Echo Assessment of the Left Ventricle

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Review Question #1

- Measurement of end-diastolic LV internal diameter (LVIDd) made by properly-oriented M-Mode techniques in the Parasternal Long Axis View (PLAX):

  A. Are identical to those made from 2D images
  B. Are larger than those made from 2D images
  C. Are less discrepant from 2D measures with advancing age
  D. Are identical if trailing edge to leading edge convention is used
  E. Are completely unreliable compared to 2D measurements

Review Question #2

- In males, the geometric pattern of left ventricular "concentric remodeling" is present when:

  A. LVMI ≤ 115 g/m^2 and RWT ≤ 0.42

  B. LVMI >115 g/m^2 and RWT >0.42

  C. LVMI ≤ 115 g/m^2 and RWT >0.42

  D. LVMI >115 g/m^2 and RWT ≤ 0.42

  E. LVMI ≤ 115 g/m^2 and RWT <0.34

Review Question #3

- "Volumetric" measurements of LV cavity size (Simpson's Method) are considered superior to strictly "Linear" techniques (Rotational Ellipse) because:

A. Small errors in linear measurements are greatly magnified by squaring terms in linear techniques.

B. Complex mathematical modeling of volumetric techniques insures precision

C. Linear measurement techniques were developed for M-mode echocardiography and have decreased accuracy when applied to 2D echocardiography.

D. Volumetric techniques directly measure volumes, whereas linear techniques measure only length and width

E. Volumetric techniques correct for shape distortions better than linear techniques.

Basic Assessment of the LV

- Ventricular Chamber Size
  - Chamber Dimensions
  - Chamber Volume
- Ventricular Muscle Mass
  - Ventricular Wall Thickness
  - Myocardial Hypertrophy
  - Ventricular Geometry
- Ventricular Function
  - Systolic
  - Diastolic

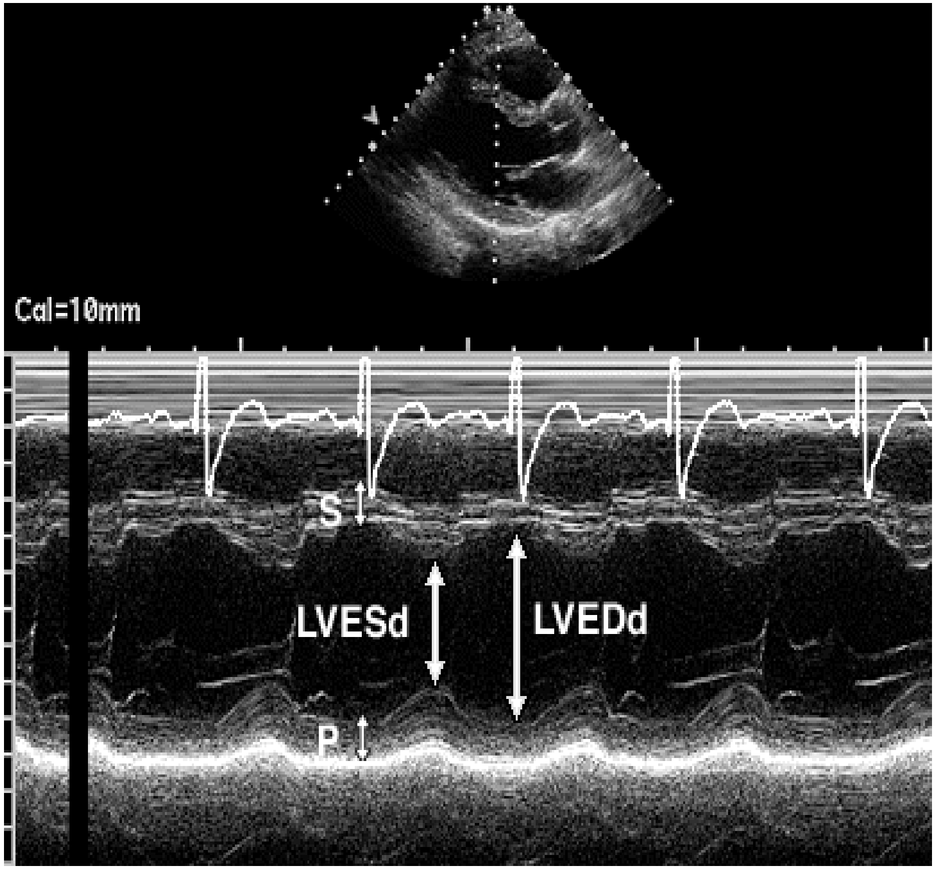
Measuring Chamber Dimensions

- M-Mode
  - 2D guided M-mode in PLAX vi
  - Leading edge to le ention

Strongly Recommended
by 2015 Guidelines!!

- 2-Dimensional
  - Useful in cases of off-axis M-mode
  - Requires good endocardial definition

Standard M-mode Assessment



- Use "leading edge" to "leading edge" convention
- 2D guidance to orient M-mode perpendicular to LV

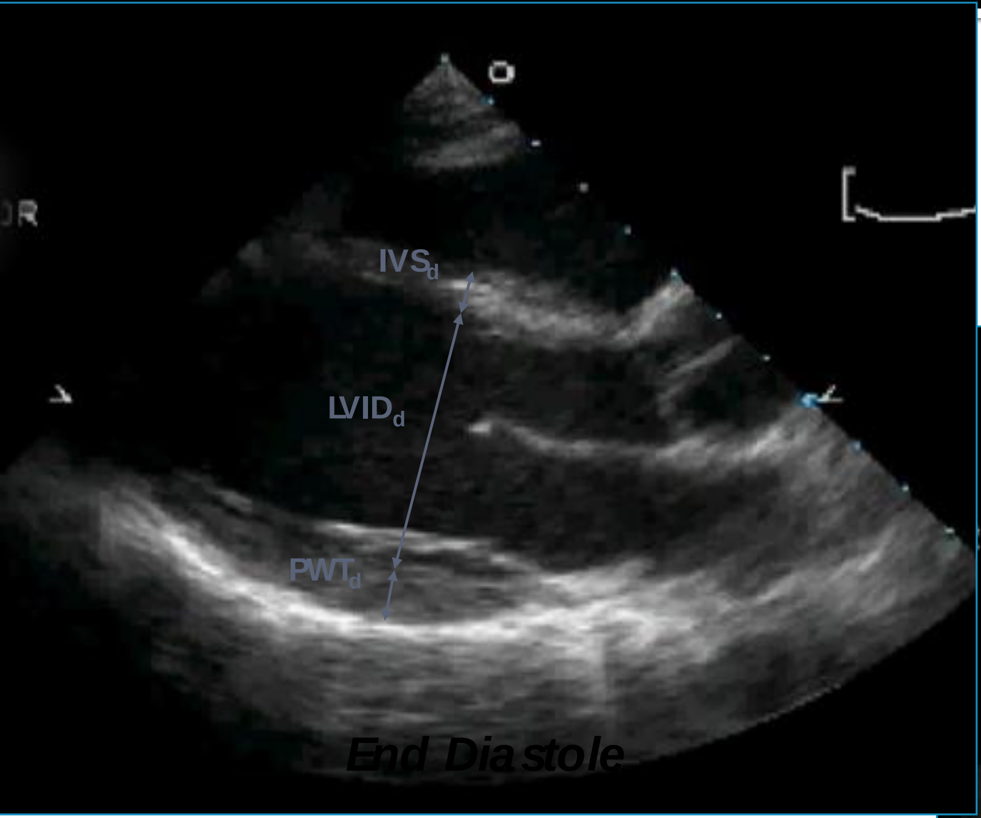
Normal M-mode Measurements

- IVS_d = <1.1 cm
- $LVID_d$ = <5.6 cm
- PWT_d = <1.1 cm
- $LVID_s$ = variable

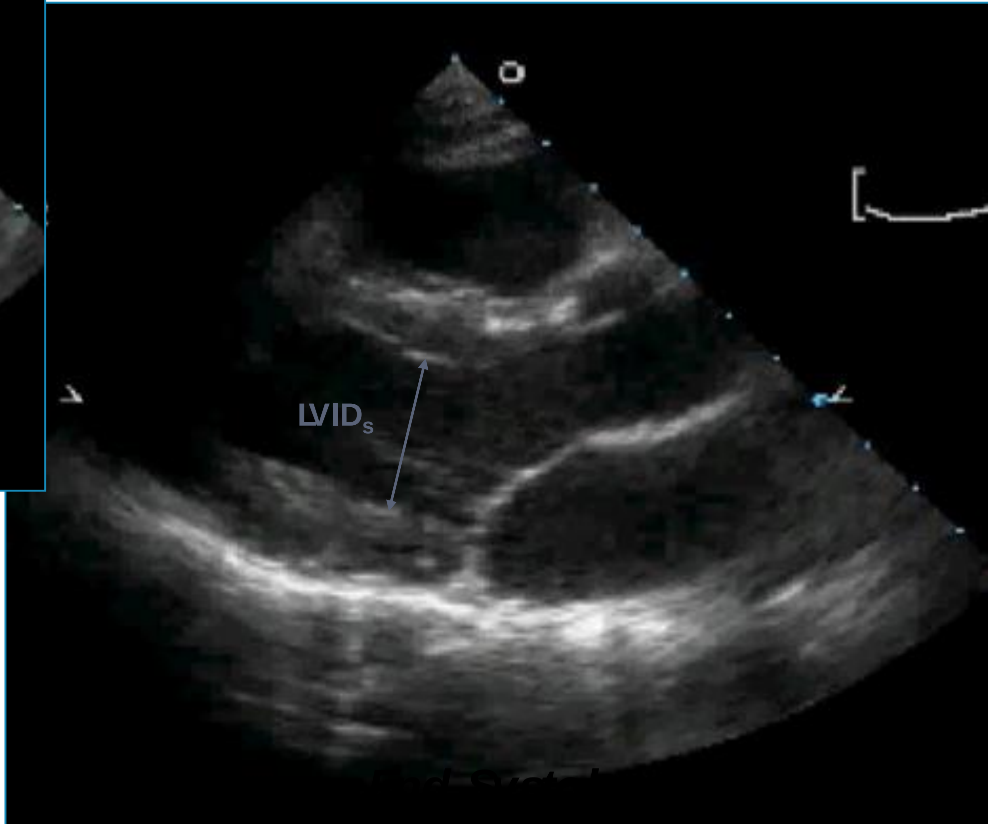
2D Measurements

- Measured in freeze-frame
  - **End-diastole –**
    - "First frame after mitral valve closure" ***or***
    - "Frame in which LV diameter is the largest"
  - **End-systole –**
    - "First frame after aortic valve closure" ***or***
    - "Frame in which LV dimension is smallest"
- Ideally in **PLAX view**
  - PSAX only if positioned perpendicular

2D Measurements



What Criterion did I use?



What are "normal" measurements?

Supplemental Table 3 Normal ranges and severity partition cutoff values for 2DE-derived LV size, function and mass

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV dimension								
LV diastolic diameter (cm)	4.2–5.8	5.9–6.3	6.4–6.8	>6.8	3.8–5.2	5.3–5.6	5.7–6.1	>6.1
LV diastolic diameter/BSA (cm/m^2)	2.2–8.0	3.1–3.3	3.4–3.6	>3.6	12.3–3.1	3.2–3.4	3.5–3.7	>3.7
LV systolic diameter (cm)	2.5–4.0	4.1–4.3	4.4–4.5	>4.5	2.2–3.5	3.6–3.8	3.9–4.1	>4.1
LV systolic diameter/BSA (cm/m^2)	1.3–2.1	2.2–2.3	2.4–2.5	>2.5	1.3–2.1	2.2–2.3	2.4–12.6	>2.6

Lang R, et al. J Am Soc Echo (2015)

LV Fractional Shortening

- Measurement of systolic function
  - Calculated from M-mode dimensions

$$= \frac{LVID_d - LVID_s}{LVID_d} \times 100$$

  - Normal ≥ 25%
  - Inherently limited
    - Assessing 3D function using 1dimensional measurement
    - Inaccurate in presence of regional wall motion abnormalities especially at the apex

Volume Measurements

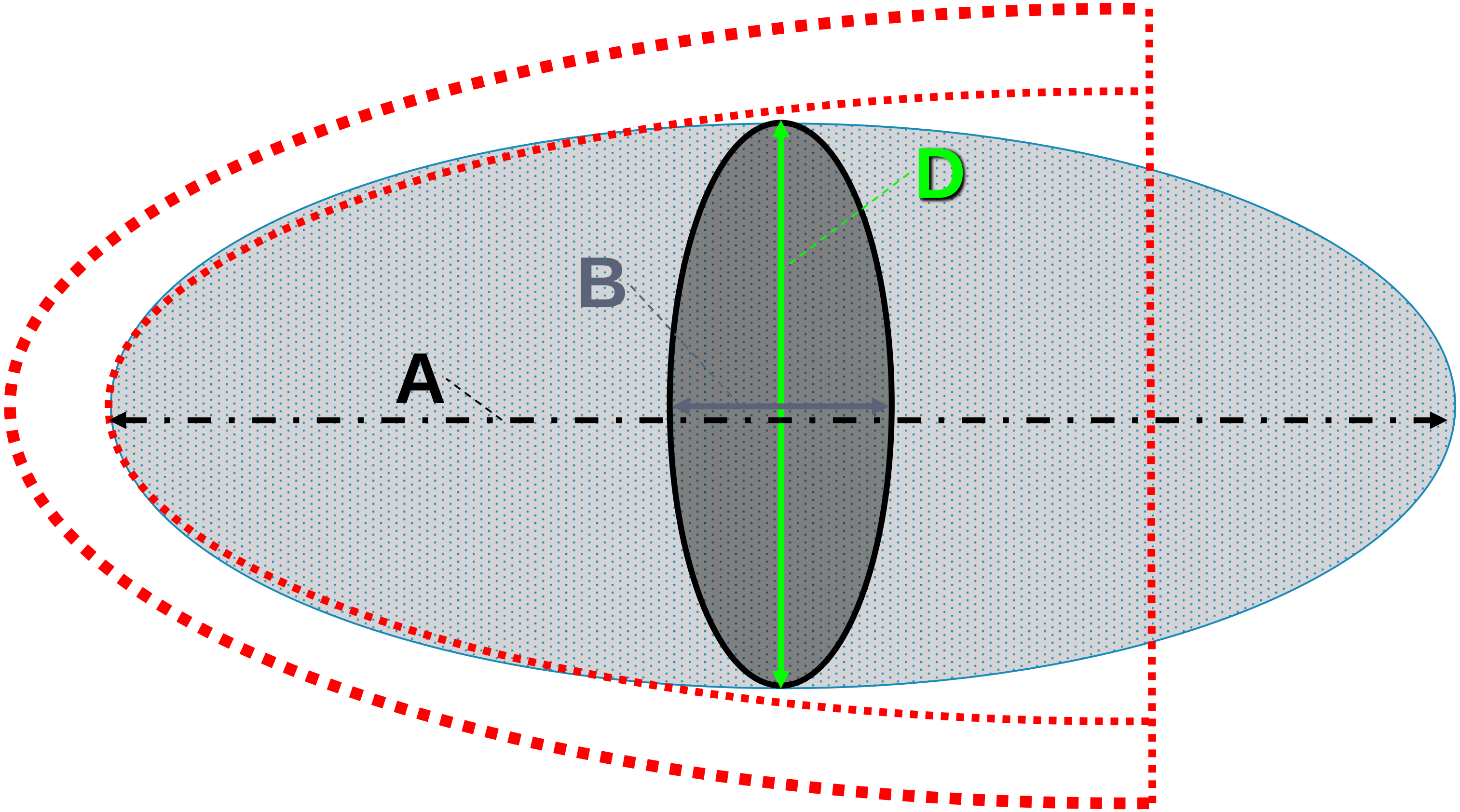
- More accurate assessment of LV size
- LV Ejection Fraction (%) can be calculated
- 2D Techniques – based on geometric assumptions
  - Simple assumptions - easier to use but less accurate
  - Complex assumptions - more accurate but less easy to use
- 3D Techniques – very accurate
  - As yet, infrequently utilized in clinical practice

Geometric Assumptions

- All are based on assumption of symmetry
- Neglects focal abnormalities
- More complex geometric models are the most accurate
  - Rotational Ellipse
  - Prolate Ellipse - Bullet shape

LV Cavity Volume

Rotational Ellipse



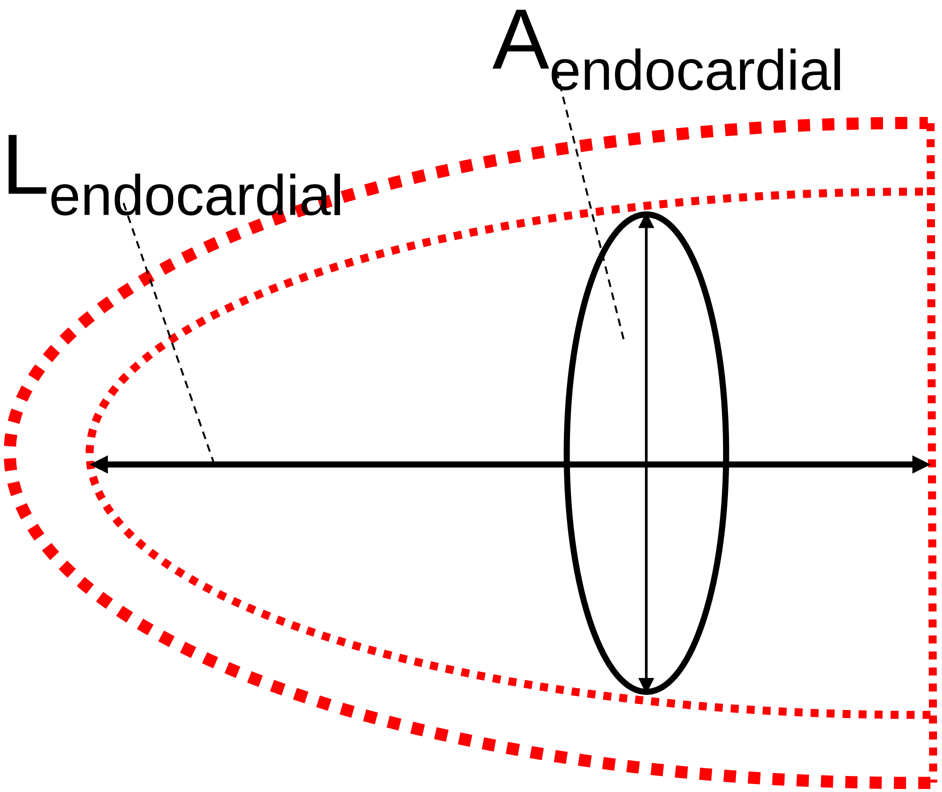
$$\text{Volume} = 4/3\pi * A * B * D \xrightarrow{\text{can be simplified to}} \boxed{\text{Volume} \approx D^3}$$

LV Cavity Volume
Rotational Ellipse

$$Volume \approx D^3$$

- Simplest geometric approximation
- Can be calculated using M-mode only
- Not accurate with abnormal LV shape
- Large-scale / epidemiologic studies
  - Framingham and other large-scale population studies (M-mode!!)

LV Cavity Volume
Area - Length Approximation



- Volume ≈ 5/6 * $Area_{(SAX)}$ * $Length_{(apical)}$

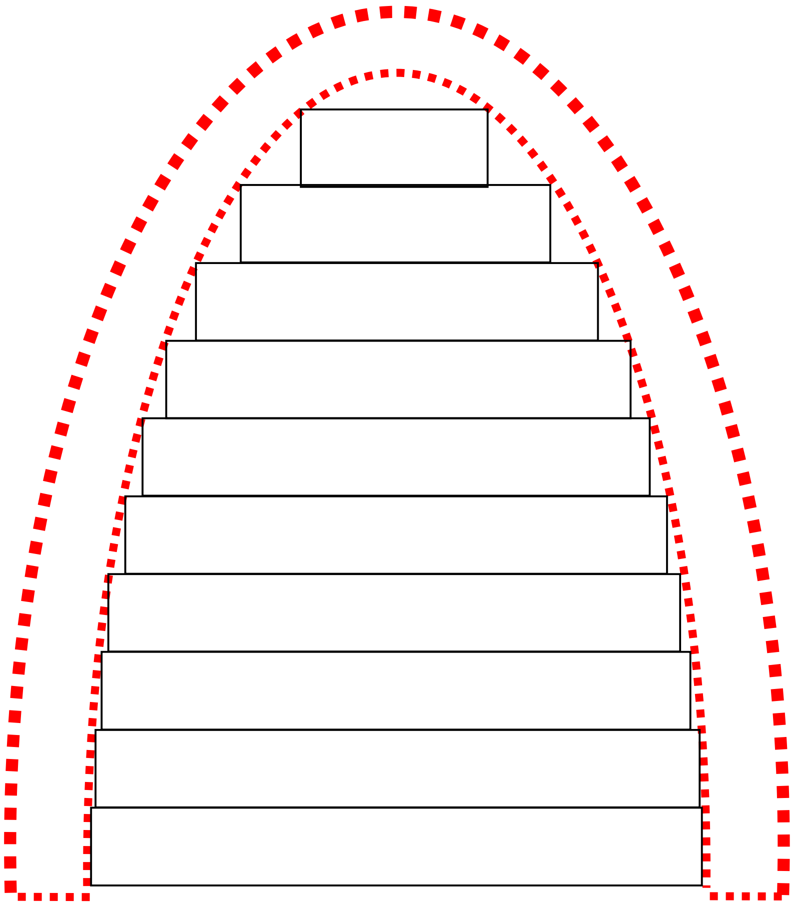
Simpson's "Method of Discs"

- Eliminates need for (most) geometric assumptions
- Volume of **asymmetric ventricle** can be calculated
- Ejection fraction can be easily calculated
- "Old Days" – off-line computer analysis
  - Now? On-line on digital systems

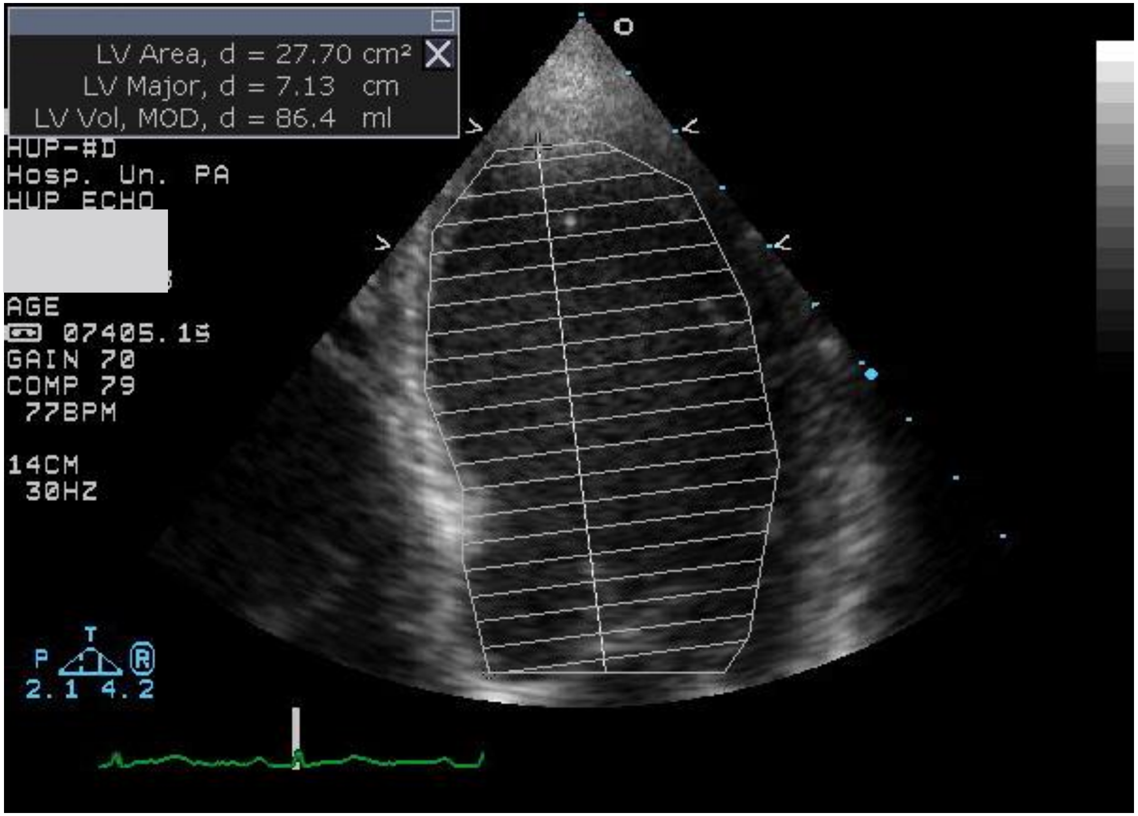
LV Volume

Simpson's Rule or "Method of Discs" (MOD)

- Subdivide LV:
  - series of discs
    - finite thickness
    - measurable area
- Disc volume =
  - ∏ * r² * h
- Sum of disc volumes = LV volume



On-line LV volume calculation
Simpson's method of disks



LV Volume

Simpson's Rule or "Method of Discs" (MOD)

- Most accurate LV volume
  - Particularly with abnormal LV shape
- Apical 4 Chamber + Apical 2 Chamber
  - **Biplane** approximation is best

Reference Range for Volumes

Supplemental Table 3 Normal ranges and severity partition cutoff values for 2DE-derived LV size, function and mass

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV volume								
LV diastolic volume (mL)	62–150	151–174	1175–200	>200	46–106	107–120	121–130	>130
LV diastolic volume/BSA (mL/m^2)	84–74	75–89	90–100	>100	29–61	62–70	71–80	>80
LV systolic volume (mL)	21–61	62–73	74–85	>85	14–42	43–55	56–67	>67
LV systolic volume/BSA (mL/m^2)	11–31	32–38	39–45	>45	8–24	25–32	83–40	>40

Lang R, et al. J Am Soc Echo (2015)

LV Ejection Fraction

- Use LV Volumes
  - LVEDV = End Diastolic Volume
    LVESV = End Systolic Volume

$$EF\,(\%) = \frac{LVEDV - LVESV}{LVEDV} \times 100$$

- Can use any LV volume technique
  - Simpson's Method of Discs is preferred

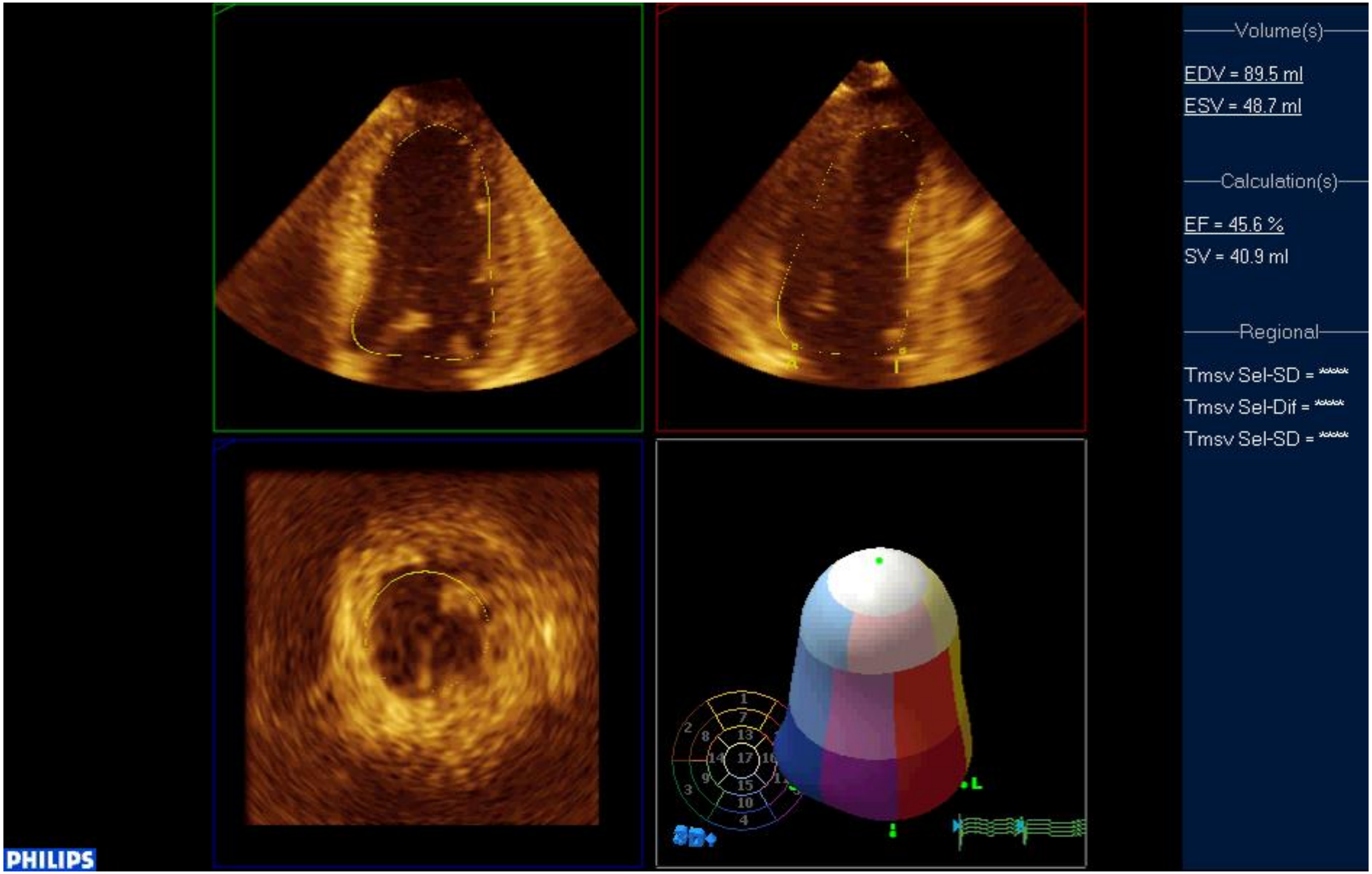
Reference Range for EF (%)

Table 4 Normal ranges and severity partition cutoff values for 2DE-derived LV EF and LA volume

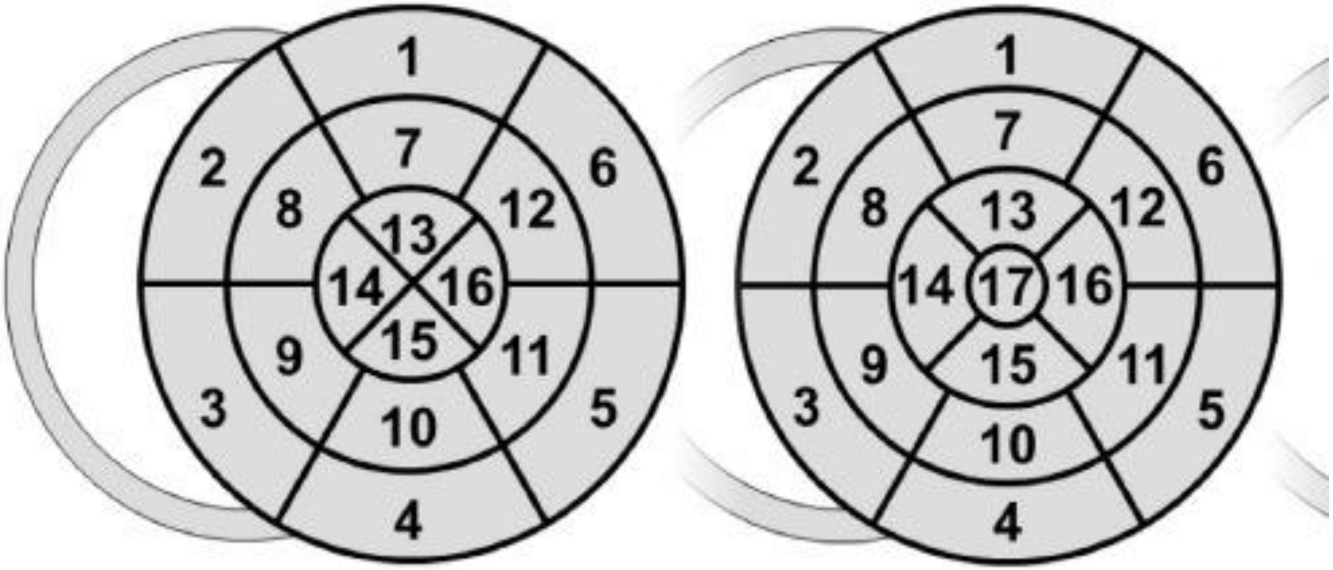
	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
LV EF (%)	52–72	41–51	30–40	<30	54–74	41–53	30–40	<30

Lang R, et al. J Am Soc Echo (2015)

3D Volumes & Ejection Fraction



Regional Wall Motion



all models

1. basal anterior
2. basal anteroseptal
3. basal inferoseptal
4. basal inferior
5. basal inferolateral
6. basal anterolateral

7. mid anterior
8. mid anteroseptal
9. mid inferoseptal
10. mid inferior
11. mid inferolateral
12. mid anterolateral

16 and 17 segment model

13. apical anterior
14. apical septal
15. apical inferior
16. apical lateral

17 segment model only

17. apex

You will hear about this in detail during Stress Echo Lectures

LV Mass

- Left Ventricular Hypertrophy
  - "Abnormal" increase in LV mass
  - Important prognostic indicator

- Basic concept for measurement:

LV Mass = Mass of Cardiac Muscle

Cardiac Muscle Mass = Volume of Muscle * Specific Gravity of Muscle

Cardiac Muscle Mass = $(LV\ Vol_{epi} - LV\ Vol_{endo}) * 1.05\ g/cm^3$

LV Mass

- Using Rotational Ellipse:
  - $[(IVS_d+LVID_d+PWT_d)^3 - (LVID_d)^3] * 1.05$
- Using Area-Length:
  - $[(5/6*Area_{epi}*L_{epi}) - (5/6*Area_{end}*L_{end})] * 1.05$
- Simpson's "Method of Discs"
  - **NOT USED!!!** **Cannot define all epicardial surfaces**

LV Hypertrophy

- Adaptive response
  - Volume and/or Pressure overload
  - Wall thickening normalizes LV wall stress
    - Optimizes myocardial oxygen consumption
- Increase in Myocyte mass
  - No change in myocyte number

LV Hypertrophy
Intrinsically Abnormal Process

- Abnormal myocardium
  - Fetal / alternate protein isomers
  - Abnormal subcellular organelles
  - Decreased capillary density
- Abnormal systolic / diastolic function
  - Subclinical initially
  - Ultimately leads to CHF

LVH Criteria

What qualifies as "Abnormal"?

Gender	M-Mode Derived	2D Derived
Male	>115 g/m^2	>102 g/m^2
Female	>95 g/m^2	>88 g/m^2

LVH Criteria
Clinical Practice

- Based on 2D wall thickness only:
  - Normal = < 1.1 cm
  - Mild LVH = 1.1 - 1.2 cm
  - Moderate LVH = 1.2 - 1.4 cm
  - Severe LVH = > 1.4 cm

LaPlace Equation

- Wall stress =

$$\frac{\text{pressure x radius}}{\text{wall thickness}}$$

- Index of LV function
- Approximates afterload

LV Geometry in LVH
Beyond Simple Mass

- Hypertrophy minimizes wall stress:

$$T_w \approx \frac{P * R}{h}$$

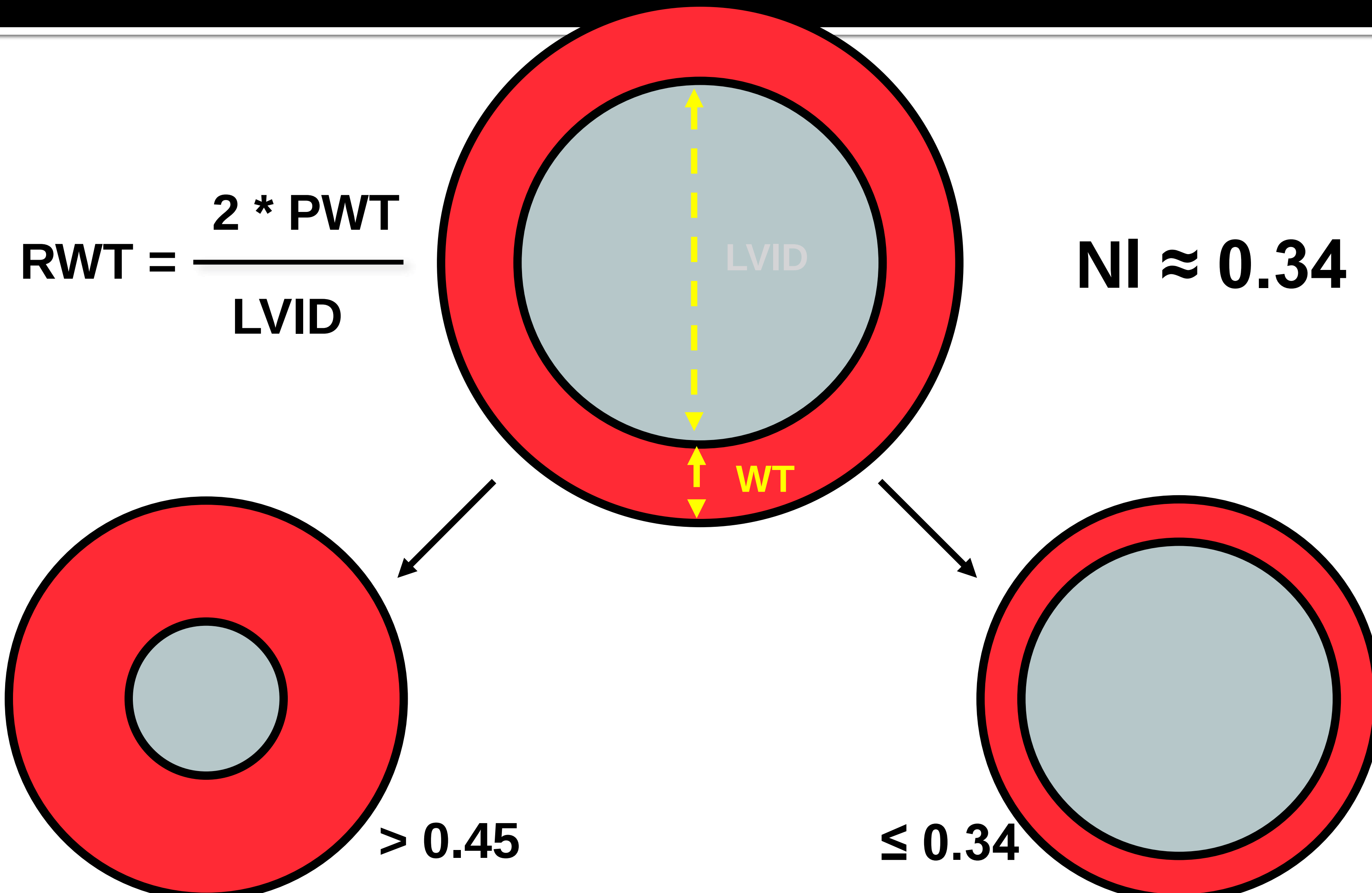
P = Intracavitary Pressure
R = Chamber Radius
h = Ventricular Wall Thickness

  - ⬆ Wall thickness (h) in BOTH pressure or volume load
  - ⬆ Cavity radius (R) in volume load

- Different loads create different geometry
  - Reflected by "Relative Wall Thickness"

Relative Wall Thickness

$$RWT = \frac{2 * PWT}{LVID}$$



Pressure Overload:
Concentric Hypertrophy

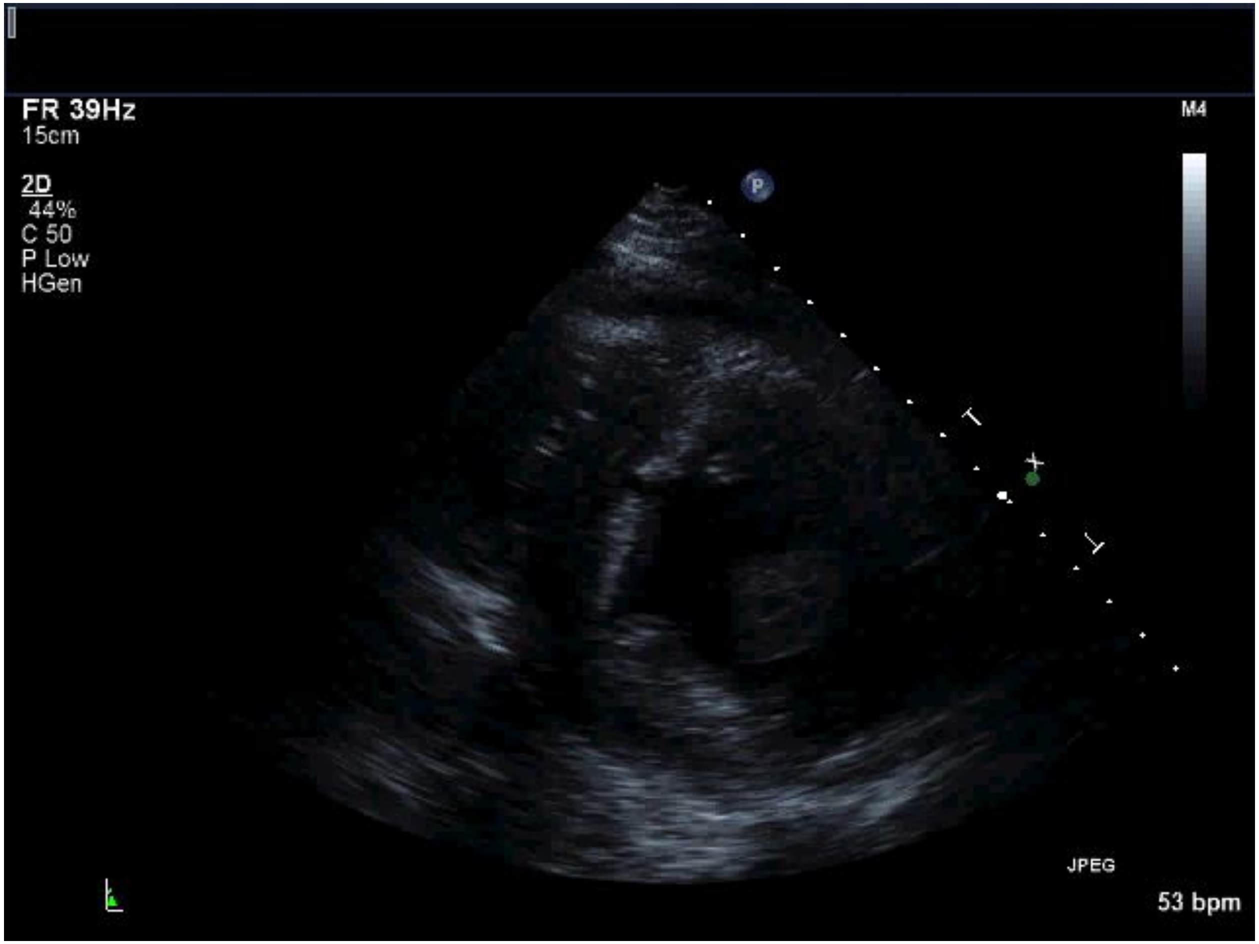
- Increase in systolic pressure w/o major change in cavity radius
- By LaPlace: $$T_w \approx \frac{\Uparrow P * R}{\Uparrow h}$$
- End Result: ⇑ LV Wall thickness
  ⇑ LV Mass
  ⇑ Relative Wall Thickness

Pressure Overload
"Concentric Hypertrophy"

LVIDd = 4.7

PWTd = 1.5

RWT = 0.62



Volume Overload:
Eccentric Hypertrophy

- Increase in diastolic chamber size

- By LaPlace:

$$T_w \approx \frac{P * \Uparrow R}{\Uparrow h}$$

- End Result: $\Uparrow$ LV wall thickness
  $\Uparrow$ LV mass
  NO CHANGE in RWT

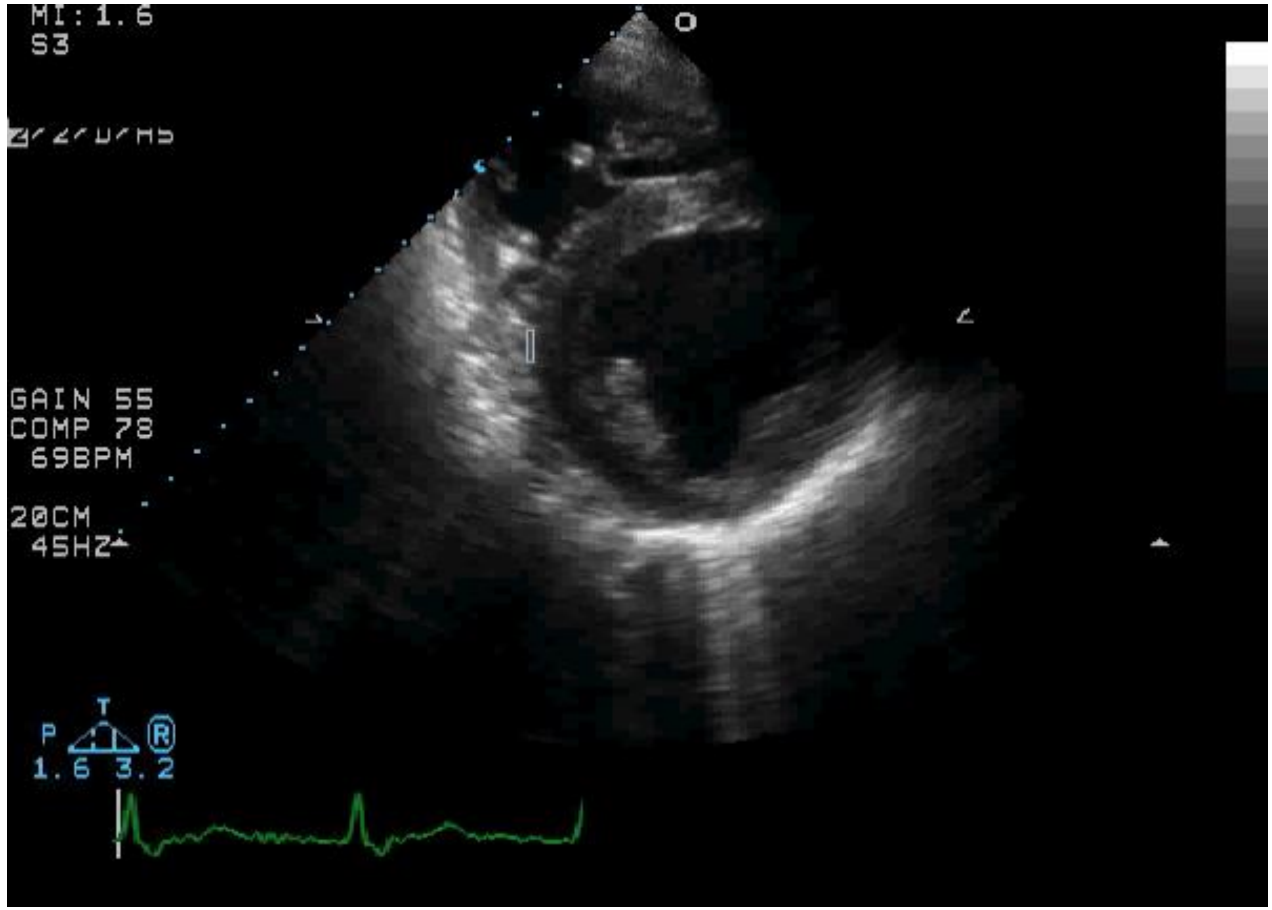
Volume Overload

"Eccentric Hypertrophy"

LVIDd = 7.0

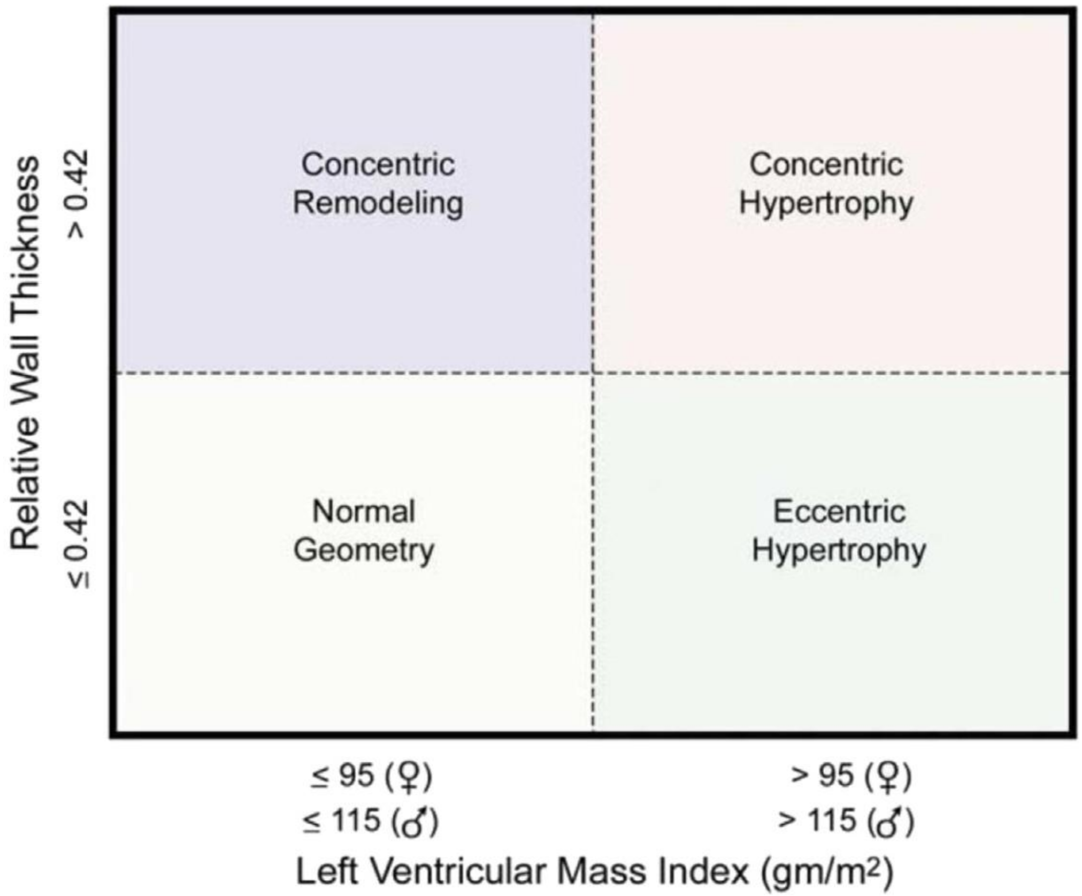
PWTd = 1.2

RWT= 0.34



LV Geometry

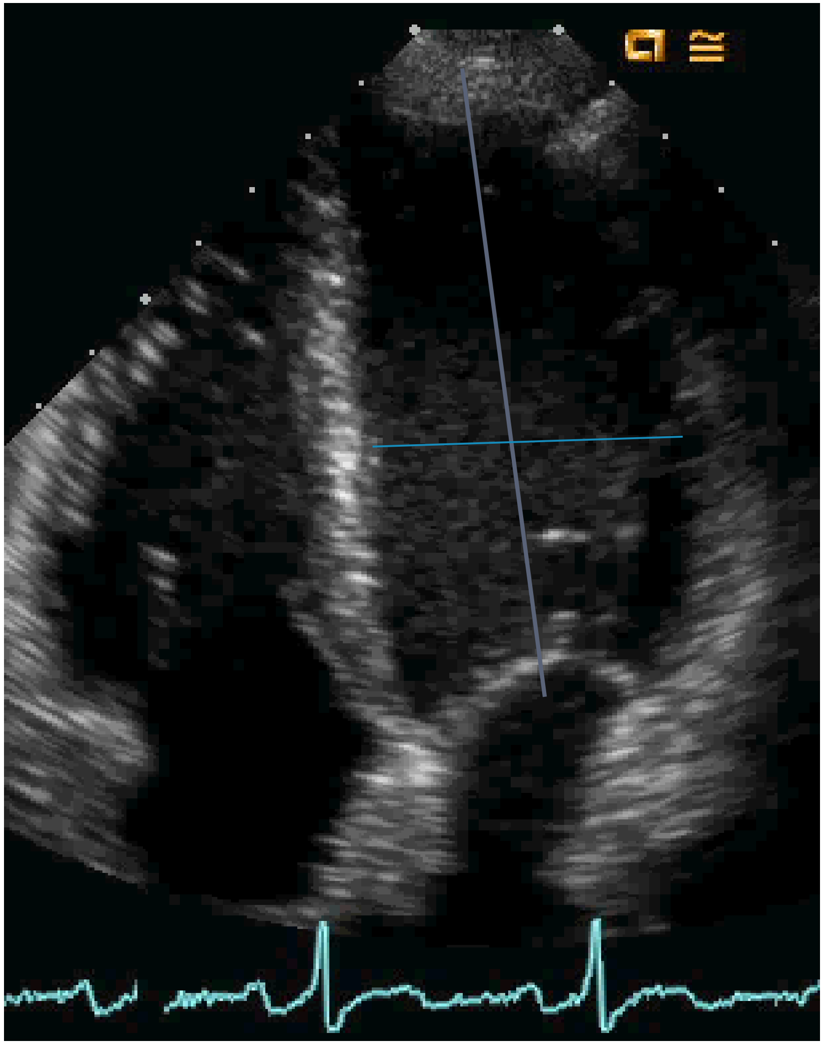
Combinations of pressure and volume overload result in a **spectrum** of LV geometry in the general population.

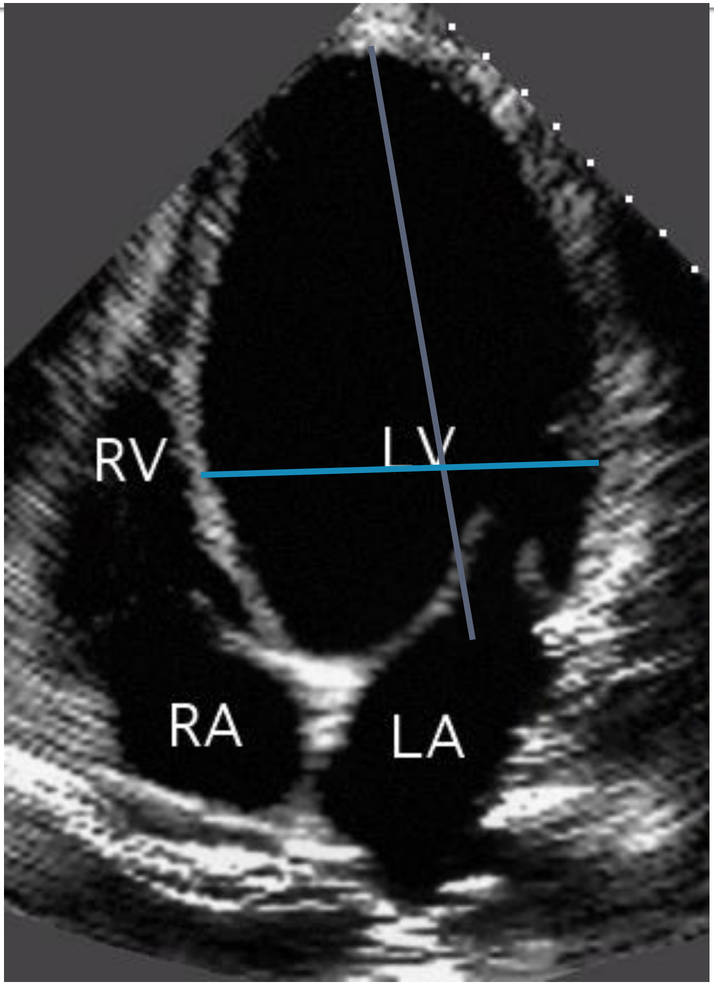


Sphericity index

- Short axis/long axis
- Spherical ventricle is at mechanical disadvantage
- Aortic regurgitation, dilated CM most common causes of increased sphericity index

Normal vs spherical ventricle





Severe AR

More LV Evaluation

- Hemodynamic (Doppler) Assessment
  - World Renowned talk by Itzhak Kronzon
- Global Longitudinal Strain (and other strain)
  - Fabulously explained by Steve Lester
- Diastolic Function and Dysfunction
  - Exquisitely delineated by Gerry Aurigemma, Miguel Quiñonez, Natesa Pandian
- Three-Dimensional (3D) Evaluation
  - Brought to you by "Dr. 3D" – Sunil Mankad

Review Question #1

- Measurement of end-diastolic LV internal diameter (LVIDd) made by properly-oriented M-Mode techniques in the Parasternal Long Axis View (PLAX):

A. Are identical to those made from 2D images
B. Are larger than those made from 2D images
C. Are less discrepant from 2D measures with advancing age
D. Are identical if trailing edge to leading edge convention is used
E. Are completely unreliable compared to 2D measurements

Question 1: Choice Explanations

- A. **Incorrect** - M-mode imaging and 2D imaging represent different modalities, and measurements derived will not be identical
- B. **Correct** - Due to angulation of the ventricle in the PLAX, subtle degrees of obliquity results in LVIDd measurements that are between 6 and 12 mm larger than measured directly on 2D images.
- C. **Incorrect** - The heart typically angulates to a more apex-upward orientation with age in the parasternal long axis view, M-Mode derived measurements become MORE discrepant over time.
- D. **Incorrect** – LEADING edge to leading edge measurements are conventional on M-mode. Even if trailing edge to leading edge measurement is made on M-mode, inherent differences in edge detection and technique result in non-identical measurements
- E. **Incorrect** – M-mode imaging affords extremely accurate spacial resolution. Performed properly in correct orientation, M-mode measurements are extremely accurate and reliable.

Review Question #2

- In males, the geometric pattern of left ventricular "concentric remodeling" is present when:

  A. LVMI ≤ 115 g/m^2 and RWT ≤ 0.42

  B. LVMI > 115 g/m^2 and RWT > 0.42

  C. LVMI ≤ 115 g/m^2 and RWT > 0.42

  D. LVMI > 115 g/m^2 and RWT ≤ 0.42

  E. LVMI ≤ 115 g/m^2 and RWT < 0.34

Question 2: Choice Explanations

A. **Incorrect** – This is normal LV mass index and normal relative wall thickness. This would be classified as ***Normal LV Anatomy***.

B. **Incorrect** – LV mass index is increased above threshold norms for males, indicating LV hypertrophy. Relative wall thickness is greater than threshold norm. This would be classified as ***Concentric Hypertrophy*** – a finding most common in cases of predominant pressure overload.

C. **Correct** – In the situation of normal LV mass index for males, but when relative wall thickness exceeds accepted norm values, is classified as ***Concentric Remodeling***. This is considered by some as a "pre-hypertrophic" state, and is common in hypertensive populations.

D. **Incorrect** – LV mass index is greater than established population norms for males, indicating left ventricular hypertrophy. Relative wall thickness is in normal range. This is classified as ***Eccentric Hypertrophy*** – a finding most common in cases of predominant volume overload.

E. **Incorrect** – This situation represents normal LV mass index and a relative wall thickness below the mean "normal" value of RWT. This would be classifies at ***Normal LV Anatomy***.

Review Question #3

- “Volumetric” measurements of LV cavity size (Simpson’s Method) are considered superior to strictly “Linear” techniques (Rotational Ellipse) because:

A. Small errors in linear measurements are greatly magnified by squaring terms in linear techniques.

B. Complex mathematical modeling of volumetric techniques insures precision

C. Linear measurement techniques were developed for M-mode echocardiography and have decreased accuracy when applied to 2D echocardiography.

D. Two-Dimensional volumetric techniques directly measure volumes, whereas linear techniques measure only length and width

E. Volumetric techniques correct for shape distortions better than linear techniques.

Question #3: Choice Explanations

A. **Incorrect** – Linear techniques and volumetric techniques utilize measurements raised to second or third power, resulting in magnification of measurement errors in both.

B. **Incorrect** - Complex models of ventricular volume are still subject to significant lack of precision, particularly with poor endocardial definition and off-axis imaging.

C. **Incorrect** – Although developed for M-mode echo, linear techniques for LV volume can be accurately applied to 2-dimensional echo imaging. Frequently, measurement of LV lengths/diameters are MORE accurately performed on 2D imaging.

D. **Incorrect** – 2D volumetric techniques calculate overall LV volume using a compilation of smaller, measurable volumes. Linear measurements are still frequently a component in volumetric techniques. Thus volume is not "directly" measured

E. **Correct** – Volumetric techniques, particularly when applied in a biplane fashion, can incorporate significant cavity shape abnormalities and focal wall motion abnormalities into estimation of diastolic and systolic ventricular volume. Linear techniques rely on broad assumptions of symmetry of cavity size and function. Depending on where abnormalities are located, linear technique assumptions of symmetry may result in significant OVER- or UNDER-estimation of LV volumes

Thank you!!!!