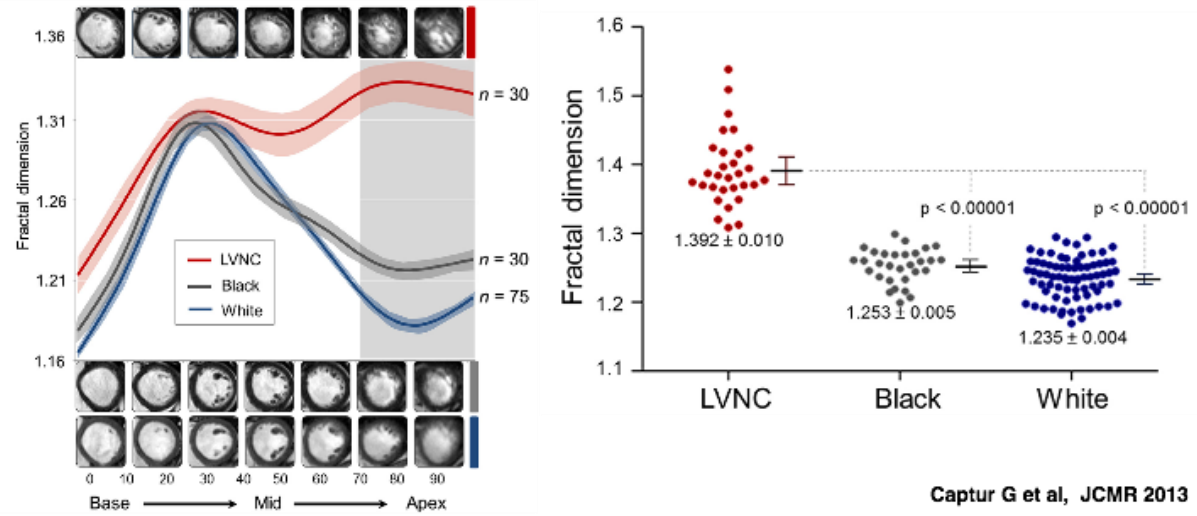
Petersen



Jacquier

ESC

Measure of endocardial complexity: Fractal dimension



Captur G et al, JCMR 2013

Table 2 Accuracy statistics for the fractal method and comparator CMR criteria.

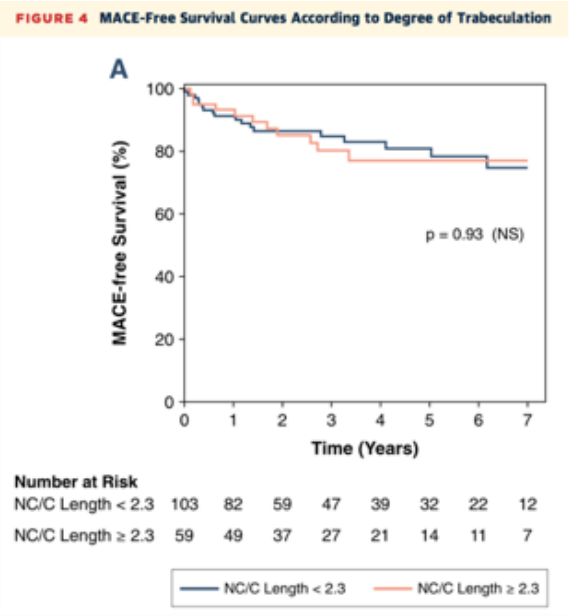
Accuracy statistic*	Max. Apical FD	Global LV FD	Perimetry	Petersen	Jacquier
Sensitivity (95% CI, UL-LL)	100 (88–100)	83 (61–92)	70 (48–85)	70 (46–87)	95 (73–100)
Specificity (95% CI, UL-LL)	100 (97–100)	86 (78–92)	91 (86–97)	98 (85–100)	53 (36–68)

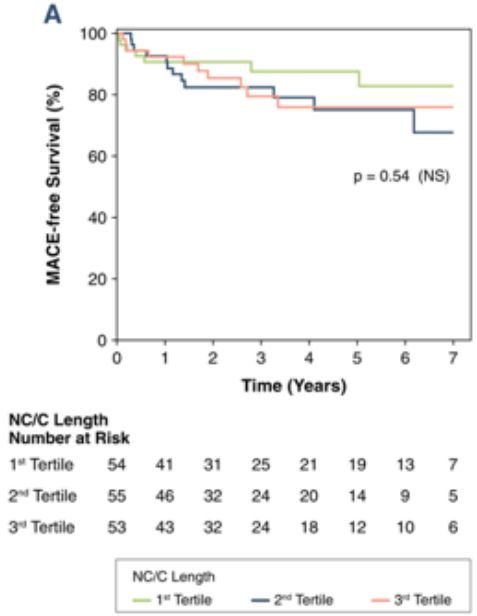
Captur G et al, JCMR 2013

Prognosis: trabeculations and DCM/LVNC

EACVI
European Association of Cardiovascular Imaging

FIGURE 4 MACE-Free Survival Curves According to Degree of Trabeculation



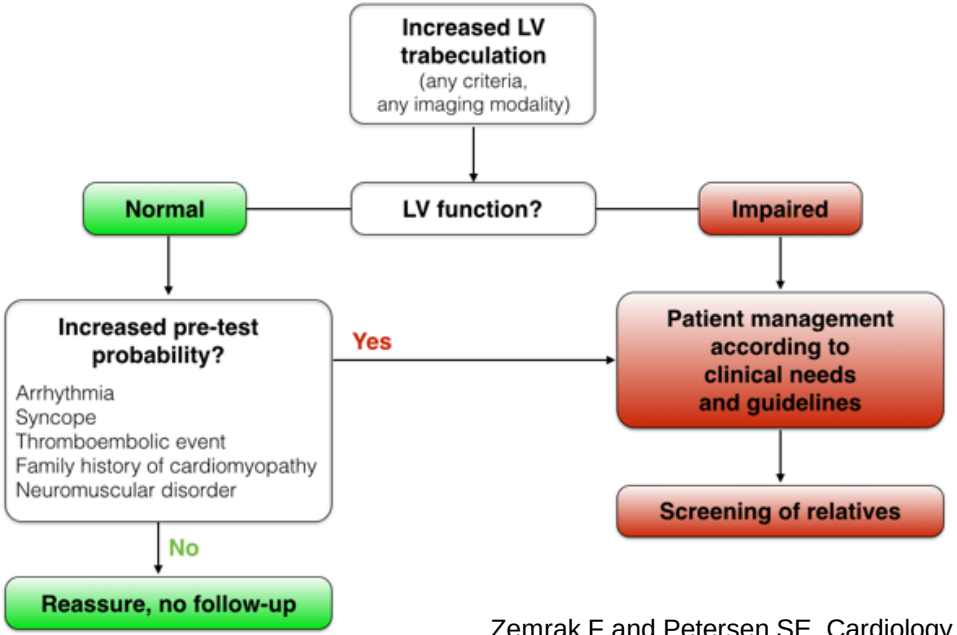


Amzulescu M-S et al. Prognostic Impact of Hypertrabeculation and Noncompaction Phenotype in Dilated Cardiomyopathy: A CMR Study. JACC Cardiovasc Imaging. 2015 Jul 8;8(8):934–46.

ESC

Management algorithm for LVNC

EACVI
European Association of Cardiovascular Imaging



Zemrak F and Petersen SE, Cardiology Today 2015

ESC

LGE and LVNC

EACVI
European Association of Cardiovascular Imaging

- **Evidence free zone**
- **Non-ischaemic pattern of LGE**
- **Ischaemic pattern of LGE**
  - if coexisting coronary artery disease
  - If thromboembolic myocardial infarction

Syllabus

EACVI
European Association of Cardiovascular Imaging

- **3.7. Transplant Cardiomyopathy**
  - 3.7.1 Sequences
  - 3.7.2 Clinical importance of CMR imaging

Heart transplant: Role of CMR in follow-up

EACVI
European Association of Cardiovascular Imaging

- **Anatomy:**
  - 'Double left atrium' appearance with older surgical technique
  - Pericardial effusion common in early phase
- **Function:**
  - EF is usually preserved but abnormalities in strain and long axis function.
  - Significant TR (valve injury due to repeated RV biopsy as part of surveillance for rejection)
  - LVH and diastolic impairment (long term)
- **Tissue characterisation:**
  - Evidence of myocardial oedema and globally elevated native T1 and T2 times (during first 5 months)
  - LGE (usually non-ischaemic pattern) -> likely due to cumulative injury from rejection episodes

Steffen E Petersen

Heart transplant: Role of CMR in follow-up

EACVI
European Association of Cardiovascular Imaging

Fig. 1 **a**, **b** Left atrial anastomosis. **c** Bicaval anastomosis. *Stars* represent superior vena cava anastomosis; *triangles* represent inferior vena cava anastomosis

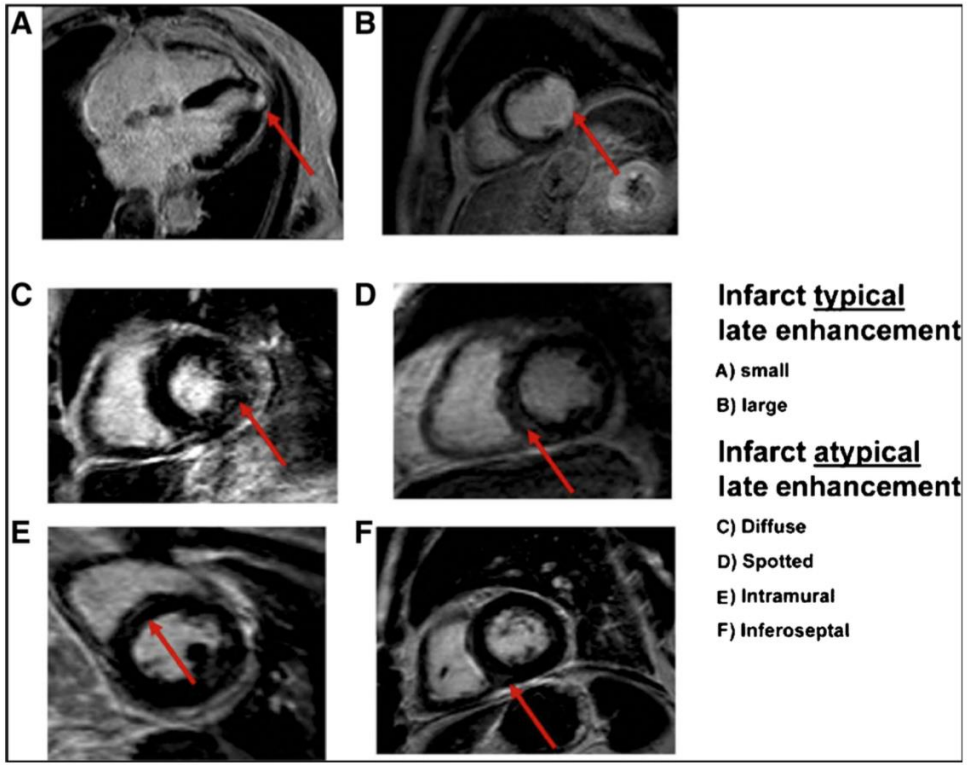
Reid, A. B., Waldron, N., Schmitt, M., & Miller, C. A. (2015). The Value of Cardiovascular Magnetic Resonance in Heart Transplant Patients. Current Cardiology Reports, 17(7), 612. http://doi.org/10.1007/s11886-015-0612-x

ESC

Heart Transplant: Role of CMR in follow-up

EACVI
European Association of Cardiovascular Imaging

Fig. 2 Patterns of late gadolinium enhancement seen in cardiac transplants. (Reproduced with permission from Steen H, Merten C, Refle S, et al: Prevalence of different gadolinium enhancement patterns in patients after heart transplantation. J Am Coll Cardiol 2008, 52:1160–1167) [8•]



Reid, A. B., Waldron, N., Schmitt, M., & Miller, C. A. (2015). The Value of Cardiovascular Magnetic Resonance in Heart Transplant Patients. Current Cardiology Reports, 17(7), 612. http://doi.org/10.1007/s11886-015-0612-x

ESC

Graft disease: Role of CMR

EACVI
European Association of Cardiovascular Imaging

- **Primary graft failure**
  - Severe LVSD (within hours/days)
- **Acute rejection**
  - Elevated T2 time (oedema); Increased EGE relative signal intensity
  - Caution with interpretation – T2 time usually elevated in first 6/12
- **Allograft vasculopathy**
  - CMR useful in detecting silent infarcts (ischaemic LGE pattern)
  - Worse strain rate (from tagging sequences)
- **Other consideration**
  - Erratic response to adenosine in stress perfusion (due to denervation)
  - Increased incidence of solid organ tumours and haematological malignancy (Careful scrutiny of extra-cardiac images)

ESC

Syllabus

EACVI
European Association of Cardiovascular Imaging

- **3.2. Dilated cardiomyopathy (DCM)**
  - 3.2.1. LGE in DCM
    - 3.2.1.1. Frequency
    - 3.2.1.2. Typical spatial distribution
    - 3.2.1.3. Prognostic importance
  - 3.2.2. Relative diagnostic yields for DCM by echo and CMR
  - 3.2.3. Potential of CMR to reveal underlying cause of DCM
  - 3.2.4. Differential diagnosis in heart failure of unclear aetiology

Syllabus

EACVI
European Association of Cardiovascular Imaging

- **3.5. Non-compaction cardiomyopathy (NCP)**
  - 3.5.1. Criteria for NCP (including differences in echo and CMR criteria)
  - 3.5.2. Relative diagnostic yields for NCP by echo and CMR
  - 3.5.3. LGE in NCP

Syllabus

EACVI
European Association of Cardiovascular Imaging

- **3.7. Transplant Cardiomyopathy**
  - 3.7.1 Sequences
  - 3.7.2 Clinical importance of CMR imaging