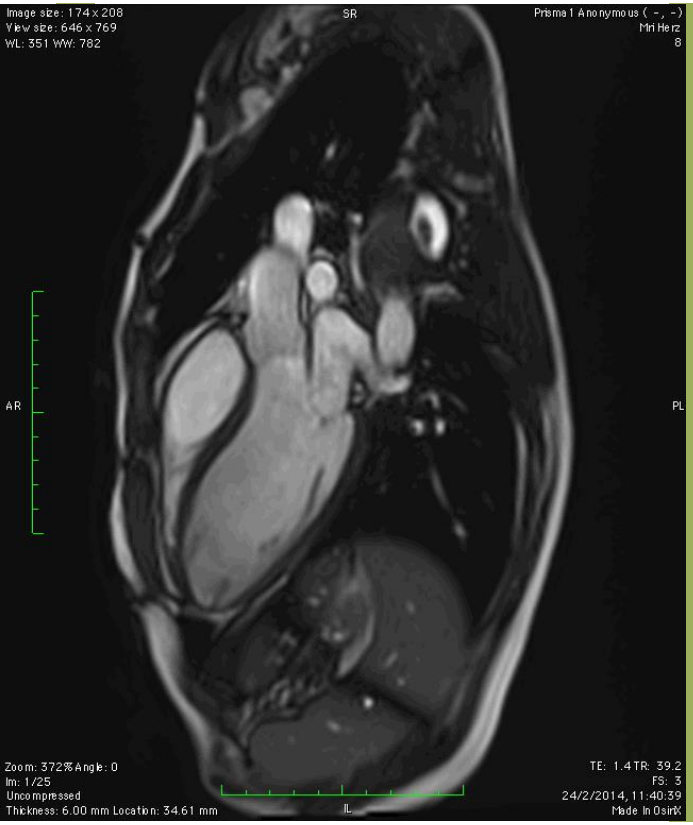


The Value of Stress MRI in Evaluation of Myocardial Ischemia

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Introduction

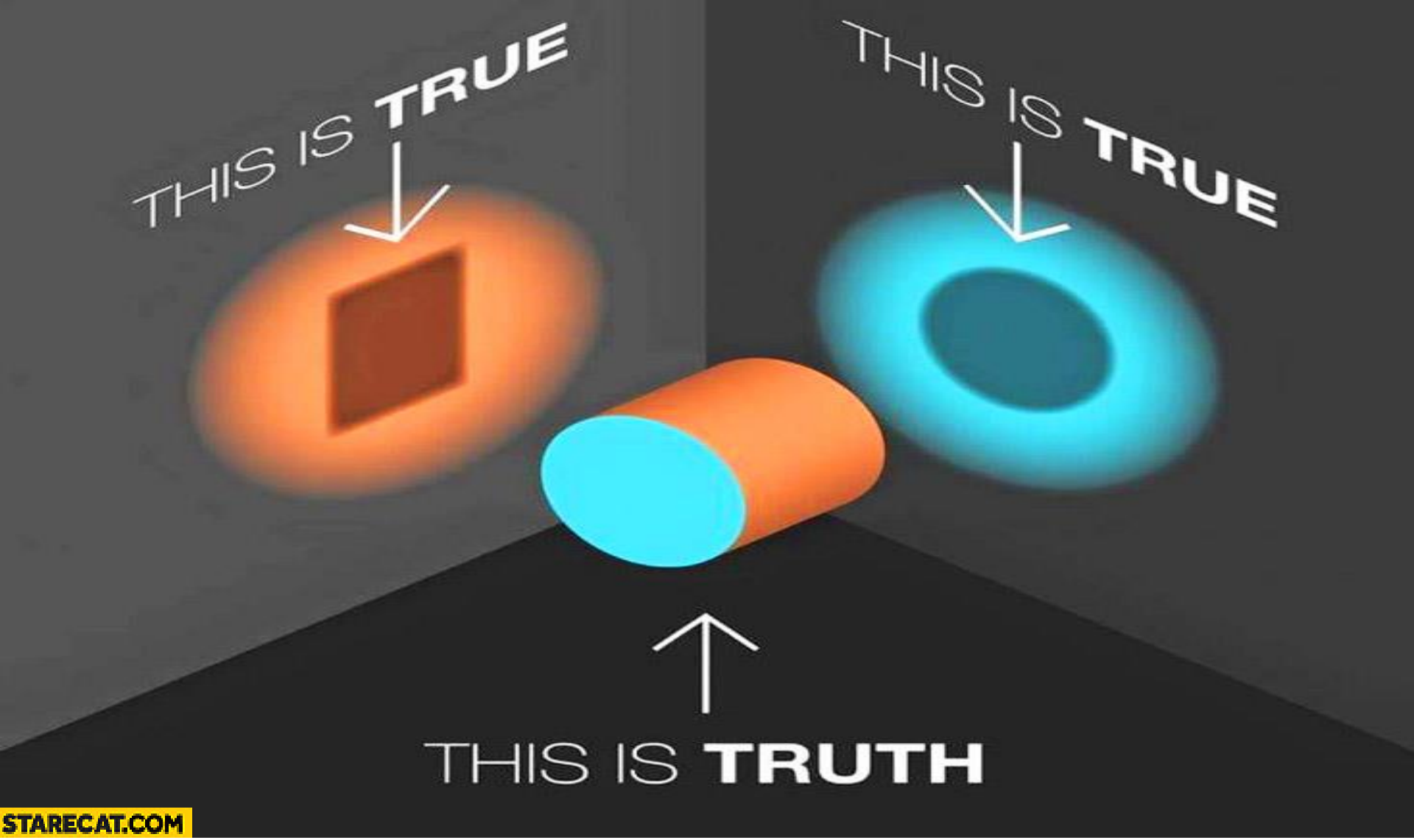
- Ischemic heart disease (IHD) is the leading cause of death worldwide.
- 7 million deaths reported in 2008.
- The burden of IHD has shifted from high-income countries to other parts of the world.
- Early detection and management of IHD is vital in decreasing mortality.

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Diagnostic Tests

- ECG
- Invasive Coronary Angiography (ICA)
- Echocardiography (Echo)
- Coronary CT Angiography (CTA)
- Single photon emission computed tomography (SPECT)
- Cardiac positron emission tomography (PET)
- Cardiac MRI (CMR)

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Complement - Not Compete

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Test Selection

- Ask yourself 3 questions:
  - 1. What is the clinical pre-test probability (PTP)?
  - 2. Can the patient exercise?
  - 3. Does the patient suffer from conditions that limit or contraindicate the use of any of the modalities?
- Stress imaging test (echo, CMR, SPECT, PET) if:

• Intermediate risk of IHD (PTP: 15-85%) • Known stenosis of unknown significance	**AND**	• Bad ECG • Cannot exercise

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Summary of Guidelines for Stress CMR Use in SCAD

1. In clinical evaluation of patients with chest pain for initial diagnosis of SCAD if patients have intermediate to high PTP of obstructive IHD and are:

→ able to exercise but have an uninterpretable ECG.
OR
unable to exercise.

2. Risk assessment in patients with known SCAD who are:

→ being considered for revascularization of known coronary stenosis of unclear physiological significance.

3. ESC guidelines state that patients with suspected SCAD and intermediate PTP of 15-85% should be considered for stress testing (echo, CMR, SPECT, PET) if:

→ PTP 15-65% and LVEF ≥ 50%
OR
PTP 66-85% or LVEF < 50% without typical angina

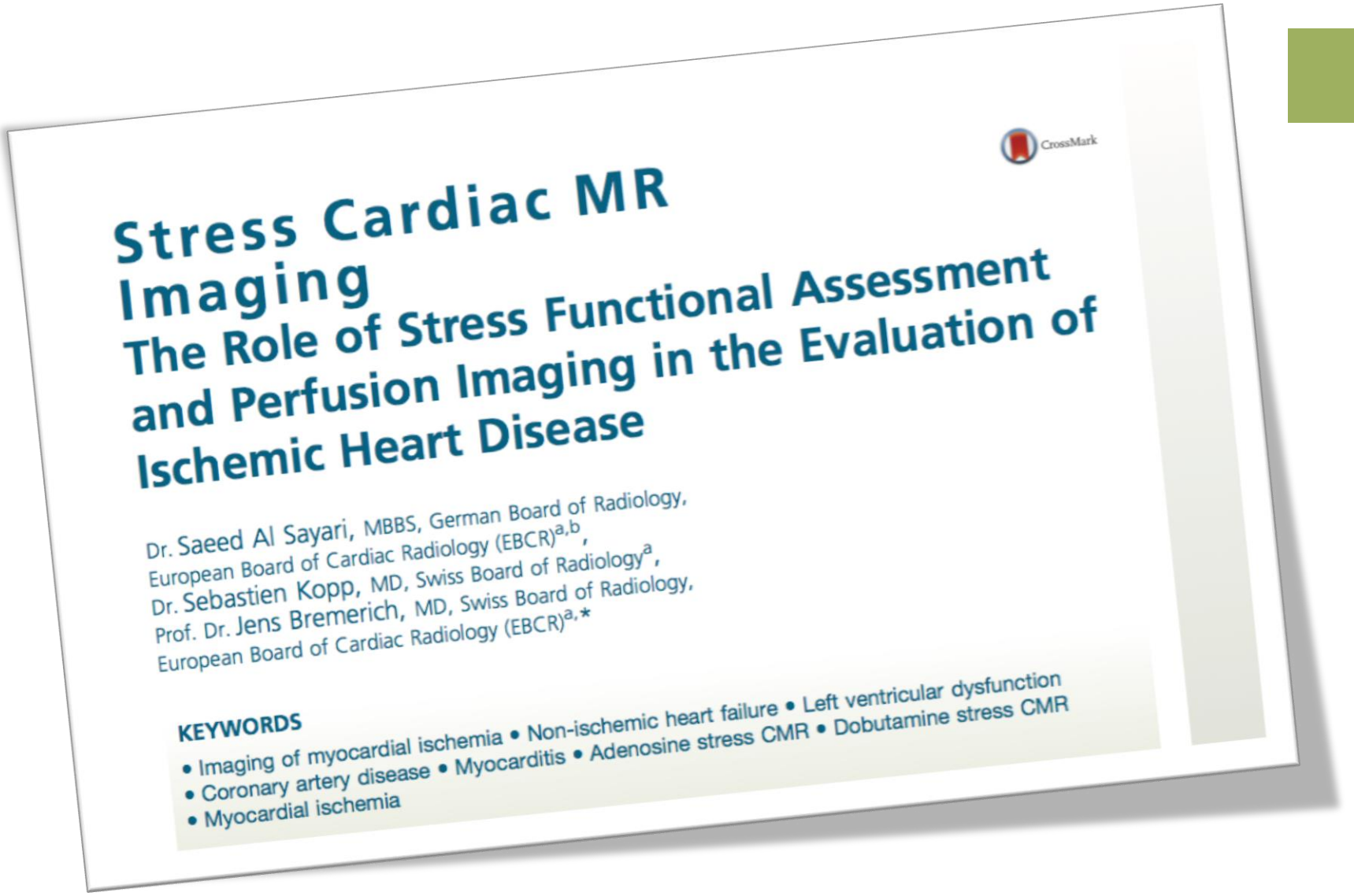
Advantages of CMR

- Non-invasive modality.
- No radiation exposure.
- Provides additional information regarding cardiac morphology, function, detection of scar tissue and hence prognostic value.
- Detection of thrombus and microvascular obstruction that are not detected by most of the other modalities.
- Detection and quantification of valve diseases if present.

(Potential) Uses of CMR

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- Risk stratification

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Stress Cardiac MR Imaging
The Role of Stress Functional Assessment and Perfusion Imaging in the Evaluation of Ischemic Heart Disease

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Prof. Dr. Jens Bremerich, MD, Swiss Board of Radiology, European Board of Cardiac Radiology (EBCR)[a,*]

KEYWORDS

- Imaging of myocardial ischemia
- Non-ischemic heart failure
- Left ventricular dysfunction
- Coronary artery disease
- Myocarditis
- Adenosine stress CMR
- Dobutamine stress CMR
- Myocardial ischemia

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In the Emergency Department

- In a multicentric study in the USA, 10,689 patients presented to ED with acute chest pain, data collected over 7months.

23% (2,459 patients) had true Acute Cardiac Ischemia (ACI) (36% acute MI, 64% unstable angina)	**77% (8,230 patients) did not have Acute Cardiac Ischemia**
94% admitted, 6% discharged	59% admitted, 41% discharged
At this rate of discharge, the estimated number of missed ACI is more than 11,000 patients/year in the USA with potential dire consequences	At this rate of admission, the estimated number of unnecessary admissions is more than 3.6 million patients/year in the USA, with huge financial burden

Pope JH, Aufderheide TP, Ruthazer R, et al. Missed diagnoses of acute cardiac ischemia in the emergency department. New England J Med 2000;342(16): 1163–70.

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In the Emergency Department

- Patients with acute ST elevation MI (STEMI) need reperfusion therapy ASAP; CMR is not for these patients.
- Kwong, evaluated 161 patients who presented to ED with acute chest pain, but no signs of ST-elevation on ECG. All patients had a resting CMR examination.
- Concluded that resting CMR imaging is suitable for triage of patients with chest pain in the ED, especially those with enzyme-negative unstable angina.
- Other studies suggested the use of CMR after resolution of chest pain to aid in risk stratification.

Kwong RY, Schussheim AE, Rekhraj S, et al. Detecting acute coronary syndrome in the emergency department with cardiac magnetic resonance imaging. Circulation 2003.

Protocol and Findings in Acute MI

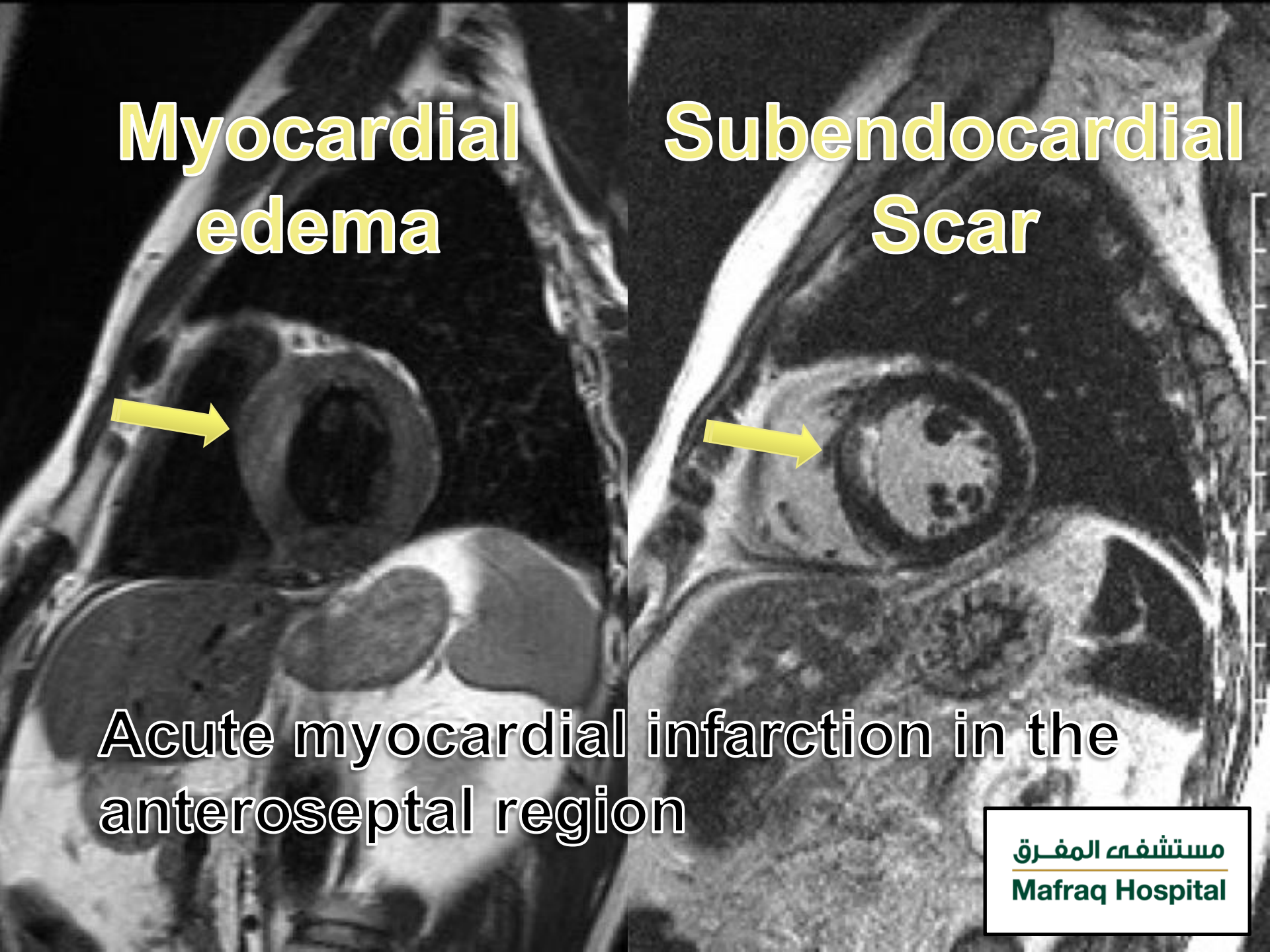
- Protocol:
  - LV function module
  - Myocardial edema module (T2W)
  - First-pass myocardial perfusion in rest (+/- in stress)
  - Late (+/- early) gadolinium enhancement.
- With T2W imaging (myocardial edema), area at risk (AAR) can be measured:
  - Includes both reversible and irreversible myocardial injury.
- With LGE:
  - Irreversible injury (scar) is measured.
- Salvageable myocardium = AAR - LGE

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Edema – Scar = Salvageable Myocardium

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Myocardial edema
Subendocardial Scar
Acute myocardial infarction in the anteroseptal region
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(Potential) Uses of CMR

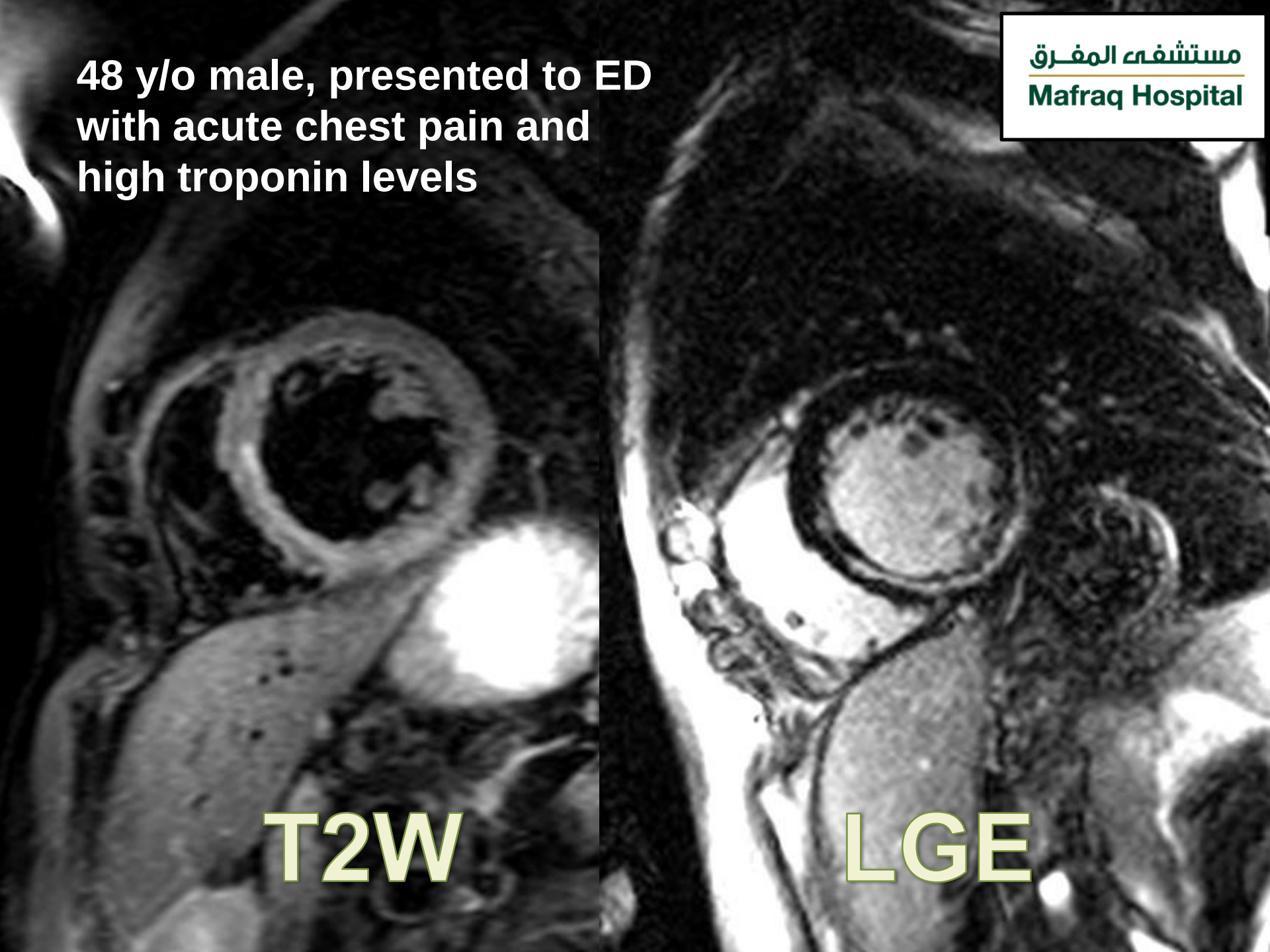
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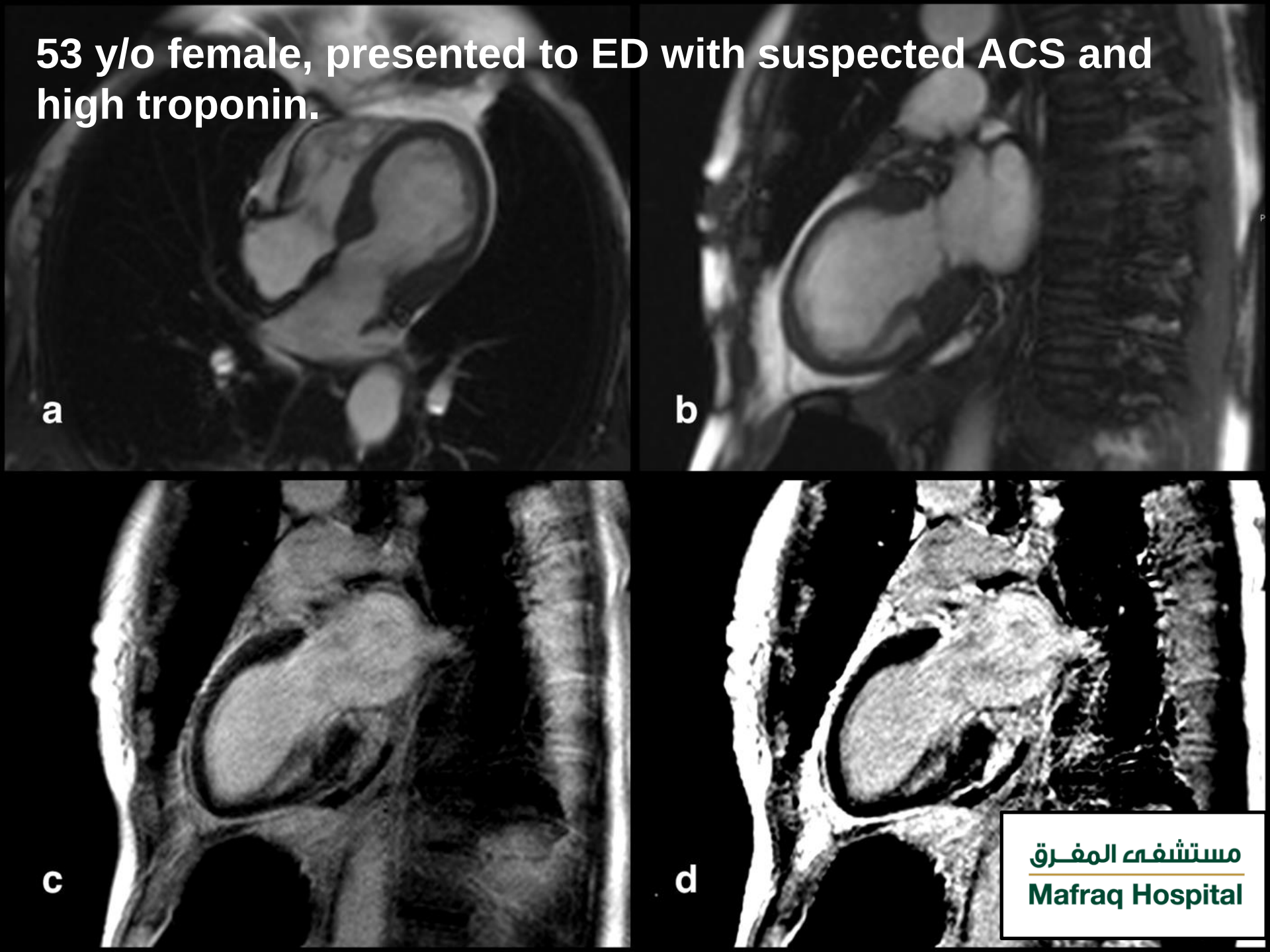
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Most important causes of chest pain from CMR point of view

- Acute myocarditis
- Acute myocardial ischemia
- Takotsubo cardiomyopathy
- Acute pericarditis
- Dilated cardiomyopathy (DCM)
- Hypertrophic cardiomyopathy (HCM)
- Pulmonary embolism
- Aortic dissection

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48 y/o male, presented to ED with acute chest pain and high troponin levels
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T2W
LGE


53 y/o female, presented to ED with suspected ACS and high troponin.
a
b
c
d
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(Potential) Uses of CMR

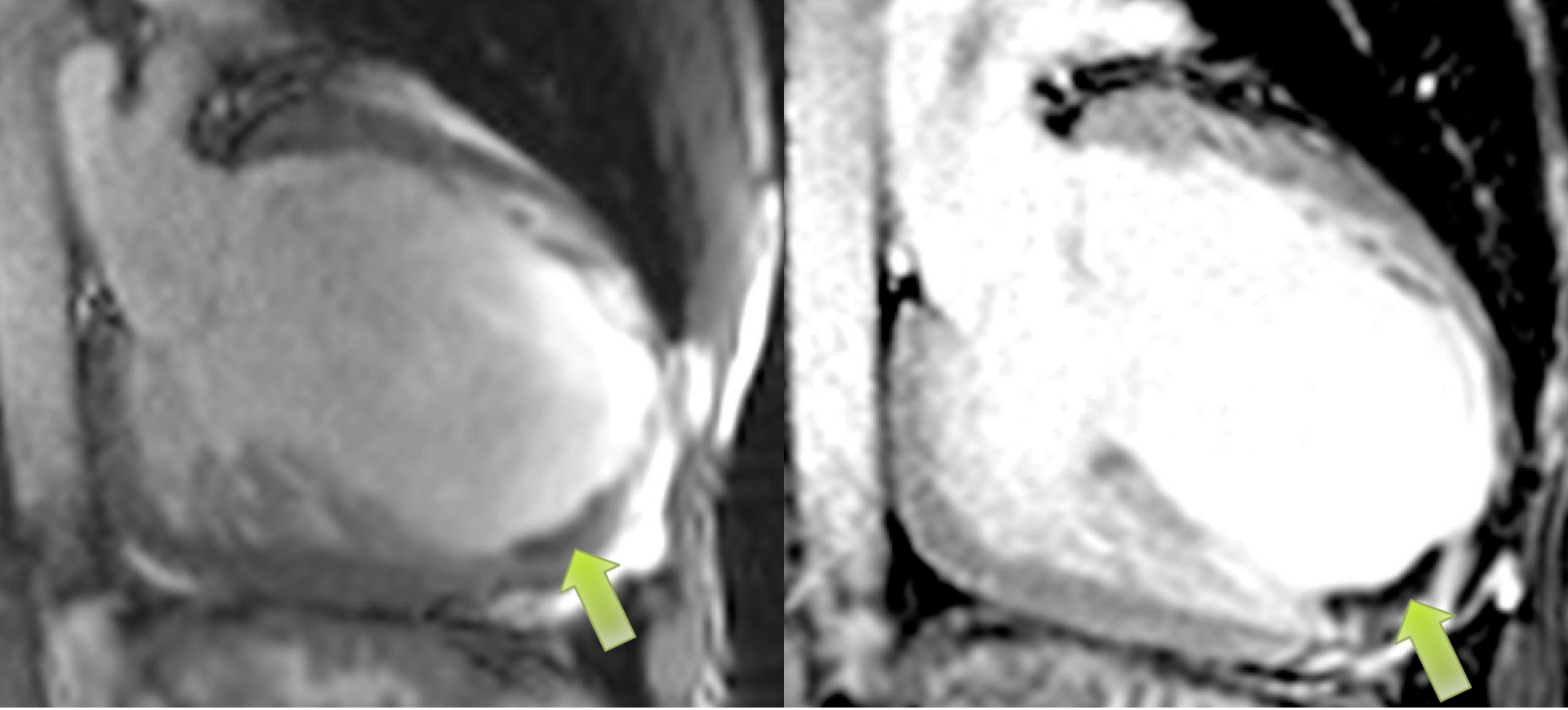
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Post MI Complications

- Ventricular aneurysm.
- Ventricular free wall rupture.
- Rupture of the interventricular septum.
- Rupture of the papillary muscle.
- Formation of LV mural thrombus.

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- **Ischemic dilatation of the LV with apical thrombus.**
- **Key feature: No contrast medium uptake in late enhancement images with high TI of 600 ms.**

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Complications due to or after Interventions

- These include:
  - Coronary dissection
  - Side-branch occlusion
  - Plaque embolization
- A strong correlation was found between increasing troponin levels at 24hrs post intervention and areas of new myocardial LGE.

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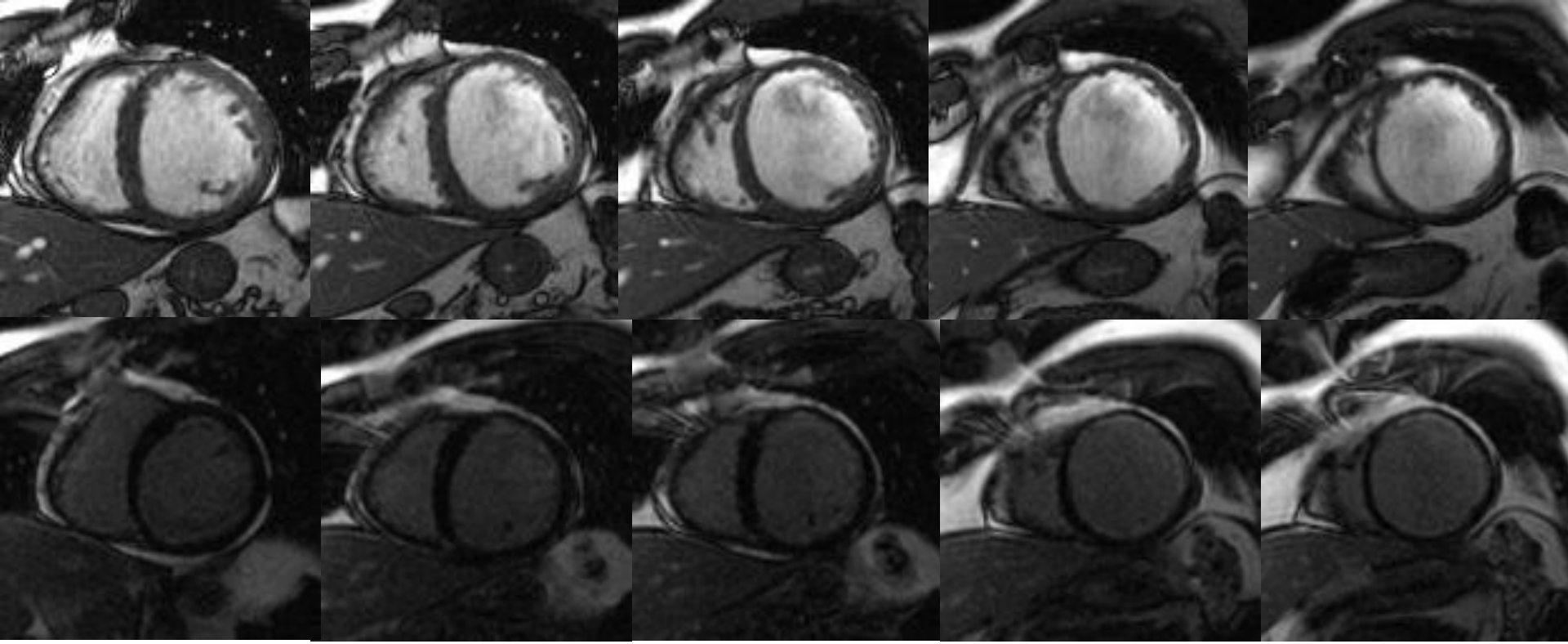
Viable myocardium?

- “The extent of infarction in each segment determines the likelihood of functional recovery post-revascularization”. (Kim et al. 2000)

% Wall thickness infarction	Likelihood of functional recovery
1-25	60%
26-50	40%
51-75	10%
>75	Almost nil

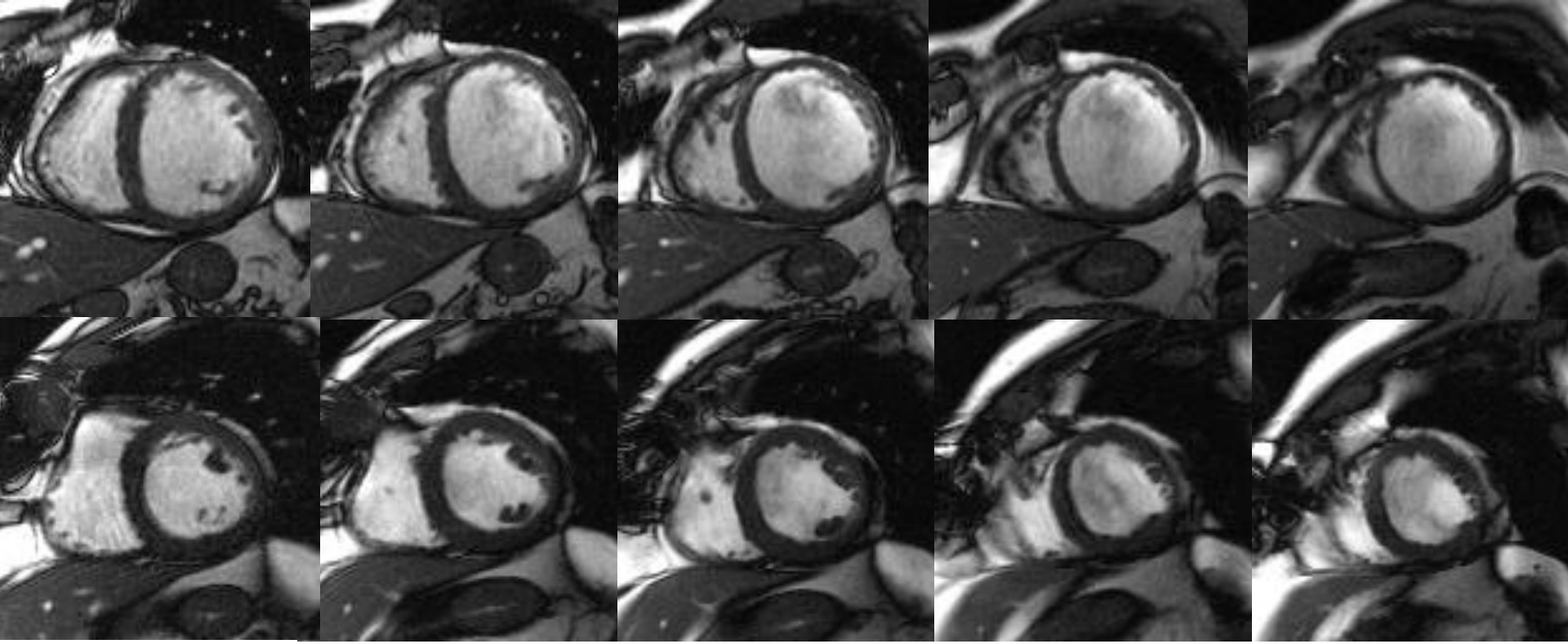
- In clinical practice, we use 50% cutoff to define “potential” viability.

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- Upper row: severe hypo- to akinesia in multiple segments
- Lower row: subendocardial scars, <50% transmurality
- → Viable myocardium → Intervention

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- Upper row: pre-intervention
- Lower row: post-intervention
- Significant improvement in function.

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Types of Stress CMR

- Pharmacological stress testing with **<u>catecholamines</u>**:
  - Dobutamine (+/- Atropine) Stress CMR
    - Positive inotropic and chronotropic effect → increased cardiac workload → increased myocardial oxygen demand
- Pharmacological stress testing with **<u>vasodilators</u>**:
  - Adenosine perfusion stress CMR
  - Regadenoson perfusion stress CMR
    - Both cause primary coronary vasodilatation → used for assessment of coronary flow reserve

Adenosine vs. Dobutamine

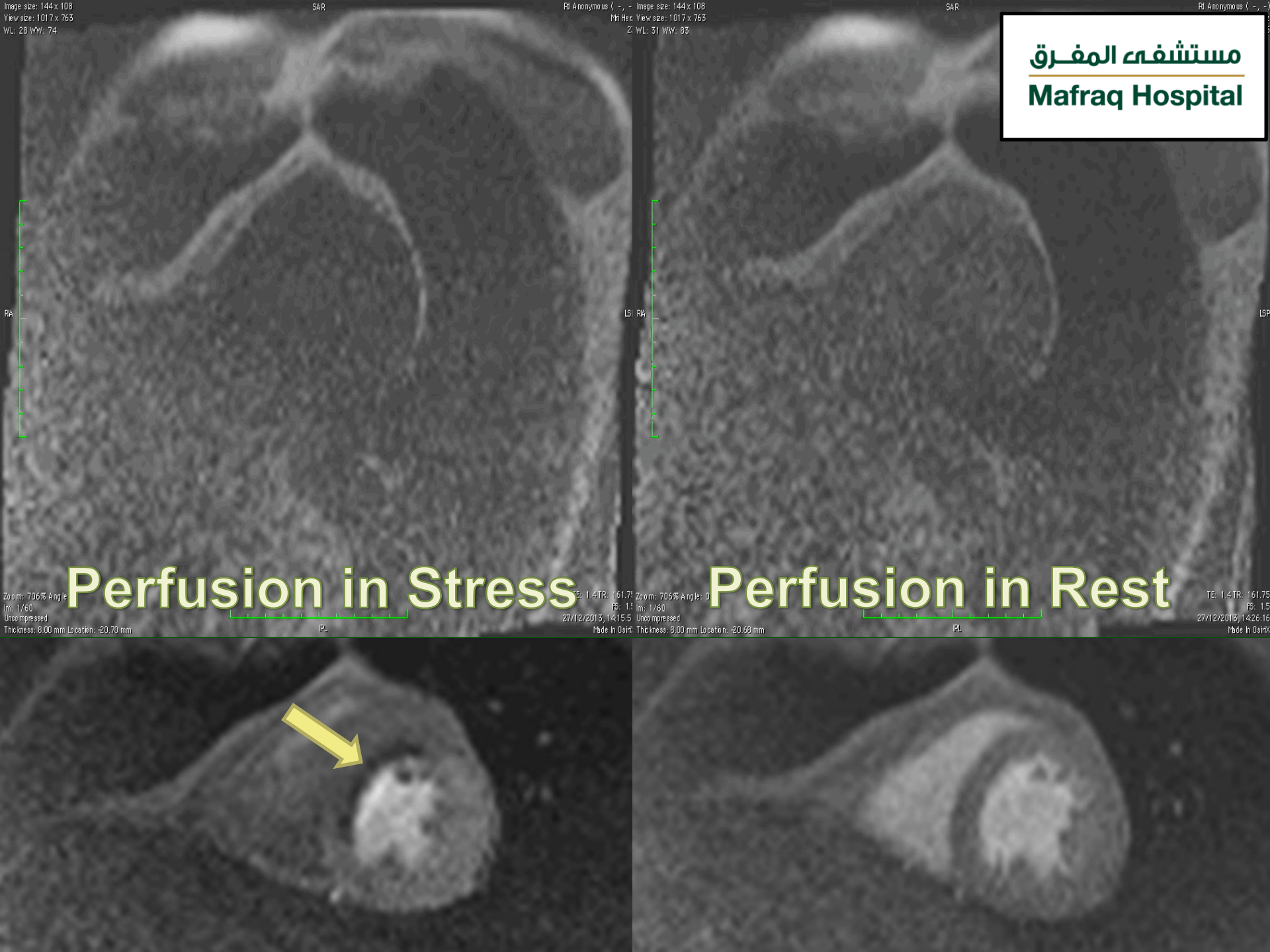
TABLE 1. Adenosine and Dobutamine Overview

	Adenosine	Dobutamine
Mechanism	Primary coronary vasodilatation → assessment of coronary flow reserve	Positive inotropic and chronotropic → increased cardiac work load → myocardial ischemia
Dose	140 µg/kg/min for 3-6 min (may be increased to 210 µg/kg/min)	Infusion starts at 5-10 µg/kg/min, then increased stepwise by 10 µg/kg/min every 3-5 min till a maximum dose of 40 µg/kg/min; if target heart rate cannot be reached, atropine is added in 0.1-0.3 mg increments (maximal dose 2 mg)
Plasma half-life time	<10 s	3 min
Contraindications	Active bronchospasm High-grade AV-block (grade II and III) Systolic blood pressure < 90 mm Hg Sinus bradycardia (heart rate < 40 bpm) Known hypersensitivity to adenosine Methylxanthines have to be avoided 24 h before the examination	Unstable angina Severe systemic arterial hypertension (≥ 220/120 mm Hg) Critical aortic valve stenosis (peak aortic valve gradient >50 mm Hg or aortic valve area < 1 cm^2) Complex cardiac arrhythmias Hypertrophic obstructive cardiomyopathy Myocarditis, endocarditis, pericarditis Uncontrolled congestive heart failure

Nadine Kawel-Boehm, Jens Bremerich. Magnetic Resonance Stress Imaging of Myocardial Perfusion and Wall Motion. J Thorac Imaging, Vol. 29, no. 1, January 2014.

- In our practice, Adenosine perfusion MRI is preferred to Dobutamine stress MRI due to its higher safety profile.

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Perfusion in Stress
Perfusion in Rest
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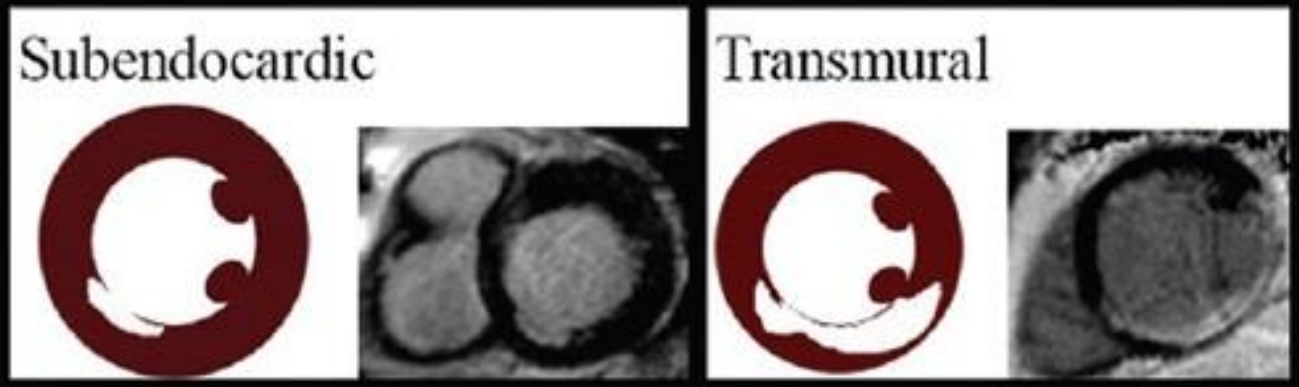
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Ischemic vs. Non-ischemic Heart Failure

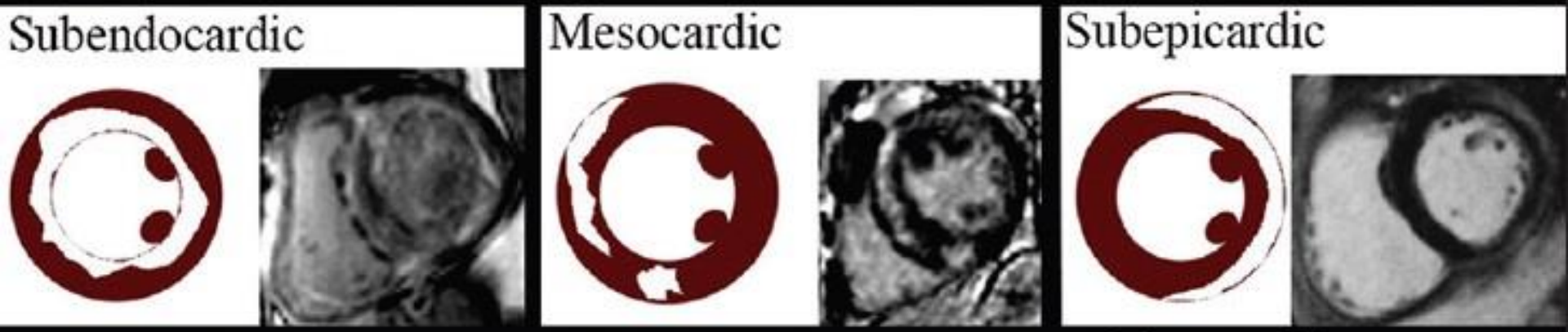
- Both ischemic and non-ischemic cardiomyopathy can cause LV dysfunction, dilatation, and heart failure.
- Identification is important due to different therapeutic approach (interventional vs. medical).
- The pattern of LGE plays a major role in distinguishing ischemic from non-ischemic cardiomyopathy.
  - LGE in IHD: subendocardial to transmural, correlates to coronary distribution.
  - LGE in DCM: midmyocardial, most commonly in the mid-interventricular septum.

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Ischemic Cardiomyopathy



Non ischemic Cardiomyopathies



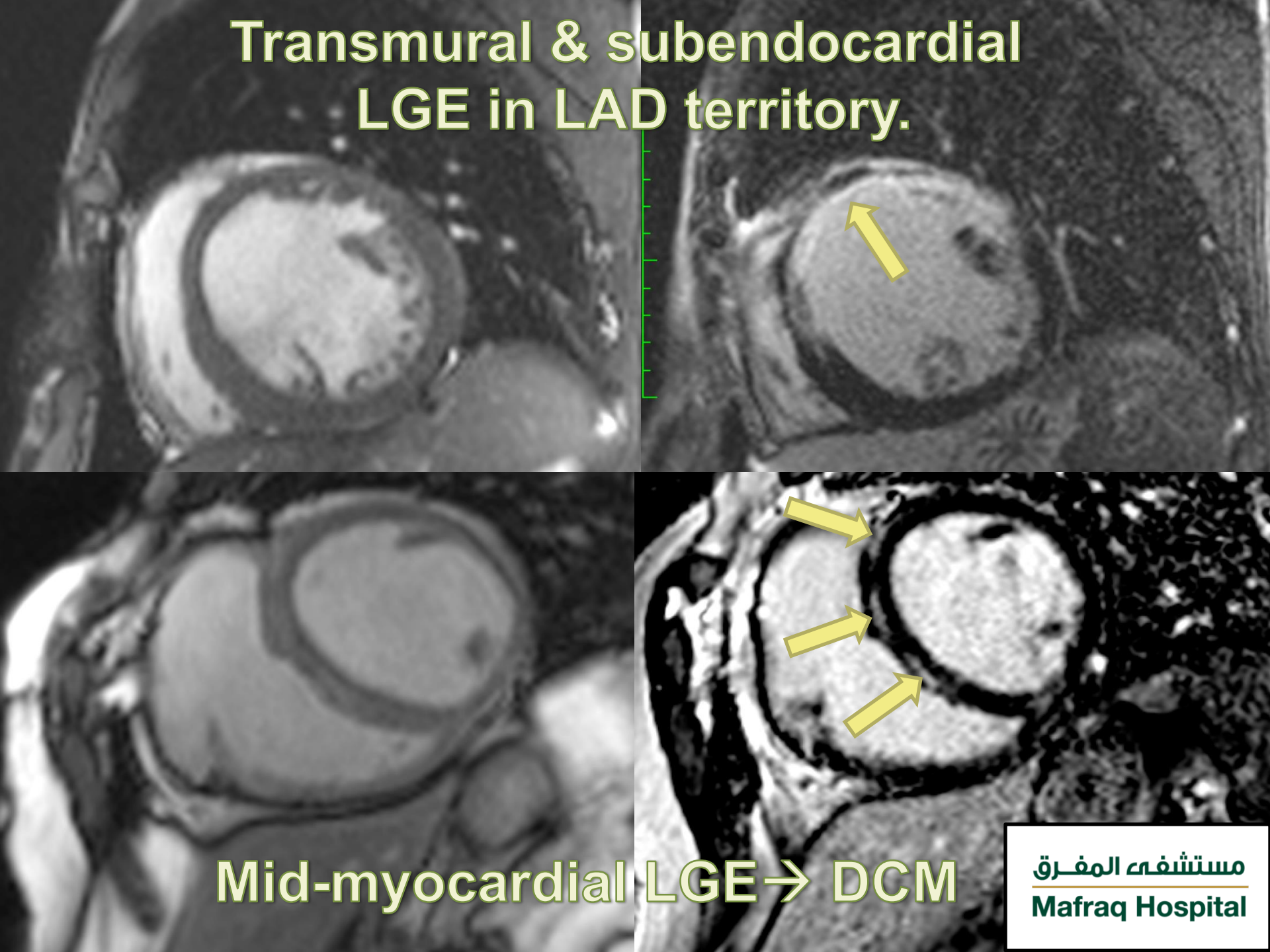
-Amyloidosis
-Loeffler endocarditis

-Hypertrophic obstructive cardiomyopathy
-Dilated cardiomyopathy

-Myocarditis
-Sarcoidosis

Olivas-Chacon et al, Magnetic Resonance Imaging of Non-ischemic Cardiomyopathies: A Pictorial Essay. Journal of Clinical Imaging Science, Vol. 5, Issue 2, Apr-Jun 2015.

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Transmural & subendocardial
LGE in LAD territory.
Mid-myocardial LGE→ DCM
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Risk Stratification

- Patients who had:
  - Stress inducible perfusion defect
  - LGE
  - → > 3-fold association with cardiac death or acute MI.
- Patients without a perfusion defect or LGE had a 98.1% negative annual event rate for death or MI.

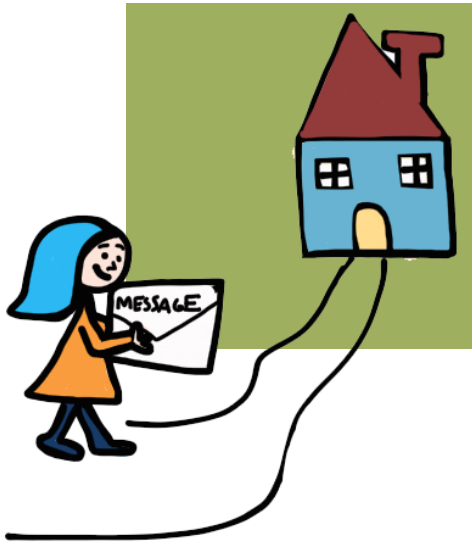
Steel K, Broderick R, Gandla V, et al. Complementary prognostic values of stress myocardial perfusion and late gadolinium enhancement imaging by cardiac magnetic resonance in patients with known or suspected coronary artery disease. Circulation 2009;120(14):1390–400.

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Take Home Message



- Cardiac MRI is a powerful tool for the diagnosis of ischemic heart disease.
- It can reveal additional or different pathologies and aid in differential diagnosis of chest pain.
- It can guide therapy and predict prognosis.
- Unfortunately, it’s underutilized mostly due to lack of knowledge of referring physicians or lack of CMR experts.

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