CMR in Heart Failure: Impact on Etiologic Assessment & Prognosis

Dipan J. Shah, MD, FACC
Professor of Medicine and Chief, Division of Cardiovascular Imaging
Director, Cardiovascular MRI Laboratory
Houston Methodist DeBakey Heart & Vascular Center

No relevant disclosures

@dipanjshah

APPROPRIATE USE CRITERIA

ACC/AATS/AHA/ASE/ASNC/HRS/SCAI/SCCT/SCMR/STS 2019 Appropriate Use Criteria for Multimodality Imaging in the Assessment of Cardiac Structure and Function in Nonvalvular Heart Disease

6.2. Evaluation of Cardiac Structure and Function in Patients Who Had Prior Testing

TABLE 3 Sequential or Follow-Up Testing to Clarify Initial Diagnostic Testing

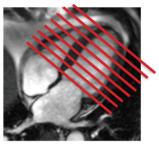
	TTE (With or Without 3D; With Contrast as Needed)	TEE (With or Without 3D	Strain/Strain Rate Imaging by Speckle or Tissue Doppler	Exercise SE/DSE	F-18 FDG-PET	Tc-99m PYP	MPI (SPECT/PET)	CMR	CT	ANG
43. Left ventricular systolic dysfunction in the absence of severe valvular disease		3 (R)	3 (R)	7 (A)	4 (M)	3 (R)	7 (A)	7 (A)	7 (A)	7 (A)
44. Pulmonary hypertension in the absence of severe valvular disease		6 (M)	4 (M)	4 (M)	1 (R)	1 (R)	1 (R)	7 (A)	7 (A)	3 (R)
45. Excluding CAD in patients with HF and LV systolic dysfunction without angina		1 (R)	1 (R)	7 (A)	3 (R)	1 (R)	7 (A)	7 (A)	7 (A)	8 (A)
46. New or increasing HF symptoms despite adherence to medical therapy		4 (M)	3 (R)	6 (M)	3 (R)	2 (R)	6 (M)	6 (M)	(M)	6 (M)
47. Comprehensive further evaluation of undefined cardiomyopathy		3 (R)	5 (M)	5 (M)	5 (M)	4 (M)	6 (M)	8 (A)	(M)	7 (A)
48. Evaluation of suspected cardiac sarcoidosis		2 (R)	3 (R)	1 (R)	7 (A)	2 (R)	3 (R)	8 (A)	(R)	1 (R)
49. Evaluation of suspected cardiac amyloidosis		1 (R)	6 (M)	1 (R)	2 (R)	7 (A)	2 (R)	8 (A)	(R)	1 (R)
50. Evaluation of suspected hypertrophic cardiomyopathy		4 (M)	7 (A)	7 (A)	1 (R)	1 (R)	1 (R)	8 (A)	(M)	2 (R)

@dipanjshah

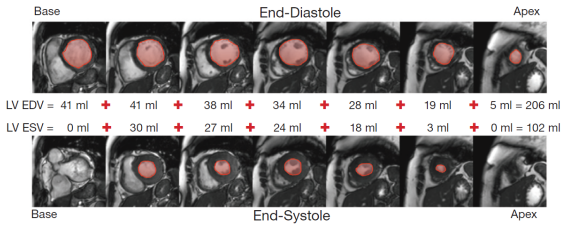
What are the tools that CMR can offer in assessment of Heart Failure ?

@dipanjshah

SSFP: Ventricular Volumes & Function



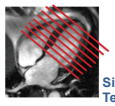
Simpson's Rule Technique



@dipanjshah

Shah. Curr Opin Cardiol 2012, 27:485–491

SSFP: Ventricular Volumes & Function



Simpson's Rule Technique

Accurate and reproducible:
1. LV and RV volumes
2. LV and RV Ejection Fraction
3. LV Mass

No geometric assumptions

= 50%

Cardiol 2012, 27:485–491

Pattynama PM. Radiology 1993;187:261–8.
Semelka RC. Am Heart J 1990;119:1367–73.
Stratemeier EJ.Radiology 1986;158:775–7.

156:717–9

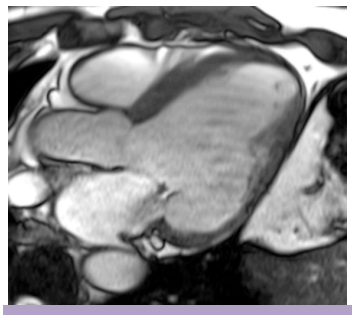
metry validated:
– Animals
– In vitro
– In vivo
– Ex vivo

- *Superior* to ECHO
  - Highly accurate
  - Highly reproducible
  - Low intra-observer variability
  - Low inter-observer variability
    - LVEF: 2-7%
  - Low inter-study variability

@dipanjshah

What are the tools that CMR can offer ?

Severity of Valvular Regurgitation



Secondary MR

@dipanjshah

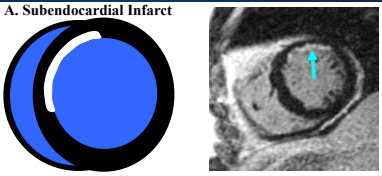
What are the tools that CMR can offer ?

- Late Gadolinium Enhancement

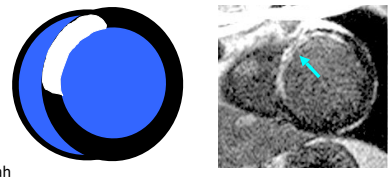
@dipanjshah

ISCHEMIC ENHANCEMENT PATTERNS

A. Subendocardial Infarct

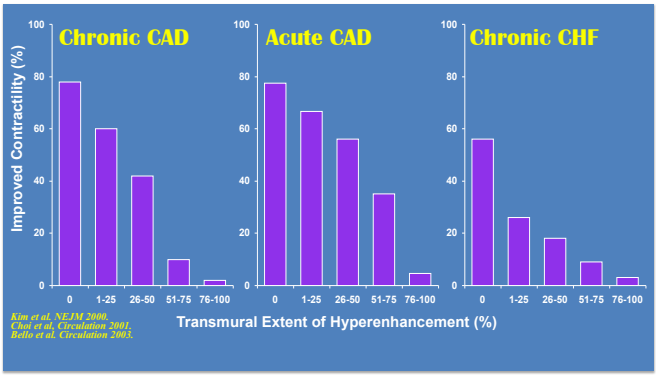


B. Transmural Infarct



@dipanjshah

Extent of LGE and Likelihood of Functional Improvement

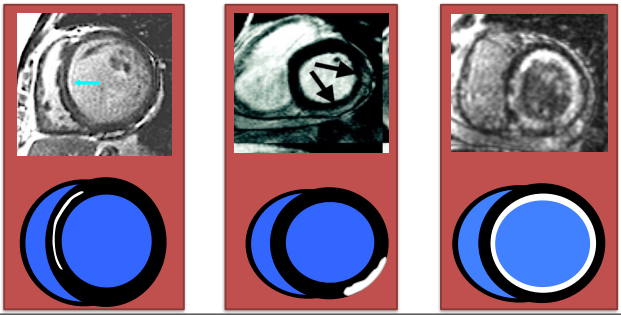


@dipanjshah

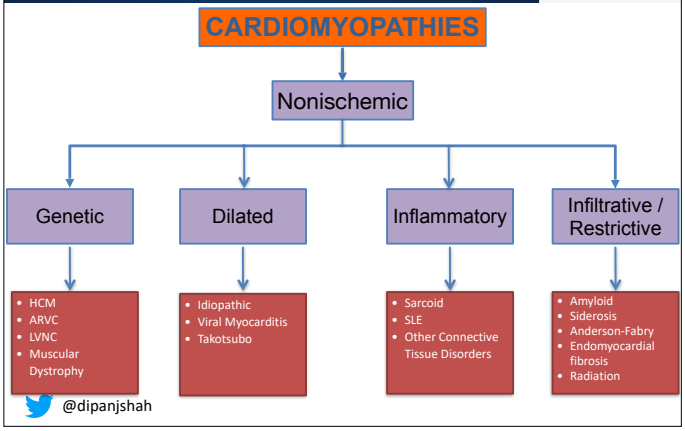
PREMISE:

Hyperenhancement patterns that do not fit with the wavefront phenomenon of ischemic injury are likely to be nonischemic.

MIDWALL | EPICARDIAL | NON-CAD PERFUSION

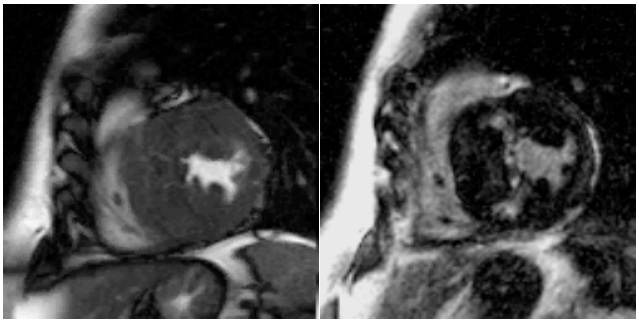


Identification of Etiology:



@dipanjshah

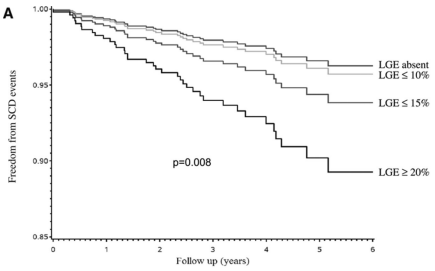
Hypertrophic Cardiomyopathy

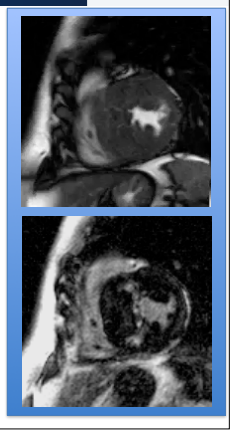


Cine **Delayed Enhancement**

@dipanjshah

Hypertrophic Cardiomyopathy: LGE Association with Sudden Death





Chan et al, Circulation 2014.

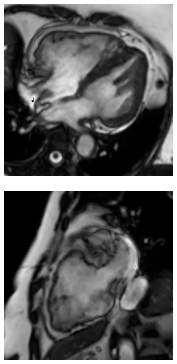
ARVC

MAJOR CRITERIA

By MRI:
- Regional RV akinesia or dyskinesia or dyssynchronous RV contraction
- *and* 1 of the following:
  - Ratio of RV end-diastolic volume to BSA ≥110 mL/m² (male) or ≥100 mL/m² (female)
  - *or* RV ejection fraction ≤40%

MINOR CRITERIA

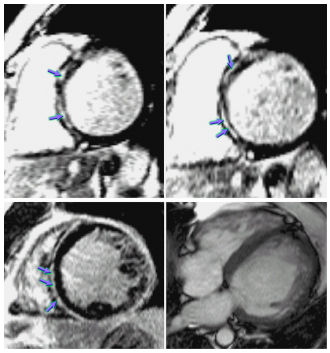
By MRI:
- Regional RV akinesia or dyskinesia or dyssynchronous RV contraction
- *and* 1 of the following:
  - Ratio of RV end-diastolic volume to BSA ≥100 to <110 mL/m² (male) or ≥90 to <100 mL/m² (female)
  - *or* RV ejection fraction >40% to ≤45%



RVEF: 39%
RVEDVI: 136ml/m2

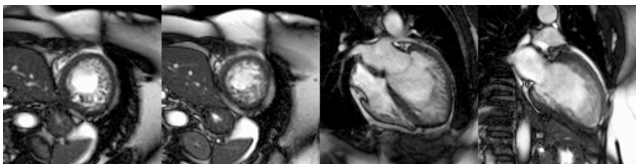
@dipanjshah

Left Dominant Arrhythmogenic Cardiomyopathy



Choudhry et al, JACC 2008

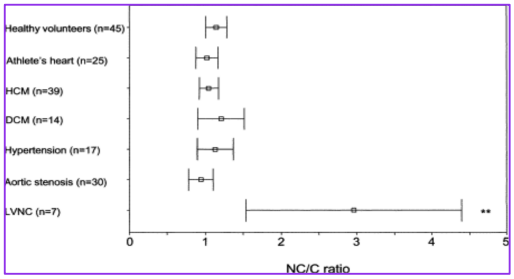
Noncompaction



- LV End Diastolic Volume: 190 ml
- LV Ejection Fraction: 29%
- Noncompacted Myocardium (NC): 17 mm
- Compacted Myocardium (C): 6 mm
- Ratio NC/C: 2.8

@dipanjshah

Noncompaction

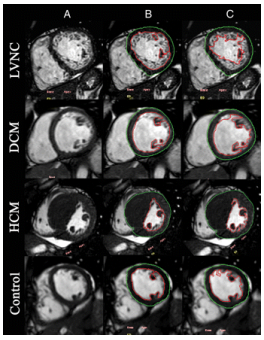


A NC/C ratio of >2.3 in diastole distinguished pathological non-compaction, with values for sensitivity, specificity, positive, and negative predictions of 86%, 99%, 75%, and 99%, respectively.

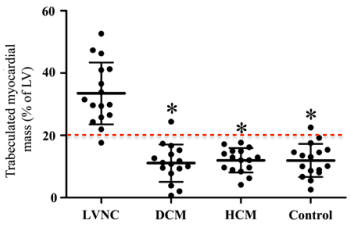
@dipanjshah

Peterson et al, J Am Coll Cardiol. 2005

Noncompaction



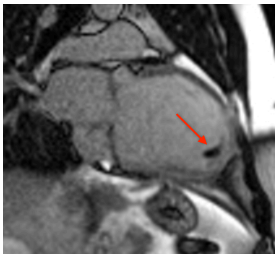
Jacquier et al. European Heart Journal 2010.



A trabeculated LV mass above 20% of the global LV mass is highly sensitive and specific for the diagnosis of LVNC

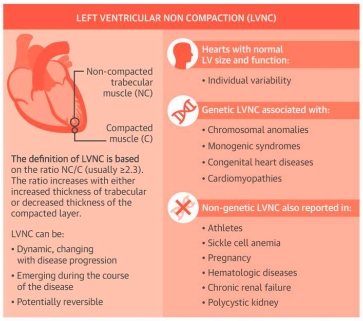
Noncompaction

LV Thrombus



@dipanjshah

CENTRAL ILLUSTRATION: Spectrum of LVNC



Arbustini, E. et al. J Am Coll Cardiol. 2016;68(9):949-66.

ORIGINAL ARTICLE

Prognostic Significance of Left Ventricular Noncompaction

Systematic Review and Meta-Analysis of Observational Studies

See Editorial by Sharain and Anavekar

Nay Aung, MD
Sara Doimo, MD
Fabrizio Ricci, MD, PhD
Mihir M. Sanghvi, MD
Cesar Pedrosa, MD
Simon P. Woodbridge, BMedSci
Amer Al-Balah, BSc
Filip Zemrak, MD, PhD
Mohammed Y. Khanji, MD, PhD
Patricia B. Munroe, PhD
Huseyin Naci, PhD
Steffen E. Petersen, MD, DPhil, MPH

BACKGROUND: Although left ventricular noncompaction (LVNC) has been associated with an increased risk of adverse cardiovascular events, the accurate incidence of cardiovascular morbidity and mortality is unknown. We, therefore, aimed to assess the incidence rate of LVNC-related cardiovascular events.

METHODS: We systematically searched observational studies reporting the adverse outcomes related to LVNC. The primary end point was cardiovascular mortality.

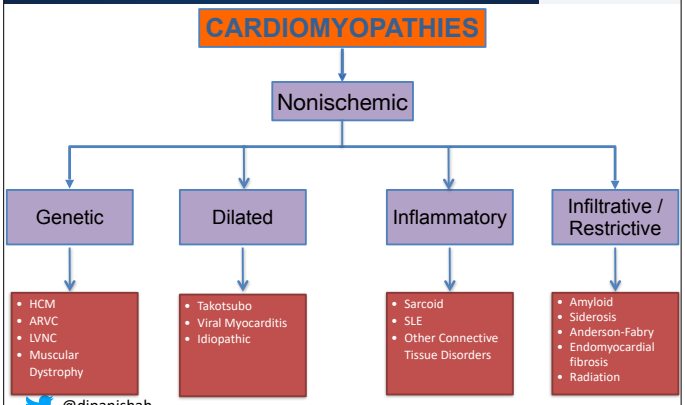
RESULTS: We identified 28 eligible studies enrolling 2501 LVNC patients (mean age, 46 years; male/female ratio, 1.7). After a median follow-up of 2.9 years, the pooled event rate for cardiovascular mortality was 1.92 (95% CI, 1.54–2.30) per 100 person-years. LVNC patients had a similar

CONCLUSIONS: Patients with LVNC carry a similar cardiovascular risk when compared with dilated cardiomyopathy patients. Left ventricular ejection fraction—a conventional indicator of heart failure severity, not the extent of trabeculation—appears to be an important determinant of adverse outcomes in LVNC patients.

@dipanjshah

Circ Cardiovasc Imaging. 2020

Identification of Etiology:



@dipanjshah

Clinical Characteristics and Cardiovascular Magnetic Resonance Findings in Stress (Takotsubo) Cardiomyopathy

Ingo Eitel, MD
Florian von Knobelsdorff-Brenkenhoff, MD
Peter Bernhardt, MD
Iacopo Carbone, MD
Kai Muellerleile, MD
Annachiara Aldrovandi, MD
Marco Francone, PhD
Steffen Desch, MD
Matthias Gutberlet, MD
Oliver Strohm, MD
Gerhard Schuler, MD
Jeanette Schulz-Menger, MD
Holger Thiele, MD
Matthias G. Friedrich, MD

Context Stress cardiomyopathy (SC) is a transient form of acute heart failure triggered by stressful events and associated with a distinctive left ventricular (LV) contraction pattern. Various aspects of its clinical profile have been described in small single-center populations, but larger, multicenter data sets have been lacking so far. Furthermore, it remains difficult to quickly establish diagnosis on admission.

Objectives To comprehensively define the clinical spectrum and evolution of SC in a large population, including tissue characterization data from cardiovascular magnetic resonance (CMR) imaging; and to establish a set of CMR criteria suitable for diagnostic decision making in patients acutely presenting with suspected SC.

Design, Setting, and Patients Prospective study conducted at 7 tertiary care centers in Europe and North America between January 2005 and October 2010 among 256 patients with SC assessed at the time of presentation as well as 1 to 6 months after the acute event.

Main Outcome Measures Complete recovery of LV dysfunction.

Results Eighty-one percent of patients (n=207) were postmenopausal women, 8% (n=20) were younger women (aged ≤50 years), and 11% (n=29) were men. A stressful trigger could be identified in 182 patients (71%). Cardiovascular magnetic resonance imaging data (available for 239 patients [93%]) revealed 4 distinct patterns of regional ventricular ballooning: apical (n=197 [82%]), biventricular (n=81 [34%]), midventricular (n=40 [17%]), and basal (n=2 [1%]). Left ventricular ejection fraction was reduced (48% [SD, 11%]; 95% confidence interval [CI], 47%-50%) in all patients. Stress cardiomyopathy was accurately identified by CMR using specific criteria: a typical pattern of LV dysfunction, myocardial edema, absence of significant necrosis/fibrosis, and markers for myocardial inflammation. Follow-up CMR imaging showed complete normalization of LV ejection fraction (66% [SD, 7%]; 95% CI, 64%-68%) and inflammatory markers in the absence of significant fibrosis in all patients.

Conclusions The clinical profile of SC is considerably broader than reported previously. Cardiovascular magnetic resonance imaging at the time of initial clinical presentation may provide relevant functional and tissue information that might aid in the establishment of the diagnosis of SC.

JAMA. 2011;306(3):277-286

Stress cardiomyopathy (SC), first reported in Japan as *takotsubo*, is characterized by acute, profound, but reversible left ventricular (LV) dysfunction in the absence of significant coronary artery disease, triggered by acute emotional or physical stress.[1] This phenomenon is identified by a distinctive pattern of "apical ballooning" and primarily affects postmenopausal women.[2,3] The majority of patients have a clinical pre-

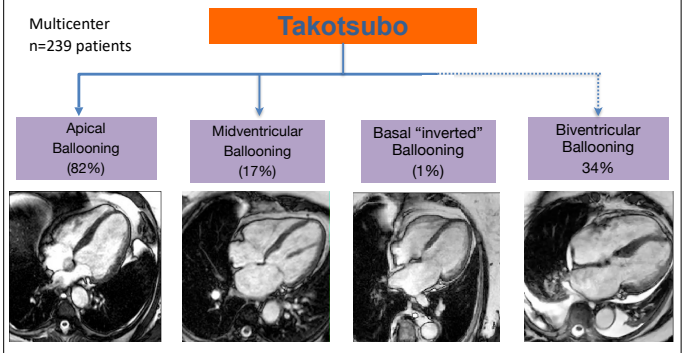
Multicenter
n=239 patients

@dipanjshah

Eitel et al JAMA. 2011

Patterns of Ballooning

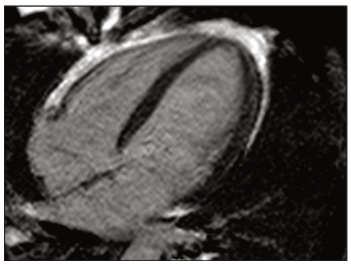
Multicenter
n=239 patients



@dipanjshah

Eitel et al JAMA. 2011

LGE in Takotsubo

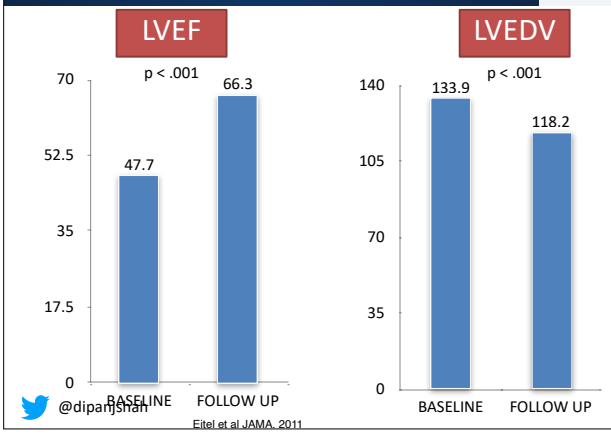


No LGE using 5 SD Threshold

@dipanjshah

Eitel et al JAMA. 2011

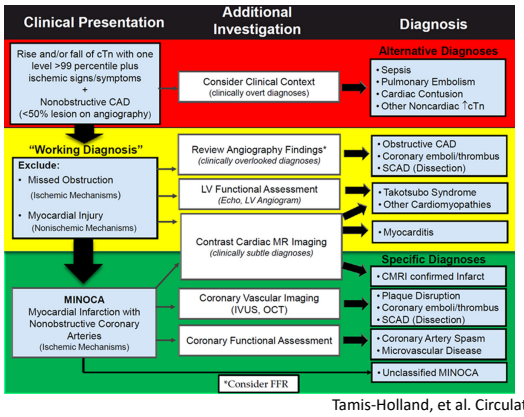
Takotsubo Follow Up



@dipanjshah

Eitel et al JAMA. 2011

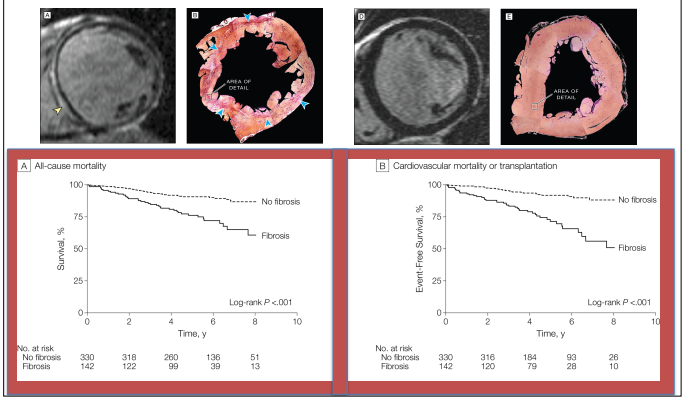
MINOCA



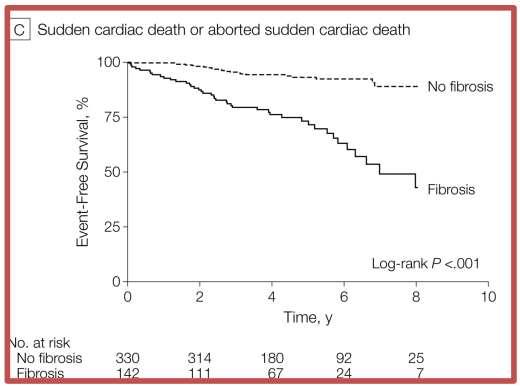
Tamis-Holland, et al. Circulation 2019

Idiopathic Dilated CMP

Gulati et al. JAMA 2013



Idiopathic Dilated CMP



Gulati et al. JAMA 2013

Circulation

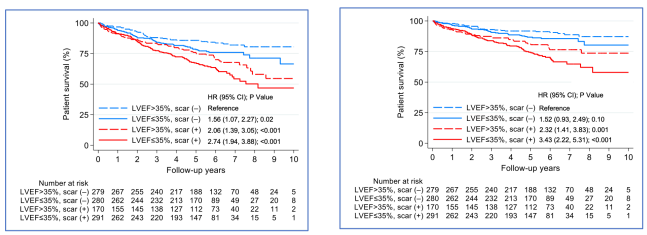
The Relationship of LVEF and Myocardial Scar to Long-Term Mortality Risk and Mode of Death in Patients with Non-Ischemic Cardiomyopathy

Igor Klem, Michael Klein, Mohammad Khan, Eric Y. Yang, Faisal Nabi, Alexander Ivanov, Lubna Bhatti, Brenda Hayes, Edward A. Graviss, Duc T. Nguyen, Robert M. Judd, Raymond J. Kim, John F. Heitner, and Dipan J. Shah

Originally published 22 Jan 2021 | https://doi.org/10.1161/CIRCULATIONAHA.120.048477 | Circulation. ;0

A. All cause death

B. Cardiac death



Klem et al, Circulation 2021

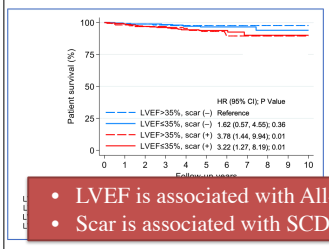
Circulation

The Relationship of LVEF and Myocardial Scar to Long-Term Mortality Risk and Mode of Death in Patients with Non-Ischemic Cardiomyopathy

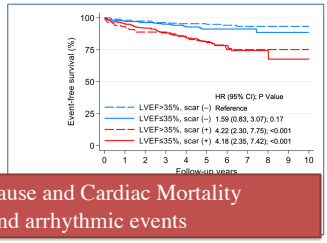
Igor Klem, Michael Klein, Mohammad Khan, Eric Y. Yang, Faisal Nabi, Alexander Ivanov, Lubna Bhatti, Brenda Hayes, Edward A. Graviss, Duc T. Nguyen, Robert M. Judd, Raymond J. Kim, John F. Heitner, and Dipan J. Shah

Originally published 22 Jan 2021 | https://doi.org/10.1161/CIRCULATIONAHA.120.048477 | Circulation. ;0

C. Sudden cardiac death



D. Arrhythmic composite events

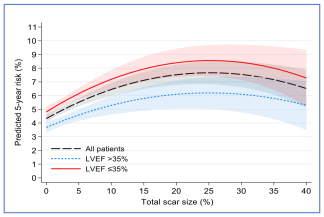


- LVEF is associated with All-cause and Cardiac Mortality
- Scar is associated with SCD and arrhythmic events

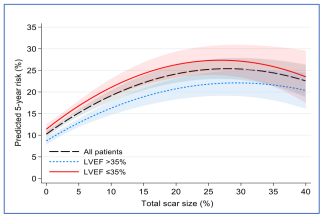
Klem et al, Circulation 2021

The Relationship of LVEF and Myocardial Scar to Long-Term Mortality Risk and Mode of Death in Patients with Non-Ischemic Cardiomyopathy

B. Sudden cardiac death



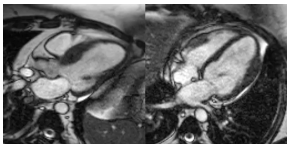
C. Arrhythmic composite events

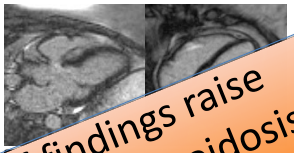


- Progressive increasing risk for SCD and arrhythmic composite events for both LVEF < 35% and also for LVEF > 35%.
- Risk plateaued ~ 20-25% scar burden.

Klem et al, Circulation 2021

CMR FINDINGS: Summary





Constellation of findings raise suspicion for cardiac sarcoidosis

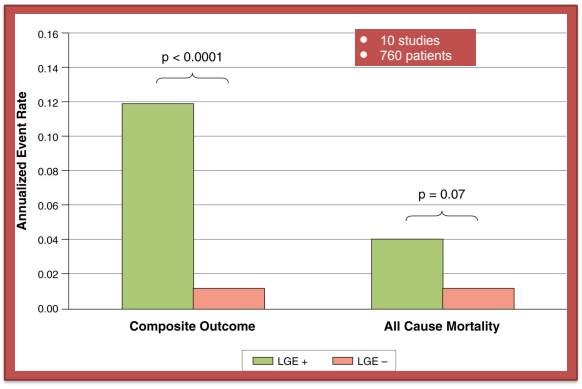
- [illegible]ptum, lateral wall, RV free wall
- L[illegible]um, lateral wall, RV free wall
- In[illegible] water content (edema) basal septum, lateral wall, RV free wall
- Hilar and paratracheal lymphadenopathy

ANATOMIC PATHOLOGY DIAGNOSIS:

A. Heart, left ventricle outflow tract, biopsy:

- Non-necrotizing granulomatous inflammation present, focal
- No organisms identified on special stains for fungi and mycobacteria
- No polarizable foreign material identified
- Consistent with sarcoidosis in the appropriate clinical setting (see Comment)

LGE and Annual Event Rates in Sarcoid



Coleman et al. JACC Imaging 2009.

What is the Role of Imaging Sarcoid?

Imaging

1. Unexplained Moritz II or 3rd degree AV Block (age < 60)
2. VT of unknown etiology
3. Heart Failure

→ 1. Identify Cardiac Involvement 2. Establish Initial Diagnosis of Sarcoidosis

Biopsy proven extra-cardiac sarcoidosis

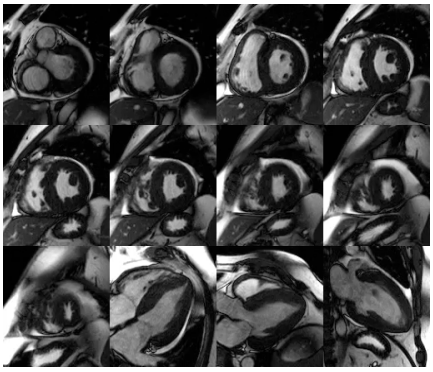
→ Identify Cardiac Involvement

1. Between 16% and 35% of patients presenting with complete atrioventricular block (age <60 years) or ventricular tachycardia of unknown etiology have previously undiagnosed CS as the underlying etiology.
2. CS as the underlying cause of heart failure:
   - core LV biopsies at the time of LVAD —> undiagnosed CS (3.4%)
   - Explanted hearts —> 3% undiagnosed CS. - Birnie et al, JACC 2014

@dipanjshah

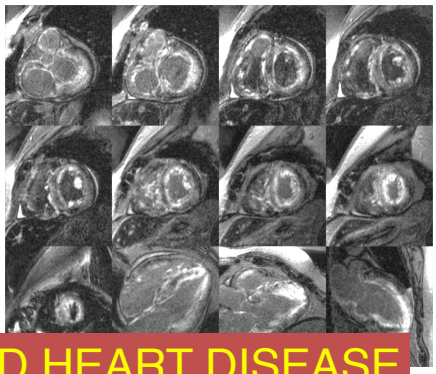
What is the most likely diagnosis ?

- Pericardial Effusion
- LV Wall Thickness: 1.6 cm
- RV Wall Thickness: 0.8 cm
- Biatrial enlargement
- LVEF: 47%
- RVEF: 38%
- LV Mass: 297 g
- LV Mass Index: 149 (58-91)

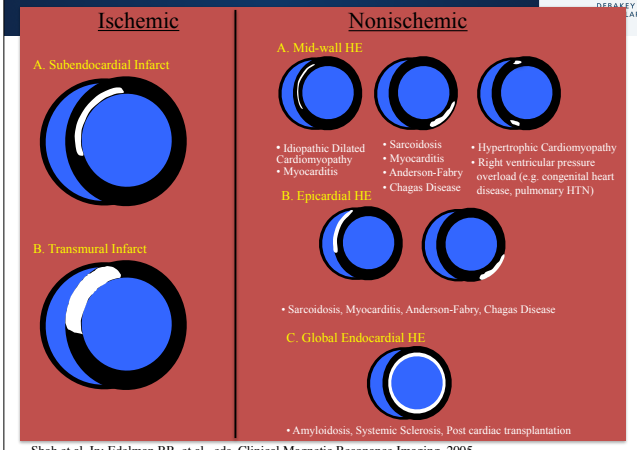


CLINICAL CASE: LGE

- Diffuse HE of LV and RV
- Diffuse HE of atria
- Papillary muscle HE



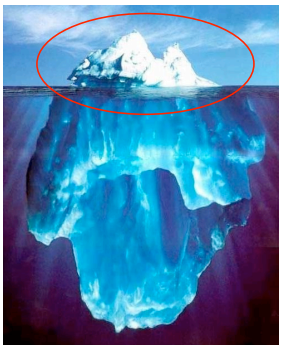
AMYLOID HEART DISEASE



Shah et al. In: Edelman RR, et al., eds. Clinical Magnetic Resonance Imaging, 2005.

Role of CMR in Cardiomyopathy/HF

- Myocardial Fibrosis via CMR LGE aids in:
  - Diagnosis
  - Prognosis

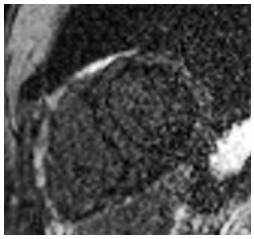


@dipanjshah

Houston Methodist CV Imaging Team

THANK YOU FOR YOUR ATTENTION !!

@dipanjshah



Inversion Time Too Short

What is the diagnosis ?