Anesthesia
UNIVERSITY OF TORONTO

APTE PREP COURSE

LV SYSTOLIC FUNCTION – FEB 17, 2021

OUTLINE

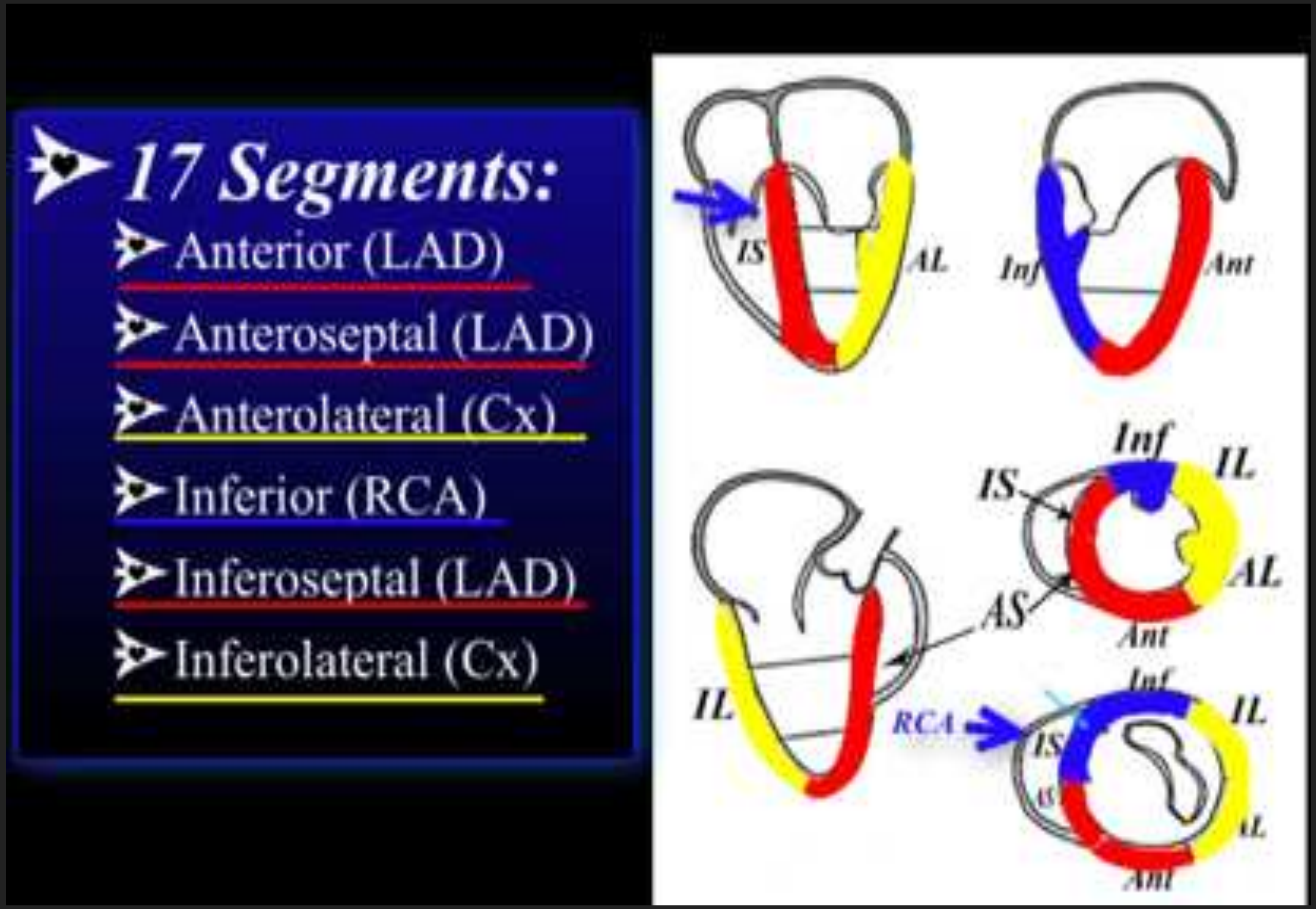
1. RMWA and coronary artery territories
2. Basic LV measurements
3. Ejection phase indices (FS, FAC, EF)
4. Isovolumetric Phase Indices (dP/dt)
5. Load-independent indices (research indices + strain)
6. Strain, Tissue doppler imaging, Speckle tracking
7. 3D LV assessment (video demos)

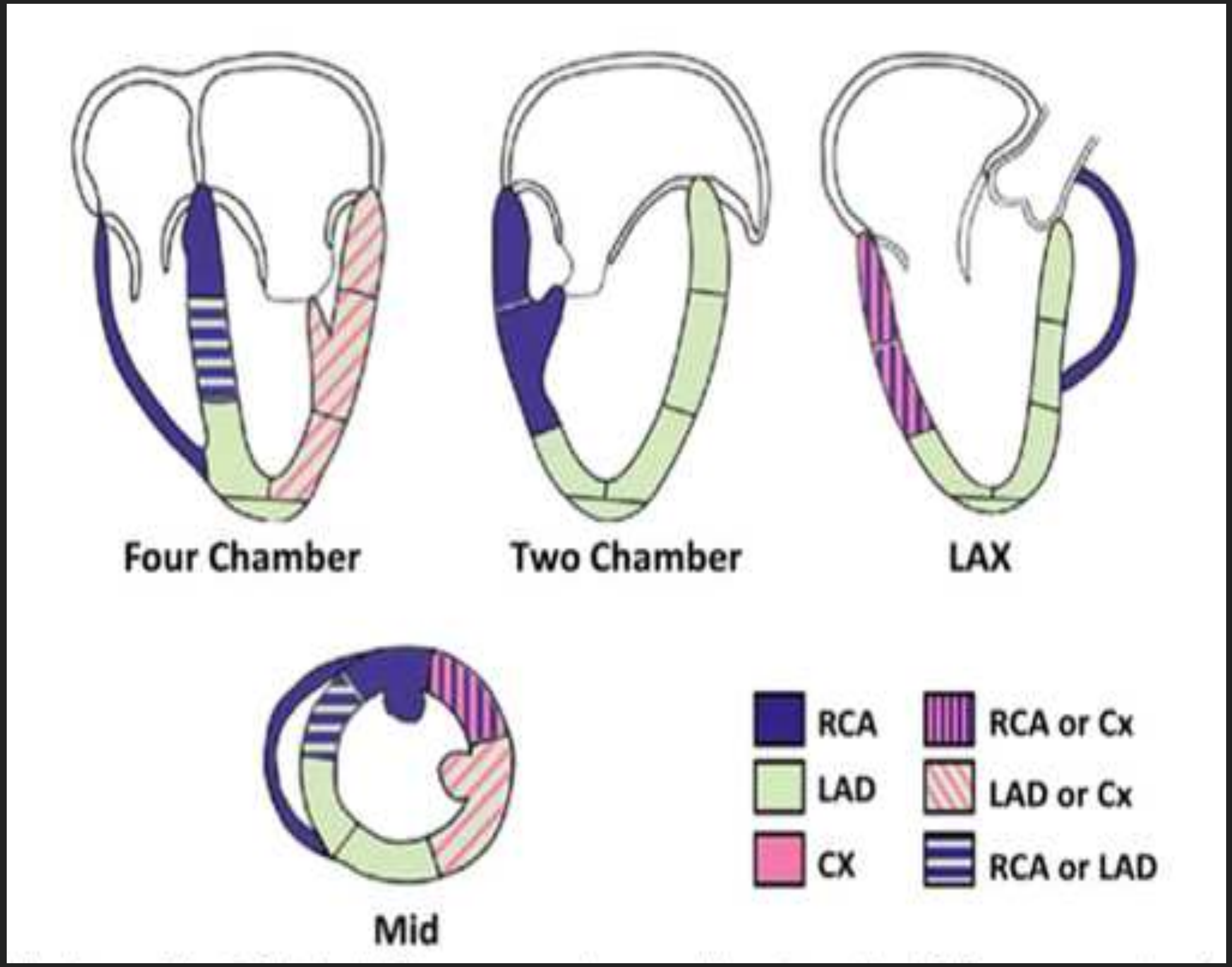
GUIDELINES TO KNOW

1. Lang, RM et al. (2015). Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Journal of the American Society of Echocardiography, 28(1): 1-39.

2. Nicoara, A et al. (2020). Guidelines for the Use of Transesophageal Echocardiography to Assist with Surgical Decision-Making in the Operating Room: A Surgery-Based Approach From the American Society of Echocardiography in Collaboration with the Society of Cardiovascular Anesthesiologists and the Society of Thoracic Surgeons. Journal of the American Society of Echocardiography 33(6): 692 - 734.

CORONARY ARTERY TERRITORIES





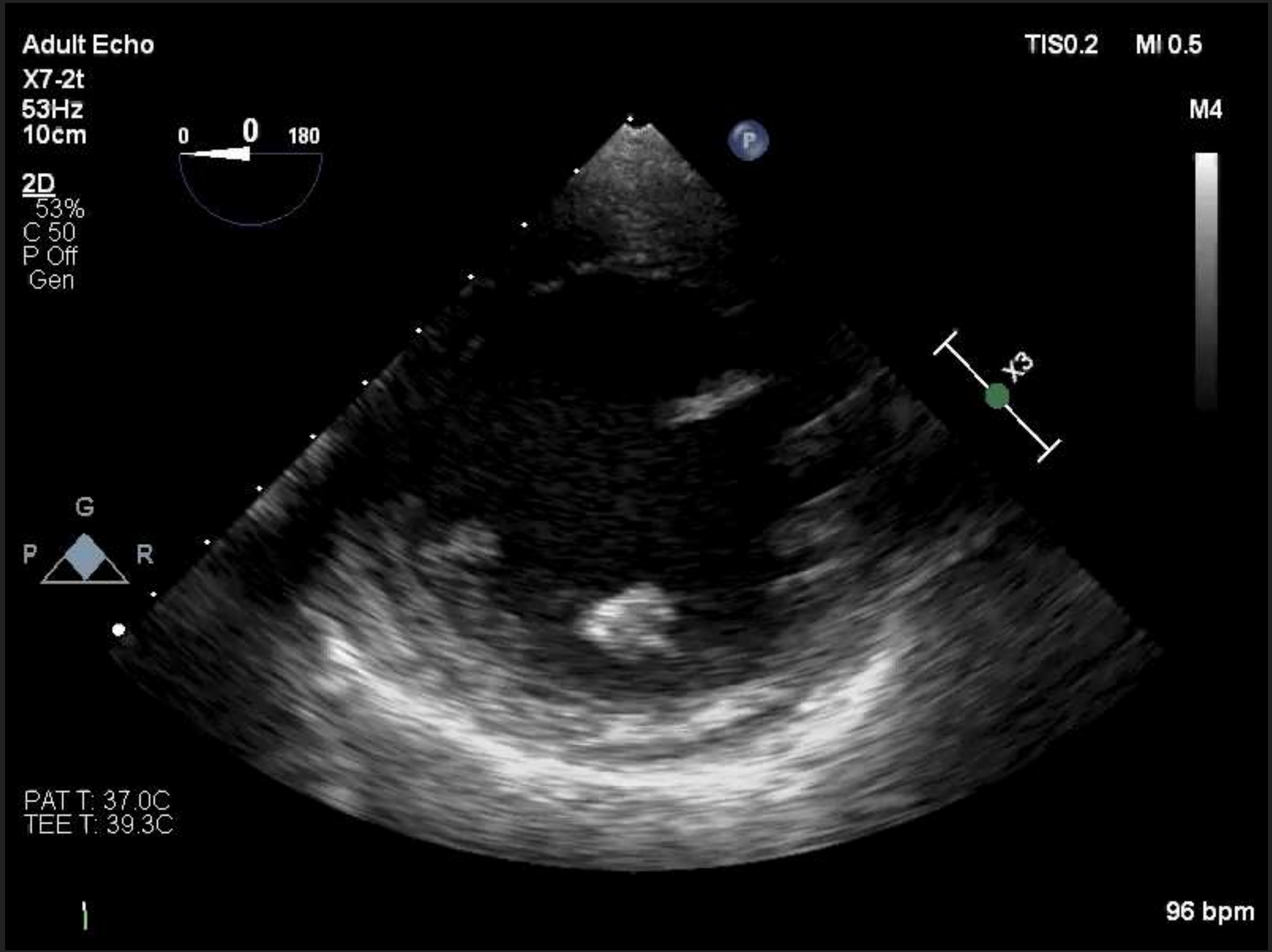
Reeves et al. (2013). Perioperative Transesophageal Echocardiography Examination: A Consensus Statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. JASE 26, 5: 443.

MYOCARDIAL THICKENING

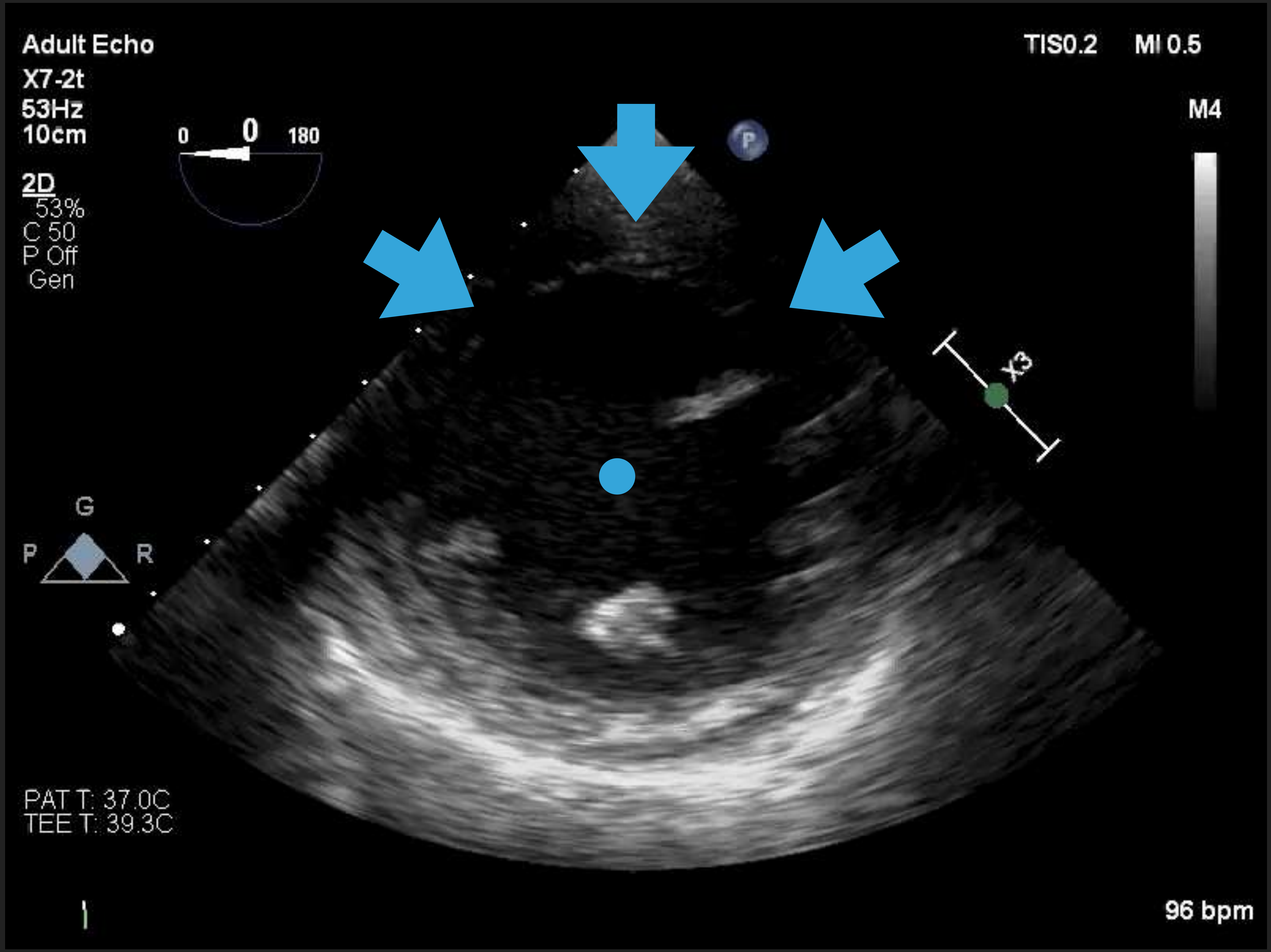
Regional Function	GRADE	Inward Radial Motion	Systolic Wall Thickness
Normal	1	>30 %	Marked
Hypokinetic	2	<10 to <30%	Reduced
Akinetic	3	< 10%	Negligible
Dyskinetic	4	Paradoxical systolic motion	Systolic thining
Aneurysmal	5	Diastolic Deformation	

Table from PTE Masters, 2021.

CASE 1


Adult Echo
X7-2t
53Hz
10cm
2D
53%
C 50
P Off
Gen
0
0
180
TIS0.2
MI 0.5
M4
X3
G
P
R
PAT T: 37.0C
TEE T: 39.3C
96 bpm

CASE 1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M4
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P
R
PAT T: 37.0C
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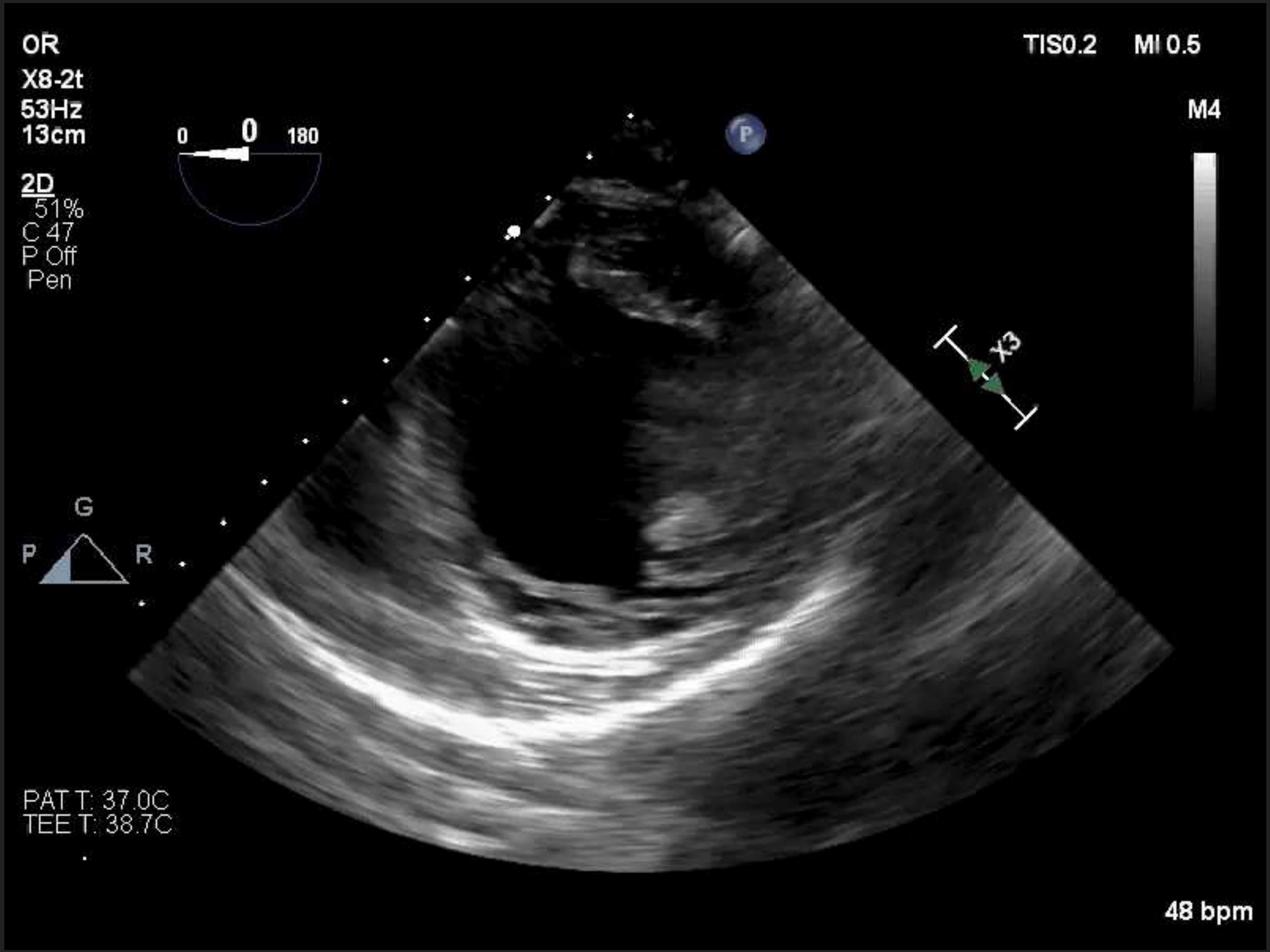
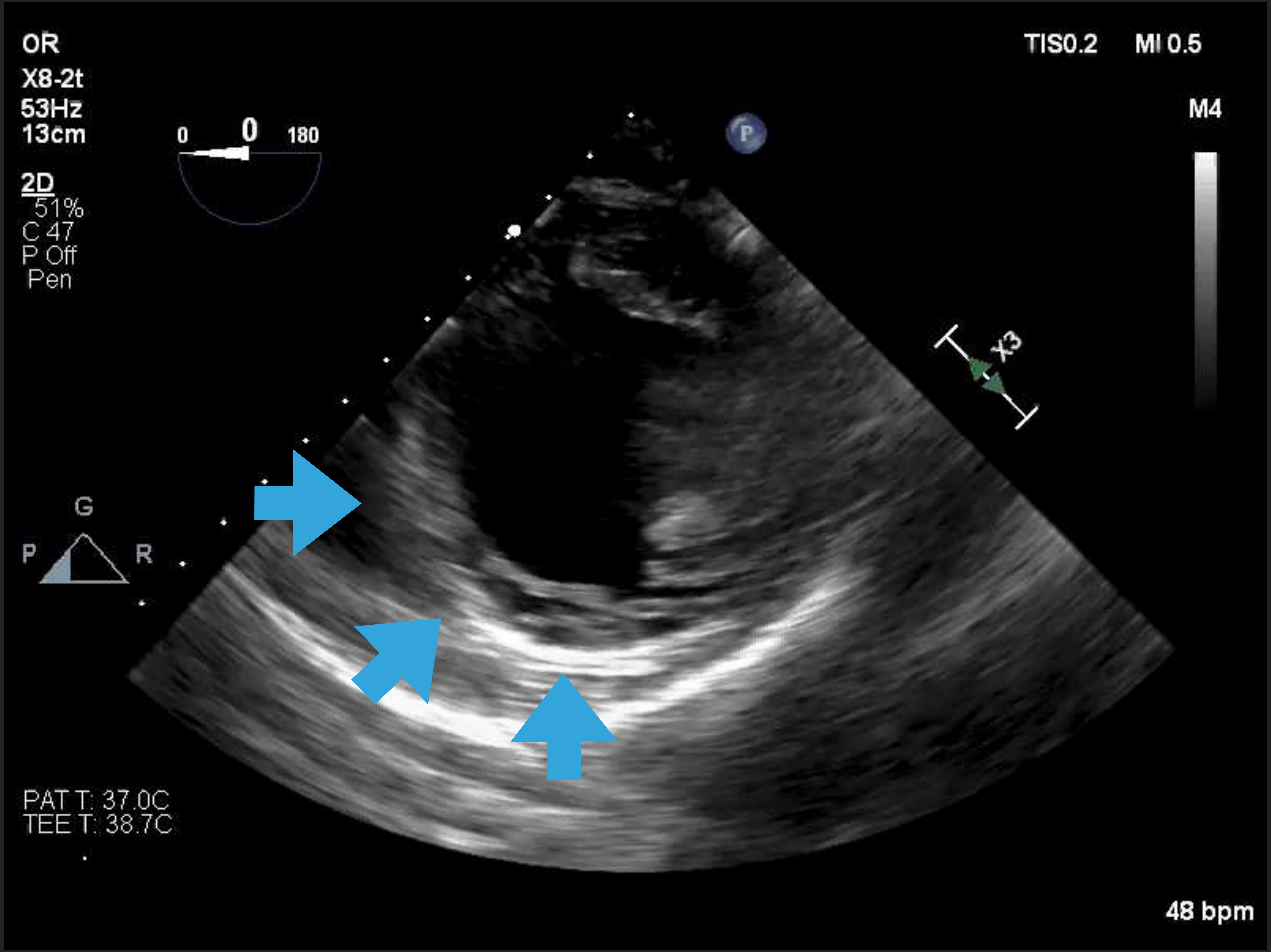
CASE 2


OR
X8-2t
53Hz
13cm
0
0
180
2D
51%
C 47
P Off
Pen
TIS0.2
MI 0.5
M4
P
X3
G
P
R
PAT T: 37.0C
TEE T: 38.7C
48 bpm

CASE 2


OR
X8-2t
53Hz
13cm
0
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M4
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G
P
R
PAT T: 37.0C
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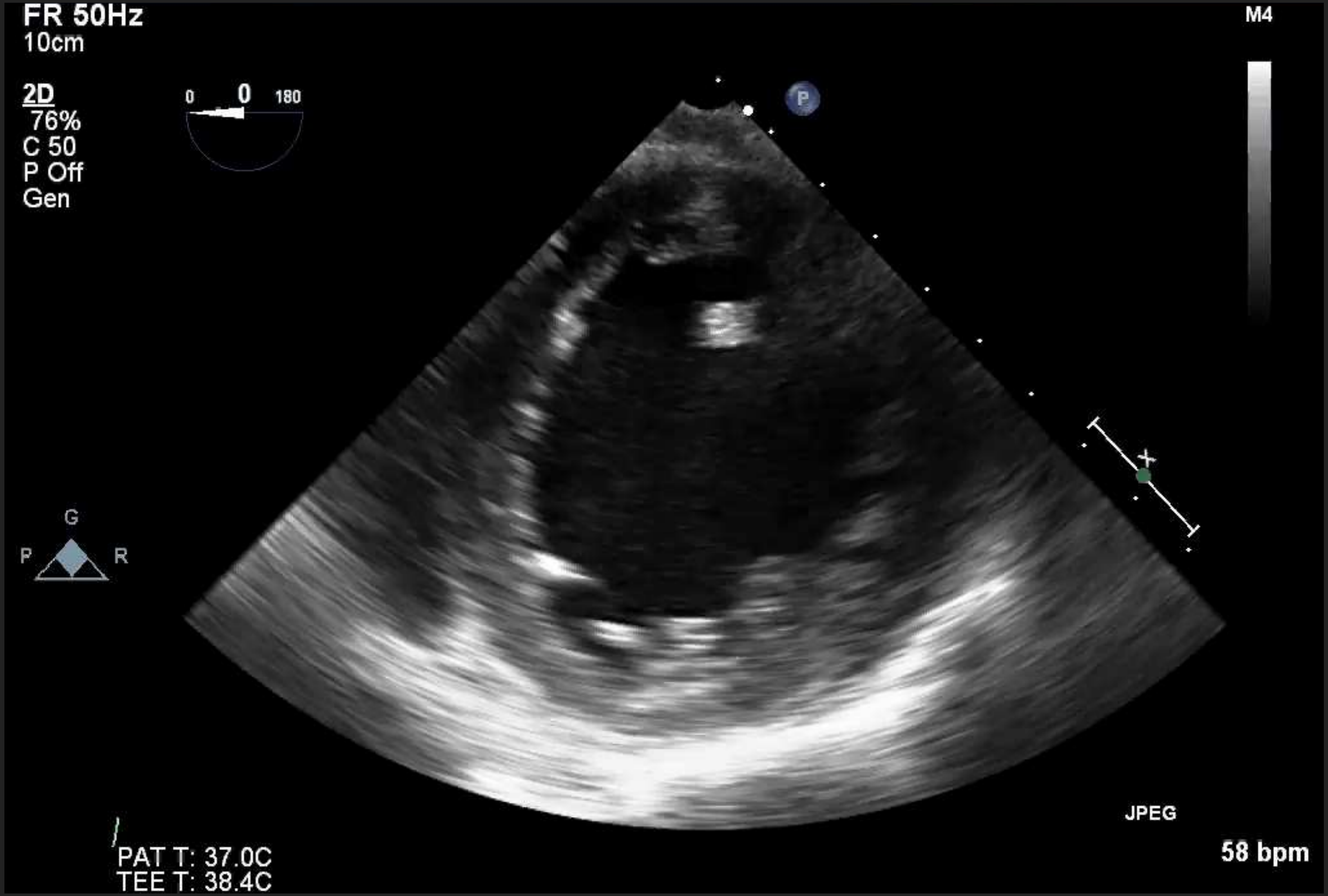
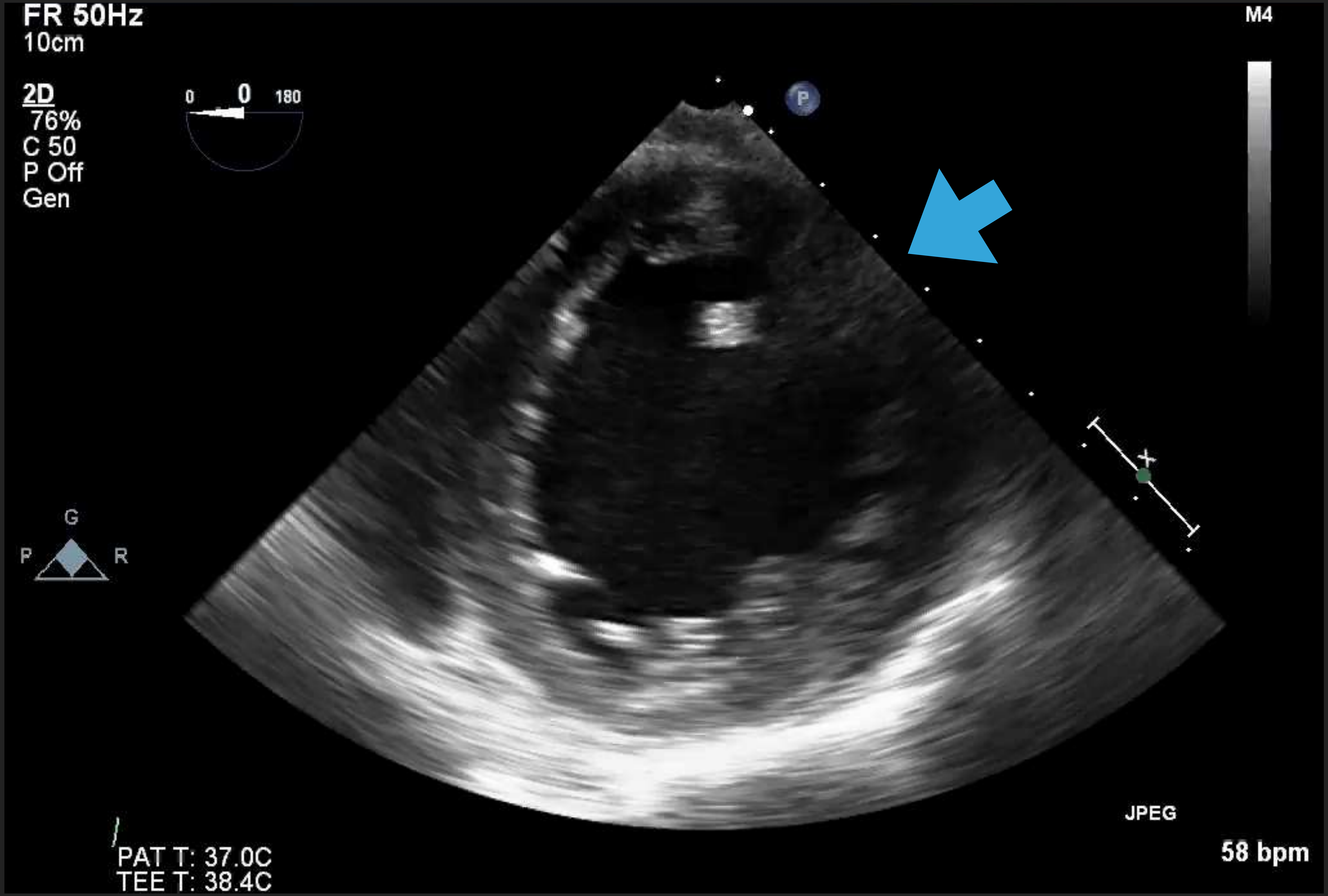
48 bpm

CASE 3


FR 50Hz
10cm
2D
76%
C 50
P Off
Gen
0
0
180
M4
P
G
P
R
JPEG
PAT T: 37.0C
TEE T: 38.4C
58 bpm

CASE 3


FR 50Hz
10cm
2D
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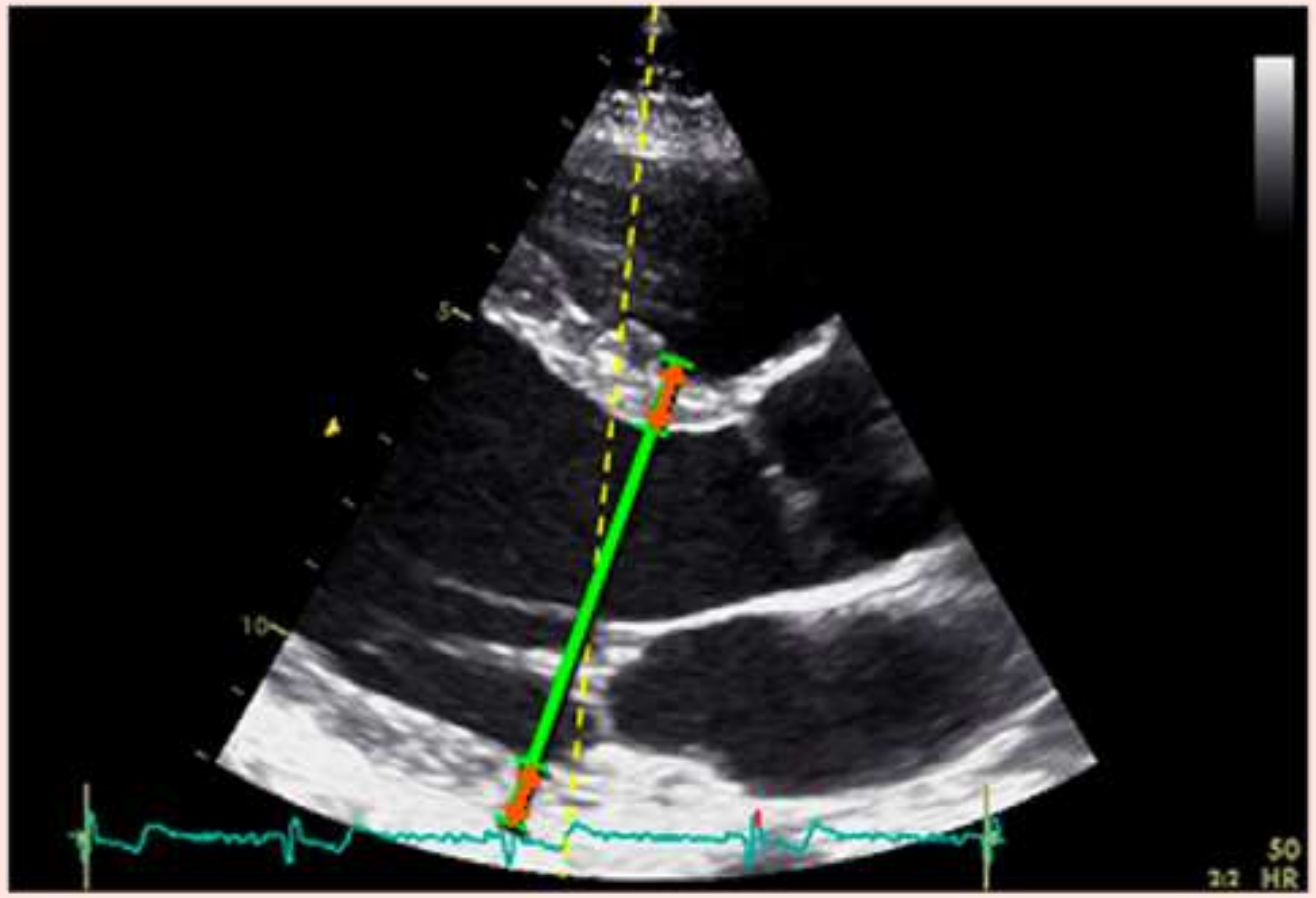
C 50
P Off
Gen
0
0
180
M4
P
G
P
R
JPEG
58 bpm
PAT T: 37.0C
TEE T: 38.4C

BASIC LV MEASUREMENTS

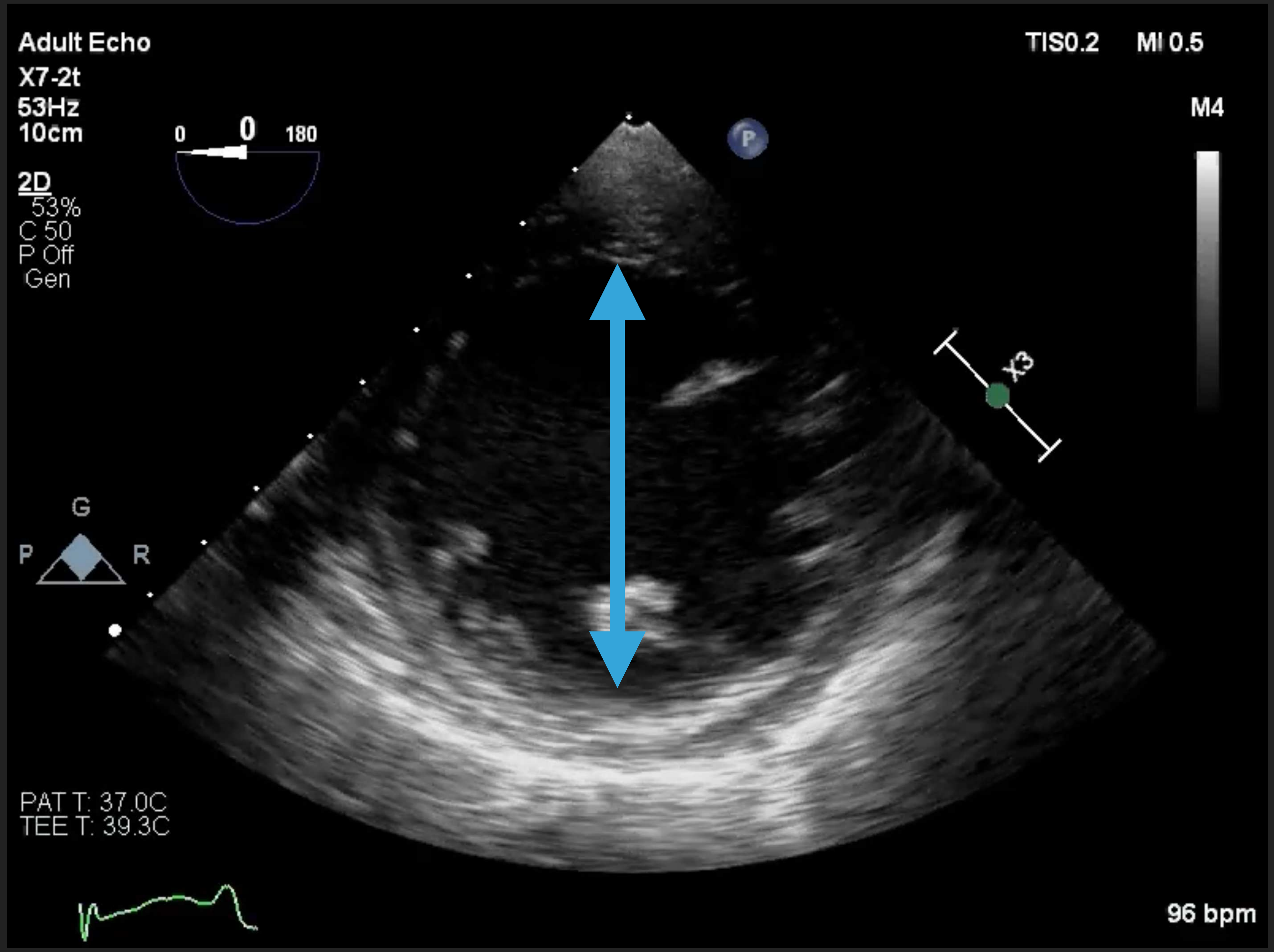
1.1. Linear Measurements. It is recommended that linear internal measurements of the left ventricle and its walls be performed in the parasternal long-axis view. Values should be carefully obtained perpendicular to the LV long axis and measured at or immediately below the level of the mitral valve leaflet 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).

2D-guided linear measurements



BASIC LV MEASUREMENTS

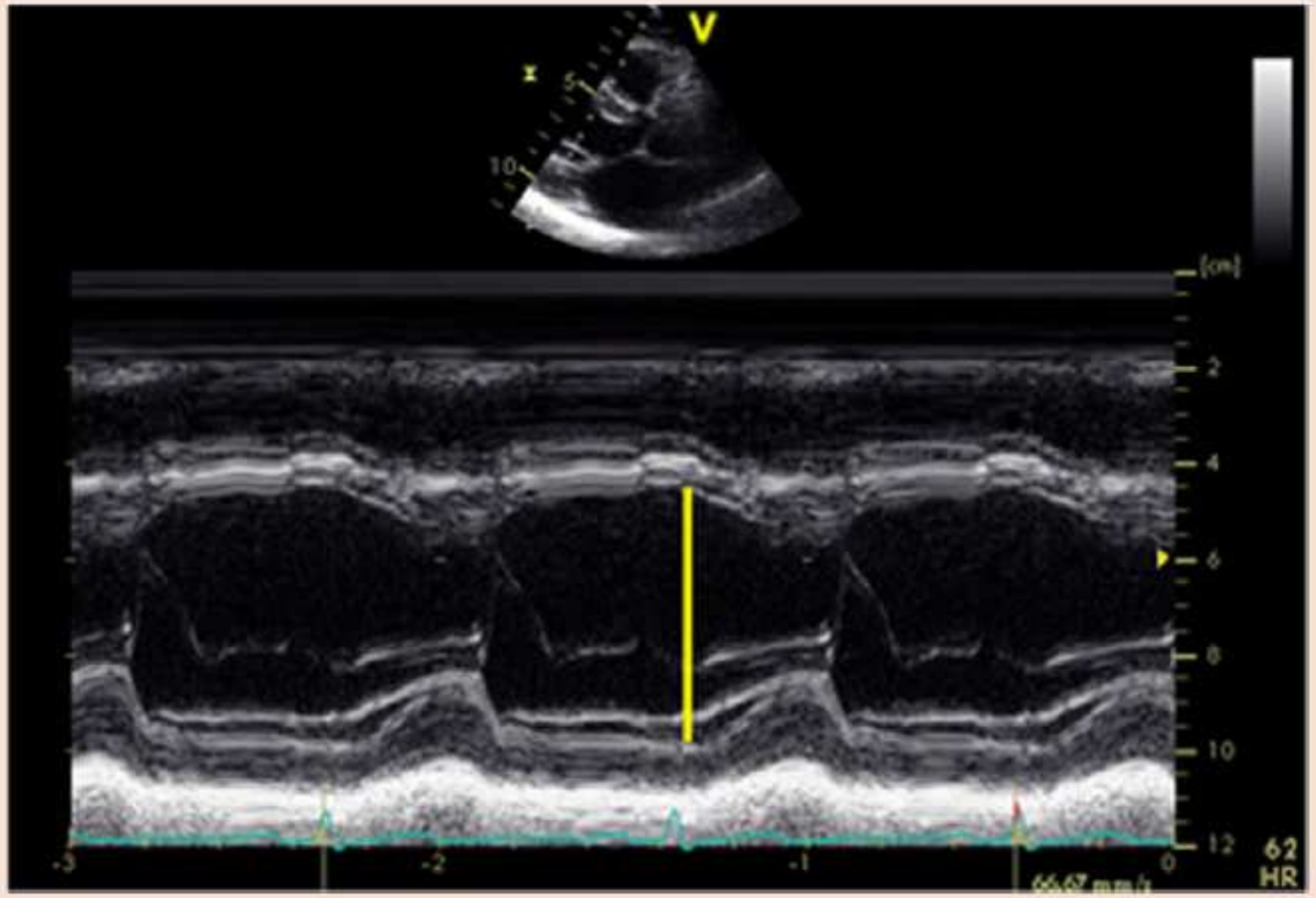
- TG SAX view
- Frame before mitral valve closure, or frame with largest ventricular dimension
- End diastolic anterior-posterior diameter at mid pap level
- Be sure to exclude the papillary muscles
- In this view, can also allows measure of wall thickness and FAC



BASIC LV MEASUREMENTS

- Alternatively, can measure dimensions using M-mode
- TG-SAX or TG-2C
- Remember to measure at end diastole, not the middle of the envelope
- Also allows measures of wall thickness and FS

M-mode tracing



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)	2.2–3.0	3.1–3.3	3.4–3.6	>3.6	2.3–3.1	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	2.4–2.6	>2.6
LV volume								
LV diastolic volume (mL)	62–150	151–174	175–200	>200	46–106	107–120	121–130	>130
LV diastolic volume/BSA (mL/m^2)	34–74	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	33–40	>40
LV function								
LV EF (%)	52–72	41–51	30–40	<30	54–74	41–53	30–40	<30
LV mass by linear method								
Septal wall thickness (cm)	0.6–1.0	1.1–1.3	1.4–1.6	>1.6	0.6–0.9	1.0–1.2	1.3–1.5	>1.5
Posterior wall thickness (cm)	0.6–1.0	1.1–1.3	1.4–1.6	>1.6	0.6–0.9	1.0–1.2	1.3–1.5	>1.5
LV mass (g)	88–224	225–258	259–292	>292	67–162	163–186	187–210	>210
LV mass/BSA (g/m^2)	49–115	116–131	132–148	>148	43–95	96–108	109–121	>121
LV mass by 2D method								
LV mass (g)	96–200	201–227	228–254	>254	66–150	151–171	172–193	>193
LV mass/BSA (g/m^2)	50–102	103–116	117–130	>130	44–88	89–100	101–112	>112

Lang, RM et al. (2015). Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Journal of the American Society of Echocardiography, 28(1): 1-39.

EJECTION PHASE INDICES

1. Fractional shortening (1D)
2. Velocity of circumferential fibre shortening
3. Fractional area change (2D)
4. Ejection fraction (3D)

EJECTION PHASE INDICES

1. Fractional shortening (1D)
2. Velocity of circumferential fibre shortening
3. Fractional area change (2D)
4. Ejection fraction (3D)

$$\frac{(\text{End-Diastolic Value}) - (\text{End-Systolic Value})}{\text{End-Diastolic Value}} \cdot 100\%$$

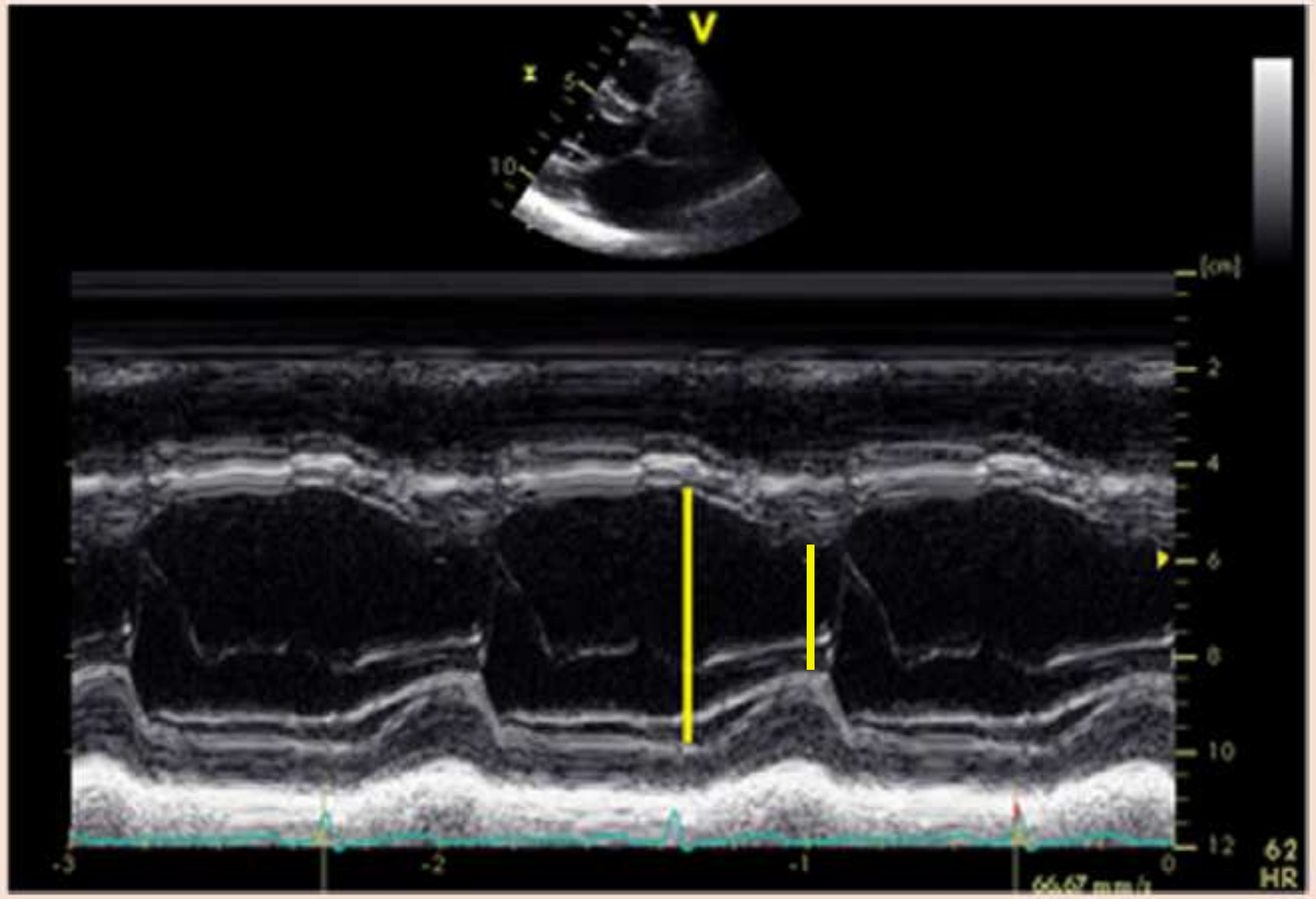
EJECTION PHASE INDICES

1. Fractional shortening (1D)

$$\frac{\text{(End-Diastolic Diameter)} - \text{(End-Systolic Diameter)}}{\text{End-Diastolic Diameter}} \cdot 100\%$$

- Quick and easy
- Inaccurate if any regional dysfunction is present

M-mode tracing



EJECTION PHASE INDICES

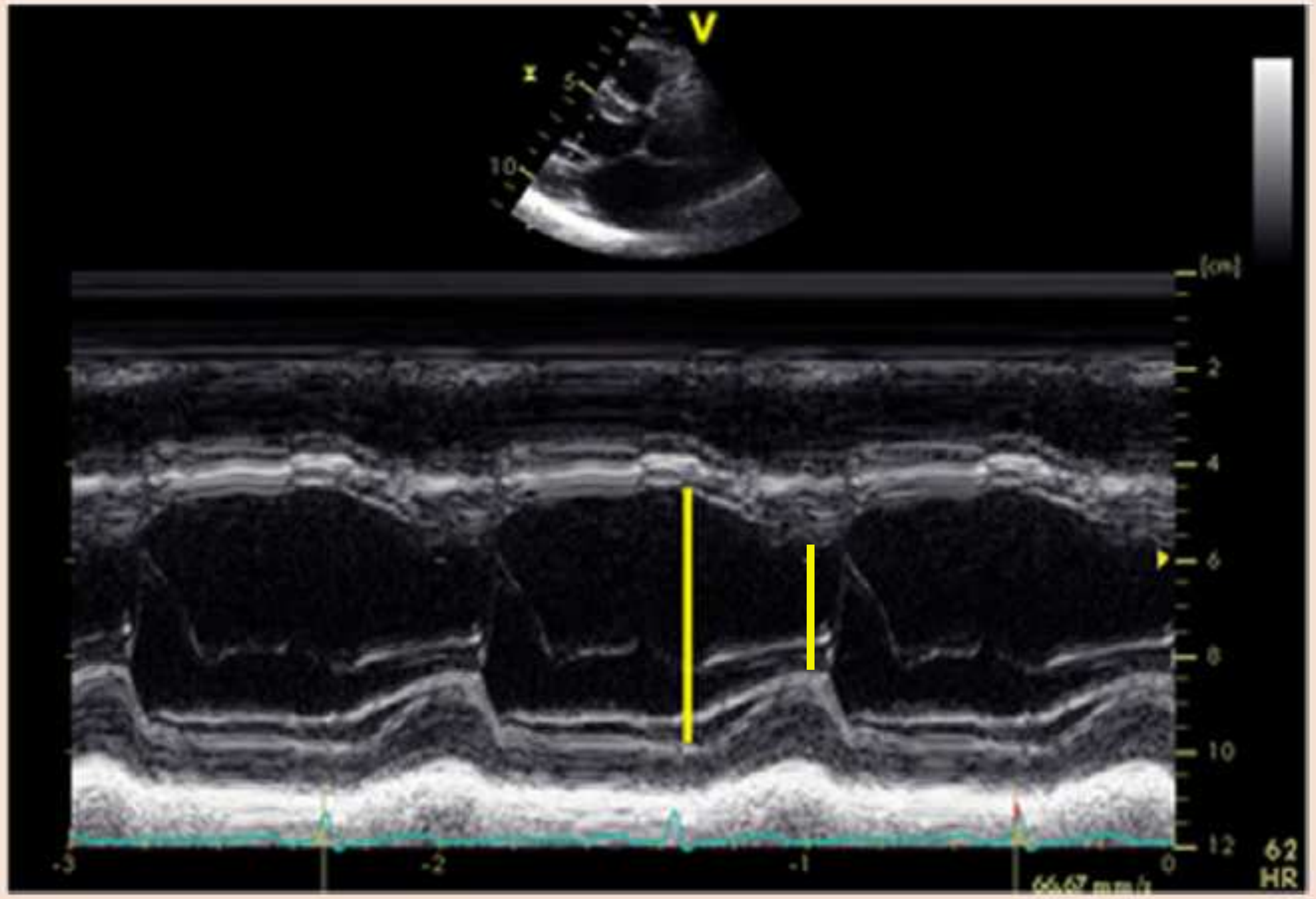
1. Fractional shortening (1D)

$$\frac{\text{(End-Diastolic Diameter)} - \text{(End-Systolic Diameter)}}{\text{End-Diastolic Diameter}} \cdot 100\%$$

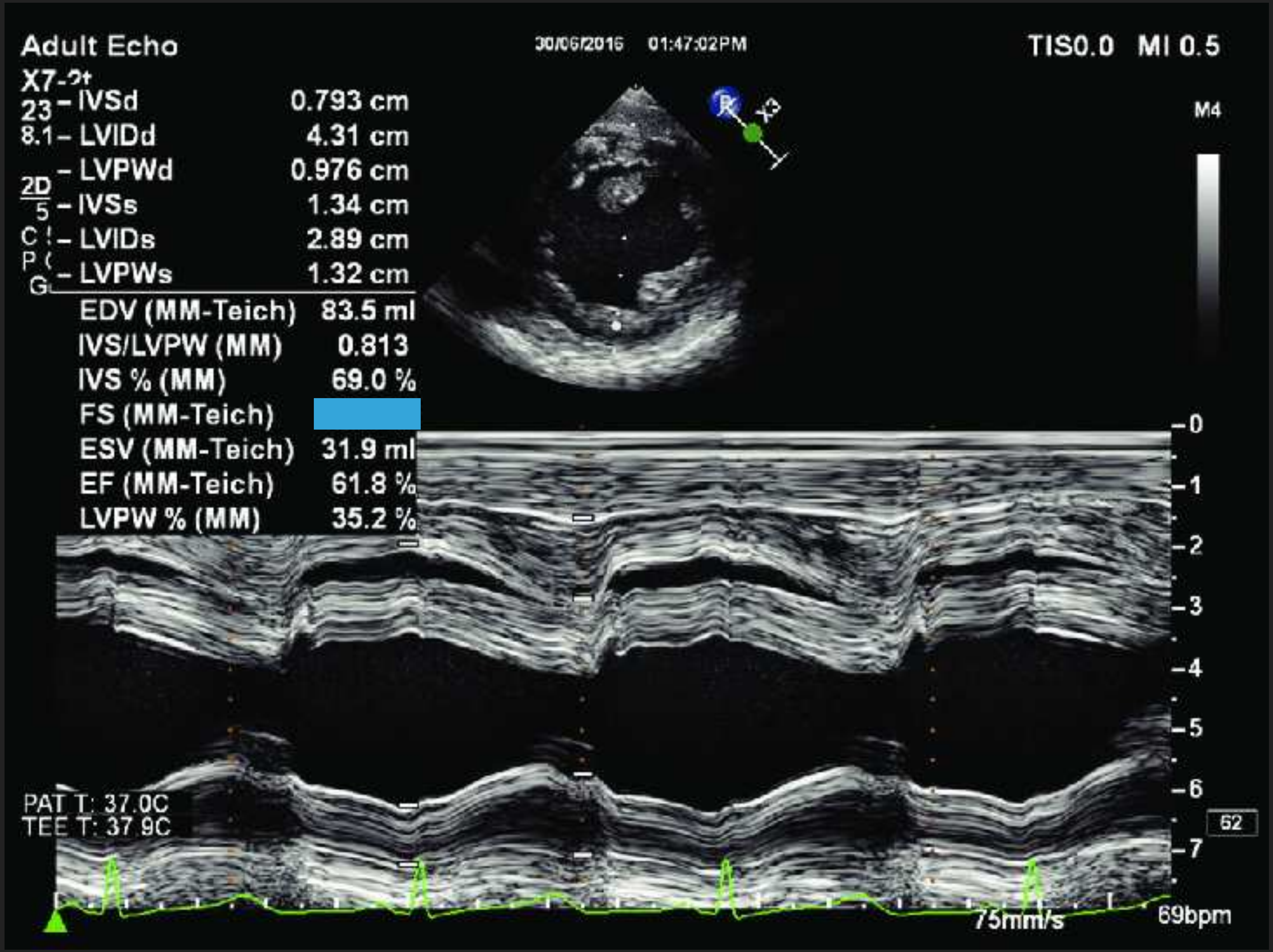
- Quick and easy
- Inaccurate if any regional dysfunction is present

25%

M-mode tracing



Q1. Does this patient appear to have normal LV function?



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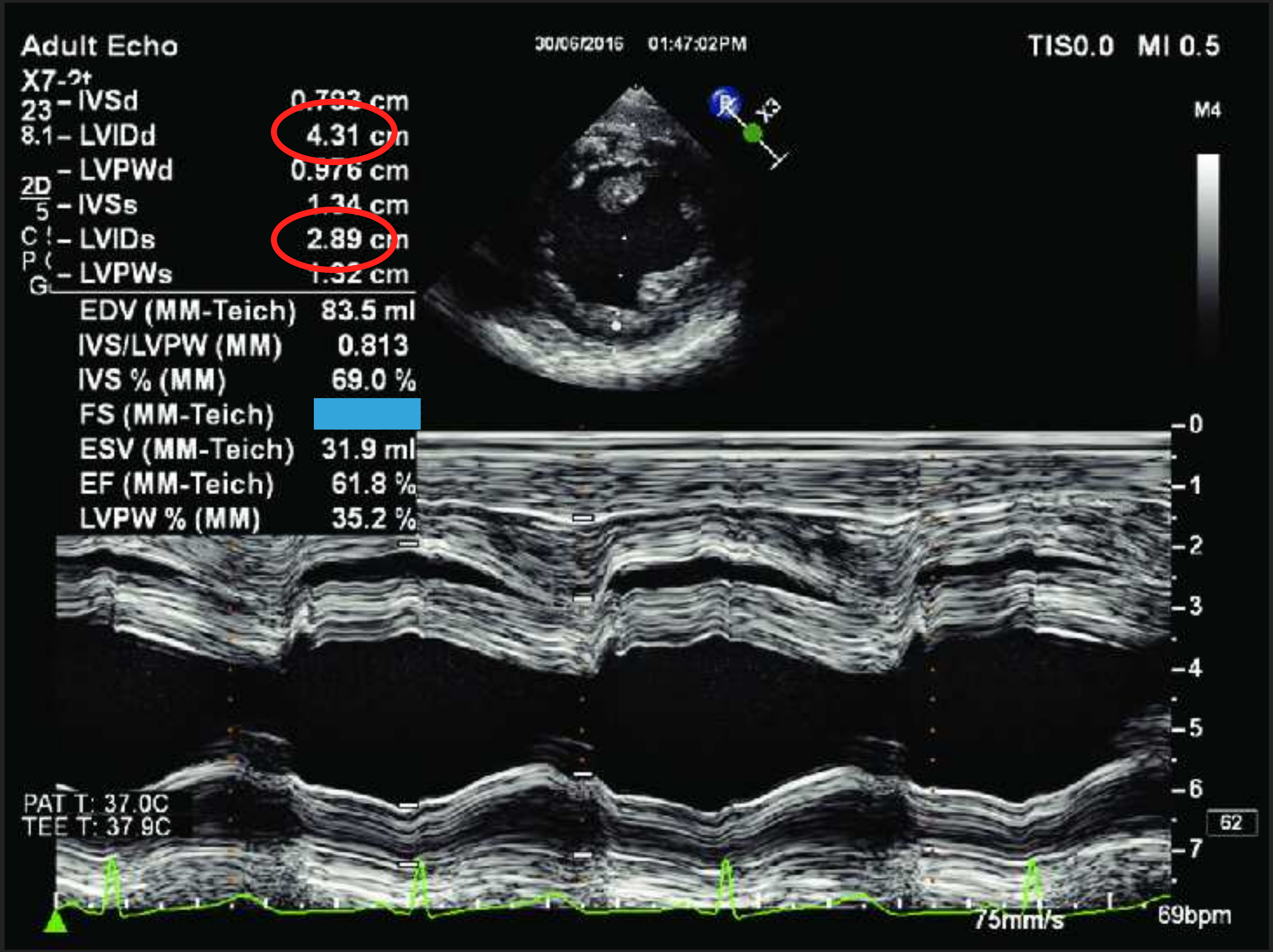

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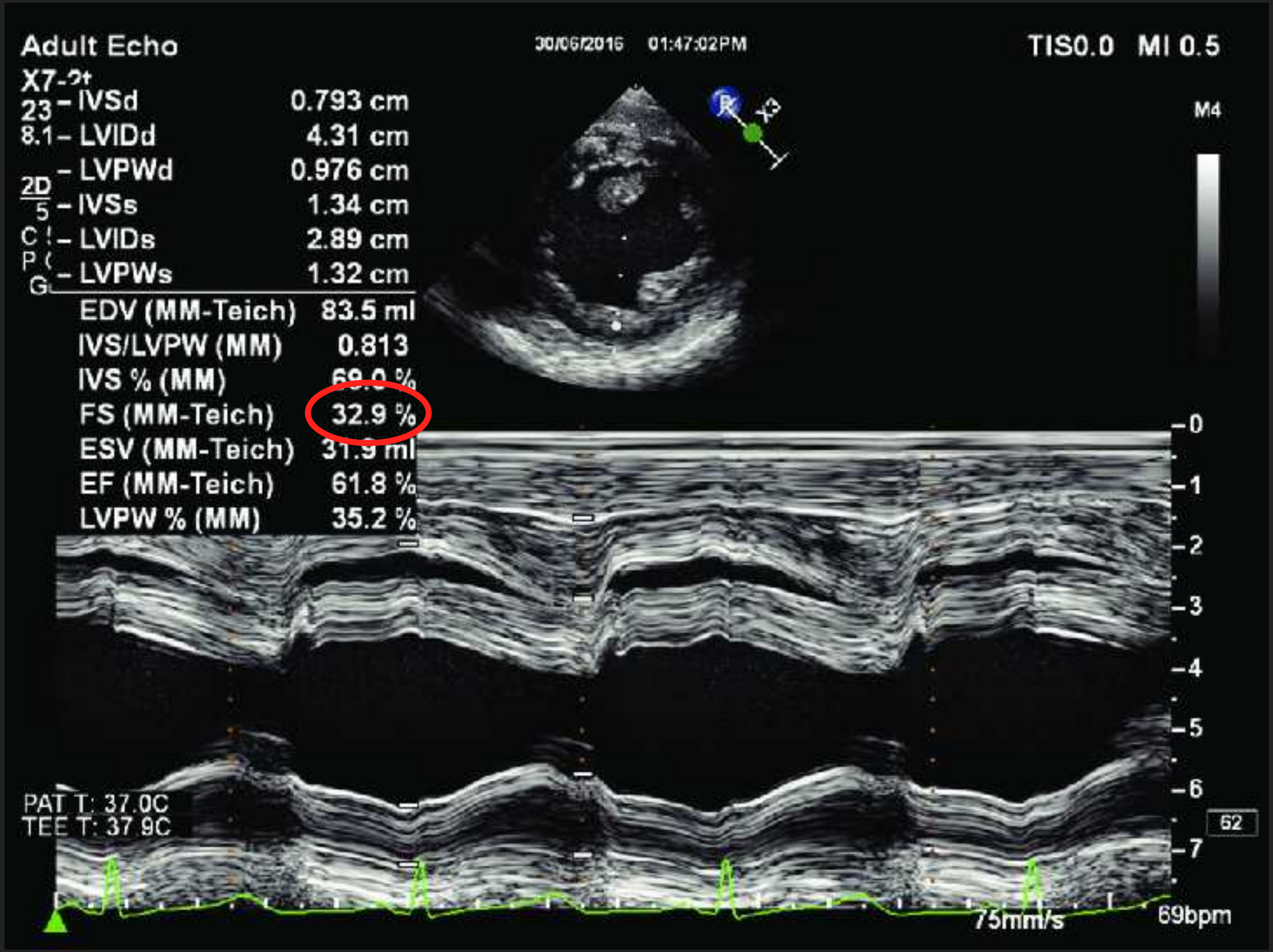

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4. Ejection fraction (3D)

$$\frac{(\text{End-Diastolic Value}) - (\text{End-Systolic Value})}{\text{End-Diastolic Value}} \cdot 100\%$$

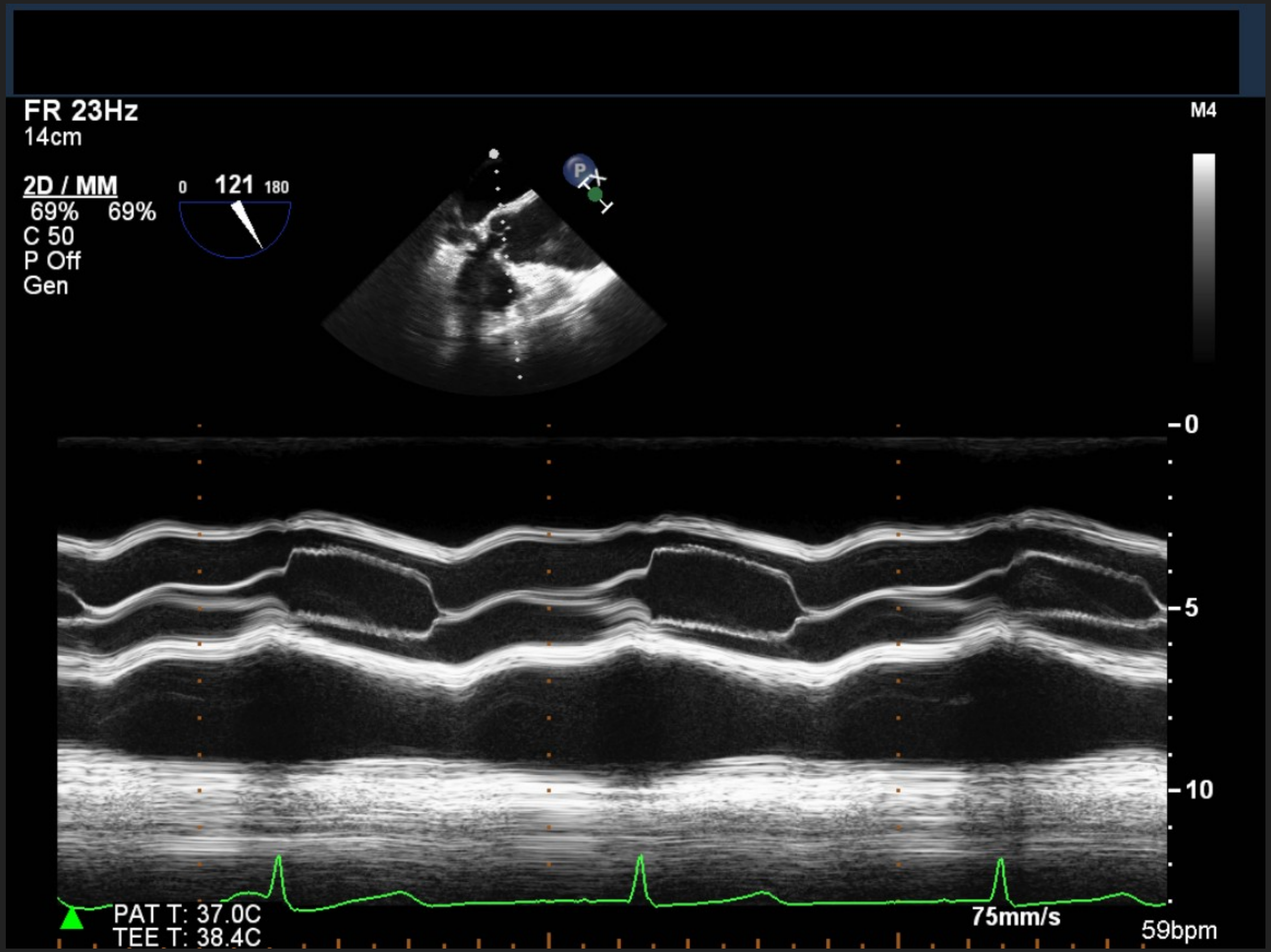
EJECTION PHASE INDICES

Velocity of circumferential fibre shortening

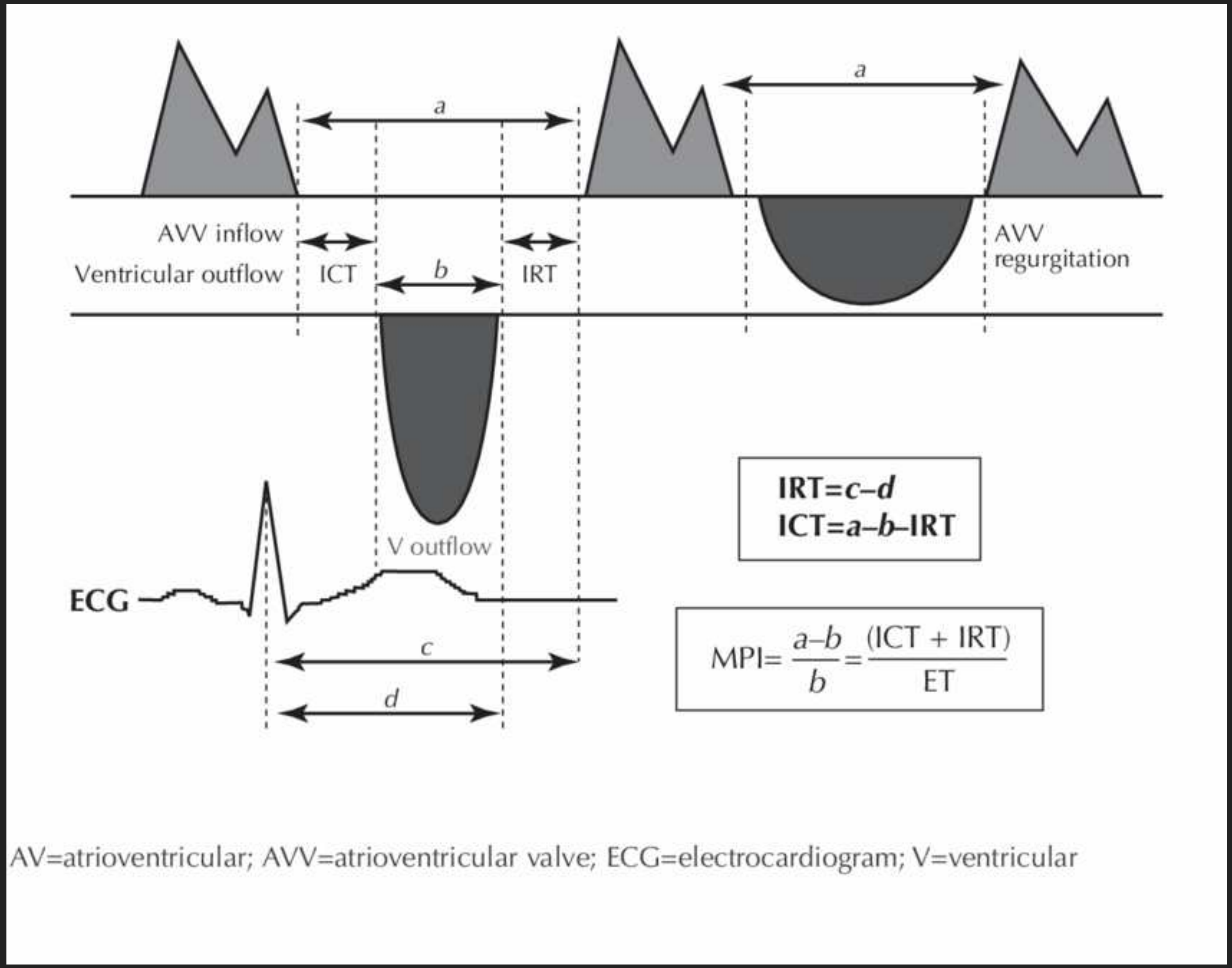
Fractional shortening * 1 / ejection time (s)

- What are two ways of measuring ejection time?
- What is the normal vcfs?

EJECTION TIME

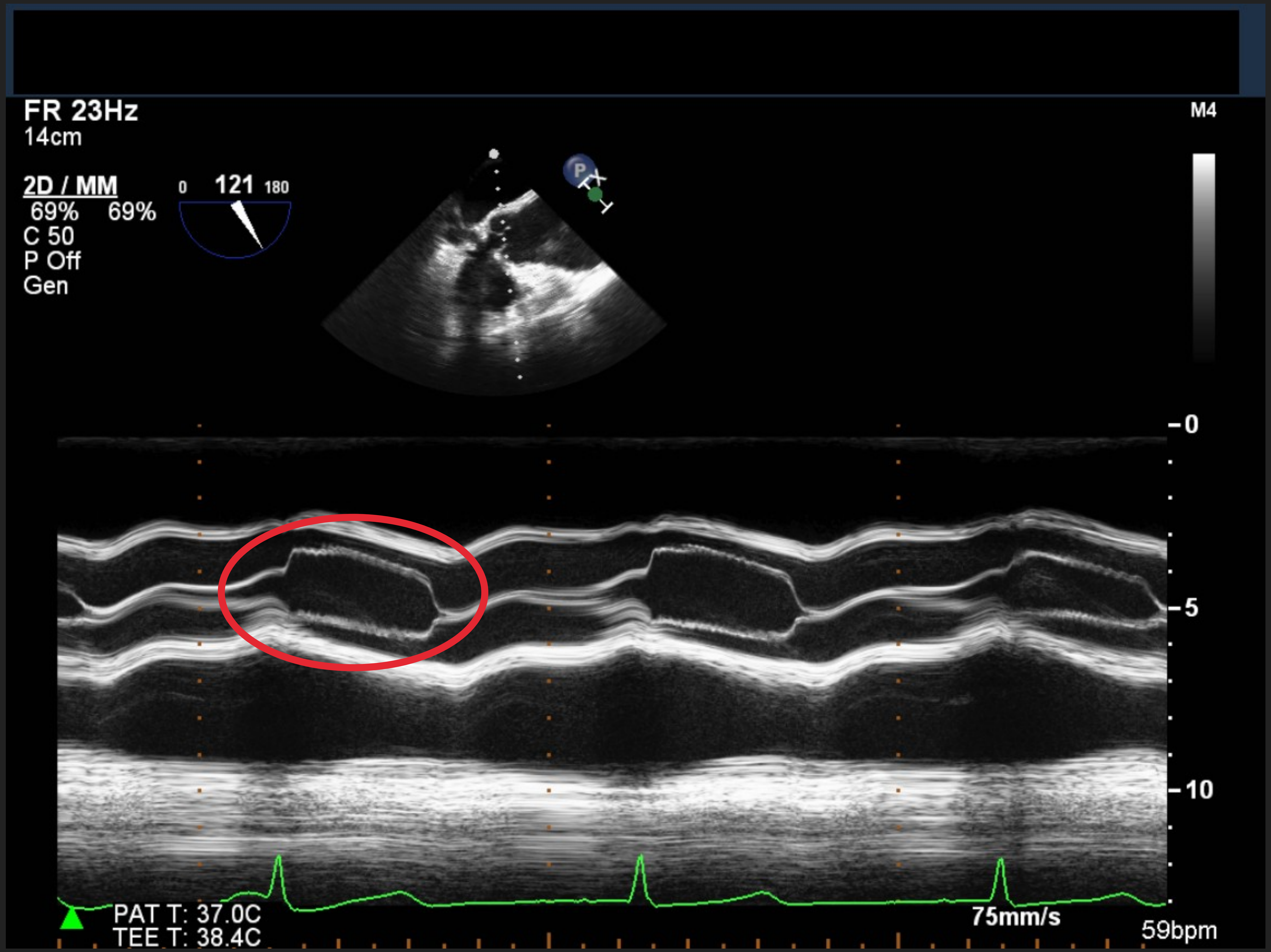


M-MODE through AV, MELAX

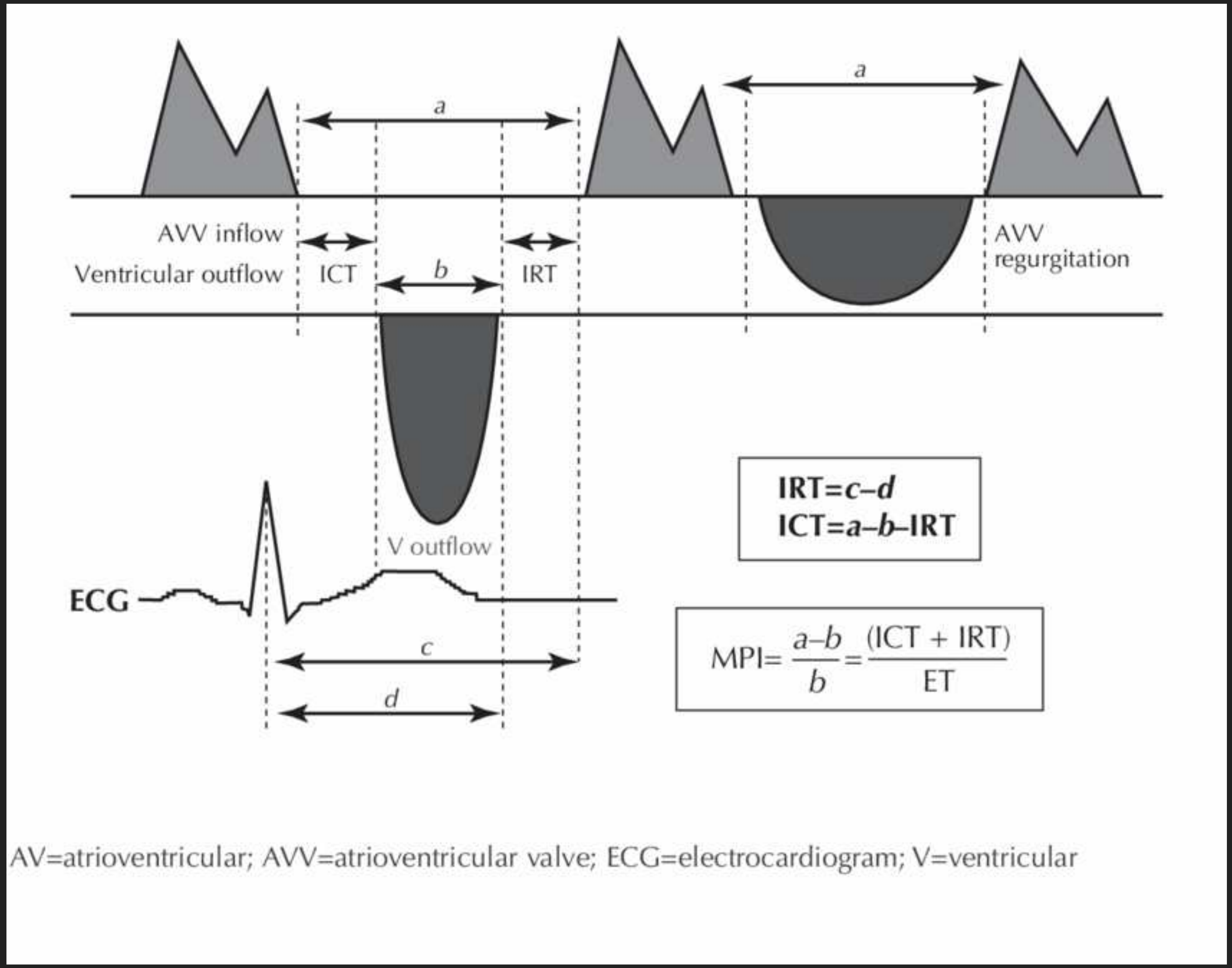


LVOTO spectral doppler in DTG

EJECTION TIME

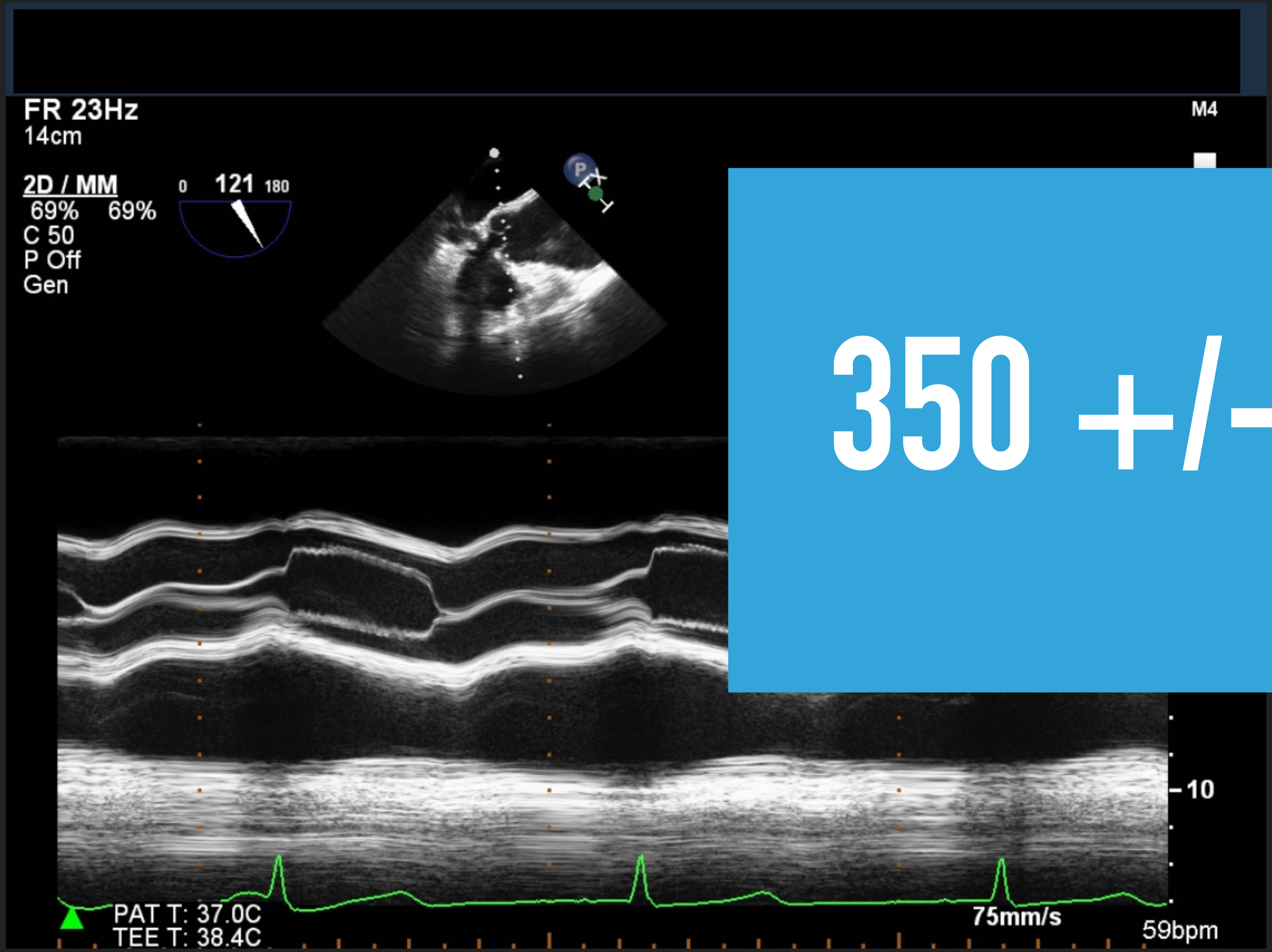


M-MODE through AV, MELAX

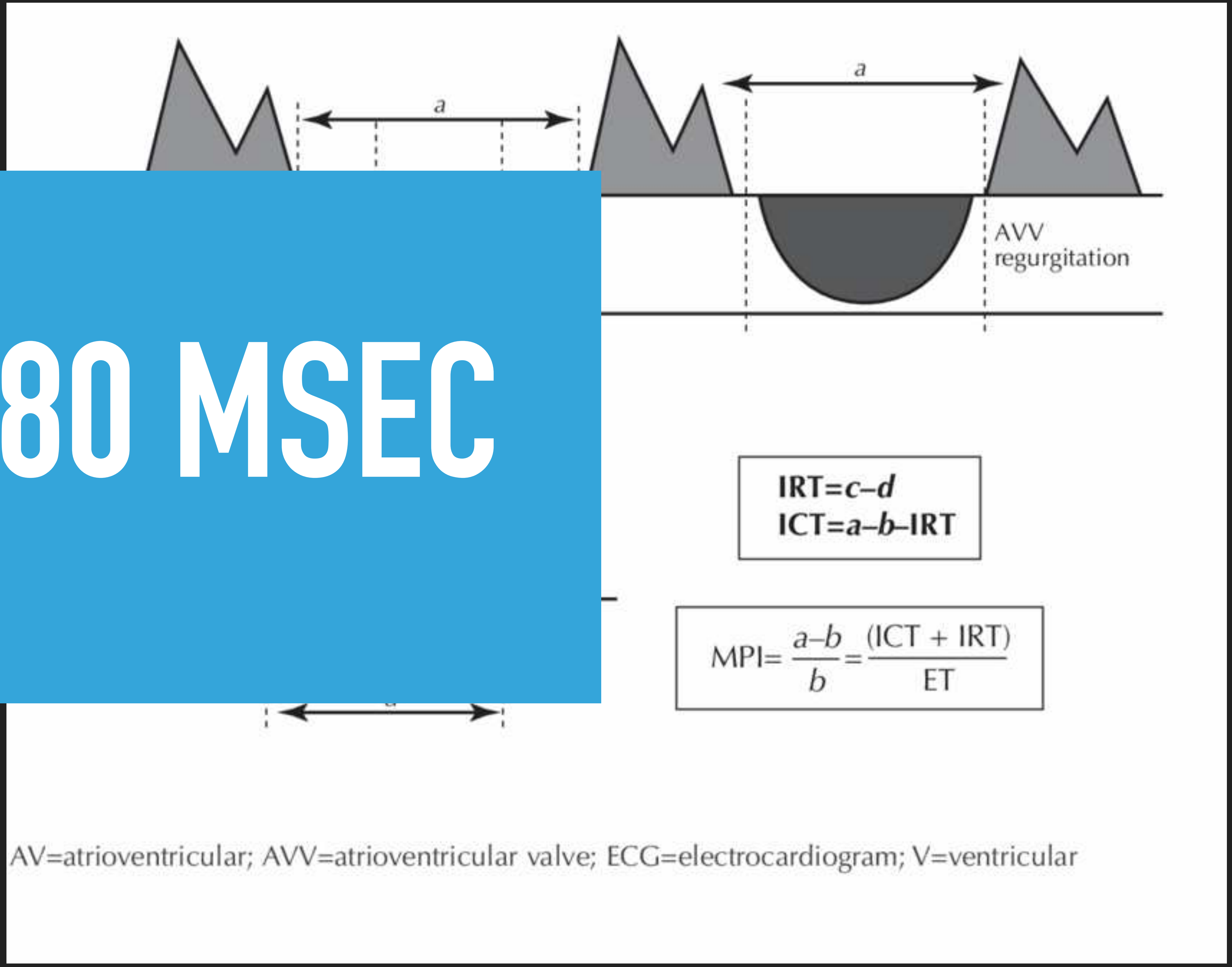


CWD through AV in DTG

EJECTION TIME



350 +/- 80 MSEC



M-MODE through AV, MELAX

LVOTO spectral doppler in DTG

EJECTION PHASE INDICES

Velocity of circumferential fibre shortening

Fractional shortening * 1 / ejection time (s)

- What are two ways of measuring ejection time?
- What is the normal vcf?

1.1 CIR/SEC

EJECTION PHASE INDICES

Velocity of circumferential fibre shortening

Fractional shortening * 1 / ejection time (s)

- For a patient with a FS of 24% and an average ejection time of 350ms, what is the VCF?

EJECTION PHASE INDICES

Velocity of circumferential fibre shortening

Fractional shortening * 1 / ejection time (s)

- **For a patient with a FS of 24% and an average ejection time of 350ms, what is the VCF?**

.24 * 1 / .35 sec = .68 circ/sec

EJECTION PHASE INDICES

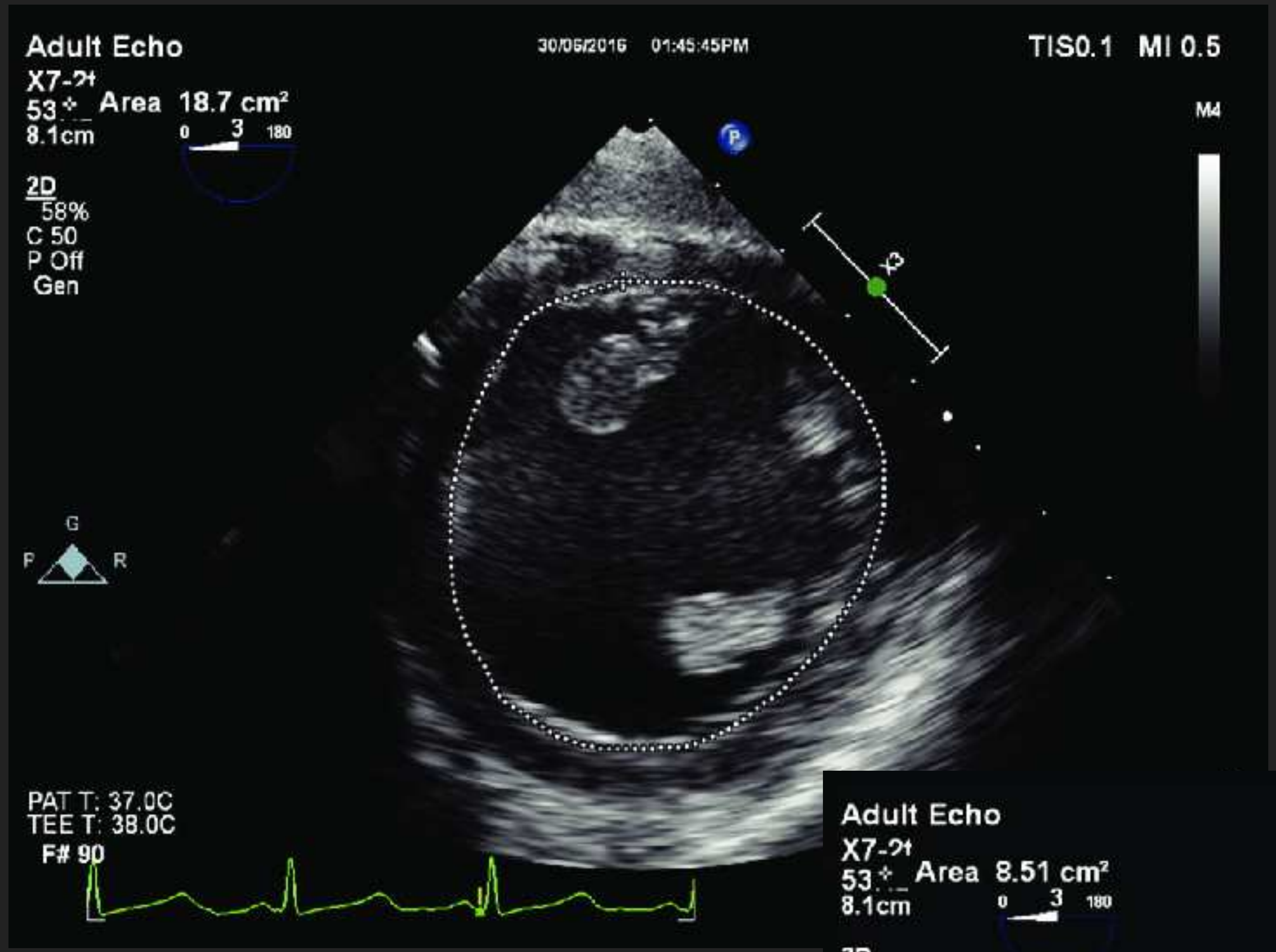
1. Fractional shortening (1D)
2. Velocity of circumferential fibre shortening
3. Fractional area change (2D)
4. Ejection fraction (3D)

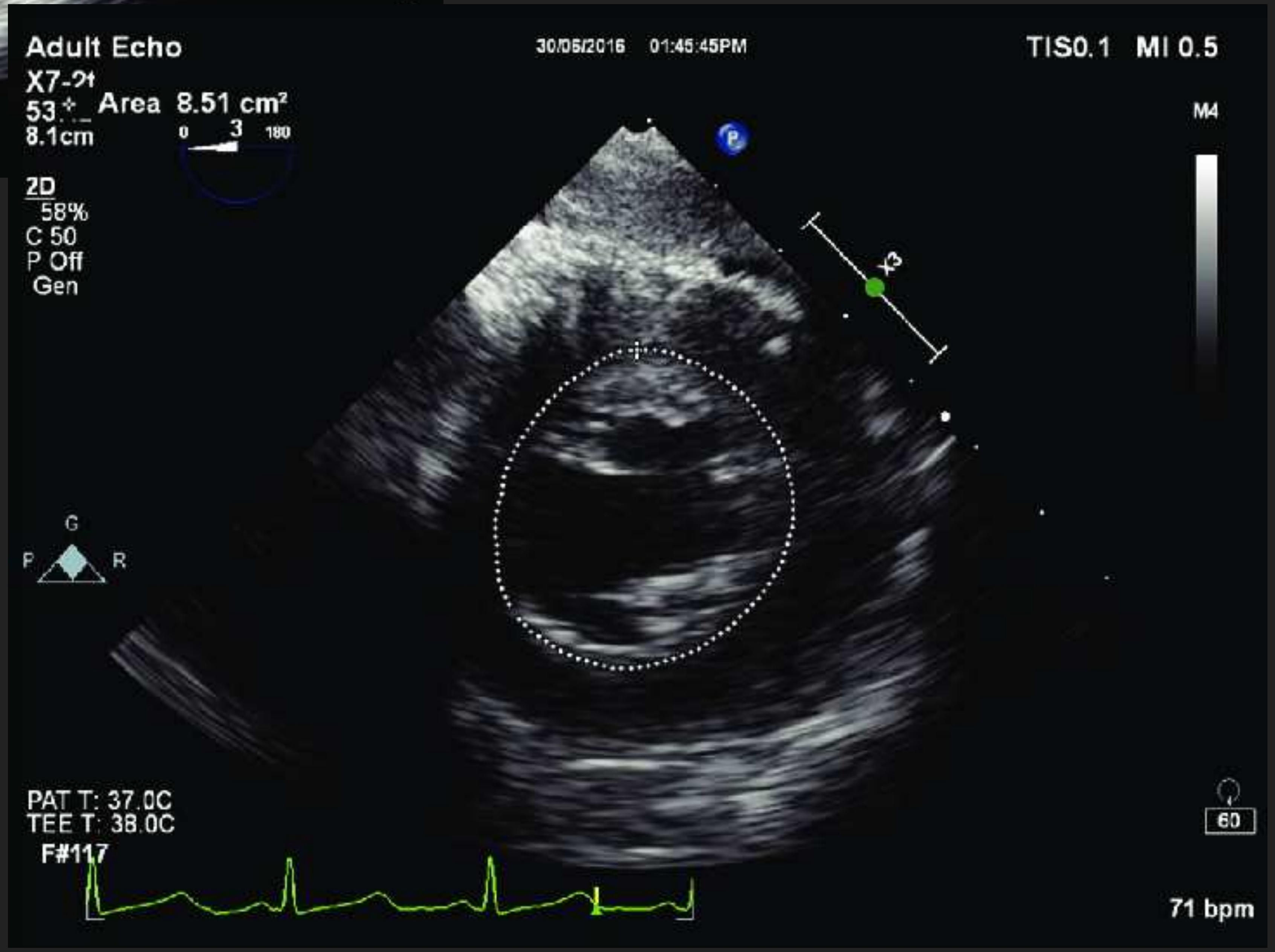
EJECTION PHASE INDICES

3. Fractional Area Change

$$\frac{\text{(End-Diastolic Area)} - \text{(End-Systolic Area)}}{\text{End-Diastolic Area}} \cdot 100\%$$

- Quick and easy
- Avoids foreshortening of the apex
- Inaccurate if any regional dysfunction is present
- Dependant upon accurate cross section





>35%

EJECTION PHASE INDICES

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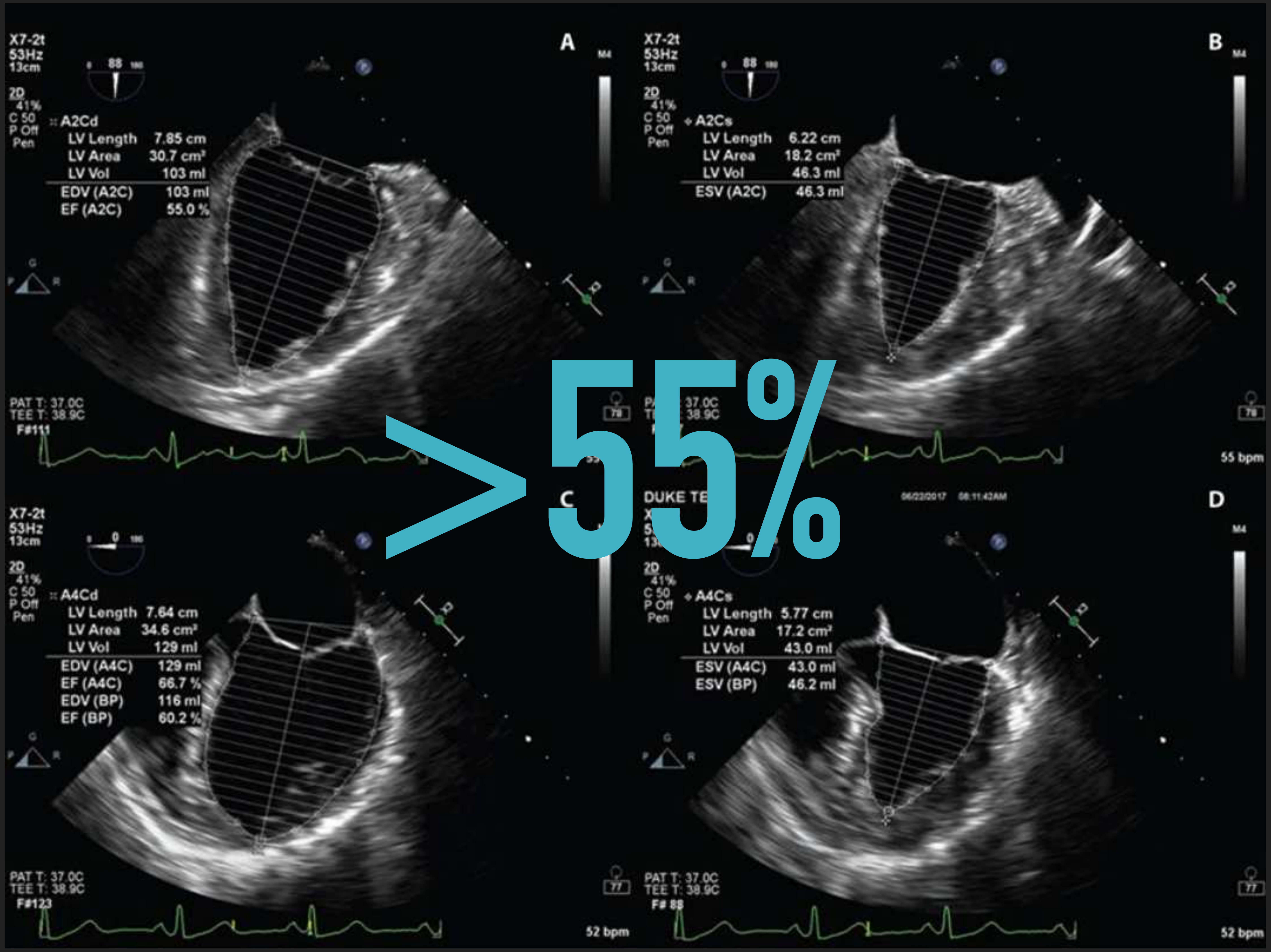
2. Velocity of circumferential fibre shortening
3. Fractional area change (2D)
4. Ejection fraction (3D)

EJECTION PHASE INDICES

3. Fractional Area Change

$$\text{Ejection Fraction} = \frac{(\text{End-Diastolic Volume}) - (\text{End-Systolic Volume})}{\text{End-Diastolic Volume}} \cdot 100\%$$

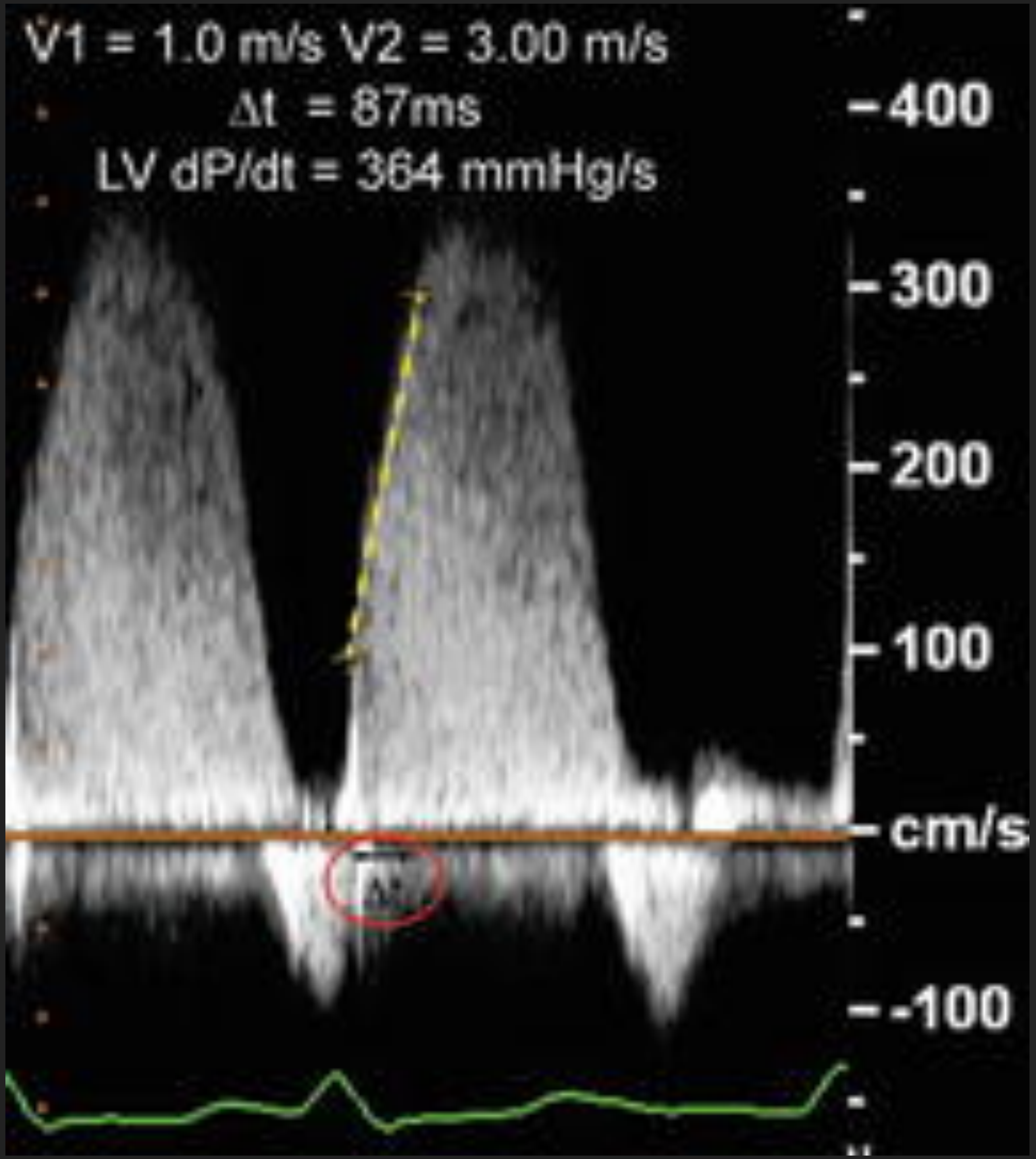
- Quick and easy
- Dependant on clear endocardial border definition, no foreshortening (TEE often underestimates)
- Does not account for MR



ISOVOLUMETRIC PHASE INDICES (DP/DT)

- The maximum rate of rise of LV pressure during systole aka how fast the myocardium can contract
- CWD through the mitral valve, requires an MR jet
- Time for the velocity to rise from 1-3 m/s aka 'rate of pressure rise'

$$dP/dt = 32 \cdot 1000/dt$$



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- CWD through the mitral valve, requires an MR jet
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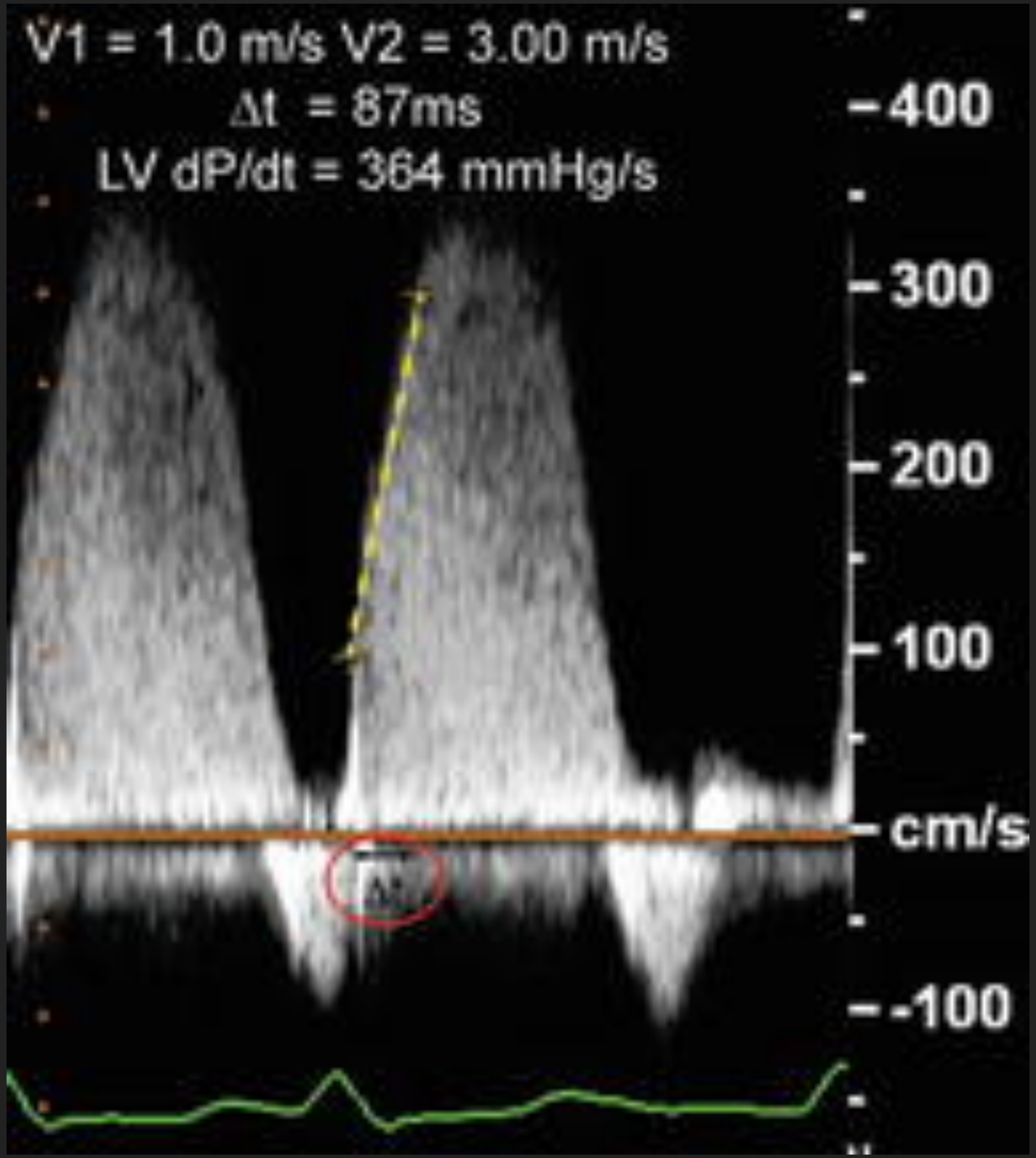
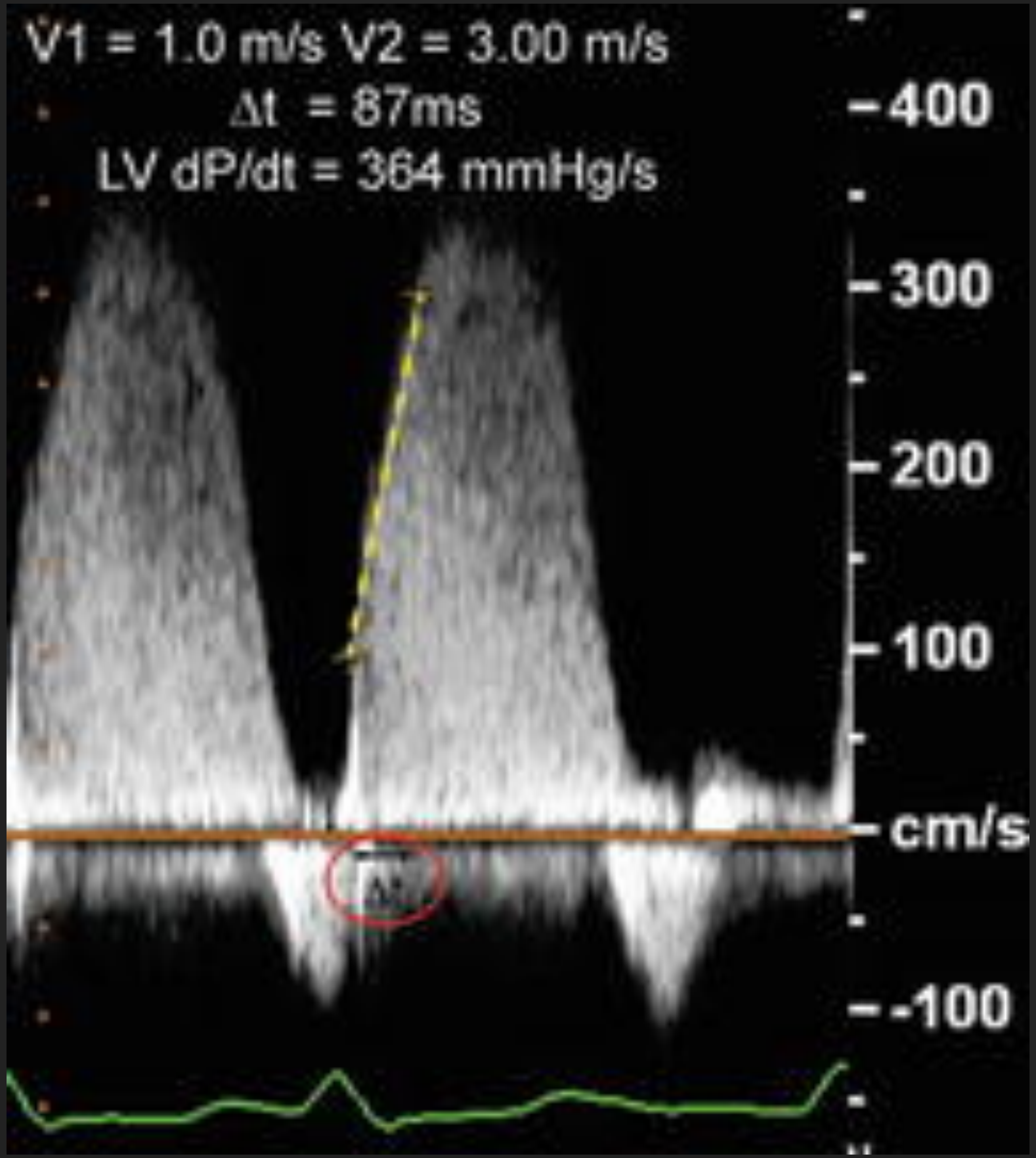
$$dP/dt = 32 \cdot 1000/dt$$

>1200



ISOVOLUMETRIC PHASE INDICES (DP/DT)

- Quick and easy
- Accurate in patients with MR
- Afterload independent
- Needs a clear MR envelope
- Preload dependant

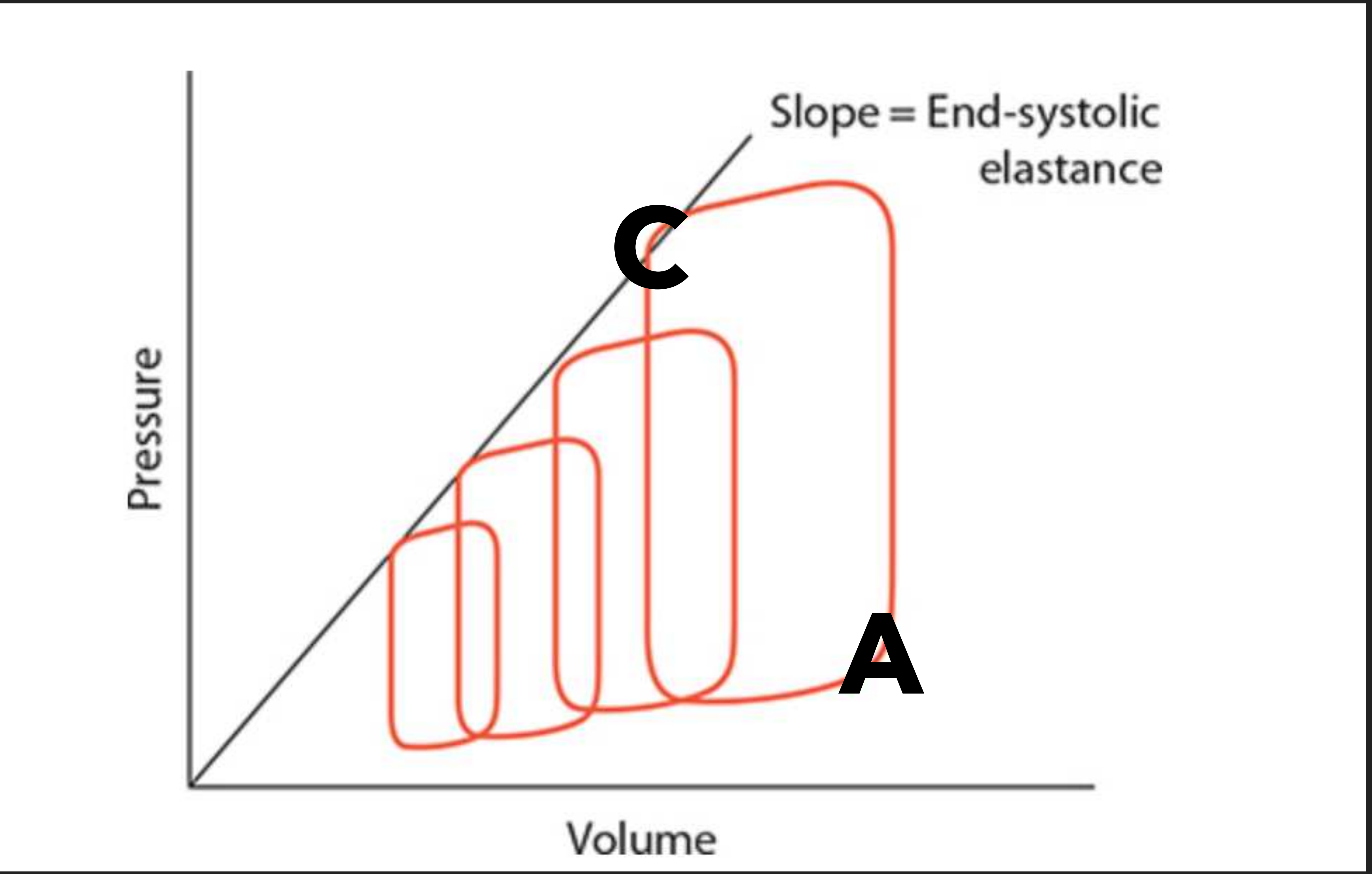


LOAD INDEPENDENT INDICES

- End systolic elastance
- Preload recruitable stroke work
- Preload adjusted max power
- Strain rate

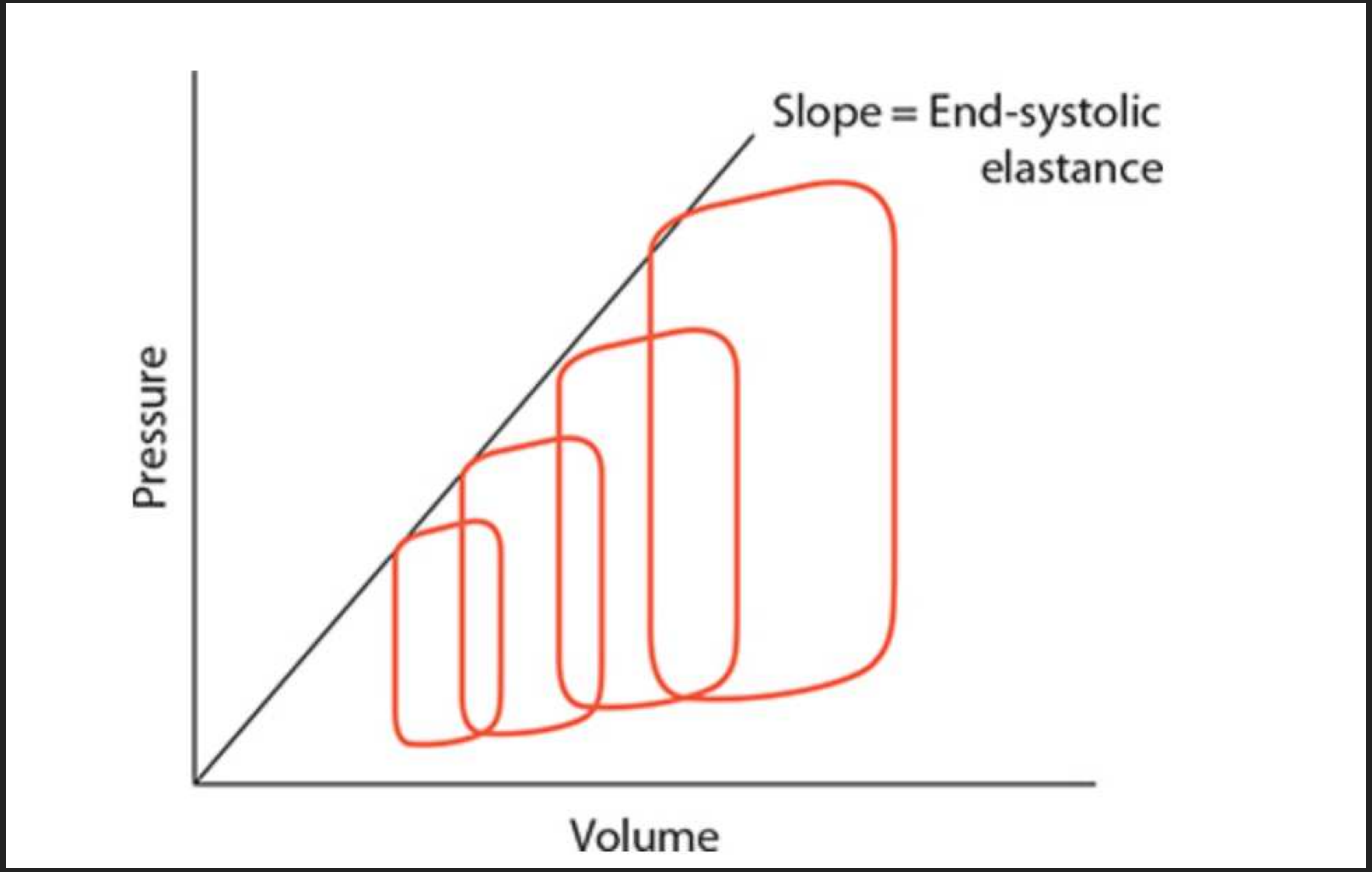
LOAD INDEPENDENT INDICES

- **End systolic elastance**
  - **Best and most load independent index of contractility**
  - Calculated from pressure volume loops under variable loading conditions (nitro, IVC compression)



LOAD INDEPENDENT INDICES

- **Preload recruitable stroke work**
  - Stroke work = Integrated area within a pressure volume loop
  - Calculate stroke work for loops with different loading conditions
  - Plot as a function of end-diastolic volume

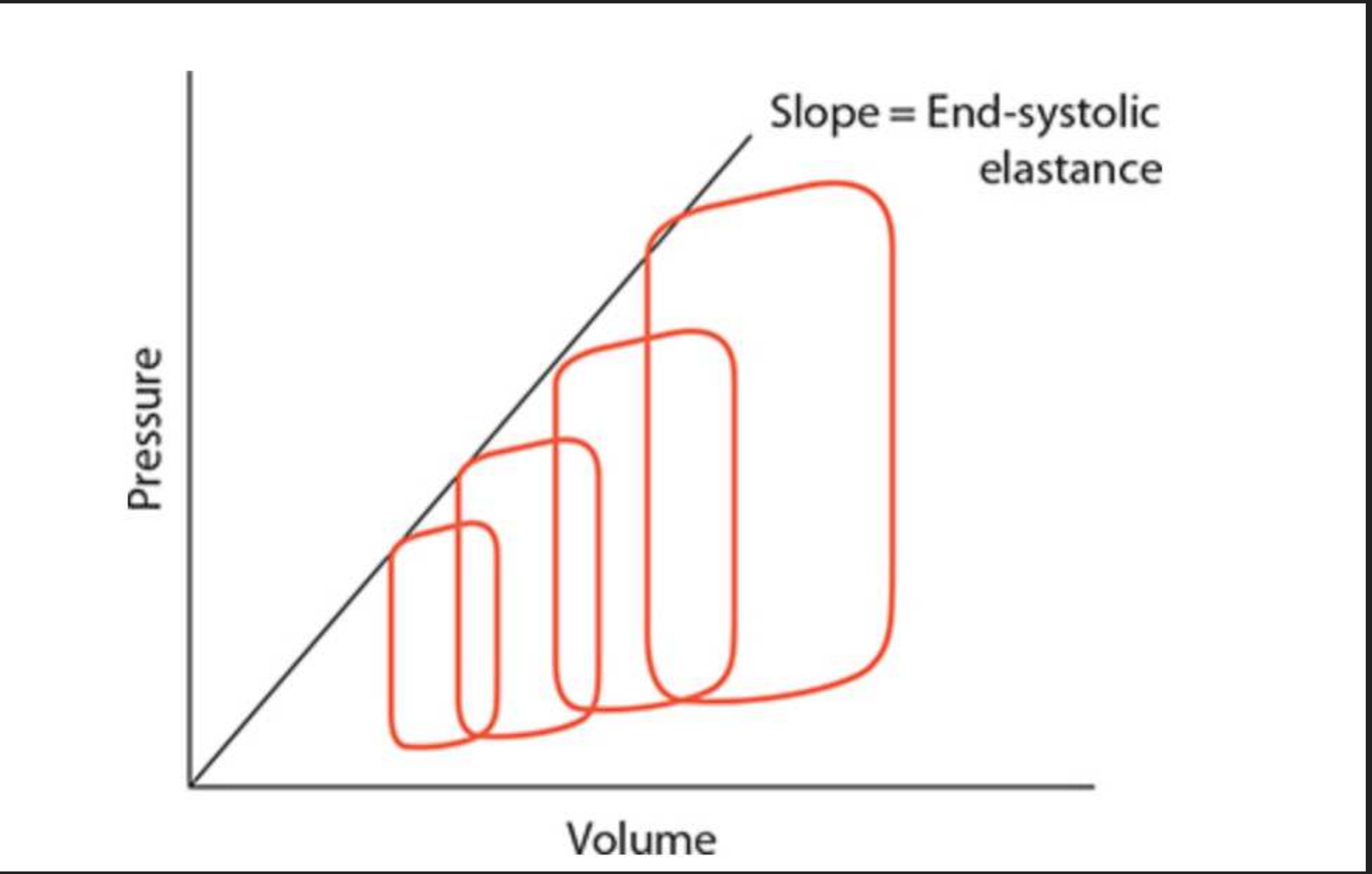


LOAD INDEPENDENT INDICES

- **Preload adjusted max power**
    - Stroke work = Integrated area within a pressure volume loop

Preload-Adjusted Maximal Power Index

$$= \frac{\text{Integrated Area within Pressure-Area Loop}}{(\text{End-Diastolic Area})^{3/2}}$$



LOAD INDEPENDENT INDICES

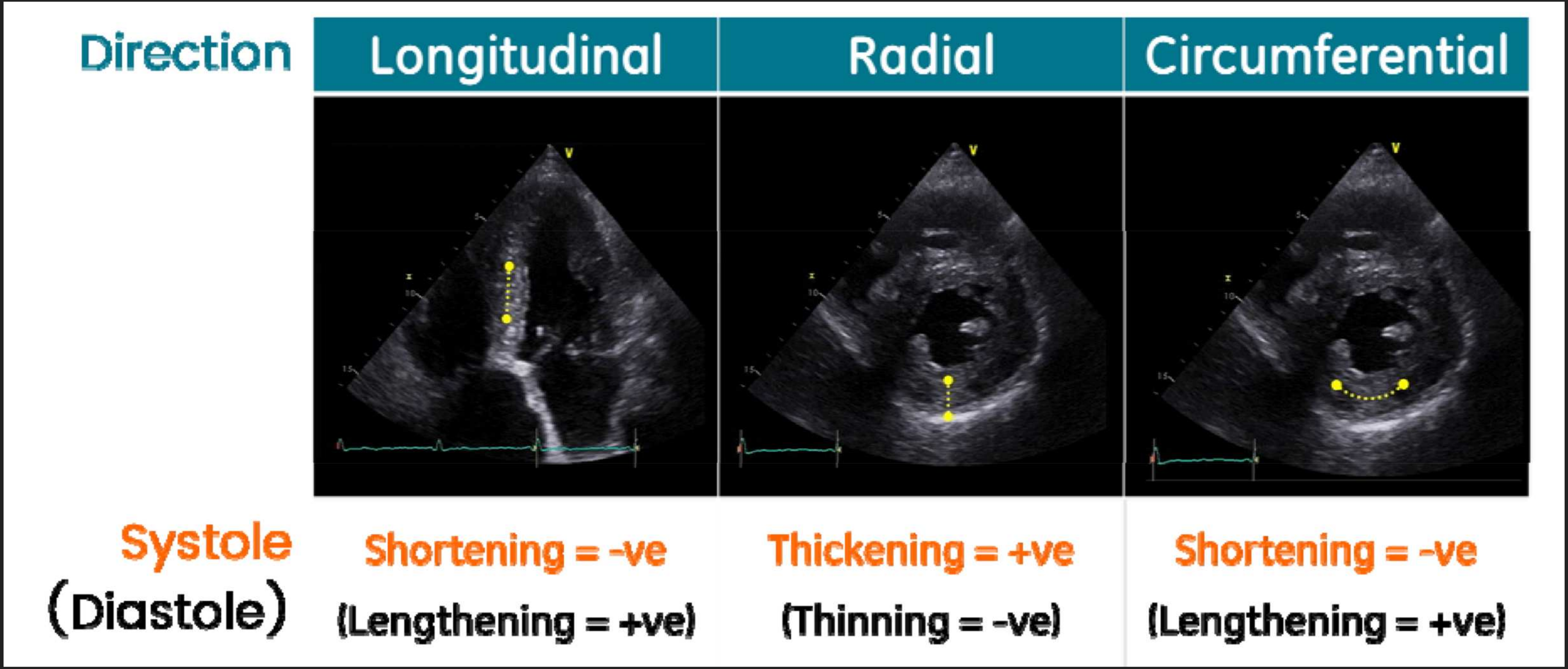
- **Strain and Strain Rate**
  - Dimensionless measure
  - “Fractional change in length produced by the application of stress”
  - Derived from Doppler Tissue Imaging or Speckle tracking

$$\text{Strain} = \frac{\text{Length} - \text{Length}_0}{\text{Length}_0}$$

$$\text{Strain Rate} = \frac{\text{Strain}}{\text{Time}}$$

$$\text{Strain Rate} \cong \frac{\text{Velocity}_a - \text{Velocity}_b}{\text{Distance}}$$

TYPES OF STRAIN



LOAD INDEPENDENT INDICES

- **Strain and Strain Rate**
  - Dimensionless measure
  - "Fractional change in length produced by the application of stress"
  - Derived from Doppler Tissue Imaging or Speckle tracking

−16% TO −19%

MORE NEGATIVE = MORE SHORTENING

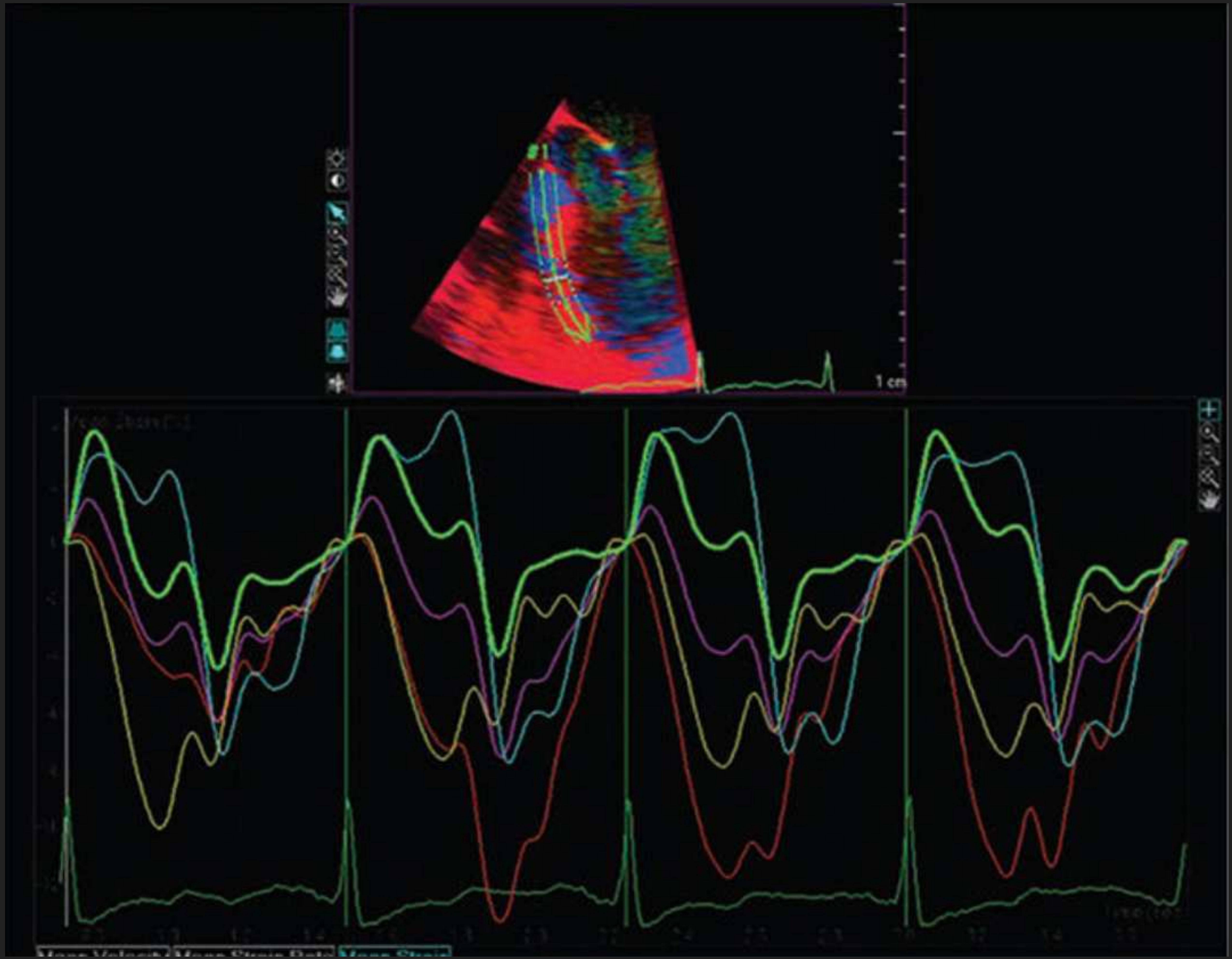
$$\text{Strain} = \frac{\text{Length} - \text{Length}_0}{\text{Length}_0}$$

$$\text{Strain Rate} = \frac{\text{Strain}}{\text{Time}}$$

$$\text{Strain Rate} \cong \frac{\text{Velocity}_a - \text{Velocity}_b}{\text{Distance}}$$

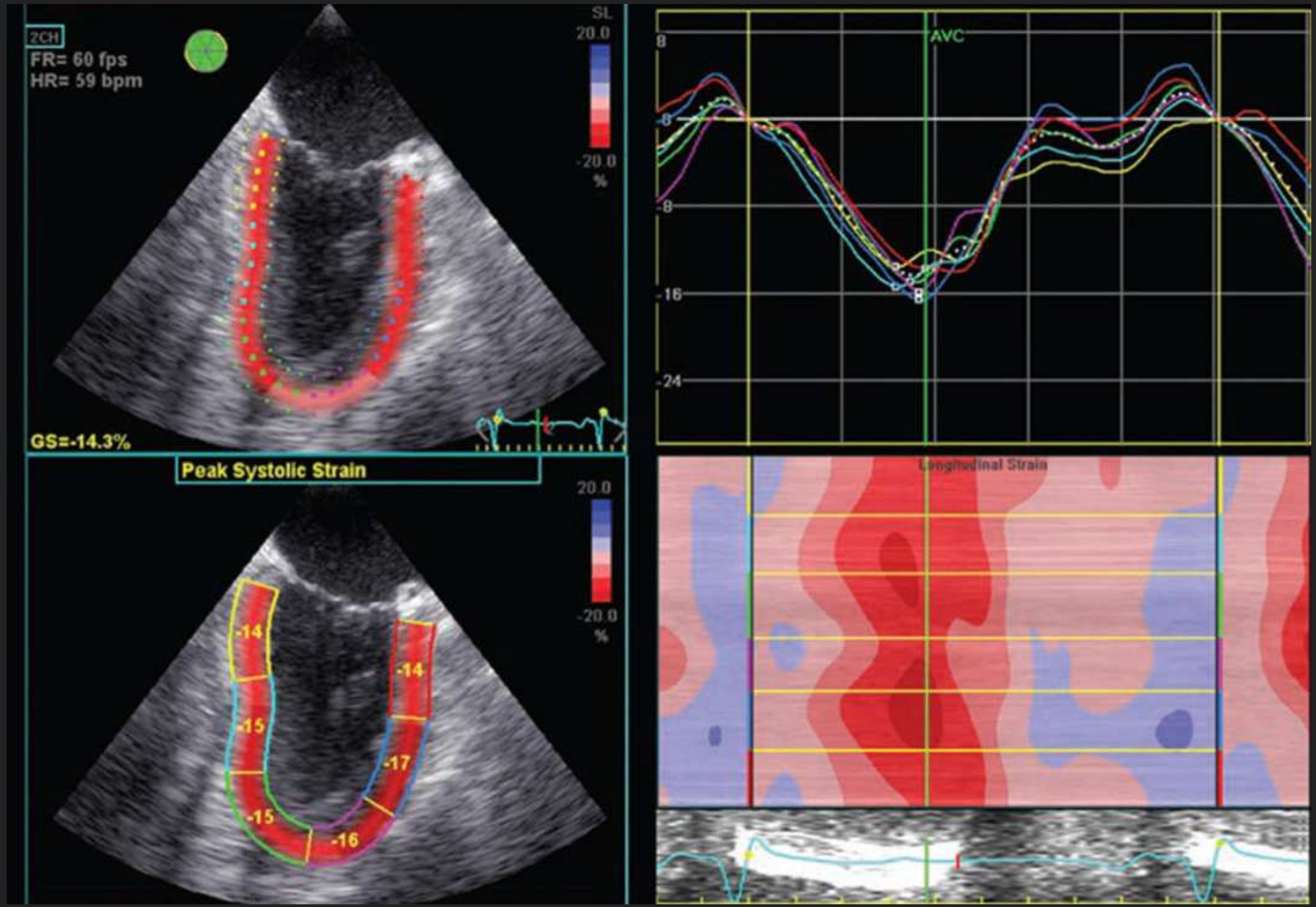
TISSUE DOPPLER IMAGING

- **Form of pulsed wave doppler**
- **Focuses on low frequency, high amplitude signals**
- **Sample gate on lateral mitral annulus gives S', or myocardial segment for strain**
- **Derive peak systolic myocardial velocity**
- Major limitations are:
  - influence from the translation of the heart
  - Angle dependence
  - Overlap for normal and abnormal values

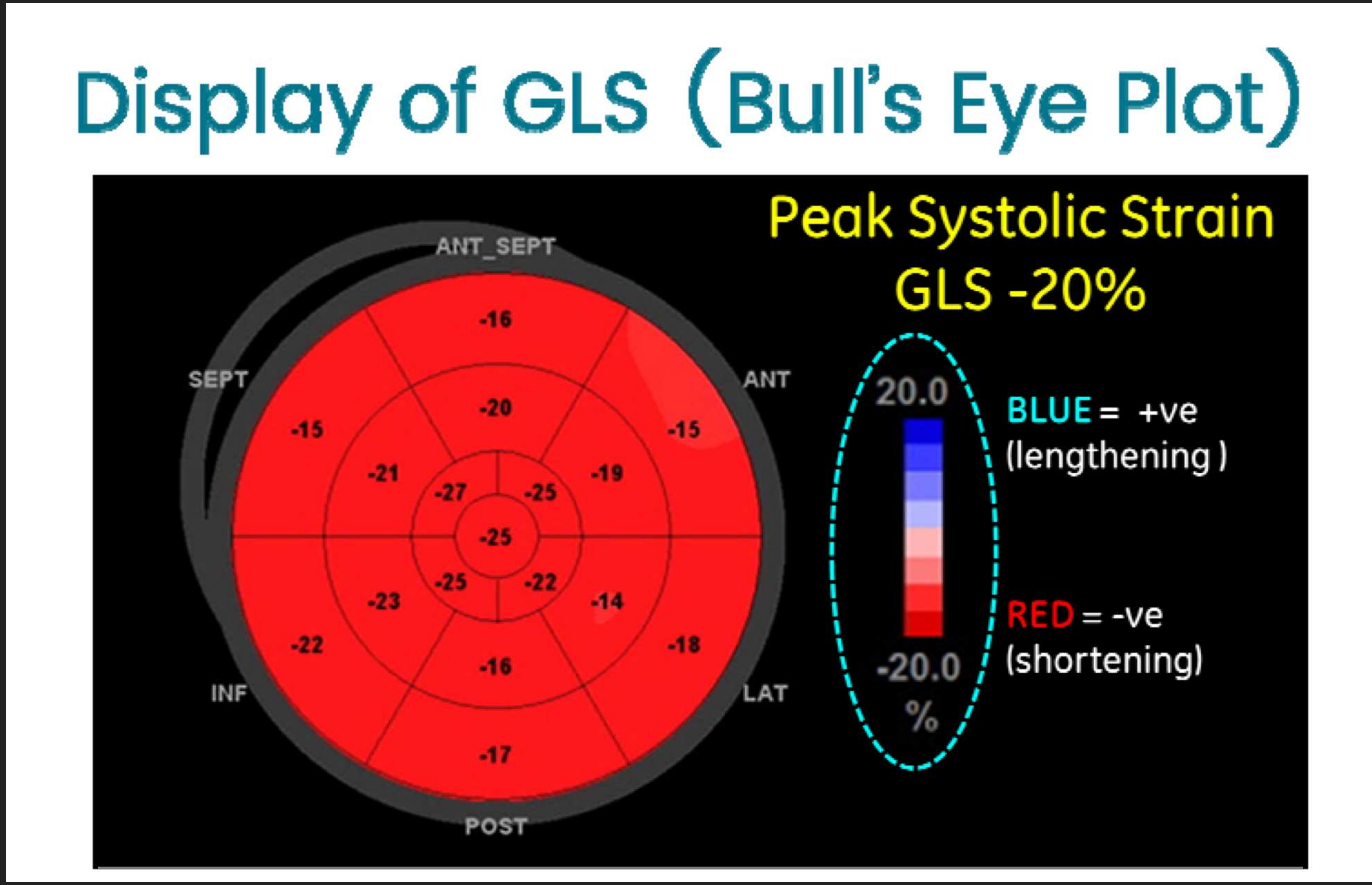


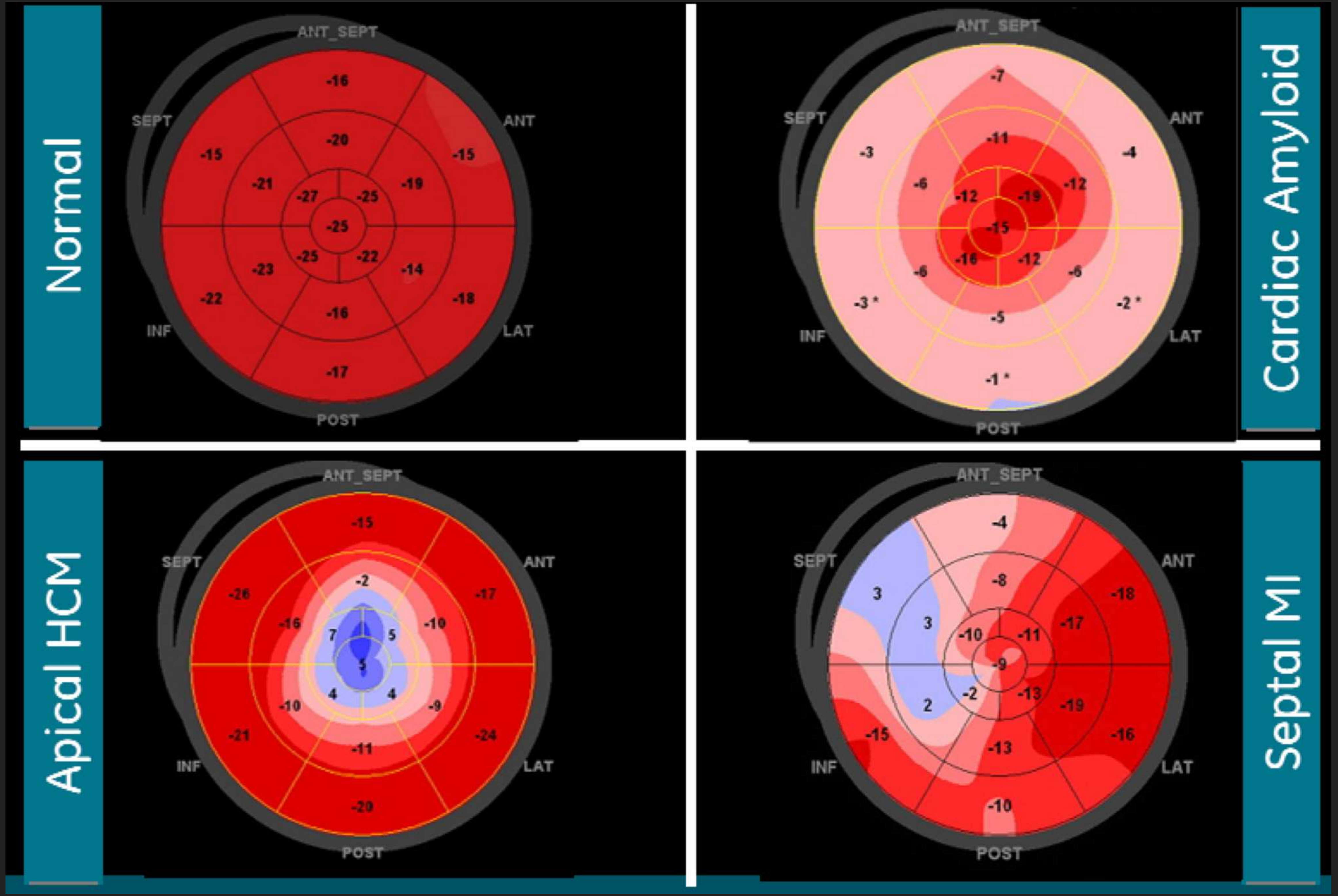
SPECKLE TRACKING

- **Ultrasound imaging of the myocardium creates speckles due to scattering, reflection, interference**
- **Individual speckles can be isolated and tracked frame to frame**
- **Analysis of movement provides angle and translation independent tool for measuring strain, strain rate**
- Limited by noise



SPECKLE TRACKING / STRAIN





OUTLINE

1. RMWA and coronary artery territories
2. Basic LV measurements
3. Ejection phase indices (FS, FAC, EF)
4. Isovolumetric Phase Indices (dP/dt)
5. Load-independent indices (research indices + strain)
6. Strain, Tissue doppler imaging, Speckle tracking
7. 3D LV assessment (video demos)

FANCY 3D STUFF

- Calculating 3D LVEF with MPR
- How to Jelly Bean


Anesthesia
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APTE PREP COURSE
LV SYSTOLIC FUNCTION - FEB 17, 2021