Guidelines for Chamber Quantification?

Roberto M Lang, MD

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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

Cardiac Chamber Quantification: What is New?

Eliminate discrepancies between previous guidelines

Database

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 Alfalho, MD, MSc, Anderson Armstrong, MD, MSc, Laura Emancio, MD, PhD, Frank A. Flachskampf, MD, FESC, Elyse Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denis 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; Creteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liege, and Ghent, Belgium; Boston, Massachusetts


In Chinese ...........

新版关于成人超声心动图心室定量方法的建议

写作小组成员： Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Alfalho, MD, MSc, Anderson Armstrong, MD, MSc, Laura Emancio, MD, PhD, Frank A. Flachskampf, MD, FESC, Elyse Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denis 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; Creteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liege, and Ghent, Belgium; Boston, Massachusetts.

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美国纽约艾伯特爱因斯坦医学院
中国上海交通大学附属仁济医院
美国内布拉斯加大学医学中心
中文校对： 中国山东大学医学院附属齐鲁医院
美国塔夫斯大学波士顿医学中心

过去10年科技的快速发展，以及这些新技术对超声心动图实践带来的变革进行全面更新，这正是美国超声心动图学会和欧洲心血管影像学会
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 (Asklepios, Flemengho, Cardia5, Cardia 25, Padua 3D Echo Normal, Norre Study)
- No contrast studies
- Age, gender, ethnicity, height and weight
- Nl BP, no diabetes, nI BMI, creatinine, glomerular filtration rate, cholesterol, LDL and triglicerides
RV ASSESSMENT: 3D Echocardiography

17 Countries

WASE Normal Values Study

Normal values anticipated for all 2D and 3D echo parameters including strain

Left Ventricle and Left Atrium
Eye ball

How do we Assess LV Function?

Qualitative Assessment

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

Left Ventricular Linear Measurement

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).
Left Ventricular Volumetric Measurement

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.

**TEICHHOLZ Formula**

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

*Am J Cardiol 1976;37:7–11*

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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

**Parameters**

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV volumes normalized by BSA</td>
<td>Mean ± SD</td>
<td>2SD</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

- **4-chamber view**
- **2-chamber view**
- **Long-axis view**
### Left Ventricular Ejection Fraction

<table>
<thead>
<tr>
<th></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>
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</tbody>
</table>

### LV Ejection Fraction

#### Male

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Mildly</th>
<th>Moderately</th>
<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF</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>LVEF</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 echocardiography.

**Why is 3D More Accurate?**

![Diagram showing why 3D is more accurate.](image)

True Apex vs. Foreshortening Error vs. Segmental Dilatation

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**Validation by MRI**


**Excellent correlation (r²>0.85)**

- But RT3DE underestimates volumes

**Sources of error**

- **Latex balloon:**
  - True volume: **150 ml**
  - 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
LV Volumes: 3DE

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

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

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**LV Mass**

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV Mass/BSA</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>
</tbody>
</table>

**2D Methods**

- Linear Method
- Area Length
- Cubed Formula
- Truncated ellipsoid

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV mass/BSA, g/m²</td>
<td>50-102</td>
<td>41-88</td>
</tr>
</tbody>
</table>
**LV Mass**

- 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

3D Methods

Normal values less well established
Dependent on image quality
Patients cooperation required

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**Relative Wall Thickness (RWT)**

\[ \text{RWT} = \frac{2 \text{PW TH}}{\text{LVIDd}} \]

- **Concentric Remodeling**
  - \( \leq 0.42 \)
- **Concentric Hypertrophy**
  - \( > 0.42 \)
- **Normal Geometry**
  - \( \leq 95 \text{ (♀)} \)
  - \( \leq 115 \text{ (♂)} \)
- **Eccentric Hypertrophy**
  - \( > 95 \text{ (♀)} \)
  - \( > 115 \text{ (♂)} \)

Left Ventricular Mass Index (gm/m²)

Lang RM, JASE 2005; 18: 1440-63
Peak GLS in the range of -20% can be expected in a healthy person

- Low Flow AS
- Cardio-oncology
- Valvular Regurgitation

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 inter-vendor measurement variability

1. Normal or Hyperkinetic
2. Hypokinetic (reduced thickening)
3. Akinetic (absent or negligible thickening)
4. Dyskinetic (systolic thinning or stretching)
Perfusion Territories

The Left Atrium

Left atrial function – 3DE

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)

Holt BD. J Am Coll Cardiol 2014;63:493-505
Left atrial function – 2DE

- 2D Speckle-tracking analysis

- Reservoir function
- Conduit function
- Booster function

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

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

Assessment of Left Atrial Size/Volumes

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

- **Area**
  - 4Ch

- **Volume**
  - Calculated from 2D
  - Measured by 3D

**TIME EVOLUTION**

3D Echo for Assessing the Left Atrium

**Assymetrical LA Remodelling**

- LA enlargement does not occur uniformly in all directions

**Time**
LA Linear Dimension

STOP

STOP AND THINK

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

Left atrial volume on 2DE

LAVi 34.0 mL/m²
LAVi 38.4 mL/m²
LA volume assessment on 2DE

Biplane method of disks

Single plane method of disks

Biplane area-length

Single plane area-length

\[ \frac{8}{3\pi} \left( \frac{A_1 \cdot A_2}{L} \right) \]

ASE/EACVI Chamber Quantification Guidelines 2015

3D Echo

Left atrial volume on 2DE

Biplane volume: 82 ml

Standard views

3D volume: 88 ml

3DE-derived views

Biplane volume: 87 ml

Atrial-focused views

3D volume: 88 ml
Left atrial volume on 2DE

- 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).

![Graph showing correlation between LAVI and LA volume](image)

V. Mor‐Avi, Addetia K and Lang RML work in progress

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<table>
<thead>
<tr>
<th>LA Vol/BSA</th>
<th>Normal</th>
<th>Mildly</th>
<th>Moderately</th>
<th>Severely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>16-28</td>
<td>29-33</td>
<td>34-39</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>


<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>16-34</td>
<td>35-41</td>
<td>42-48</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

2DE vs. 3DE for LA Volume Quantification

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

<table>
<thead>
<tr>
<th>LA Function</th>
<th>LA Volume Fraction</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global function; reservoir</td>
<td>LA EF (or total EF)</td>
<td>([\text{LA}<em>{\text{max}} - \text{LA}</em>{\text{mini}}]/\text{LA}_{\text{max}})</td>
</tr>
<tr>
<td>Reservoir function</td>
<td>Expansion index</td>
<td>([\text{LA}<em>{\text{max}} - \text{LA}</em>{\text{mini}}]/\text{LA}_{\text{min}})</td>
</tr>
<tr>
<td>Conduit</td>
<td>Passive EF</td>
<td>([\text{LA}<em>{\text{max}} - \text{LA}</em>{\text{pre-A}}]/\text{LA}_{\text{max}})</td>
</tr>
<tr>
<td>Booster pump</td>
<td>Active EF</td>
<td>([\text{LA}<em>{\text{pre-A}} - \text{LA}</em>{\text{min}}]/\text{LA}_{\text{pre-A}})</td>
</tr>
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- Conduit volume = LV SV – LA max – LA min
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Singh A, Addetia K...Lang RM ASE 2015

Aorta
Aortic Annulus Measurements

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

- 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.
Summary

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! @RobertoMLang