LV FUNCTION ASSESSMENT
CLINICAL APPLICATIONS OF IMAGING

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LEARNING OBJECTIVES

- Role and evolution of diagnostic testing for assessment of LV function
- Properties of typical imaging tests
- Current clinical applications of such imaging techniques
IMAGING IN DECISION MAKING

- Look at systolic and/or diastolic function
- Estimation of LVEF
- Selection of therapies
  - Medical
  - Device
  - Surgery
  - Transplant
- Therapeutic decisions should be made on the basis of volumetric and EF measurements.
NON-INVASIVE IMAGING

- 2D Echo
- Radionuclide ventriculography
- Gated SPECT
- Cardiac MRI
- Cardiac CT
- New techniques
  - Echo: 3D, DTI, speckle tracking
CLINICAL CASE 1

- 34 yo male with cardiac arrest in ICU
- TTE
Suggested echo criteria:
1. Maximum ratio of noncompacted to compacted myocardium > 2:1 at end-systole in the parasternal short-axis view
2. Color Doppler evidence of flow within the deep intertrabecular recesses.
3. Prominent trabecular meshwork in the LV apex or midventricular segments of the inferior and lateral wall.

Other non-specific criteria
1. Global LV systolic dysfunction
2. Diastolic dysfunction
3. LV thrombus
4. Abnormal papillary muscles
CLINICAL CASE 2

- 58 yo male with decompensated CHF (non-compliant with meds, known CAD)
- Initial test: 2D Echo
NEXT STEP?

1. No further imaging, optimize medical therapy.
2. Nuclear stress test to rule out myocardial ischemia.
3. Cardiac catheterization to rule out coronary artery disease.
4. MUGA to confirm LVEF for ICD consideration.
CLINICAL CASE 2

- Cath: diffuse 3 VD: EF 20-21%
- PET scan for viability
  1. EXTENT OF SCAR: Nontransmural scar in the LAD territory (19% of LV)
  2. EXTENT OF HIBERNATING MYOCARDIUM: None.
  3. EXTENT OF Viable, NON-ISCHEMIC MYOCARDIUM AT REST: The remainder of the myocardium is viable.
  5. LV FUNCTION AT FDG: Severely dilated. Severely reduced ejection fraction. Severe global hypokinesis.

CLINICAL RECOMMENDATIONS:
- Moderate nontransmural scar. No hibernating myocardium. EF is unlikely to improve with revascularization.

- Follow up 3 months (MUGA); EF = 33 %
CLINICAL CASE 3

- 35 yo woman with breast cancer HER2+
- Treated with anthracycline base chemo
- Has undergone previous multiple CT scans for staging purposes
- Initial EF normal
- Surveillance to identify cardiotoxicity early
NEXT STEP?

1. MUGA for accurate LVEF assessment
2. Cardiac PET to rule ischemia and LVEF assessment
3. Cardiac MRI with gadolinium enhancement
4. 2D echocardiography with tissue doppler
In patients with DCM, filling patterns correlate better with filling pressures, functional class, and prognosis than LVEF.
CLINICAL DELIVERABLES

- Detection and diagnosis
  - Etiology
    - Ischemic vs non ischemic (or both)
    - Exclude valvular contribution
    - Exclude ischemic contribution
  - Type of dysfunction
    - Systolic vs diastolic
    - Early stages of disease (DTI)
GLOBAL ASSESSMENT

- Risk stratification, therapy and prognosis
  - Ejection fraction
  - Diastology
    - Normal vs pseudonormal
    - Estimation of filling pressures

- Complications
  - Detection/evaluation of MR
    - Functional vs ischemic MR (prognosis)
    - Important even for CRT
  - LVH
  - Pulmonary hypertension
THE EVOLUTION OF ECHO

- Contrast echo to better delineate the endocardial border
  - Scattering beam and oscillation of microbubbles

- Doppler tissue imaging (DTI)
  - Low-velocity frequency shifts of ultrasound waves to calculate myocardial velocity.
  - Measurement of both regional and global LV function through the assessment of myocardial velocity data using the basal segments.
  - Even if technically difficult study
MORE THAN LV MORPHOLOGY

- Myocardial mechanics and rotation
- Strain (function of TDI or stress echo)
  - Reflects deformation of the myocardium during contraction/relaxation pattern calculated in several dimensions; longitudinal, circumferential, or radial.
- Speckle-tracking echocardiography (STE)
  - Quantify myocardial motion in 2D by using reflected particles as speckle tracked frame by frame
  - LV maximal internal dimension long axis/short axis at end-diastole (not angle dependent like TDI)
  - Assessment of torsion or twist (layers of myocardium
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STRAIN RATE – SYSTOLIC DEFORMITY
MITRAL ANNULAR VELOCITY

- Peak systolic mitral annular velocity is also a sensitive indicator for inotropic stimulation–induced alterations in LV contractility.
- LV function assessment by mitral annular velocity on DTI is valuable especially when endocardial delineation is suboptimal.
- Sm < 7 cm/sec was the most accurate parameter in identifying patients with LV EFs < 45% (sensitivity, 93%; specificity, 87%).
- Sm < 2.8 cm/sec was associated with worse survival in patients with chronic heart failure and LV EFs < 45%.

Nikitin et al., Heart 2006;92:775-
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Nikitin et al., Heart 2006;92:775-9.
COMPLETE ASSESSMENT - ECHO

- Accuracy and reliability
- Structural
  - LV mass and geometry
- Functional
  - LVEF (ESV and EDV)
  - LV size
  - Filling pressures
    - E wave, A wave, E/A ratio, A width, DT
  - Filling characteristics
  - RV function
  - ?MR
LIMITATIONS: HIGHLY VARIABLE
LIMITATIONS: 2D IMAGING

- Standard 2D imaging planes are limiting
- Echo: modified Simpson’s (semi-automated)
- Solutions
  - Scintigraphic counts: attenuation and “overlying chambers”
    - HR variability (arrhythmias)
  - 3D imaging
    - Echo, MRI, single photon SPECT, cardiac CT
    - MRI: better spatial resolution, entire LV measured
    - CT: single breath hold (radiation)
    - 3D echo very comparable with MRI for certain measurements
ROLE OF LV FUNCTION IN HF

- Diagnosis of early stage disease
- Imaging in new-onset HF
- Advanced HF
- Sequential imaging as surveillance
EARLY STAGE DISEASE

- Early detection of HF
  - Echo is the mainstay
    - Consider strain/speckle tracking
- Diastolic dysfunction
  - LV filling abnormalities
  - LA volumes
- LVH
  - 3D techniques more accurate and reproducible
  - Pathologic vs athlete’s heart, HCM, hypertensive heart disease
STAGES OF EARLY DISEASE

**STAGE A**
At high risk for HF but without structural heart disease or symptoms of HF.

- hypertension
- atherosclerotic disease
- diabetes
- obesity
- metabolic syndrome
  or
- Patients
  - using cardiotoxins
  - with Fx CM

**STAGE B**
Structural heart disease but without signs or symptoms of HF.

- previous MI
- LV remodeling including LVH and low EF
- asymptomatic valvular disease
MYOCARDIAL CHARACTERIZATION

- Subclinical dysfunction (ie Stage A-B)
  - What is the etiology?
- Contribution of fibrosis in diastolic dysfunction
- Techniques
  - Echo (quantitative acoustic characterization of myocardial structure, tissue Doppler, strain)
  - MRI (contrast, T1 and T2* imaging) - myocarditis
  - Nuclear (patterns of perfusion defects, metabolic/functional markers)
  - CT perfusion
IMAGING IN NEW OVERT HF

- Hemodynamics
  - Confirm HF, evaluate severity, etiology
- Echo is the most suitable initial technique
  - Systolic (EF, volumes), diastolic (including LA volumes), valvular disease
  - Others can do this but are more expensive and less available (MRI)
- R/O regional wall motion abnormalities suggestive of CAD
Etiologic Considerations in HF Imaging

Confirmation of HF diagnosis and functional assessment

Exclusion of coronary artery disease (depends on age, setting)

Angiography/CTA
Functional testing
Transmural pattern on ceMRI

Coronary artery disease

Viability testing (depends on scenario)

Which non-coronary etiology?
EXCLUDING CAD

- Coronary angiography
- Hybrid imaging
  - SPECT and PET-CT to assess perfusion
- Myocardial characterization
  - MRI and Echo
  - Distribution of scar
  - Look at both ventricles
- Viability
  - PET
  - MRI
MYOCARDIAL VIABILITY

• What is the likelihood of tissue recovery with revascularization?
• Risk-benefit decision
• Detect/quantify ischemic burden
  ◦ Stress SPECT/perfusion PET or stress echo
• Viability
  ◦ PET
  ◦ Gadolinium enhanced MRI
    • MRI is gold standard for assessment of myocardial inflammation and scar
    • Substantial scar makes recovery unlikely
CARDIAC MRI AS A GATEKEEPER FOR CARDIAC CATH IN NON-ISCHEMIC CHF

- Used late gadolinium enhancement
- 120 consecutive patients
- Overall, useful gatekeeper, avoids angiography
- Patients may have features of both ischemic and non-ischemic etiologies (mixed)
  - What is their prognosis?

Late gadolinium-enhanced cardiovascular magnetic resonance (LGE-CMR) and associated coronary angiogram (CA) images of diagnosis subtypes.
NONISCHEMIC CARDIOMYOPATHY

- MRI
  - Subepicardial edema with late gadolinium vs. diffuse subepicardial edema.
  - Greater reproducibility of LV volumes and LVEF quantification
  - Scar quantification and location superior to most techniques

- Infiltrative CM patterns
  - Sarcoid, HCM, endomyocardial fibrosis, amyloid
  - T2 signal characterization in iron overload states
MYOCARDITIS

- Clinical assessment
  - Viral illness, inflammatory biomarkers
  - “Troponitis”

- MRI
  - Spatial resolution plus late enhancement can more precisely identify irreversible injury
  - Can be used to monitor therapy in such diseases as sarcoid and CTD
ADVANCED HF

- Selection for ICD Therapy
  - LVEF 30-35%
  - Which technique? (Echo vs. MUGA)
  - 3D techniques less variable
- Nuclear gated scan vs MRI
  - Accurate and reliable
- Other prognostic markers
  - Cardiac sympathetic imaging with $^{131}$-MIBG may be additive
ADVANCED HF

- Clinical evaluation before CRT (on optimal medical therapy)
  - LV dysfunction
  - Functional limitation (NYHA)
  - ECG evidence of dyssynchrony

- Is the LVEF really less than 30%?
  - Especially in close to cutoff values
MUGA

- Advantages
  - High accuracy and reproducibility.
  - Measurements do not rely on geometric assumptions.
  - Global and regional LV systolic function.
  - Phase analysis of segmental ventricular contraction conveys information for regional dysnergy.
  - Patient's body habitus is not limiting.
  - Not time consuming

- Disadvantages
  - Radiation
  - Overlapping of structures
  - Improper visualization of septum
  - ECG gating
  - Limited analysis of other structures.
SURVEILLANCE - SEQUENTIAL IMAGING

• Echo really the most useful technique
  ◦ New techniques feature 3D as well as deformation imaging
  ◦ Good initial technique: feasible, available, lower cost

• What is test-retest reliability?
  ◦ Echo is 11% for EDV and 15% for ESV
  ◦ MUGA is about 5% (less inter-observer and operator dependence)
  ◦ MRI gold standard, although contrast 3D echo is a reasonable alternative (less than 5% difference)
FUTURE OF IMAGING FOR LV FUNCTION

- Echo most commonly used
- MUGA remains the reference tool (accuracy)
- New techniques (no geometric assumptions)
  - MRI, PET-CT, quantitative 2D and 3D echo
- Imaging modality must do the following:
  - Treatment and device selection
  - Dose titration of medical therapy
  - Avoid decompensated CHF /readmissions
- When in doubt, consider other study
## COMPARISON OF MODALITIES

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<thead>
<tr>
<th>Modality</th>
<th>+</th>
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<tbody>
<tr>
<td>2D Echo</td>
<td>No radiation</td>
<td>Variability</td>
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<tr>
<td></td>
<td>Portable</td>
<td>Angle dependent</td>
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<tr>
<td></td>
<td>No ECG gating required</td>
<td>Inter and intra observer</td>
</tr>
<tr>
<td></td>
<td>Additional tools (contrast, TDI, strain)</td>
<td>Geometric assumptions</td>
</tr>
<tr>
<td>3D Echo</td>
<td>Minimal geometric assumptions</td>
<td>Accessibility</td>
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<tr>
<td></td>
<td>Similar accuracy as MRI</td>
<td>Gating required</td>
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<tr>
<td>Gated SPECT/PET</td>
<td>Reconstructed 3D, no assumptions</td>
<td>Radiation</td>
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<tr>
<td></td>
<td>Automated LV cavity detection</td>
<td>Gating required</td>
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<td></td>
<td>Perfusion assessment</td>
<td>Less accuracy with perfusion defects</td>
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<tr>
<td></td>
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<td>Understampling LV (ESV)</td>
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<td></td>
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<td>Variability with different cameras, software</td>
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<tr>
<td>MUGA</td>
<td>No geometric assumptions of LV cavity</td>
<td>Gating required</td>
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<td>Reliable with different body habitus</td>
<td>Poor labeling</td>
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<td>LV ROI and background counts (semi-automated)</td>
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<tr>
<td>Cardiac MRI</td>
<td>High spatial resolution</td>
<td>Contra-indications</td>
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<tr>
<td></td>
<td>No radiation</td>
<td>Accessibility</td>
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<tr>
<td></td>
<td>Few geometric assumptions</td>
<td>Breath holds</td>
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<td>Slice selection</td>
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<tr>
<td>CTA</td>
<td>Single breath hold</td>
<td>Radiation, contrast</td>
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<tr>
<td></td>
<td>Accurate</td>
<td>Temporal resolution of end-systole</td>
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