Echocardiography: basics and illustrations

(Everything you always wanted to know about echocardiography, but were afraid to ask)

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VP Medical Director
SCOR Global Life Americas
Agenda

- Types of Echocardiography
- Common Indications for Echocardiography
- Anatomy (Basics)
- Reviewing the Report
  - Chamber dimensions
  - Valves
  - LV systolic and diastolic functions
  - LV regional wall motion
  - Right Ventricle function
  - Pulmonary pressure
  - Aortic Root
  - Pericardium
Types of echocardiography

- Transthoracic echocardiography (TTE)
  - M-mode
  - 2D
  - Doppler: Pulse wave, continuous wave, color
  - Tissue Doppler imaging

- Transesophageal echocardiography (TEE)

- Stress echocardiography (SE)

- Contrast echocardiography (CE)

- 3D echocardiography

- 2D strain or 2D speckle tracking
Main indications of echocardiography

<table>
<thead>
<tr>
<th>TTE</th>
<th>CAD, VHD, Cardiomyopathies, Heart failure, Congenital heart diseases, Aortic root, Pericardium, Prosthetic valves, Tumors, Thrombi, Endocarditis</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEE</td>
<td>TTE non diagnostic, VHD, Aortic root, Prosthetic valves, Thrombi, Endocarditis, Congenital heart diseases</td>
</tr>
<tr>
<td>SE</td>
<td>CAD, Aortic stenosis, HCM</td>
</tr>
<tr>
<td>CE</td>
<td>Shunts R-L, PFO, LVEF</td>
</tr>
<tr>
<td>3D</td>
<td>VHD, Heart failure, Congenital heart diseases</td>
</tr>
<tr>
<td>2D Strain</td>
<td>CAD, Heart failure</td>
</tr>
</tbody>
</table>
Healthy heart valves
The cardiac pump

RA

LV

RV

LA
Echocardiography doppler
Different views of transthoracic echocardiography

4 major windows to explore the heart and the aorta:

- **Parasternal window**: parasternal long and short axis.
- **Apical window**: 5, 4, 3 and 2 chambers views.
- **Subcostal window**: 4 chambers and short axis views.
- **Suprasternal window**: ascending, horizontal and beginning of descending aorta.
Long axis parasternal view
Echocardiography 2D (4 chambers apical view)
Echocardiography
CHAMBERS DIMENSIONS AND LVEF
Echocardiography 2D and TM (long axis parasternal view)
Fractional shortening and LVEF in Time Motion mode

\[
FS = \frac{\text{LVED } d - \text{LVES } d}{\text{LVED } d}
\]

\[
\text{LVEF} = \frac{\text{LVED vol} - \text{LVES vol}}{\text{LVED vol}}
\]
Linear trend for LVEF as a continuous variable and unadjusted all-cause mortality
Survival in coronary heart disease is related to LVEF

Importance of LVEF on MR prognosis

Source: Enriquez-Sarano, Circulation 1994;90:830-7
Pronostic factors of aortic insufficiency

Source: Chaliki. Circulation. 2002; 106: 2687
Recommendations for the echocardiographic assessment of LV size and function
LVEF: 2-D Simpson’s biplane method
Biplane method of discs or Volumes reduction method aka biplane Simpson’s method
Shortcomings of 2D LVEF

1. **Modest reproducibility**, as the exact imaging planes are difficult to recapture. As a rule of thumb, 2D LVEF changes of less than 10 percentage points between examinations do not necessarily represent an actual change in systolic function. This limits the usefulness of 2D LVEF in sequential follow-up of patients.

2. **LVEF depends on good imaging quality** for manual or automated tracking of endocardial border.

3. Even under optimal imaging conditions, LVEF can be an incomplete or even an incorrect estimate of LV function. This is especially true in **significant concentric remodeling**, hypertrophic cardiomyopathy or **small cavity size**, where there is significant systolic dysfunction with reduced stroke volume despite a normal or supranormal LVEF.

4. **LVEF is dependent on current loading conditions** and can be both over- and underestimated due to loading conditions. An example of this is the reduced preload in severe mitral regurgitation, which may cause increased LVEF due to significant regurgitation volume. The opposite might be true in severe aortic stenosis and other states with markedly increased afterload.

5. **Bradycardia** may cause an overestimation of LVEF due to increased stroke volume. Inversely, the reduced stroke volume in **tachycardia** or variable R–R interval of **atrial fibrillation** may lead to LVEF underestimation.
3D Echocardiography
3 D LV reconstruction volumetry
Speckle tracking imaging
Types of strain
LV contraction in 3 planes: longitudinal, radial, circumferential.
Myocardial strain: measurement of deformation

\[ \text{Strain (}\varepsilon\text{)} = \frac{L_1 - L_0}{L_0} \]

- \( L_0 \): initial length = 10 cm
- \( L_1 \): final length after deformation

- 8 cm: initial deformation
- 12 cm: final deformation

+20% increase
0% deformation

Strain rate : rate of strain change
Longitudinal Strain rate : normal
Cardio-oncology
Normal values and severity partition cutoff for 2DE derived LV size, LVEF, LV mass and LA size according to gender

<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>
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<tr>
<td><strong>LV dimension</strong></td>
<td></td>
<td></td>
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<tr>
<td>LV diastolic diameter (cm)</td>
<td>4.2–5.8</td>
<td>5.9–6.3</td>
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<tr>
<td>LV diastolic diameter/BSA (cm/m²)</td>
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<td>3.1–3.3</td>
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<td>LV systolic diameter (cm)</td>
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<td>LV systolic diameter/BSA (cm²/m²)</td>
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<td><strong>LV volume</strong></td>
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<td>LV diastolic volume/BSA (mL/m²)</td>
<td>34–74</td>
<td>75–89</td>
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<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>
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<tr>
<td>LV EF (%)</td>
<td>52–72</td>
<td>41–51</td>
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<tr>
<td><strong>LV mass by linear method</strong></td>
<td></td>
<td></td>
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<tr>
<td>Septal wall thickness (cm)</td>
<td>0.6–1.0</td>
<td>1.1–1.3</td>
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<tr>
<td>Posterior wall thickness (cm)</td>
<td>0.6–1.0</td>
<td>1.1–1.3</td>
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<tr>
<td>LV mass/BSA (g/m²)</td>
<td>49–115</td>
<td>116–131</td>
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<td><strong>LV mass by 2D method</strong></td>
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<tr>
<td>LV mass (g)</td>
<td>96–200</td>
<td>201–227</td>
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<tr>
<td>LV mass/BSA (g/m²)</td>
<td>50–102</td>
<td>103–116</td>
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<tr>
<td>Maximum LA volume/BSA (mL/m²)</td>
<td>16–34</td>
<td>35–41</td>
</tr>
</tbody>
</table>

Source: Journal of the American Society of Echocardiography January 2015
CAD : LV SEGMENTAL WALL MOTION
Typical distribution of coronary arteries
LV segmentation

1. Four chamber
   - Apical cap
   - Apical lateral
   - Mid inferoseptum
   - Basal inferoseptum

2. Two chamber
   - Apical cap
   - Apical inferior
   - Mid anterior
   - Basal inferolateral

3. Long axis
   - Apical cap
   - Apical lateral
   - Mid inferolateral
   - Basal anteroseptum

4. Base
   - Anterior
   - Anteroseptum
   - Inferolateral
   - Inferior

5. Mid
   - Anterior
   - Anteroseptum
   - Inferolateral
   - Inferior

6. Apex
   - Anterior
   - Septal
   - Lateral
   - Inferior
Stress Echocardiography

- Exercise or pharmacologic (dobutamine)

- Usually supine bicycle ergometer

- Procedure
  - Rest echocardiogram recorded
  - Exercise to maximal capacity
  - Move to supine within seconds before heart rate decreases
  - Record exercise echocardiogram within 60 seconds
  - Compare the images for regional wall motion changes

- Regional Wall abnormalities
  - normal or hyperkinetic - 1
  - Hypokinetic (reduced thickening) - 2
  - akinetic (absent or negligible thickening, e.g. scar) - 3
  - dyskinetic (moves paradoxically during systole) – 4
  - Aneurismal myocardium (remains deformed during diastole)

- Fall in EF or increase in LV ESV may indicate L Main or 3V disease
VALVULAR HEART DISEASES
Valves

Left Side
Mitral and Aortic

Right side
Tricuspid and Pulmonary

Stenosis – gradient & area

Regurgitation – size of jet

Both/Either – chamber enlargement/hypertrophy
Doppler echocardiography

- Doppler permits assessment of motion by using frequency shifts in ultrasound waves
- Frequency of returned ultrasound is higher when movement is toward the transducer
- Doppler can measure the motion of blood or the motion of tissue
- Color flow imaging displays flow toward the transducer in red and flows away from the transducer in blue, lighter shades depict higher velocities of flow
Severe mitral regurgitation
Aortic regurgitation
Quantification of an aortic valvular disease with Doppler

78 y, female, AP, syncope
Real time 3D imaging: High Volume Rate
Transesophageal 3D: normal mitral valve
DIASTOLIC FUNCTION
Pulsed Doppler of Mitral Inflow

- **E/A ratio**
  - (N.8 – 1.5) USU > 1
- **Isovolumetric relaxation time (IVRT)**
  - (N 70-90 ms)
- **Diastolic deceleration time (DDT) or DT**
  - (N 160-240 ms)

![Diagram of Doppler diastolic transmitral flow velocity](image)

- Atrial contraction
- Aortic valve closure
- Mitral valve opens
- Aortic valve opens

*UpToDate*
TDI of septal and lateral mitral annular velocities
Evaluation of diastolic function with preserved LVEF

In patients with normal LV EF

1. Average E/e’ > 14
2. Septal e’ velocity < 7 cm/s or Lateral e’ velocity < 10 cm/s
3. TR velocity > 2.8 m/s
4. LA volume index > 34 ml/m²

- <50% positive
  - Normal Diastolic function
- 50% positive
  - Indeterminate
- >50% positive
  - Diastolic Dysfunction

(J Am Soc Echocardiogr 2016;29:277-314.)
Evaluation of diastolic function with depressed LVEF

Mitral Inflow

- E/A ≤ 0.8 + E ≤ 50 cm/s
- E/A > 0.8 - <2

3 criteria to be evaluated

2 of 3 or 3 of 3
Negative

1. Average E/e’ > 14
2. TR velocity > 2.8 m/s
3. LA Vol. index > 34 ml/m²

Positive

When only 2 criteria are available

2 negative

1 positive and 1 negative

2 positive

Normal LAP
Grade I Diastolic Dysfunction

Cannot determine LAP and Diastolic Dysfunction

Grade*

↑ LAP
Grade II Diastolic Dysfunction

↑ LAP
Grade III Diastolic Dysfunction

If Symptomatic
Consider CAD, or proceed to diastolic stress test

(J Am Soc Echocardiogr 2016;29:277-314.)
LV MASS AND LVH
Left Ventricular Hypertrophy

Is there a secondary cause?
- Hypertension,
- Aortic or mitral lesion

Is it symmetric?

Echo: measured during diastole
- Intraventricular septum (IVSd)
- Posterior Wall (LVPWd)

Septal/posterior wall thickness should be ≤ 1.4
Otherwise consider asymmetric septal hypertrophy (type of HCM)
Normal ranges for LV Mass indices

<table>
<thead>
<tr>
<th></th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linear method</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>67–162</td>
<td>88–224</td>
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<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><strong>2D method</strong></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.

Consider the diagnosis of Hypertrophic Cardiomyopathy if LV wall thickness $\geq 15$ mm, without obvious cause (Athlete’s Heart, HBP, valve disorder, etc.), or if there is a history of syncope, arrhythmia, family history of sudden death or heart failure, or a strain pattern (ST depression and T Wave inversion) on the ECG. The hypertrophy is asymmetric (septal/posterior wall thickness $\geq 1.4$) or concentric or apical.
Hypertrophic obstructive cardiomyopathy
PULMONARY ARTERY SYSTOLIC PRESSURE (PASP)
Estimating Pulmonary Artery systolic pressure (PASP)

Echocardiography uses Doppler ultrasound to estimate the pulmonary artery systolic pressure. The maximum tricuspid regurgitant jet velocity (TRV) is recorded and the right atrial pressure (RAP) is estimated from the size and variation of flow in the inferior vena Cava. The pulmonary artery systolic pressure (PASP) is then calculated using simplified Bernoulli equation:

$RVSP = (4 \times [TRV]^2) + RAP$

In the absence of a gradient across the pulmonic valve or RVOT, PASP = RVSP
Estimation of RA pressure on the basis of IVC diameter and collapse

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal (0-5 [3] mm Hg)</th>
<th>Intermediate (5-10 [8] mm Hg)</th>
<th>High (15 mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC diameter</td>
<td>≤2.1 cm</td>
<td>≤2.1 cm</td>
<td>&gt;2.1 cm</td>
</tr>
<tr>
<td>Collapse with sniff</td>
<td>&gt;50%</td>
<td>&lt;50%</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>Secondary indices of elevated RA pressure</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Restrictive filling</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Tricuspid E/E' &gt; 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Diastolic flow predominance in hepatic veins (systolic filling fraction &lt; 55%)</td>
</tr>
</tbody>
</table>

*(J Am Soc Echocardiogr 2010;23:685-713.)*
### Pulmonary artery systolic pressure estimates in normal subjects

**TABLE 4. Reference Ranges for RV to RA Pressure Gradient and PASP**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women (n=2065)</th>
<th>Men (n=1147)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RV to RA Gradient, mm Hg</td>
<td>PASP†, mm Hg</td>
</tr>
<tr>
<td></td>
<td>Mean±SD</td>
<td>95% CI</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>856</td>
<td>16.4±4.0</td>
</tr>
<tr>
<td>20 to 29</td>
<td>669</td>
<td>16.8±3.9</td>
</tr>
<tr>
<td>30 to 39</td>
<td>650</td>
<td>17.5±4.2</td>
</tr>
<tr>
<td>40 to 49</td>
<td>494</td>
<td>18.7±4.5</td>
</tr>
<tr>
<td>50 to 59</td>
<td>344</td>
<td>19.8±4.9</td>
</tr>
<tr>
<td>≥60</td>
<td>199</td>
<td>21.3±5.5</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>645</td>
<td>16.7±4.5</td>
</tr>
<tr>
<td>20 to &lt;25</td>
<td>1464</td>
<td>17.6±4.2</td>
</tr>
<tr>
<td>25 to &lt;30</td>
<td>753</td>
<td>18.5±4.7</td>
</tr>
<tr>
<td>30 to &lt;35</td>
<td>241</td>
<td>19.9±5.2</td>
</tr>
<tr>
<td>≥35</td>
<td>95</td>
<td>20.8±4.8</td>
</tr>
<tr>
<td>All</td>
<td>3212</td>
<td>17.9±4.6</td>
</tr>
</tbody>
</table>

*After exclusion of subjects (n=578) potentially at higher risk of pulmonary hypertension on the basis of clinical referral categories (Table 3); †assuming RA pressure=10 mm Hg.*
Regional Assessment of RV Systolic Function

- TAPSE (Tricuspid annular plane systolic excursion) or TAM (Tricuspid Annular Motion). The systolic movement of the base of the RV free wall provides one of the most visibly obvious movements on normal echocardiography: a method to measure the distance of systolic excursion of the RV annular segment along its longitudinal plane, from a standard apical 4-chamber window. A TAPSE cutoff value < 17 mm yielded high specificity, though low sensitivity to distinguish abnormal from normal subjects.
AORTIC ROOT
1. Aortic valve annulus
2. The sinuses of Valsalva
3. The sino-tubular junction
4. The proximal ascending aorta

Aortic root dimensions

**Figure 13** The 95% confidence intervals for aortic root diameter at sinuses of Valsalva on the basis of BSA in children and adolescents (A), adults aged 20 to 39 years (B), and adults aged ≥40 years (C). Reprinted with permission from Roman et al. 195

**Table 14** Aortic root dimensions in normal adults

<table>
<thead>
<tr>
<th>Aortic Root</th>
<th>Absolute values (cm)</th>
<th>Indexed values (cm/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Annulus</td>
<td>2.6 ± 0.3</td>
<td>2.3 ± 0.2</td>
</tr>
<tr>
<td>Sinuses of Valsalva</td>
<td>3.4 ± 0.3</td>
<td>3.0 ± 0.3</td>
</tr>
<tr>
<td>Sinotubular junction</td>
<td>2.9 ± 0.3</td>
<td>2.6 ± 0.3</td>
</tr>
<tr>
<td>Proximal ascending aorta</td>
<td>3.0 ± 0.4</td>
<td>2.7 ± 0.4</td>
</tr>
</tbody>
</table>

Adapted from Roman et al. 195 and Hiratzka et al. 204

## Risk of complications (rupture, dissection, death) by aortic diameter and BSA

<table>
<thead>
<tr>
<th>AO/BSA</th>
<th>3.5</th>
<th>4.0</th>
<th>4.5</th>
<th>5.0</th>
<th>5.5</th>
<th>6.0</th>
<th>6.5</th>
<th>7.0</th>
<th>7.5</th>
<th>8.0</th>
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<tr>
<td>1.3</td>
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<td>3.85</td>
<td>4.23</td>
<td>4.62</td>
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<td>3.67</td>
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<td>1.60</td>
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<td>1.70</td>
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<td>2.65</td>
<td>2.94</td>
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<td>1.80</td>
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<td>1.60</td>
<td>1.80</td>
<td>2.00</td>
<td>2.20</td>
<td>2.40</td>
<td>2.60</td>
<td>2.80</td>
<td>3.00</td>
<td>3.20</td>
</tr>
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</table>

- **Low risk (1%/y)**
- **Moderate risk (8%/y)**
- **Severe risk (20%/y)**
Indications for surgery in aortic root disease (whatever the severity of AR)

<table>
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<tr>
<th>Class</th>
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<td>IIa</td>
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</table>

Surgery is indicated in patients who have aortic root disease with maximal ascending aortic diameter ≥ 50 mm for patients with Marfan syndrome.

Surgery should be considered in patients who have aortic root disease with maximal ascending aortic diameter:
- ≥ 45 mm for patients with Marfan syndrome with risk factors,
- ≥ 50 mm for patients with bicuspid valve with risk factors,
- ≥ 55 mm for other patients.
PERICARDIUM
Pericardial effusion
Things I routinely check on the Echocardiogram report

- Interpretation

- Ejection Fraction (EF): Simpson’s method

- Chamber sizes
  - LAVI or diameter of LA
  - LV dimensions in diastole and systole
  - Wall thickness (IVSd, LVPWd)
  - RV dimensions

- Valve gradients, area if stenosis, and/or regurgitant jets (if abnormal)

- LV mass

- E/A ratio
  - E/e’ if abnormal

- RVSP
THANK YOU!