LV FUNCTION ASSESSMENT:
WHAT IS BEYOND EJECTION FRACTION

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Introduction

• LV function assessment in Heart Failure:
  • Abnormal myocardial excitation-contraction coupling (systolic failure)
  • Abnormal relaxation and increased myocardial passive stiffness (diastolic failure)

HFPEF
Doppler Echocardiography

1. LV structure:
   • Dilated, hypertrophied, or of normal size

2. LV function:
   • Systolic or Diastolic

3. Valvular heart disease

4. Pericardial disease

5. Right ventricular abnormalities
LV STRUCTURE
Measurement of LV Size

1. Linear Internal Dimensions:
   - Commonly reported for end-diastole and end-systole
   - Performed in the parasternal long-axis view
   - Perpendicular to the LV long axis and measured at or immediately below the level of the mitral valve leaflet tips
   - Obtained with (2D) echocardiography or 2D guided M-mode approach
   - Chamber measurements should be reported indexed to BSA.
**Measurement of LV Size**

- **II. Volumetric Measurements using 2D or 3D:**
  - Volumetric measurements are usually based on tracings of the interface between the compacted myocardium and the LV cavity in 4ch & 2 ch.

\[
\text{Volume} = \frac{5 \times (\text{area})(\text{length})}{6}
\]
LV Size By 3D Echo

- 3D echo volume measurements do not rely on geometric assumptions.
- Accurate and reproducible, should be used when available and feasible.
- The issue of foreshortening is less relevant in 3D data sets.
LV Mass

- Methods: M-mode echocardiography, 2DE, and 3DE

\[
\text{LV mass} = 0.8 \times \{1.04[(\text{LVIDd} + \text{PWTd} + \text{SWTd})^3 - (\text{LVIDd})^3]\} + 0.6 \text{ g}
\]
LV Systolic Function

• **LV Global Systolic Function**
  I. Fractional Shortening
  II. EF
  III. Global Longitudinal Strain

• **LV Regional Function**
  i. Segmentation of the Left Ventricle
  ii. Visual Assessment
  iii. Regional Wall Motion during Infarction and Ischemia
  iv. Regional Abnormalities in the Absence of Coronary Artery Disease
  v. Regional LV Deformation Measurements using Doppler & STE
LV GLOBAL SYSTOLIC FUNCTION

I. Fractional Shortening
II. EF
I. Fractional Shortening

- Represents a simple method for estimating ventricular function in the symmetrically contracting ventricle
  \[ \text{FS(\%)} = \frac{\text{LVEDD} - \text{LVESD}}{\text{LVEDD}} \times 100 \]
- % change of LV cavity dimension with systole
- Derived from 2D-guided M-mode imaging or preferably from 2D images.
- Normal range is 25-45% (95% CI)

☑️ Only measures the base of the heart
ئة Apical motion abnormalities
II. Ejection Fraction

- LV volume estimates may be derived from 2DE or 3DE
- EF % = EDV - ESV/EDV x100
- The biplane method of disks (modified Simpson’s rule) is the currently recommended 2D method by consensus of the committee.

- Image poorly optimized
- Traced outside 2D sector
- Traced around the papillary muscle
- Far from MV annulus
LV Assessment Derived From 3DE

PHILIPS

Volume(s)
EDV = 214.9 ml
ESV = 84.3 ml

Calculation(s)
EF = 60.8 %
SV = 130.5 ml

Global Regional Normalized
### Supplemental Table 3: Normal ranges and severity partition cutoff values for 2DE-derived LV size, function and mass

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal range</td>
<td>Mildly abnormal</td>
</tr>
<tr>
<td><strong>LV dimension</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV diastolic diameter (cm)</td>
<td>4.2–5.8</td>
<td>5.9–6.3</td>
</tr>
<tr>
<td>LV diastolic diameter/BSA (cm/m²)</td>
<td>2.2–3.0</td>
<td>3.1–3.3</td>
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<tr>
<td>LV systolic diameter (cm)</td>
<td>2.5–4.0</td>
<td>4.1–4.3</td>
</tr>
<tr>
<td>LV systolic diameter/BSA (cm/m²)</td>
<td>1.3–2.1</td>
<td>2.2–2.3</td>
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<tr>
<td><strong>LV volume</strong></td>
<td></td>
<td></td>
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<tr>
<td>LV diastolic volume/BSA (mL/m²)</td>
<td>34–74</td>
<td>75–89</td>
</tr>
<tr>
<td>LV systolic volume/BSA (mL/m²)</td>
<td>11–31</td>
<td>32–38</td>
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<tr>
<td><strong>LV function</strong></td>
<td></td>
<td></td>
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<tr>
<td>LV EF (%)</td>
<td>52–72</td>
<td>41–51</td>
</tr>
<tr>
<td><strong>LV mass by linear method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septal wall thickness (cm)</td>
<td>0.6–1.0</td>
<td>1.1–1.3</td>
</tr>
<tr>
<td>Posterior wall thickness (cm)</td>
<td>0.6–1.0</td>
<td>1.1–1.3</td>
</tr>
<tr>
<td>LV mass/BSA (g/m²)</td>
<td>49–115</td>
<td>116–131</td>
</tr>
<tr>
<td><strong>LV mass by 2D method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>96–200</td>
<td>201–227</td>
</tr>
<tr>
<td>LV mass/BSA (g/m²)</td>
<td>50–102</td>
<td>103–116</td>
</tr>
</tbody>
</table>
LV REGIONAL FUNCTION

i. Segmentation of the Left Ventricle
ii. Visual Assessment
iii. Regional Abnormalities in the Absence of Coronary Artery Disease
I. Segmentation of the Left Ventricle

- The ventricle is divided into segments reflect coronary perfusion territories. 17-segment model is commonly used.
- The 16-segment model is recommended for routine assessing wall motion.
  - *Endocardial excursion and thickening of the tip of the apex are imperceptible*
Coronary Perfusion Territories
II. Visual Assessment

- Assessment & observation of segmental wall thickening and endocardial motion, analyzed individually in multiple (thickening, shortening).
  - Watch for myocardial motion may be caused by adjacent segment tethering or overall LV displacement.
- A semiquantitative wall motion score assessment: LV wall motion score index (average of the scores of all segments visualized).
  - (1) Normal or hyperkinetic
  - (2) Hypokinetic (reduced thickening)
  - (3) Akinetic (absent or negligible thickening, e.g., scar)
  - (4) Dyskinetic (systolic thinning or stretching, e.g., aneurysm).
  - An aneurysm is focal dilatation and thinning (remodeling) with either akinetic or dyskinetic systolic deformation.

*The committee refrains from assigning a separate wall motion score for aneurysm.*
Use Of Contrast Agents

- Needed to improve endocardial delineation
- If two or more contiguous LV endocardial segments are poorly visualized in apical views.
- Normal reference values for LV volumes with contrast enhancement are not well established.
III. Regional Abnormalities in the Absence of Coronary Artery Disease

- Rationality noted in conditions as
  - Myocarditis, sarcoidosis, and stress-induced (takotsubo) cardiomyopathy.

- Abnormal Septal motion patterns
  1. Postoperative status
  2. RV dysfunction caused by RV pressure or volume overload.
  3. Presence of conduction abnormalities as LBBB, RV epicardial pacing......
NEW MODALITIES

- (2D) myocardial strain measurements by speckle-tracking echocardiography (STE), especially global longitudinal strain (GLS)
- 3DE STE
Global Longitudinal Strain

- Strain: change in length of an object within a certain direction relative to its baseline length

\[
\text{Strain} \% = \frac{L_t - L_0}{L_0},
\]

- \(L_t\) is the length at time \(t\), and \(L_0\) is the initial length at time \(0\).

- Assessed by speckle-tracking echo, in the three standard apical views and averaged

- Measurements should begin with the apical long-axis view to visualize aortic valve closure

- Peak GLS describes the relative length change of the LV myocardium between end-diastole and end-systole:

\[
\text{GLS} \% = \frac{ML_s - ML_d}{ML_d},
\]

- \(ML\) is myocardial length at end-systole (\(ML_s\)) and end-diastole (\(ML_d\)). \(GLS\) is a negative number \((\text{Normal -20\%})\).

- Limitation: intervendor and intersoftware variability
Global Longitudinal Strain

- Several studies have demonstrated that abnormal global longitudinal strain develops prior to a fall in ejection fraction and precedes the appearance of clinically apparent heart failure. **Detect subclinical decreases in cardiac function before the LVEF falls.**

- Recent studies demonstrated good relation between global left ventricular longitudinal systolic strain and LVEF
Regional LV Deformation Measurements

• Echo quantification of regional myocardial function based on DTI or speckle-tracking techniques.
  ✓ Longitudinal strain during LV systole for global strain is the most commonly used.
• Despite promising data, quantitative assessment of the magnitude of regional LV deformation cannot be recommended yet because of lack of reference values, suboptimal reproducibility, and considerable intervendor measurement variability.
Color DTI Velocity Tracings
LONGITUDINAL STRAIN CURVES AND BULL’S-EYE PLOTS SHOWING SEGMENTAL PEAK SYSTOLIC LONGITUDINAL STRAIN

Examples
chronic ischemic heart failure
Regional LV GLS Measurements

• Several studies demonstrated a good correlation between global left ventricular longitudinal strain measured with speckle tracking imaging and wall motion score index.
Cardiac Resynchronization Therapy in Chronic Heart Failure

• An established therapy for patients with NYHA III/IV HR, prolonged QRS duration (130 ms) and LV dyssynchrony.
New Techniques For Detection Of LV Dyssynchrony Response To CRT
New Techniques For Detection Of LV Dyssynchrony Response To CRT
3D Speckle-Tracking Echocardiographic Slices At End-systole
3D Regional And Slice Voxel Mechanics
DIASTOLIC LV FUNCTION
Echo Parameters To Evaluate The Diastolic Function

- 2-D Echocardiography and Morphology
  - LA Volume and function/LVH
- M-Mode Echocardiography
  - Color M-Mode Flow Propagation Velocity
- **Pulsed Wave Doppler**
  - **Mitral Inflow/Pulmonary Veins**
- **Tissue Doppler**
  - **Mitral Annular velocities**
- Other Modalities
  - Deformation Measurements
  - Left Ventricular Untwisting
  - Estimation of Left Ventricular Relaxation
  - Estimation of Left Ventricular Stiffness
  - Diastolic Stress Test
Normal Ranges & Severity For 2DE LA Volume

- **LA volume measurement is recommended by the disk summation algorithm**

<table>
<thead>
<tr>
<th>Max LA Volume/ BSA (ml/m²)</th>
<th>Normal range</th>
<th>Mildly abnormal</th>
<th>Moderately abnormal</th>
<th>Severely abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male / Female</td>
<td>16-34</td>
<td>35-41</td>
<td>42-48</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

*Increase number of reviewed studies has resulted in a change in the recommended upper normal indexed LA volume*
Grading Diastolic Dysfunction

Septal e’  >8
Lateral e’  >10
LA <34 ml/m²

Septal e’  >8
Lateral e’  >10
LA >34 ml/m²

Normal function, athlete’s heart or constriction

Septal e’  <8
Lateral e’  <10
LA >34ml/m²

E/A <0.8
DT>200 ms
Av E/e’ <8
Ar-A<0ms
Val Δ E/A <0.5

Grade I

E/A 0.8 –1.5
DT 160 -200 ms
Av E/e’ 9-12
Ar-A>30ms
Val Δ E/A >0.5

Grade II

E/A >2
DT<160ms
Av E/e’ >13
Ar-A>30ms
ValΔE/A>0.5

Grade III

JASE 2009; 22(2): 107-133
Diastolic Dysfunction

**Normal**
- $E/A$ 1–2
- LV inflow (m/s)
- DT 150–200

**Mild**
- $E/A < 0.8$
- Tissue Doppler (m/s)
- $E/E' \leq 8$
- $E' \geq 0.1$
- IVRT (m/s)
- IVRT 50–100
- Pulmonary vein (m/s)
- $PV_a < 0.35$

**Moderate**
- $E/A$ 0.8–2.0
- LV inflow (m/s)
- DT 150–200
- Tissue Doppler (m/s)
- $E/E' = 9–14$
- $E' < 0.05$
- IVRT (m/s)
- IVRT 60–100
- Pulmonary vein (m/s)
- $PV_a \geq 0.35$

**Severe**
- $E/A \geq 2$
- LV inflow (m/s)
- DT < 150
- Tissue Doppler (m/s)
- $E/E' \geq 15$
- $E' < 0.05$
- IVRT (m/s)
- IVRT < 60
- Pulmonary vein (m/s)
- $PV_a \geq 0.35$

$E$ = Early diastolic wave, $A$ = Late diastolic wave, $DT$ = Deceleration time, $E'$ = Early diastolic tissue Doppler wave, $A'$ = Late diastolic tissue Doppler wave, $S$ = Peak systolic wave, $PV_a$ = Peak velocity of the aortic regurgitant jet.
VALSALVA MANEUVER
Limitation

• Impaired mitral inflow velocities occur in:
  • Sinus tachycardia
  • Conduction abnormalities: 1st AV Block
  • Arrhythmia: Atrial fibrillation / Flutter
  • Diastolic mitral regurgitation

• A restrictive filling and LA enlargement in normal EF are associated with a poor prognosis, most commonly seen in restrictive cardiomyopathies (amyloidosis, heart transplant)
60 year-old with HF & Normal EF

Septal E/e' = 80/4 = 20

Lateral E/e' = 80/5 = 16
Patient with an anteroseptal MI
Septal e’ 5cm/s, lateral e’ 10cm/s
ESTIMATION OF LV FILLING PRESSURES
Estimation of LV Filling Pressures in Patients With Depressed EFs

**Mitral E/A**

- **E/A <1 & E <50 cm/s**
  - Normal LAP

- **E/A >1-<2 or E/A <1 & E>50cm/s**
  - E/e’<8, S/D >1
  - Ar-A<0 ms
  - Valsalva ΔE/A <0.5
  - PAS <30mmHg
  - Normal LAP

- **E/A>2, DT<150ms**
  - E/e’>15
  - S/D <1
  - AR-A >30 ms
  - Valsalva Δ E/A >0.5
  - PAS>35 mmHg
  - ↑LAP
Estimation of LV Filling Pressures in Patients With Normal EFs

- **E/e’ <8**
  - Normal LAP

- **E/e’ 9-14**
  - LA <34ml/m²
  - Ar-A <0ms
  - Val ΔE/A <0.5
  - PAS <30mmHg
  - Normal LAP

- **E/e’ >15 or Lat E/e’ >12 or Av E/e’ >13**
  - Sep E/e’ >15 or Lat E/e’ >12 or Av E/e’ >13
  - LA >34ml/m²
  - Ar-A >30ms
  - Val ΔE/A >0.5
  - PAS >35 mmHg
  - ↑ LAP

- **↑ LAP**
LV SYSTOLIC FUNCTION

Normal
- Septal e' < 8
- Lateral e' < 10
- LA > 34 ml/m²

E/A
- < 0.8
  - DT > 200 ms
    - Grade I
  - > 0.8
    - DT 160 - 200 ms
      - Grade II
    - < 160 ms
      - Grade III

Abnormal
- Filling Pressure (Av E/e')
  - >= 13
    - Inc LAP
  - < 12
    - Normal

Diastolic Dysfunction

JASE 2009; 22(2): 107-133
Conclusion

• The ASE guidelines currently recommend the use of 2D biplane Simpson method
• With ongoing technical advancement 3DE will likely replace 2DE as the routine method to assess LV volumes and EF
• Although strain and SR are still largely of research interest, once standardization of measurement is achieved and diagnostic accuracy is confirmed, strain and SR will become an integral part of clinical echocardiography for the evaluation of myocardial mechanics
GUIDELINES AND STANDARDS
RECOMMENDATIONS FOR CARDIAC CHAMBER QUANTIFICATION BY ECHOCARDIOGRAPHY IN ADULTS: AN UPDATE FROM THE AMERICAN SOCIETY OF ECHOCARDIOGRAPHY AND THE EUROPEAN ASSOCIATION OF CARDIOVASCULAR IMAGING

Journal of the American Society of Echocardiography
January 2015
GUIDELINES AND STANDARDS

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography

RECOMMENDATIONS FOR THE EVALUATION OF LEFT VENTRICULAR DIASTOLIC FUNCTION BY ECHOCARDIOGRAPHY

Journal of the American Society of Echocardiography
February 2009
CURRENT AND EVOLVING ECHOCARDIOGRAPHIC TECHNIQUE FOR THE QUANTITATIVE EVALUATION OF CARDIAC MECHANICS: ASE/EAE CONSENSUS STATEMENT ON METHODOLOGY AND INDICATIONS ENDORSED BY THE JAPANESE SOCIETY OF ECHOCARDIOGRAPHY

Journal of the American Society of Echocardiography
March 2011
Questions !!