Cardiac MR: Typical Indications

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Outline

• 3 Top Advantages of CMR
• Toolbox in Cardiac MR
• Class I indications of Cardiac MR
• Take Home Messages
Objectives

• List the most relevant advantages of CMR
• Describe the tools used in a CMR examination
• Discuss class I CMR indications
Cardiac Imaging Modalities

Horiz Long Axis (Post→Ant)

Vert Long Axis (Sep→Lat)
EuroCMR (European Cardiovascular Magnetic Resonance) Registry

Results of the German Pilot Phase

11,040 consecutive patients enrolled

3 most important indications:

✓ Workup of myocarditis/cardiomyopathies (32%)
✓ Risk stratification in suspected CAD/ischemia (31%)
✓ Assessment of viability (15%)

• CMR is safe (0.005% severe complications-stress testing)
• Diagnostic image quality of 98%
• Strong impact on patient management (16% CMR changed diagnosis and management and 86% no further test needed after CMR)
Top 4 Cardiac MR Advantages

- Unrestricted access to the chest regardless of body habitus
  - Wide FOV and multiplanar capabilities
- Non-invasive modality that can routinely image myocardial anatomy, function, perfusion and tissue characterization
  - No ionizing radiation, no radioactive isotopes, no iodinated contrast
  - Excellent for repeated, life-long investigations,
  - Able to answer multiple clinical questions within 1 exam
- CMR is able to quantify meaningful measures of cardiovascular structure and performance that discriminate normal vs. abnormal pathological conditions
- Safe examination

Circulation. 2010;121:2462-2508
CMR Limitations

- Claustrophobia -2% of patients
- Renal insufficiency-NSF-Gadolinium
- Pacemakers, ICD and other electronic implants are usually not scanned (unless CMR compatible)
**Toolbox in Cardiac MR**

<table>
<thead>
<tr>
<th>Black blood/ Bright blood</th>
<th>b-SSFP CINES</th>
<th>3D-MR Angiography &amp; 3D-SSFP</th>
<th>Phase Contrast</th>
<th>Late Gadolinium Enhancement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular and mediastinal anatomy</td>
<td>Cardiac function, wall motion and valvular disease</td>
<td>Anatomy of the great vessels</td>
<td>Valvular disease Shunt quantification</td>
<td>Presence and pattern of LGE</td>
</tr>
</tbody>
</table>

- CMR consists of several protocols that can be combined during a single examination\(^1\)

Cardiac MR Sequences - Morphology

Black blood sequences

Bright blood sequences
Cardiac MR sequences-Function

Functional Imaging of LV and RV
Wall motion abnormalities
Valvular abnormalities
Cardiac MR Sequences Flow

• Phase Contrast Sequences
  • Velocity, Volume of blood flow
  • Pressure Gradient (stenosis)
  • Regurgitant Fraction (regurgitation)
  • Qp/Qs (shunt)
50-year-old patient with a lesion on echocardiography, MR tissue characterization demonstrating a fat containing lesion in the septum consisting with a lipoma.

Markedly thickened and inflamed pericardium in a patient with suspected constrictive pericarditis.
Tissue Characterization

- Late Enhancement - Expansion interstitial space
- Enhancing (abnormal) myocardium
  - Scarring/ Fibrosis
  - Necrosis
  - Infiltrative Process
  - Inflammation

Normal Myocardium=Black

Abnormal Myocardium=Enhancing (increase in extracellular space)

Delayed-Enhancement Short Axis Oblique View
Top CMR Indications

1. Congenital heart disease
2. Diseases of the aorta
3. Assessment of cardiomyopathy
4. Viability assessment-post myocardial infarction
5. Ischemia detection
6. Assessment of cardiac volumes and function
7. Pericardial disease
8. Cardiac and pericardial tumors
9. Origin and course of anomalous coronary arteries
10. Valvular disease
## Indications for CMR in Congenital Heart Disease

<table>
<thead>
<tr>
<th>Indication</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial evaluation and follow up of adult CHD</td>
<td>I</td>
</tr>
<tr>
<td>Assessment of shunt size (Qp/Qs)</td>
<td>I</td>
</tr>
<tr>
<td>Situs anomalies with complex congenital heart disease</td>
<td>I</td>
</tr>
<tr>
<td>Anomalous Pulmonary Venous Return, especially in complex anomalies and in cor triatriatum</td>
<td>I</td>
</tr>
<tr>
<td>Anomalous systemic venous return</td>
<td>I</td>
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<tr>
<td>Systemic or pulmonary venous obstruction following intra-atrial baffle repair or correction of anomalous pulmonary venous return</td>
<td>I</td>
</tr>
<tr>
<td>VSD associated with complex anomalies</td>
<td>I</td>
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<tr>
<td>Supracristal VSD</td>
<td>I</td>
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Indications for CMR in Congenital Heart Disease

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<tr>
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<tr>
<td>Evaluation of right/left ventricular volumes, mass and function</td>
<td>I</td>
</tr>
<tr>
<td>Pulmonary Regurgitation</td>
<td>I</td>
</tr>
<tr>
<td>Aortic Coarctation</td>
<td>I</td>
</tr>
<tr>
<td>Post operative follow up of Shunt</td>
<td>I</td>
</tr>
<tr>
<td>Aortic (sinus of Valsalva) Aneurysm</td>
<td>I</td>
</tr>
<tr>
<td>Vascular Rings</td>
<td>I</td>
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<tr>
<td>Pulmonary Atresia</td>
<td>I</td>
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<tr>
<td>Central Pulmonary Stenosis</td>
<td>I</td>
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<tr>
<td>Systemic to Pulmonary Collaterals</td>
<td>I</td>
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</table>

35-year-old man asymptomatic with abnormal echo findings showing dilated right ventricle

Qp:Qs = 120/50 = 2.3 - Severity of Shunt
Anomalies of Visceroatrial Situs

Situs inversus

Right sided aortic arch

LA, RA
RV, LV

AV and VA discordance
Congenital Anomalies of Great Arteries and Conduits

Estimating Collateral Circulation

Flow volume in A – flow volume in B on phase contrast imaging

*Any increase in flow from proximal To distal descending thoracic Ao is Diagnostic of collateral circulation and indicator of severity of coarctation
32 year old woman post Dacron patch coarctation repair. Sagittal oblique VIBE post gadolinium administration demonstrates an aneurysm at the level of the patch.

40 year old woman post coarctation repair with end to end anastomosis demonstrating narrowing of proximal descending aorta (yellow arrow) in keeping with recoarctation. There is collateral circulation (red arrow).
Anomalies of the Ventricle

74 year old woman with unrepaired Tetralogy of Fallot

- VSD
- Ao
- Subpulmonic stenosis
- RV hypertrophy
Anomalies of the Valves

Ebstein’s anomaly
Congenital Coronary Anomalies

30-year-old axial MR images demonstrating the origin of the LCA from the main PA (arrow) and the dilated RCA (arrowhead)

Courtesy of Dr. Elsie Nguyen Toronto General Hospital
## Indications for CMR in Acquired Diseases of the Vessels

<table>
<thead>
<tr>
<th>Indication</th>
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<tbody>
<tr>
<td>Diagnosis and follow up of thoracic aortic aneurysm including Marfan</td>
<td>I</td>
</tr>
<tr>
<td>Diagnosis and follow up chronic aortic dissection</td>
<td>I</td>
</tr>
<tr>
<td>Diagnosis of penetrating aortic ulcers</td>
<td>I</td>
</tr>
<tr>
<td>Assessment of thoracic, abdominal and pelvic veins</td>
<td>I</td>
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<tr>
<td>Assessment of renal arteries</td>
<td>I</td>
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<tr>
<td>Assessment of the origin of the great vessels</td>
<td>I</td>
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<tr>
<td>Assessment of pulmonary veins</td>
<td>I</td>
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19 years-old man with Marfans disease. CMR performed for assessment of the thoracic aorta

Enlargement of the aortic root

Mitral valve prolapse and mitral and tricuspid valve regurgitation

Assessment of size and extent of aorthopathy

Pectus carinatum, dural ectasia and Perineural cysts
## Indications for CMR in Coronary Artery Disease

<table>
<thead>
<tr>
<th>Indication</th>
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<tbody>
<tr>
<td>Assessment of global ventricular function and mass</td>
<td>I</td>
</tr>
<tr>
<td>Coronary MRA (assessment of coronary artery anomalies)</td>
<td>I</td>
</tr>
<tr>
<td>Detection and assessment of acute and chronic myocardial infarction</td>
<td>I</td>
</tr>
<tr>
<td>Assessment of Myocardial Viability</td>
<td>I</td>
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</table>

Assessment of ventricular function, volumes and mass

• Accurate, reproducible and validated in vivo and ex vivo\textsuperscript{1,2} for LV and RV volumes and mass
• Ideal for monitoring function
• No geometric assumptions
• Reproducible LV and RV functional parameters allow for reduction of sample size
• Regional wall motion abnormalities

\textsuperscript{1}Caputo GR, AJR 1987; 148:33-8
\textsuperscript{2}Koch JA. Eur Radiol 2000;10:455-8
Assessment of Chronic Coronary Artery Syndromes

- Workhorse for viability is DE-MR after IV injection of gadolinium
- Great spatial resolution that depicts infarcts that may not be seen on SPECT
- Useful to detect thrombi associated to infarcts
Basics of DGE
Measuring the Interstitial Space

Delayed Enhancement

Enhancing (abnormal) myocardium

- Scarring/ Fibrosis
- Necrosis
- Infiltrative Process
- Inflammation

Normal Myocardium=Black

Abnormal Myocardium=Enhancing
(increase in extracellular space)

Delayed-Enhancement Short Axis Oblique View
Ischemic

Transmural Infarction

Subendocardial Infarction

Non-ischemic

Mid-myocardial DGE

DCM, Myocarditis
HCM, RV pressure overload
Sarcoid, Myocarditis
Fabry’s disease, Chagas

Subepicardial DGE

Sarcoid, Myocarditis, Fabry’s disease, Chagas

Subendocardial DGE (non vascular)

Amyloid, Systemic Sclerosis, post heart transplant, Hyperesoinophilic syndrome

Significance of DGE in Ischemic CM

• Differentiates viable vs non-viable myocardium

• Successful revascularization depends on the degree of TEI

DGE >50% TEI* unlikely to recover after revascularization

DGE <50% TEI* likely to recover after revascularization

CMR best modality to assess transmurality


TEI= Transmural Extent of Infarction
Transmural DGE in the LAD territory
Unlikely to recover function after revascularization
Indications for CMR in Patients with Pericardial Disease, Cardiac Tumors, Cardiomyopathies and Cardiac Transplants

<table>
<thead>
<tr>
<th>Indication</th>
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<tbody>
<tr>
<td>Detection and characterization of cardiac and pericardial tumors</td>
<td>I</td>
</tr>
<tr>
<td>Hypertrophic Cardiomyopathy (Apical)</td>
<td>I</td>
</tr>
<tr>
<td>Dilated Cardiomyopathy (Differentiation from ischemic dilated CM)</td>
<td>I</td>
</tr>
<tr>
<td>ARVC</td>
<td>I</td>
</tr>
<tr>
<td>Siderotic cardiomyopathy (Thalassemia)</td>
<td>I</td>
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43-year-old man with apical HCM

- Spade shaped ventricular cavity in systole
- Delayed enhancement in the apex

- Echo may miss 6% of HCM compared to CMR [1]. CMR is class I indication in apical HCM

Differential Diagnosis
Delayed Gadolinium Enhancement

Mesocardial
- Hypertrophic CM
- Dilated CM
- PH

Patchy
- Sarcoid
- Amyloid
- Myocarditis

Transmural
- Infarction (most common)
- Myocarditis (severe)
- Sarcoid (chronic)

Subendocardial
- Vascular
- Infarction

Non-vascular
- Amyloid
- Hypereosinophilic syndrome
- Cardiac Transplant
- Histiocytoid CM

Subepicardial
- Myocarditis (most common)
- Sarcoid

Cardiac and Pericardial Tumors

72 yo male with history of non small cell lung cancer presenting with dispnea and signs and symptoms suggestive of cardiac tamponade.
Cardiac and Pericardial Tumors

T1 W-Intermediate SI

T2 W FS-High SI

SSFP
PSIR Delayed Gadolinium Enhancement

Metastatic lung cancer in the pericardium
55-year-old with monomorphic VT arrest CMR for assessment of structural heart disease

RVEF = 27%
RVEDVI = 143 ml/sq m (59-108)
Late Gadolinium Enhancement Axial Image

Axial PSIR
## Indications for CMR in Patients with Valvular Heart Disease

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<tr>
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<tbody>
<tr>
<td>Cardiac chamber anatomy and function</td>
<td>I</td>
</tr>
<tr>
<td>Quantification of regurgitation</td>
<td>I</td>
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</tbody>
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Valvular Heart Disease

20-year-old male with quadricuspid aortic valve and regurgitation

59-year-old woman with aortic regurgitation and associated LV enlargement

LVEF=48%
LVEDVI=119 cc/sqm (41-81)
Regurgitant Fraction= 41%
Valvular Heart Disease

- Forward Volume: 108 mL/beat
- Reverse Volume: 19.17 mL/beat
- Regurgitant Fraction: 17.5 %

49-year-old patient with bicuspid aortic valve
Take Home Messages

• CMR may routinely imagine myocardial anatomy, function, perfusion and viability without the need of ionizing radiation

• Cardiac MR can separate ischemic from non-ischemic cardiomyopathy

• Useful in the diagnosis and follow up of patients with congenital heart disease
Take Home Messages

• Infarct detection can be used to predict functional recovery as well as overall risk and prognosis
• Useful modality for assessment of pericardial disease and cardiac tumors
• CMR useful in follow up of quantification of regurgitation and effects on ventricular volumes, function and myocardial mass in valvular disease
References

• Hundley WG et al. Circulation 2010, 121:2462-2508
Thank you!

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