NOVEL DIAGNOSTIC TECHNIQUES
FOR HEART FAILURE
Focus on Imaging

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## 2013 ACC/AHA GUIDELINES FOR THE MANAGEMENT OF HEART FAILURE

### Recommendations for Imaging

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>COR</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with suspected, acute, or new-onset HF should undergo a chest x-ray</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>A 2-dimensional echocardiogram with Doppler should be performed for initial evaluation of HF</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Repeat measurement of EF is useful in patients with HF who have had a significant change in clinical status or received treatment that might affect cardiac function or for consideration of device therapy</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Noninvasive imaging to detect myocardial ischemia and viability is reasonable in HF and CAD</td>
<td>Ila</td>
<td>C</td>
</tr>
<tr>
<td>Viability assessment is reasonable before revascularization in HF patients with CAD</td>
<td>Ila</td>
<td>B (281–285)</td>
</tr>
<tr>
<td>Radionuclide ventriculography or MRI can be useful to assess LVEF and volume</td>
<td>Ila</td>
<td>C</td>
</tr>
<tr>
<td>MRI is reasonable when assessing myocardial infiltration or scar</td>
<td>Ila</td>
<td>B (286–288)</td>
</tr>
<tr>
<td>Routine repeat measurement of LV function assessment should not be performed</td>
<td>III: No Benefit</td>
<td>B (289,290)</td>
</tr>
</tbody>
</table>

“The most useful diagnostic test in the evaluation of patients with or at risk for HF is a comprehensive 2-D echocardiogram”

Yancy C et al, 2013 JACC 62; e147
# Grades of Diastolic Dysfunction
Classification by Echocardiography

- Relies on annular velocity and LA size
- Mitral inflow and the ratio E/e’ allow grade distinction
- PV and mitral inflow during Valsalva are useful

<table>
<thead>
<tr>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal subjects</strong></td>
<td><strong>Normal/athlete/constriction</strong></td>
<td><strong>Impaired relaxation</strong></td>
</tr>
<tr>
<td>Septal e’≥8</td>
<td>Septal e’≥8</td>
<td>Septal e’&lt;8</td>
</tr>
<tr>
<td>Lateral e’≥10</td>
<td>Lateral e’≥10</td>
<td>Lateral e’&lt;10</td>
</tr>
<tr>
<td>LA&lt;34 ml/m²</td>
<td>LA≥34 ml/m²</td>
<td>LA≥34 ml/m²</td>
</tr>
</tbody>
</table>

- E/A<0.8 | E/A 0.8–1.5 | E/A≥1.5 |
- DT>200 ms | DT 160–200 ms | DT<160 ms |
- Average E/e’≤8 | Average E/e’ 9–12 | Average E/e’≥13 |
| Ar-A<0 ms | Ar-A≥30 ms | Ar-A≥30 ms |
| Valsalva | Valsalva | Valsalva |
| ΔE/A<0.5 | ΔE/A≥0.5 | ΔE/A≥0.5 |

- Valsalva ΔE/A<0.5
- Relies on annular velocity and LA size
- Mitral inflow and the ratio E/e’ allow grade distinction
- PV and mitral inflow during Valsalva are useful
SEVERITY OF HFrEF AND OUTCOMES
Quantitation of Myocardial Fibrosis by CMR-Derived Extracellular Volume

Schelbert EB et al, 2017
JAMA Cardiol 2: 995
## Prevalence of Coronary Disease in Multicenter Heart Failure Trials

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>n</th>
<th>CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHEHF-1</td>
<td>1986</td>
<td>642</td>
<td>282</td>
</tr>
<tr>
<td>CONSENSUS</td>
<td>1987</td>
<td>253</td>
<td>146</td>
</tr>
<tr>
<td>Milrinone</td>
<td>1989</td>
<td>230</td>
<td>115</td>
</tr>
<tr>
<td>PROMISE</td>
<td>1991</td>
<td>1088</td>
<td>590</td>
</tr>
<tr>
<td>SOLVD-T</td>
<td>1991</td>
<td>2569</td>
<td>1,828</td>
</tr>
<tr>
<td>VHEFT-2</td>
<td>1991</td>
<td>804</td>
<td>427</td>
</tr>
<tr>
<td>SOLVD-P</td>
<td>1992</td>
<td>4,228</td>
<td>3,518</td>
</tr>
<tr>
<td>RADIANCE</td>
<td>1993</td>
<td>178</td>
<td>107</td>
</tr>
<tr>
<td>Vesninone</td>
<td>1993</td>
<td>477</td>
<td>249</td>
</tr>
<tr>
<td>CHF-STAT</td>
<td>1995</td>
<td>674</td>
<td>481</td>
</tr>
<tr>
<td>Carvedilol</td>
<td>1996</td>
<td>1,094</td>
<td>521</td>
</tr>
<tr>
<td>PRAISE</td>
<td>1996</td>
<td>1,153</td>
<td>732</td>
</tr>
<tr>
<td>DIG</td>
<td>1997</td>
<td>6,800</td>
<td>4,793</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>20,190</td>
<td>13,789</td>
</tr>
</tbody>
</table>

- **CAD**: 32%
- **No CAD**: 68%

Georghiade and Bonow  
*Circulation* 1998; 97: 282
EVALUATION FOR ISCHEMIC ETIOLOGY

- Stress echo: Limitations in setting of LV dysfunction
- CMR perfusion: limited data with HF patients
- SPECT: Extensive literature support
- PET: Mostly viability studies
- CCTA: High NPV, but limited recommendations
- ICA: Class I or II recommendation for HF unless not eligible for revascularization
- When renal dysfunction present, avoid potentially nephrotoxic agents when possible

Patel MR et al
JACC 2013; 61: 2207
### ASSESSMENT OF MYOCARDIAL VIABILITY

**Physiologic Basis of Imaging**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Imaging Modality</th>
<th>Marker of Viability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfusion/intact cell membrane</td>
<td>Thallium-201 SPECT Rb-82 PET</td>
<td>Tracer activity &gt;50%</td>
</tr>
<tr>
<td></td>
<td>Contrast CT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contrast CMR</td>
<td></td>
</tr>
<tr>
<td>Perfusion/intact mitochondria</td>
<td>Tc-99m SPECT</td>
<td>Redistribution &gt;10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tracer activity &gt;50%</td>
</tr>
<tr>
<td>Glucose metabolism</td>
<td>F-18 FDG PET</td>
<td>Increased tracer uptake</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Perfusion/metabolism mismatch</td>
</tr>
<tr>
<td>Free fatty acid metabolism</td>
<td>C-11 fatty acid PET BMIPP SPECT</td>
<td>Tracer activity &gt;50%</td>
</tr>
<tr>
<td>Contractile reserve</td>
<td>Dobutamine echo Dobutamine CMR Dobutamine SPECT</td>
<td>Improved contraction</td>
</tr>
<tr>
<td>Microvascular integrity</td>
<td>Contrast echo</td>
<td>Hypoenhancement</td>
</tr>
<tr>
<td>Scar identification</td>
<td>Contrast CT</td>
<td>Hyperenhancement</td>
</tr>
<tr>
<td></td>
<td>Contrast CMR</td>
<td></td>
</tr>
</tbody>
</table>
SURVIVAL BASED ON THE PRESENCE OR ABSENCE OF VIABILITY AND TREATMENT WITH MEDICAL THERAPY OR REVASCULARIZATION

- Meta-analysis 24 studies
  - TI-201
  - FDG PET
  - DSE

- 3,088 patients
  - Follow-up: 25 ± 10 months
  - LVEF: 23-45% (mean 35%)

- No difference in performance based on technique used

Allman et al, 2002
J Am Coll Cardiol 39: 1151-8
MYOCARDIAL VIABILITY AND MORTALITY
The STICH Trial

Limitations:

• Non-randomized, with likely selection bias
• Extensive crossover to CABG
• Analysis limited to SPECT and dobutamine echo, not PET or cardiac MRI
• Lack of viability data for all patients (subpopulation of STICH)
• Viability testing cohort had more MI’s, afib, more prior revascularizations, high use of medical Rx, lower EF’s
CMR FOR MYOCARDIAL NECROSIS: LATE GADOLIUM ENHANCEMENT

Risk of 3-year death according to presence or absence of viability and treatment patients with dysfunctional myocardium

Subendocardial

Transmural

Intramycocardial

Shah SJ et al, 2011
AHJ 162: 3-15

Gerber BL et al, 2012
JACC 59: 825
CARDIAC SARCOIDOSIS

- Cardiac involvement portends a worse prognosis
- Endomyocardial biopsy has 20-30% sensitivity
- Echo has minimum value in early stages
- Cardiac magnetic resonance
  - Late gadolium enhancement or increased T2
- Ga-67 useful but low sensitivity; still part of HRS diagnostic criteria.
- F-18 FDG PET (preferred imaging technique)
  - High sensitivity (89%)
  - Detection of activated macrophages
  - Useful in early stages, before perfusion defects of CMR abnormalities
  - Can track response to therapy
USE OF CARDIAC MAGNETIC RESONANCE IN CARDIAC SARCOIDOSIS

T2 LGE

CMR may be preferred test for serial imaging

Coleman GC et al, 2017 JACC Img 10: 411
SARC OIDOSIS: PET

Slart RHJA et al
JNC 2018; 25: 298
PET IMAGES OF WOMAN WITH CARDIAC SARCOIDOSIS

Before Treatment
Gated LVEF 33%

After Treatment
Gated LVEF 47%
CARDIAC AMYLOIDOSIS

- Restrictive cardiomyopathy
- Systemic process
- Should be suspected in setting of heart failure with increased wall thickness and noon-dilated LV
- Types of amyloidosis
  - AL (AKA primary)
  - ATTRwt [(transthyretin wild type) AKA senile]
  - ATTRm [(transthyretin mutant type) AKA hereditary]
ECHOCARDIOGRAPHY FOR CARDIAC AMYLOIDOSIS

- Effusion
- LV thickening, “speckled”
- LA dilation
- RV thickening
- Reduced GLS
- Apical sparing

Siddiqi and Rudberg
Trends in CV Med, 2017
Relationship Between LGE and ECV

No LGE  Subendocardial LGE  Transmural LGE

Normal ECV  High ECV  Very High ECV

Asymmetric Hypertrophy

Sigmoid Septal Contour 55%
Reverse Septal Contour 24%
Symmetric Hypertrophy 18%
No LVH 3%

Survival Function for ECV in All ATTR Subjects

DETECTION AND RISK ASSESSMENT OF ATTR WITH Tc-99m PYROPHOSPHATE IMAGING

- Multicenter trial (n=229)
- High accuracy for detection of ATTR
- Sensitivity=91%
- Specificity=92%
- Worse survival if H:L>1.6

Castano A et al, 2016
JAMA Cardiol 1:880
THE ROLE OF ECHOCARDIOGRAPHY IN HEART FAILURE

Phenotyping and prognostic assessment

Role of echocardiography in the evaluation of heart failure patients

Additional markers of prognosis

- LV volumes and EF
- LV mass
- 3D LV volumes and EF
- LV myocardial deformation
- Intracardiac flow mapping
- PASP
- LV diastolic function and filling pressures
- LA volume
- Functional MR
- LV dyssynchrony

Sengupta PP et al JACC Img 2017; 10: 1056
HAND-HELD ULTRASOUND

- Use by ED physicians, hospitalists, APP
- May enable more rapid, appropriate Rx
THE ROLE OF CARDIAC MAGNETIC RESONANCE IN HEART FAILURE

Role of CMR in the evaluation of heart failure patients

- Cine imaging – LV volumes, mass, function
- LGE imaging – scar/fibrosis
- Myocardial tagging – strain imaging
- T1 mapping – interstitial fibrosis/edema
- T2 mapping – myocardial edema
- T2* mapping – myocardial iron

Sengupta PP et al, 2017
JACC Img 10: 1056
THE ROLE OF NUCLEAR CARDIOLOGY IN HEART FAILURE

- **Perfusion**
- **Metabolism**
- **Function**
- **Cell death**
- **RAAS system**
- **Amyloidosis**
- **Sarcoidosis**
- **Innervation**
- **Microvasculature**

**A** Ischemia
- 99mTc-MIBI SPECT
- 82Rb PET
  - Stress
  - Rest

**B** Viability
- Perfusion (82Rb, Rest)
- Mismatch
- Metabolism (18F-FDG)

**C** Innervation
- MIBG, HED

**D** Inflammation
- 82Rb rest
- 18FDG (fasting)

PET, SPECT agents
FDG, C-11 agents
Gated SPECT, PET
PYP, annexin
Labelled “prils”
PYP, diphosphonate
FDG, gallium-67
MIBG, HED
PET MBF

Caobelli, Bengel JNC 2015; 22: 971
FUTURE DIRECTIONS FOR CARDIAC IMAGING IN HEART FAILURE

- Improved assessment of hemodynamics
- Evaluation of LV remodeling
- Better differentiation between ICM and NICM
- Addition characterization of HFP EF
- Implications of inflammation, edema, necrosis
- Non-invasive endomyocardial biopsy
- Identification of therapeutic targets
- Delineation of candidacy for ICD use
- Optimization of cardiac resynchronization therapy