Imaging in Heart Failure: 
A Multimodality Approach

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Heart Failure

HFrEF

EF<40%

HFP EF

EF>50%

Lifetime risk – 20%
Prevalence = 6M Americans
Societal costs - $30B
50% 5-year survival
Systolic Heart Failure

Risk Factors → Myocardial Injury → Remodeling → Reduced EF

- Hypertension
- Diabetes
- CAD
- Valve disease

Pump Failure → Chronic Heart Failure

Symptoms → Arrhythmias

Diastolic Heart Failure

Risk Factors → LVH Fibrosis → Diastolic dysfunction → Preserved EF

- Hypertension
- Diabetes
- CAD

Inc LVEDP → Chronic Heart Failure

Symptoms → Arrhythmias
Heart Failure Stages

D  End-Stage HF
C  Symptomatic HF
B  Asymptomatic LV dysfunction
A  High risk for developing HF

Hunt et al, ACC/AHA Heart Failure Guidelines, 2001

Effect of LV Dysfunction on Survival

Wang et al, Circ '03
Key Questions in Heart Failure

- Are the Sx due to heart failure?
- Can I exclude heart failure as a Dx?
- If it is heart failure, how bad is it?
- Can the imaging results help with therapy?
Noninvasive Diagnostic Testing

Class I Recommendations:
1. Laboratory studies, including BNP
2. ECG
3. CXR
4. 2D Echo

Class IIa Recommendations:
1. Viability/ischemia assessment, in selected pts
2. MUGA or MRI, when echo is inadequate
3. MRI to assess infiltrative process or scar

Class III Recommendations:
1. Routine repeat assessment of LV function

Differential Dx of heart failure Sx

- Pulmonary Causes:
  - COPD
  - Pulmonary hypertension
  - Pulmonary embolus

- Non-cardiopulmonary Causes:
  - Anemia, anxiety, etc

- Cardiac Causes:
  - Valve disease
  - Pericardial disease, including constriction
  - Diastolic heart failure – restrictive CM
  - Systolic heart failure
  - Hypertensive heart disease
Goals of Initial Evaluation

1. Determine the etiology of HF
2. Assess prognosis
3. Determine functional status
4. Measure ventricular function
5. Assess volume status

Echo in Heart Failure

- Systolic function
  - EF
  - Wall motion
  - LV volume
  - Remodeling
  - New approaches – strain, torsion
- Diastolic function – filling pressure
  - Restrictive CM
- Valve disease
- Pericardial disease - constriction
- Viability
- Resynchronization therapy
Ischemic vs Nonischemic?
MRI in Heart Failure

- Systolic function
  - Precise quantitation (gold standard)
  - LV mass
- Diastolic function
  - Scar burden
- Etiology
  - Ischemia, infarction
  - Htn
  - Myocarditis
  - Infiltrative – Iron, amyloid, sarcoid, etc
  - Genetic – ARVC, HCM
- Viability

Shah, Judd, Kim, Clinical MRI, '06
Late Gadolinium Enhancement Imaging

Diffuse hyperenhancement of both ventricles

Dark signal within cardiac chambers due to T1 shortening of amyloid protein in blood

Where CMR Adds the Most Value: Myocardial Characterization

- T1  T2  T2*
- Magnetic resonance parameters that reflect intrinsic tissue properties
  - Coronary artery disease, hypertension
  - Myocarditis
  - Infiltrative (iron overload, amyloidosis, sarcoidosis)
  - Genetic (HCM, ARVC, Anderson-Fabry, lamin A/C, dystrophin, etc.)
Imaging Approach to HF

- Measure global LV systolic function
- r/o valve disease
- Assess the pericardium
- Evaluate diastolic function
- Estimate filling pressures
- Assess the right heart

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  - Systolic heart failure
  - Pericardial disease, including constriction
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  - Hypertensive heart disease
  - Valve disease
Can heart failure be “ruled out” with echo?

- Measure LV function
- LA size, LVH
- E/A, Decel time, E/e'
- Septal motion, atria, IVC, hepatic veins

Yes, with a few simple steps

If EF >50%, systolic dysfunction has been ruled out
LV Systolic Function

How to Measure LV Ejection Fraction

2D single plane
2D biplane
Real-time 3D

\[ A = \pi r^2 \]

\[ D \]
Corsi et al, Circ '05
MRI for LV Function

Precise Quantitation of Function

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
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<tbody>
<tr>
<td>LV End Diastole</td>
<td>2.19 ml</td>
<td>77-193</td>
<td>14-72</td>
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<tr>
<td>LV End Systole</td>
<td>1.07 ml</td>
<td>51-133</td>
<td>56-78</td>
</tr>
<tr>
<td>LV Stroke Volume</td>
<td>1.12 ml</td>
<td>118-238</td>
<td>76-113</td>
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<tr>
<td>LV Ejection Fraction</td>
<td>51.5%</td>
<td>76-113</td>
<td></td>
</tr>
<tr>
<td>LV Mass</td>
<td>24.3 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV Mass Index</td>
<td>1.25 g/m²</td>
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</tbody>
</table>
Echo vs MRI?

T2 Increases with Myocardial Water Content...

Percent Water Content = (1 – Dry Weight/Wet Weight) * 100

3 – 30% ↑ in T2

Is It Heart Failure???

Is the LVEF normal?

No, <50%
- Measure EF
- Assess FP
- Therapy?

Yes, >50%
- Rule out other causes
- LVH/IVC
- Septal motion
- E/A, E/e'
- RCM
- Con Per
- Htn
- Valve Disease
- Valves
- Atrial size

Can heart failure be “ruled out” with echo?

- Measure LV function
- LA size, LVH
- E/A, Decel time, E/e'
- Septal motion, atria, IVC, hepatic veins

If normal, Htn and diastolic dysfunction are unlikely
Can heart failure be “ruled out” with echo?

- Measure LV function
- LA size, LVH
- E/A, Decel time, E/e'
- Septal motion, atria, IVC, hepatic veins

If normal, diastolic fcn and filling pressure are probably NI.
Diastolic Heart Failure

Normal Impaired Relaxation Pseudonormal Restrictive

**Mitral Inflow**

**Mitral Annulus Velocity**

**IVRT**

**Mitral Annulus TDI**

**Mitral Inflow**

Increasing mean LV dias pressure

E/A

10 cm/s

80 cm/s

E/E' = 5 to 15
Normal

E/E' = 20 to 40
High LVDP

Normal Impaired Relaxation Pseudonormal Restrictive

E/A

E/E' = 5 to 15
Normal

E/E' = 20 to 40
High LVDP
Mitral Annulus TDI

\[ \frac{E}{E'} = 8.4 \]

Range of Severity

\[ \frac{E}{E'} = \frac{100}{4} = 25 \]
Mitral Annulus TDI

Nagueh et al, JACC ’97

E/E’ < 10: Normal
E/E’ > 15: High PCWP

E/E’ < 10: Normal
E/E’ > 15: High PCWP

Nagueh et al, JACC ‘97
Increasing Fibrosis → Progressive Diastolic Dysfunction


Advanced Measures of LV Function: Strain, Rotation, Torsion

Refined Measures esp. for HFpEF
Can heart failure be “ruled out” with echo?

- Measure LV function
- LA size, LVH
- E/A, Decel time, E/e'
- Septal motion, atria, IVC, hepatic veins

This excludes constriction and restriction as causes

Constrictive Pericarditis

- Rigid, noncompliant pericardium
- Equalization of pressures
- Intrathoracic and intrapericardial pressures are dissociated
- Increased ventricular interdependence
Constrictive Pericarditis

Constrictive Pericarditis

[Image of echocardiogram showing pericardial constriction]
Constrictive Pericarditis

- >25% respiratory variation in mitral E velocity
- Reciprocal respiratory relationship between LV and RV

Mitral Annulus DTI

- High E' indicates preserved myocardial function
Restrictive Cardiomyopathy

- Diastolic dysfunction – “restrictive filling”
  - High E wave, increased E/A
  - Short deceleration time
  - Little or no respiratory variation
- Normal or slightly decreased LV systolic function
- Dilated LA and RA
- Normal or slightly increased LV mass
Restrictive Cardiomyopathy

- Restrictive MV filling
- Very Low e'

Constriction vs Restriction

**Constriction**
- Increased E wave
- High E/A
- Short decel time
- Marked resp variation
- High E' = Low E/E'

**Restrictive CM**
- Increased E wave
- High E/A
- Short decel time
- No resp variation
- Low E' = High E/E
Myocardial Amyloidosis

T2* - Measure of Tissue Iron Content

Signal intensity $\propto e^{\frac{TE}{T2^*}}$

Echo time (TE)

Myocardium T2* = 32 ms

Liver T2* = 3.5 ms
Summary

- Heart failure is a clinical diagnosis
- Imaging provides diagnostic support, information on etiology, severity and prognosis
- Echo is the backbone of HF assessment
- MRI is becoming increasingly important

☑️ Heart Failure Present?

Low EF

- Measure EF
- E/e’ – filling press.
- MR severity
- ?CRT candidate

Normal EF

- Assess valves
- LVH, atrial size
- E/A, decel time
- E/e’
- Septal motion, IVC