Echocardiography in Heart Failure

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2009 Focused Update Incorporated Into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines

Developed in Collaboration With the International Society for Heart and Lung Transplantation

7. Two-dimensional echocardiography with Doppler should be performed during initial evaluation of patients presenting with HF to assess LVEF, left ventricular size, wall thickness, and valve function. Radionuclide ventriculography can be performed to assess LVEF and volumes. (Level of Evidence: C)
Dyspnea: Clinical Questions

• Is heart failure present?
• What is the etiology?
  — Structural, systolic or diastolic dysfunction
• What is the state of systolic function
• What is the optimal treatment?
• How is the pt responding to therapy?
• What is the prognosis?
• Is the pt compensated or decompensating
Dyspnea: Clinical Questions

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BNP vs Echocardiography

• Echocardiography provides data regarding cardiac structure and performance

• BNP provides information regarding LV/LA wall stress and pressure
BNP vs Echocardiography

• BNP provides information regarding LV/LA wall stress and pressure
  – Distinguishes heart failure from other SOBs
  – Tracks efficacy of therapy
  – Assessment of prognosis, compensation and decompensation currently underway
BNP vs Echocardiography

- **Echocardiography** provides data regarding cardiac structure and performance

- Identify etiology
  - Mechanical (structural) vs Functional
  - Systolic vs Diastolic
  - Ischemic vs Nonischemic

- Quantify abnormality

- Select therapy

- Define prognosis

- Follow course
Etiology of Heart Failure by Echo

- Valve Disease  —  Stenosis/Regurgitation
- Coronary Disease  —  Segmental dysfunction
- Congenital Disease  —  Abnormal anatomy
- Pericardial Disease  —  Effusion/constriction
- Hypertension  —  LVH
- Cardiomyopathy  —  Composite (cavity size, wall thickness, contraction)
# Echo Distinction of Cardiomyopathy

<table>
<thead>
<tr>
<th></th>
<th>DCM</th>
<th>HCM</th>
<th>RCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV volume</td>
<td>↑↑↑↑↑↑</td>
<td>↓↓</td>
<td>↔</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>↑↓</td>
<td>↑↑↑↑ (IVS)</td>
<td>↑↑↑↑</td>
</tr>
<tr>
<td>Contractility</td>
<td>↓↓↓↓↓↓</td>
<td>↑(↓)</td>
<td>↔</td>
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Diagnostic Features of Nonischemic Cardiomyopathy

• Generalized myocardial dysfunction
  – Absence of regional contractile abnormality
    • Dobutamine or rest
  – Absence of localized scar
  – Absence of aneurysm
• Right ventricular dysfunction
• Diastolic dysfunction
• Increased LV sphericity
Ischemic Heart Disease
Assess LV Structure/Function

- Volumes and mass
- Ejection fraction
- Endocardial motion (Velocity)
- Wall thickening (Extent)

- Susceptible to in-plane motion and tethering
- Transition from motion to deformation (strain)
Published Trials in Which EF was Part of the Entry Criteria (Partial List)

- SOLVD Treatment Trial
- SOLVD Prevention Trial
- SAVE
- US Cravedilol Trials
- MERIT-HF
- CIBIS 1 & 2
- COPERNICUS
- CAPRICORN
- RALES
- ELITE 1 & 2
- Val-HEFT
- PRAISE 1 & 2
- OVERTURE

- ICD
- Bi-ventricular pacing
Quantitation of LV Function by Echocardiography

Lang et al; JASE, 18: 2005
Echo vs Cine: Ejection Fraction

- **3D Echo EF**
  - Correlation coefficient: $r = 0.94$
  - Standard Error of the Estimate (SEE): $0.054$
  - Equation: $y = 0.95x + 0.06$

- **2D Echo EF**
  - Correlation coefficient: $r = 0.76$
  - Standard Error of the Estimate (SEE): $0.105$
  - Equation: $y = 0.72x + 0.22$
Deformation (Strain) vs Movement

Strain = Change in Length / Original Length

Thickening

Passive Movement

Courtesy Toshiba Corp.
Calculation of Strain From Speckle Tracking

\[ \text{Strain} = \frac{\text{Change in Length}}{\text{Original Length}} \]

Modified from Freedman Z. and Lysysanksyv P
CHF with Normal LVEF

- Wrong Diagnosis
- Volume Overload
- High Output Failure
- LV Underloading
  - Mechanical lesions
  - Pericardial disease
- Diastolic dysfunction
Diastolic Dysfunction

• Multiple determinants
• Difficult to measure
• Diagnosis by exclusion
• Nonspecific treatment
Determinants of Diastolic Function

- Myocardial Relaxation
- Chamber stiffness
- Compliance
- Atrial function
- Pericardial restraint
- Ventricular interaction
- Coronary blood volume
Echo Assessment of Diastole

- Transmitral filling velocities (E, A, integrated)
- Decleration time
- Isovolumic Relaxation Time (IVRT)
- Pulmonary Vein Flow
- Tissue Doppler Velocities
- Color Doppler flow propagation
Patterns of Diastolic Function

Mitral inflow

PV flow

TDE

CMM - Vp

NL (Young)  NL (Adult)  Delayed Relaxation  Pseudo normal  Restrictive
Aproaches to Estimate LV/LA Diastolic Pressure

- MV systolic gradient with MR
- Transmitral filling dynamics
  - E/A, DcT, IVRT, etc (with Valsalva)
- Pulmonary vein systolic filling fraction
- Ratio of pulmonary vein Ar/mitral A
- $E/E_a \ (E/E' \ )$ ratio
- E/Vpm (color Doppler flow propagation)
LA Systolic Pressure from MR Jet Velocity

BP = 115/75
Peak grad = 100
LVSP = 15
Deceleration Time
Diastolic Function

CAD EF < 50%

CAD - EF > 50%
Deceleration Time Predicts Mortality and Events

Figure 1. Cumulative survival rates for cardiac mortality as an event (A); cumulative survival rates free of hospital admission for CHF (B); and cumulative survival rates free of all cardiac events (death, transplantation and hospital admission for worsening heart failure) in the two study groups according to the value of DT of early filling: prolonged DT (>125 ms) versus persistent short DT (≤125 ms).
E/Ea Estimates LV Filling Pressure

Nagueh et al; JACC, 1997
Evaluation of Left Ventricular Filling Pressures by Doppler Echocardiography in Patients With Hypertrophic Cardiomyopathy Correlation With Direct Left Atrial Pressure Measurement at Cardiac Catheterization (Circulation. 2007;116:2702-2708.)

Jeffrey B. Geske, MD; Paul Sorajja, MD; Rick A. Nishimura, MD; Steve R. Ommen, MD
Limitations of E/E’ for Diastolic Function

Tissue Doppler Imaging in the Estimation of Intracardiac Filling Pressure in Decompensated Patients With Advanced Systolic Heart Failure

Wilfried Mullens, MD; Allen G. Borowski, RDCS; Ronan J. Curtin, MD; James D. Thomas, MD; W.H. Tang, MD
Limitations of E/E’ for Diastolic Function

Bhella et al; Circ CV Image, 2011
E/E’ Ratio May Not Apply

- Normal heart
- Constrictive pericarditis
- Mitral stenosis or insufficiency
- Mitral or aortic valve replacement
- Mitral annular calcification
- Hypertrophic cardiomyopathy
- Acute decompensated heart failure (CRT)
Diastolic Dysfunction and Mortality in CHARM

• Subgroup of CHARM Preserved
• 66% had evidence of diastolic dysfunction
  – 44% moderate to severe
• Adverse prognosis in those with dysfunction
Diastolic Dysfunction and Mortality in CHARM

log-rank p=0.0015

Persson et al; JACC, 2007
Step Approach to Diastole (E/E’):

- Consider only $E/E’ > 15$
  - 12 if lateral included
- Evaluate corroborating findings
  - Particularly LA size
- Combine all findings and include clinical picture
PROGNOSTIC FACTORS IN CHF

• Clinical class
• Age
• Diabetes
• Etiology
• LV size and function
• Cardiac pressures
• Ventricular arrhythmias
• Electrolyte and neurohormonal abnormalities
Table 3. Predictors of Cardiac Death by Cox Proportional Hazards Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Chi-Square Value</th>
<th>p Value</th>
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<tbody>
<tr>
<td>TMF (restrictive vs. nonrestrictive)</td>
<td>6.99</td>
<td>0.008</td>
</tr>
<tr>
<td>Patient gender (F vs. M)</td>
<td>4.59</td>
<td>0.03</td>
</tr>
<tr>
<td>NYHA functional class (IV vs. II)</td>
<td>3.95</td>
<td>0.05</td>
</tr>
<tr>
<td>LVEF</td>
<td>2.97</td>
<td>0.08</td>
</tr>
<tr>
<td>NYHA functional class (IV vs. III)</td>
<td>1.71</td>
<td>0.19</td>
</tr>
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LVEF = left ventricular ejection fraction; TMF = transmitral flow pattern; other abbreviations as in Table 2.
Figure 7. Effect of transmitral flow patterns on cumulative cardiac mortality. The 1-year mortality rate was 19% in the restrictive group and 5% in the nonrestrictive group (p < 0.05). Note the wide divergence of two mortality rate curves after 1 year, resulting in a 2-year mortality rate of 51% in the restrictive group but only 5% in the nonrestrictive group (p < 0.01). Numbers in parentheses = number of survivors at 12 and 24 months.
## Differences Between Echocardiograms According to Parameter

<table>
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<tr>
<th>Parameter</th>
<th>Absolute difference</th>
<th>Relative difference</th>
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<tbody>
<tr>
<td>Δ Left ventricular EF</td>
<td>8.1% ± 11.5%</td>
<td>17% ± 30%</td>
</tr>
<tr>
<td>Δ Left atrial area</td>
<td>4.0 ± 5.2 cm²</td>
<td>17% ± 23%</td>
</tr>
<tr>
<td>Δ Tissue Em</td>
<td>2.1 ± 2.7 cm/s</td>
<td>27% ± 36%</td>
</tr>
<tr>
<td>Δ E/e’</td>
<td>5.0 ± 7.0</td>
<td>46% ± 64%</td>
</tr>
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Em = mitral annular tissue diastolic velocity.

Marwick; JNM: 2015
Thavendiranathan et al; JACC: 2013
Jenkins et al; JACC: 2004
Biphasic Response to Dobutamine for Viability
7. Two-dimensional echocardiography with Doppler should be performed during initial evaluation of patients presenting with HF to assess LVEF, left ventricular size, wall thickness, and valve function. Radionuclide ventriculography can be performed to assess LVEF and volumes. (*Level of Evidence: C*)