Chamber Quantitation Guidelines: What is New?

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CARDIAC IMAGING CENTER

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

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J AM Soc Echocardiogr 2005; 18:1440-1463
• Approximately 10,000 citations

iASE in iTUNE

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

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In Chinese ..........
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 based on consensus
• LV EF, LA, LA size and LV mass

Normal Reference Values for 2DE

• Seven data bases (Aklepios, Flemengho, Cardia5, Cardia 25, Padua 3D Echo Normal, Norre Study)
• No contrast studies
• Age, gender, ethnicity, height and weight
• NL BP, no diabetes, nl BMI, creatinine, glomerular filtration rate, cholesterol, LDL and triglicerides
Left Ventricle and Left Atrium

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

How do we Assess LV Function?

Qualitative Assessment

Eye ball
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).

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.

**TEICHOLZ Formula**

\[ V = \frac{7 \times D^3}{2.4 + D} \]

*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

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**LV Volumes by 2D**

**Biplane LV End-Systolic Volume**

**Biplane LV End-Diastolic Volume**

**Biplane disc’s summation**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV volumes normalized by BSA</td>
<td>Mean ± SD</td>
<td>2SD Range</td>
</tr>
<tr>
<td>LV end-diastolic volume, mL/m²</td>
<td>54 ± 10</td>
<td>34 - 74</td>
</tr>
<tr>
<td>LV end-systolic volume, mL/m²</td>
<td>21 ± 5</td>
<td>11 - 31</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 Segmentation

Left Ventricular Ejection Fraction

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

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
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<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LVEF</strong></td>
<td>52-72</td>
<td>41-51</td>
<td>30-40</td>
<td>&lt;30</td>
</tr>
</tbody>
</table>

Female

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Mildly</th>
<th>Moderately</th>
<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LVEF</strong></td>
<td>54-74</td>
<td>41-53</td>
<td>30-40</td>
<td>&lt;30</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 echocardio-
Why is 3D More Accurate?

Validation by MRI

EDV, ESV

Excellent correlation ($r^2 > 0.85$) but RT3DE underestimates volumes

Sources of error

- **Latex balloon:**
  - Mor-Avi V. et al, *JACC Cardiovasc Img* 2008: 1: 413-423

- **Human ventricles:**
  - Tracing error is the most important factor contributing to LV volume underestimation

**True volume:** 150 ml

Patient A

Patient B

**Advantages**
- Avoid image foreshortening
- No geometric assumptions
- More accurate and reproducible

**Disadvantages**
- Low temporal resolution
- Less data on normals

LV Volumes: 3DE
LV Mass

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV Mass/BSA, g/m²</td>
<td>49-115</td>
<td>43-95</td>
</tr>
<tr>
<td>RWT, cm</td>
<td>0.24-0.42</td>
<td>0.22-0.42</td>
</tr>
<tr>
<td>Septal WT, cm</td>
<td>0.6-1.0</td>
<td>0.6-0.9</td>
</tr>
<tr>
<td>PWT, cm</td>
<td>0.6-1.0</td>
<td>0.6-0.9</td>
</tr>
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2D Methods

- **Linear Method**
  - Direct measurement without geometrical assumptions about cavity shape and hypertrophy distribution
  - More accurate than the linear or the 2D measurements
  - Higher inter-measurement and test/retest reproducibility
  - Better discriminates small changes within a patient

- **Area Length**

- **Truncated ellipsoid**

LV Mass

- **Cubed Formula**

3D Methods

- Normal values less well established
- Dependent on image quality
- Patients cooperation required
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
LV Global Longitudinal Strain

Because of intervendor and intersoftware variability and age and load dependency, serial assessment of GLS in individual patients should be performed using the same vendor’s equipment and the same software. The preponderance of currently available data is for midwall GLS. There are concurrent definitions as a basis for GLS calculation using endocardial, midwall, or average deformation. This committee refrains from recommendations in this regard and refers to the ongoing joint standardization initiative of the ASE, EACVI, and the ultrasound imaging industry.

LV Segmentation: Regional Deformation

- Quantitative assessment of the magnitude of regional LV deformation is not recommended
  - lack of reference values
  - suboptimal reproducibility
  - considerable intervendor measurement variability
1. Normal or Hyperkinetic
2. Hypokinetic (reduced thickening)
3. Akinetic (absent or negligible thickening)
4. Dyskinetic (systolic thinning or stretching)
The Left Atrium

Reservoir  Conduit  Booster Pump

15-30% LV SV

Left atrial function – 3DE

LV Volume

Reservoir  Conduit  Booster

QRS  T  P
### Left atrial function

#### Table 1: Volumetric Indexes of LA Function

<table>
<thead>
<tr>
<th>LA Function</th>
<th>LA Volume Fraction</th>
<th>Calculation</th>
</tr>
</thead>
</table>
| Global function; reservoir   | LA EF (or total EF)        | \[
\frac{(L_{\text{max}} - L_{\text{min}})}{L_{\text{max}}} \]
| Reservoir function           | Expansion index            | \[
\frac{(L_{\text{max}} - L_{\text{min}})}{L_{\text{min}}} \]
| Conduit*                     | Passive EF                 | \[
\frac{(L_{\text{max}} - L_{\text{pre-A}})}{L_{\text{max}}} \]
| Booster pump                 | Active EF                  | \[
\frac{(L_{\text{pre-A}} - L_{\text{min}})}{L_{\text{pre-A}}} \]

- Conduit volume = LV SV – LA max – LA min
- Max = End-systole, just before mitral valve opening
- Min = End-diastole, when the mitral valve closes
- Pre-A = Immediately before atrial systole (p-wave)

Hoit BD. J Am Coll Cardiol 2014;63:493–505

### Left atrial function – 2DE

- 2D Speckle-tracking analysis

![Graph showing reservoir, conduit, and booster functions with different grades](Singh A, Addetia K...Lang RM ASE 2015)
LA Remodeling

Diastolic Dysfunction
Hypertension
Ischemia
Sleep Apnea
Mitral /aortic valve disease

Volume/Pressure Overload

LA Enlargement

Clinical Outcomes

• atrial fibrillation
• systolic heart failure
• diastolic dysfunction
• chronic coronary artery disease
• myocardial infarction
• mitral regurgitation
• systemic hypertension
• stroke
• hypertrophic cardiomyopathy
• renal failure

3D Echo for Assessing the Left Atrium

LA size has a powerful prognostic value in a variety of clinical conditions:

Assessment of Left Atrial Size/Volumes

**Diameters**
- M-mode
- 2D guided

**Area**
- 4Ch

**Volume**
- Calculated from 2D
- Measured by 3D
3D Echo for Assessing the Left Atrium

Assymetrical LA Remodelling

- LA enlargement does not occur uniformly in all directions
LA Volume

Accuracy of 2DE is limited:
- View-dependent
- Geometrical assumptions
- Measured on apical views optimized for LV

Left atrial volume on 2DE
Left atrial volume on 2DE

LA volume assessment on 2DE

LA axis

LV axis

View optimized for LV

View optimized for LA

LAVi 34.0 mL/m²

LAVi 38.4 mL/m²

ASE/EACVI Chamber Quantification Guidelines 2015
• LA volumes obtained from non-foreshortened LA-focused views correlated highly with those obtained from conventional A4C views \((r=0.94)\), but were larger (Bland Altman bias 7 ml, limits of agreement ±19 ml).
**LA Volume**

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<tr>
<td><strong>LA Vol/BSA</strong></td>
<td>16-28</td>
<td>29-33</td>
<td>34-39</td>
<td>&gt;40</td>
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<td>35-41</td>
<td>42-48</td>
<td>&gt;48</td>
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### 2DE vs. 3DE for LA Volume Quantification

![Graphs showing comparison between 2DE and 3DE for LA volume quantification.](image)

*Mor-Avi V, Lang RM et al.: Real-time 3D echocardiographic quantification of left atrial volume: Multicenter study for validation with magnetic resonance imaging. JACC Imaging 2012.*
Left atrial function

**Table 1**  Volumetric Indexes of LA Function

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<td>[\frac{(L_{a_{\text{max}}} - L_{a_{\text{min}}})}{L_{a_{\text{max}}}}]</td>
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<tr>
<td>Reservoir function</td>
<td>Expansion index</td>
<td>[\frac{(L_{a_{\text{max}}} - L_{a_{\text{min}}})}{L_{a_{\text{min}}}}]</td>
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<td>Passive EF</td>
<td>[\frac{(L_{a_{\text{max}}} - L_{a_{\text{pre-A}}})}{L_{a_{\text{max}}}}]</td>
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Left atrial function – 2DE

- 2D Speckle-tracking analysis

![Graph showing reservoir, conduit, and booster functions with strain values and grades 0 to 3.](Singh A, Addetia K..Lang RM ASE 2015)
Aorta

NCC
LCC
RCC

Hinge points
Hinge point plane = virtual ring
Hinge points

When: mid-systole: slightly larger and rounder
Where: mid right coronary cusp and the edge of the commissures between the LCC and NCC from inner edge to inner edge

Aortic Annulus Measurements
• Sinuses of Valsalva (End-diastole)
• Sino-tubular junction (End-diastole)
• Maximal diameter of the proximal Asc Ao (End-diastole)

Leading edge to leading edge
Aortic Root Measurements
(Sinus of Valsalva)
Summary

1. Reference ranges for left ventricular volumes and ejection fraction as well as LA volumes have changed in the recent guidelines due to the use of large echo databases.
2. Left ventricular wall motion scoring has changed to a 4-grade system.
3. Three-dimensional echocardiography is recommended for measurement of left and right ventricular volumes if possible.

4. If global longitudinal strain is being used to follow patients, it should be using the same vendors machine and analysis package.


Thanks for your attention