MAYON VOLCANO: FAST FACTS

Type of Volcano: Stratovolcano
Elevation: 2.46 km
Base Diameter: 20 km
Base Circumference: 62.8 km
Area: 314.1 km²

Sizing up the situation:
Cardiac Chamber Quantification using Echocardiography

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Philippine Society of Echocardiography
Session Outline

• Understanding the importance of correct chamber quantification techniques
• Knowing which aspects to quantify: chamber dimensions, parameters of function*
• Mastering the technique of quantification:** image optimization, basic strategies, tips and pitfalls

*Will not include RV assessment (separate session)
**2015 ASE/EACI Recommendations
Session Roadmap

Technical Tips

Key Insight
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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Main Reference: why update?

- Rapid flux of technological and methodological advances
- Clamor for “normative values”
- Existence of discrepancies between previous guidelines
- Need for general guidance across centers in the world
Importance of Chamber Quantification
Why measure?

• Measurements reduce doubt about size conclusions.
• Measurements can be compared objectively.
• Measurements transcend language barriers.
Why measure properly?

• Incorrect measurements lead to incorrect assumptions and conclusions
• Echo reports can greatly affect the end-users’ (physician, sonographer, laboratory, patient, community) decisions and behavior
• Harmonized and accurate techniques minimize variability and allow for comparison
Why measure chambers properly?

- Cardiac size is “important” to the lay
- Heart function is crucial to the physician
- Cardiomegaly may be the first clue to pathology
- Chamber size and function reflect hemodynamics and overall cardiac physiology
- Chamber dimensions on echo usually serve as reference standard for basic non-invasive imaging tests (e.g. electrocardiogram, chest radiograph)
Clinical implications of abnormal dimensions

• Left ventricular mass (LVM) can independently predict adverse cardiovascular events and premature death. \(^1\)\(^-\)\(^3\)
• LA size is a powerful prognostic factor independent of left ventricular systolic dysfunction during stress echo\(^4\) and in patients with preserved ejection fraction\(^5\)
• LV ejection fraction is a powerful predictor of mortality among patients with LV systolic dysfunction.

“The quantification of chamber size and function is the cornerstone of cardiac imaging.” -- ASE/EACI 2015
Where did my patient go???
Items to measure on echocardiography
What to quantify

- Chamber dimensions
- Global systolic function
- Regional function

- Left ventricle
- Right ventricle
- Atria
- Aortic territory
- Vena cava
What to quantify

LEFT VENTRICLE

- Cavity size: LVEDD, LVEDD indexed to BSA
- Wall thickness: IVSD, PWD, RWT
- Mass: LVM, LVMI
- Volumes: LVEDV, LVESV
- Systolic function: LVEF (biplane Simpson’s)
What to quantify

**LEFT ATRIUM**

- Length: LA length$_{4C}$, LA length$_{2C}$
- Area: LA area$_{4C}$, LA area$_{2C}$
- Volume: LAV, LAV indexed to BSA
What to quantify

AORTIC ROOT (diamters)

• LV outflow tract (LVOT)
• AV annulus
• Sinus of Valsalva (SOV)
• Sinotubular junction (STJ)
• Prox. Ascending aorta
The debate: thresholds for severity

- Partition values for severity of abnormality
- Normative data on classification of severity
- Standard cut-off

The resolution
- Experience-based partition values only for: LVEF and LA volume

Correct quantification techniques
General guidelines

• All measurements should be performed on more than 1 cardiac cycle (to account for interbeat variability)
  • e.g. average of 3 beats for sinus, and at least 5 beats for AF
  • However, the use of representative bets is acceptable in the clinical setting

• The same range of normal values generally apply for TTE and TEE, but certain views are more optimal in selected scenarios

• Range of normal values are provided for LV size, function and mass as well as LA volume,

• For other parameters, measurements exceeding +- 1.96 SDs should be classified as abnormal.

General guidelines

• Get basic clinical profile to come up with a pre-test analysis.

• Accurately measure the patient’s height and weight, and compute the body surface area.

• Check the patient’s rhythm and ensure a good ECG tracing.
Internal linear dimensions

- Linear dimensions are used to provide geometric conclusions about the left ventricle

Internal linear dimensions

- Two methods: M-mode approach and direct 2D measurement
- M-mode approach has high temporal resolution but is prone to tangentiality issues

Left ventricle: Size

Internal linear dimensions

- M-mode measurements guided by targeted SAX or PLAX view
- Simple for screening large populations
- Beam orientation may be off-axis
- Inaccurate in abnormal LV geometry

Left ventricle Size

Internal linear dimensions

- get good 2D PLAX view
- measure LVEDD at end-diastole, when MV leaflets are fully open
- draw caliper perpendicular to long axis of LV, at level of MV leaflet tips
- locate landmarks properly: endocardium-cavity interface

LV internal dimensions: directly measure on 2D PLAX

LV mass

- Perform all measurements at end-diastole
- 3 methods
  - Linear or Cube method
  - 2D truncated ellipsoid
  - 3D based formula

Cube formula

\[
LV \ mass = 0.8 \cdot 1.04 \cdot [(IVS + LVID + PWT)^3 - LVID^3] + 0.6 \ g
\]

LV mass

- Perform all measurements at end-diastole
- 3 methods
  - Linear or Cube method
  - 2D truncated ellipsoid
  - 3D based formula

Lang R et al. EHJ-Cardiovasc Imaging
Left ventricle Size

LV mass

• Perform all measurements at end-diastole
• 3 methods
  • Linear or Cube method
  • 2D truncated ellipsoid
  • 3D based formula

LV mass: 2D-guided, or 3D ideally

Left ventricle Size

LV mass index

- Reference values

Normal ranges for LV mass indices

<table>
<thead>
<tr>
<th>Method</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>67–162</td>
<td>88–224</td>
</tr>
<tr>
<td>LV mass/BSA (g/m²)</td>
<td>43–95</td>
<td>49–115</td>
</tr>
<tr>
<td>Relative wall thickness (cm)</td>
<td>0.22–0.42</td>
<td>0.24–0.42</td>
</tr>
<tr>
<td>Septal thickness (cm)</td>
<td>0.6–0.9</td>
<td>0.6–1.0</td>
</tr>
<tr>
<td>Posterior wall thickness (cm)</td>
<td>0.6–0.9</td>
<td>0.6–1.0</td>
</tr>
<tr>
<td>2D method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>66–150</td>
<td>96–200</td>
</tr>
<tr>
<td>LV mass/BSA (g/m²)</td>
<td>44–88</td>
<td>50–102</td>
</tr>
</tbody>
</table>

Bold italic values: recommended and best validated.

LV geometrical conclusions

• Based on:
  • LVMI
  • RWT
  • sex

LV geometry conclusion is important

Key Insight

LV linear dimensions provide information regarding geometrical conclusions.
Clinical scenario

- 45 male
- Hypertensive
- Non-adherent to meds
- Height: 1.5 m
- Weight: 60 kg
- BSA: 1.58 m$^2$
Sample Computations

**LV dimensions**

- LVEDD: 4.0 cm
- IVSD : 1.3 cm
- PWD : 1.6 cm
Sample Computations

LV dimensions

- LVEDD indexed to BSA
  
  \[ \text{LVEDD indexed to BSA} = \frac{4.0 \text{ cm}}{1.58 \text{ m}^2} = 2.5 \text{ cm/m}^2 \]

- RWT
  
  \[ \text{RWT} = \frac{1.6 \times 2}{4.0} = 0.80 \]
Sample Computations

LV dimensions
• LV mass
  = 0.8 x 1.04 \((\text{IVSD} + \text{LVEDD} + \text{PWD})^3 - \text{LVEDD}^3\) + 0.6 g
  = 0.8 x 1.04 \((1.3 + 4.0 + 1.6)^3 - 4.0^3\) + 0.6 g
  = 221 g
• LV mass index
  = \frac{\text{LV mass}}{\text{BSA}}
  = \frac{221 \text{ g}}{1.58 \text{ m}^2}
  = 140 \text{ g/m}^2

Patient data
• LVEDD: 4.0 cm
• IVSD : 1.3 cm
• PWD : 1.6 cm

Cube formula
\[
\begin{align*}
\text{LV mass} &= 0.8 \cdot 1.04 \cdot [(\text{IVS} + \text{LVID} + \text{PWT})^3 - \text{LVID}^3] + 0.6 \text{ g}
\end{align*}
\]

Sample Computations

LV geometrical conclusions

- Patient data:
  - 45 male
  - LVEDD: 4.0 cm (N)
  - $\text{LVEDD}_{\text{BSA}}$: 2.5 cm/m² (N)
  - LVMI: 140 g/m²
  - RWT: 0.8

Concentric LV hypertrophy

Left ventricle Size

Volumes

• Volumes are used for EF calculation

\[ EF = \frac{(EDV - ESV)}{EDV}. \]

Left ventricle Size

Volumes

- Two methods: using 2DE or 3DE
- Linear derivations based on geometric assumptions may be inaccurate
- Teichholz and Quinones methods are no longer recommended for clinical use

Left ventricle Size

Volumes: Biplane disk summation

- Corrects for shape distortions
- Apex frequently foreshortened
Left ventricle Size

Volumes: Area-length

• Partial correction for shape distortion
• Heavily based on geometrical assumptions

Left ventricle Size

Volumes: Endocardial enhancement

- Useful for suboptimal windows
- Acoustic shadowing in LV basal segments with excess contrast

Left ventricle Size

Volumes: 3D data sets

- No geometrical assumption
- Unaffected by foreshortening
- More accurate and reproducible
- Lower temporal resolution
- Image quality dependent

Global longitudinal strain

- Angle and vendor independent
- With established prognostic value

\[ \text{GLS(\%)} = \frac{\text{MLs} - \text{MLd}}{\text{MLd}}, \]

where ML is myocardial length at end-systole (MLs) and end-diastole (MLd).

Left ventricle: Global systolic function

2DE-derived LVEF

- Severity classification
- Adjusted for sex

LV systolic function: 2DE-derived LVEF (biplane Simpson’s formula) or 3D-derived, if applicable

<table>
<thead>
<tr>
<th>Normal Range</th>
<th>Mildly Abnormal</th>
<th>Moderately Abnormal</th>
<th>Severely Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52–72</td>
<td>41–51</td>
<td>30–40</td>
<td>&lt;30</td>
</tr>
<tr>
<td>16–34</td>
<td>35–41</td>
<td>42–48</td>
<td>&gt;48</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54–74</td>
<td>41–53</td>
<td>30–40</td>
<td>&lt;30</td>
</tr>
<tr>
<td>16–34</td>
<td>35–41</td>
<td>42–48</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

LV volumes are used to indicate systolic function via the ejection fraction.
Left ventricle: Regional function

LV segmentation

Left ventricle: Regional function

Correlation

Keep perfusion territories in mind when regional wall motion

When numbers do not fit, re-assess and correlate with visual estimation and clinical data.
Left atrial dimensions

**LA functions**
- Contractile pump
- Reservoir
- Conduit

**Echo uses of LA size**
- Diastolic function
- LV function
- Intracardiac pressure
- Valve lesions

TTE is preferred approach

Left atrial dimensions

Correlation

Left atrial dimensions

LA volumetric measurement

• Area-length
• Disc summation
• 3D volumes

Left atrial dimensions

Biplane area length method

• Enables accurate assessment of the asymmetric remodeling of the left atrium

• More robust predictor of cardiovascular events than linear or area measurements
Left atrial dimensions

Biplane area length method

LA volume index: biplane area-length is preferred

Left atrial dimensions

**LA volume index**

- 2006 cut-off: 28 ml/m²
- 2015 cut-off: 34 ml/m²
- much more studies to back up new cut-off

*Volume index is the preferred measure of LA size*

Key Insight

Take equally great care in measuring the LA size, since this will have several echo and clinical implications.
Right atrial dimensions

RA size measurement

• Less research and fewer clinical outcomes
• Apical 4 chamber view is preferred
• Diameters and volumes

Right atrial dimensions

RA size measurement

• Less research and fewer clinical outcomes
• Apical 4 chamber view is preferred
• Diameters and volumes

<table>
<thead>
<tr>
<th>Normal RA size obtained from 2D echocardiographic studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>RA minor axis dimension (cm/m²)</td>
</tr>
<tr>
<td>RA major axis dimension (cm/m²)</td>
</tr>
<tr>
<td>2D echocardiographic RA volume (mL/m²)</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD.

Right atrial dimensions

RA size measurement

• RA volume
• Calculated using single-plane area-length or disk summation techniques
• normal ranges
  • 25+7 mL/m² in men
  • 21+6 mL/m² in women

RA size: recommended parameter is RA volume

Aortic territory

General rules

• Get good long-axis view with a central AV coaptation point

• calcium protuberances should be considered as part of the lumen, not of the aortic wall, and therefore excluded from the diameter measurement

• AV annulus: Inner edge to inner edge technique

• Other parts: leading edge to leading edge

Aortic root dimensions

Correlation

- Annulus
- root

Aortic root dimensions

Proper measurement

AV annulus: Inner edge technique; the rest: leading edge technique

- AV annulus
- STJ
- Asc
- SOV

Aortic root dimensions

Optimize the view before taking aortic measurements.
Recap of Session Outline

• Understanding the importance of correct chamber quantification techniques
• Knowing which aspects to quantify: chamber dimensions, parameters of function
• Mastering the technique of quantification: image optimization, basic strategies, tips and pitfalls
Questions

• Sigmoid septum: how to address?
• HCM: how to report?
• When EF values differ: how to decide?
• When numbers and visual estimate contradict
• LV mass: when LVMI is increased, LVEDD and RWT are normal: how to conclude?
• RWT: double PWD or average IVSD and PWD?