Left Ventricular Function
How to Measure and How Accurate is Echo

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Disclosures

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- Abbott Vascular
- Boston Scientific
- Biotronic
- Direct Flow
- Edwards LifeScience
- Medtronic
- MitrAlign
- St. Jude
- Sorin/ Carbomedics

For a full list, visit www.EchoCoreLab.org
Thanks to our ASE Past President:

Michael H. Picard
Massachusetts General Hospital
Harvard Medical School
LV function in clinical practice: What is the echocardiographer asked?

• Diagnosis – systolic (and diastolic) dysfunction
  – Etiology for symptoms
• Assessing response to treatment
• Assessing risk and prognosis
  – Need for interventions
    • Defibrillators, valve surgery, meds, CRT
  – Timing of interventions
Systolic function by echo: an important marker of risk

Post - MI

CHF EF < 35%

GISSI - 2

SOLVD Registry Data
Quinones et al : JACC 2000;1237-1244
When is it appropriate to use echo to quantify ventricular function?

- When ever echo is performed
- Why?
  - Echo measures of ventricular function are all validated and standard
  - Requesting MDs expect it and will use it
    - Keeps echo competitive with other modalities
- If concern that image quality is insufficient to measure LV systolic function
  - Then use contrast
  - Consider methods that do not require border delineation
Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology

Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, Michelle Bierig, MPH, RDGS, FASE, Richard B. Devereux, MD, Frank A. Flachskampf, MD, Elyse Foster, MD, Patricia A. Pelliakka, MD, Michael H. Picard, MD, Mary J. Roman, MD, James Seward, MD, Jack S. Shanewise, MD, FASE, Scott D. Solomon, MD, Kirk T. Spencer, MD, FASE, Martin St John Sutton, MD, FASE, and William J. Stewart, MD
Approximately 5500 citations

ASE COMMITTEE RECOMMENDATIONS

Recommendations pour la Quantification des Cavités Cardiaques: Le Rapport de La Société Américaine d’Échocardiographie, La comité de Direction des Standards et le bureau de rédaction sur La quantification des Cavités Cardiaques, développé avec l’association Européenne d’Échocardiographie, une branche de La société Européenne de Cardiologie

RECOMENDACIONES DEL COMITÉ DE LA ASE

Recomendaciones para la Cuantificación de las Cavidades: Informe del Comité de Guías y Estándares de la Sociedad Americana de Ecocardiografía y del Grupo Redactor de la Cuantificación de las Cavidades, desarrollado conjuntamente con la Asociación Europea de Ecocardiografía, rama de la Sociedad Europea de Cardiología
Cardiac Chamber Quantification: What is New?

Database

Eliminate discrepancies between previous guidelines

Deformation Imaging

RT3DE
Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Afilalo, MD, MSc, Anderson Armstrong, MD, MSc, Laura Emane, MD, PhD, Frank A. Flachskampf, MD, FESC, Elyse Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denisa Muraru, MD, PhD, Michael H. Picard, MD, FASE, Ernst R. Rietzschel, MD, PhD, Lawrence Rudski, MD, FASE, Kirk T. Spencer, MD, FASE, Wendy Tsang, MD, and Jens-Uwe Voigt, MD, PhD, FESC, Chicago, Illinois; Padua, Italy; Montreal, Quebec and Toronto, Ontario, Canada; Baltimore, Maryland; Créteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liège, and Ghent, Belgium; Boston, Massachusetts
Partition Values for Severity of Abnormalities

Cutoffs based on SD
- Data readily exist
- Echo parameters are not normally distributed
- Asymmetric distribution

Cutoffs based on percentile values (95th)
Cutoffs based on outcomes or prognosis
Cutoffs experienced based on consensus
LV EF, LA, LA size and LV mass
Normal Reference Values for 2DE

Seven data bases (Asklepios, Flemengho, Cardia5, Cardia 25, Padua 3D Echo Normal, Norre Study)

No contrast studies

Age, gender, ethnicity, height and weight

NI BP, no diabetes, nl BMI, creatinine, glomerular filtration rate, cholesterol, LDL and triglycerides
Left Ventricle and Left Atrium
How do we Assess LV Function?

- Subjective
- Experience dependent
- Lack of standardization
- Large inter- and intra-observer variability

Eye ball assessment

Qualitative Assessment
1.1. **Linear Measurements.** It is recommended that linear internal measurements of the left ventricle and its walls be performed in the parasternal long-axis view. Values should be carefully obtained perpendicular to the LV long axis and measured at or immediately below the level of the mitral valve leaflet tips. In this regard, the electronic calipers should be positioned on the interface between the myocardial wall and cavity and the interface between the wall and the pericardium. Internal dimensions can be obtained with a two-dimensional (2D) echocardiography (2DE)–guided M-mode approach, although linear measurements obtained from 2D echocardiographic images are preferred to avoid oblique sections of the ventricle (Table 1).
LV Dimensions

2D-guided linear measurements

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV internal dimension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diastolic dimension, mm</td>
<td>50.2 ± 4.1</td>
<td>45.0 ± 3.6</td>
</tr>
<tr>
<td></td>
<td>42.0 - 58.4</td>
<td>37.8 - 52.2</td>
</tr>
<tr>
<td>Systolic dimension, mm</td>
<td>32.4 ± 3.7</td>
<td>28.2 ± 3.3</td>
</tr>
<tr>
<td></td>
<td>25.0 - 39.8</td>
<td>21.6 - 34.8</td>
</tr>
</tbody>
</table>
# LV Dimensions

## Male

<table>
<thead>
<tr>
<th></th>
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<th>Mildly</th>
<th>Moderately</th>
<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV Diastolic Diameter/BSA</td>
<td>2.2-3.0</td>
<td>3.1-3.3</td>
<td>3.4-3.6</td>
<td>&gt;3.6</td>
</tr>
<tr>
<td>LV Systolic Diameter/BSA</td>
<td>1.2-2.1</td>
<td>2.2-2.3</td>
<td>2.4-2.5</td>
<td>&gt;2.5</td>
</tr>
</tbody>
</table>

## Female

<table>
<thead>
<tr>
<th></th>
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<td>2.4-2.6</td>
<td>&gt;2.6</td>
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</table>
1.2. Volumetric Measurements. LV volumes are measured using 2DE or 3DE. Volume calculations derived from linear measurements may be inaccurate, because they rely on the assumption of a fixed geometric LV shape such as a prolate ellipsoid, which does not apply in a variety of cardiac pathologies. Accordingly, the Teichholz and Quinones methods for calculating LV volumes from LV linear dimensions are no longer recommended for clinical use.

\[ V = \frac{2.4 + D}{2} \]

*Am J Cardiol 1976;37:7–11*
Left Ventricular Volumetric Measurement

1. Biplane Disk Summation
   - Corrects for shape distortions
   - Less geometrical assumptions compared with linear dimensions
   - Apex frequently foreshortened
   - Endocardial dropout
   - Blind to shape distortions not visualized in the apical two- and four-chamber planes

2. Area Length Method
   - Partial correction for shape distortion
   - Apex frequently foreshortened
   - Heavily based on geometrical assumptions
   - Limited published data on normal population
LV Volumes by 2D

Biplane disc’s summation

<table>
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<tr>
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<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV volumes normalized by BSA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV end-diastolic volume, mL/m²</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td>54 ± 10</td>
<td>45 ± 8</td>
</tr>
<tr>
<td></td>
<td>34 - 74</td>
<td>29 - 61</td>
</tr>
<tr>
<td>LV end-systolic volume, mL/m²</td>
<td>21 ± 5</td>
<td>16 ± 4</td>
</tr>
<tr>
<td></td>
<td>11 - 31</td>
<td>8 - 24</td>
</tr>
</tbody>
</table>

2-D measurements for LV volume calculations using the biplane method of discs, in the apical four-chamber (A4C) and apical two-chamber (A2C) views at end diastole (LV EDD) and at end-systole (LV ESD).
## LV Volumes by 2D

### Male

<table>
<thead>
<tr>
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<th>Moderately</th>
<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV Diastolic Volume/BSA</td>
<td>34-74</td>
<td>75-89</td>
<td>90-100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>LV Systolic Volume/BSA</td>
<td>11-31</td>
<td>32-38</td>
<td>39-45</td>
<td>&gt;45</td>
</tr>
</tbody>
</table>

### Female

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<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV Diastolic Volume/BSA</td>
<td>29-61</td>
<td>62-70</td>
<td>71-80</td>
<td>&gt;80</td>
</tr>
<tr>
<td>LV Systolic Volume/BSA</td>
<td>8-24</td>
<td>25-32</td>
<td>33-40</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>
**LV Volumes by 3D**

**Upper limits of normal:**

- **EDV:**
  - 79 ml/m² for men
  - 71 ml/m² for women

- **ESV:**
  - 32 ml/m² for men
  - 28 ml/m² for women

**Recommendation.** LV size should be routinely assessed on 2DE by calculating volumes using the biplane method of disks summation technique. In laboratories with experience in 3DE, 3D measurement and reporting of LV volumes is recommended when feasible depending on image quality. When reporting LV linear dimensions, the recommended method is 2D-guided measurements. LV size and volume measurements should be reported indexed to BSA. For general reference, 2D echocardiog-
3D echo for volume and EF triplane imaging and manual tracing
Linear regression of LVEF in all patients, measured by 3D echocardiography by Simpson's method (3DS) vs radionuclide angiography (RNA)

\[ y = 3.7 + 0.9x \]

\[ n = 25 \]
\[ r = 0.99 \]


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Results of LVEF measurements plotted as differences between methods and analysis of agreement

Potential problems with LVEF

• Load dependency
• Measurement issues
  – Endocardial dropout
    • Overestimation of volume
  – Foreshortening of the ventricle
    • Underestimation of volume
    • less effect on EF
Potential pitfalls of EF measurement (continued)

– Geometric assumptions
  • Influence EF measure when LV distorted

– Regional dysfunction
  • Over or under-represented with some methods

– Paradoxical septal motion, other discoordinations of contraction
  • Underestimation of EF

– Heart rate effects
  • tachycardia

– reproducibility
### Left Ventricular Ejection Fraction

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015</strong></td>
<td>&gt;52</td>
<td>51-41</td>
<td>40-30</td>
<td>&lt;30</td>
</tr>
<tr>
<td><strong>2005</strong></td>
<td>&gt;55</td>
<td>54-45</td>
<td>44-30</td>
<td>&lt;30</td>
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</tbody>
</table>
## LV Ejection Fraction

<table>
<thead>
<tr>
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<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVEF</td>
<td>52-72</td>
<td>41-51</td>
<td>30-40</td>
<td>&lt;30</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LVEF</td>
<td>54-74</td>
<td>41-53</td>
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<td>&lt;30</td>
</tr>
</tbody>
</table>
LV Global Longitudinal Strain

Peak GLS in the range of -20% can be expected in a healthy person

- Low Flow AS
- Cardio-oncology
- Valvular Regurgitation
1. Normal or Hyperkinetic
2. Hypokinetic (reduced thickening)
3. Akinetic (absent or negligible thickening)
4. Dyskinetic (systolic thinning or stretching)

Despite promising data, quantitative assessment of the magnitude of regional LV deformation cannot be recommended at this stage because of lack of...
Perfusion Territories

Four chamber

Two chamber

Long axis

RCA
LAD
CX
RCA or CX
LAD or CX
RCA or LAD
Real-time 3D echo and automated border detection: assessment of LV volumes and EF
What if image quality inadequate?
Use contrast for LVO to assess LV global and regional function
Segmental Wall Motion

Without contrast

With contrast
Comparison with RNA of echo LV EF by Simpson’s method, fundamental or harmonic, contrast or non-contrast

Nahar et al, AJC 2000;86:1358
Interobserver Variability Lowered with Contrast Down to MRI Levels

Other measures of LV systolic function that do not rely on endocardial border delineation

- Isovolumic indices
  - \(\frac{dP}{dt}\)

- Ejection phase indices
  - Time interval (Doppler)
    - Tei index
  - M mode
    - Fractional shortening (FS)
    - Velocity of circumferential fiber shortening (Vcf)
Quantitation of global LV systolic function

- Isovolumic indices
  - \( \frac{dP}{dt} \)
    - Easy to measure – MR CW Doppler
    - Automated
    - Mean \( \frac{dP}{dt} \) correlates well but underestimates \( \frac{dP}{dt} \) max (\( \frac{dP}{dt} \) max depends on time of peak systolic pressure)
    - Instantaneous \( \frac{dP}{dt} \) accurate measure of \( \frac{dP}{dt} \) max

- MR must be present
- Maximum spectra must be recorded
  - Can use contrast to enhance weak signal
- Not truly isovolumic
Measuring mean dP/dT

- CW Doppler of MR
- Measure time interval for velocity to increase from 1 m/s to 3 m/s
- dP/dt = 32/t

Improved dP/dt after CRT

Fan et al, JASE 2004:17:553
dP/dt by echo for HF outcomes

Quantitation of global LV systolic function: Ejection phase indices

Doppler total ejection isovolume index

Tei index

- Doppler measure
- No geometric assumptions
- Less dependent on load
- Requires accurate IVRT, ET, ICT
- Pseudonormalization

\[
\text{Tei Index} = \frac{(\text{ICT} + \text{IRT})}{\text{ET}} = \frac{a - b}{b}
\]
Prognostic value of Tei Index in CHF

Cardiac amyloidosis
Tei et al, JACC 1996;28:658-64

Idiopathic dilated cardiomyopathy
Am J Cardiol 1998;82:1071-1076
2D strain without need for border delineation

tracking speckle with 2 ROIs

ROI 1

ROI 2

\[ y = 0.882x + 0.1413 \quad R^2 = 0.9918 \quad P<0.0001 \]

\[ y = 1.0537x + 0.9193 \quad R^2 = 0.9646 \quad P<0.0001 \]

Apical Rotational Mechanics

Courtesy of Manni Vannan, MD
Summary

– Quantitation of LVEF
  • 2D Biplane Simpson or 3D
  • Still the foundation of LV systolic function
  • limitations exist but it remains a trusted measure that has prognostic value

– Semi-quantitative assessment of regional LV function
  • Qualitative function, quantitative location and size

– Use of contrast to improve LV function assessment

– Specialized conditions may require novel measures (strain, speckel tracking, torsion)
Questions?