Echo Evaluation of Left Ventricular Support

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Objectives

1. Introduction to left sided support devices including LVAD (left ventricular assist device), and Impella.
2. Explanation of the echo measurements and views required to properly assess whether the device is functioning correctly
3. Case examples highlighting measurements, qualitative assessment, and imaging strategies

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ASE GUIDELINES & STANDARDS

Echocardiography in the Management of Patients with Left Ventr
from the

Raymond F. Stainback, FASE, Emma J. F
James N. Kirkpatrick,
Cleveland, Ohio; Louis

(J Am Soc Echocardic

Keywords: Echocardio
examination

GUIDELINES AND STANDARDS

Recommendations for Multimodality Imaging of Patients With Left Ventricular Assist Devices and Temporary Mechanical Support: Updated Recommendations from the American Society of Echocardiography

Check for updates

Jerry D. Estep, MD, FASE, Chair, Alina Nicoara, MD, FASE, Co-Chair, Joao Cavalcante, MD, FASE, Su Min Chang, MD, FASE, Sheela Pai Cole, MD, FASE, Jennifer Cowger, MD, MS, Mani A. Daneshmand, MD, Brian D. Hoit, MD, FASE, Navin K. Kapur, MD, Eric Kruse, BS, ACS, RDCS, RVT, FASE, G. Burkhard Mackensen, MD, PhD, FASE, Venkatesh L. Murthy, MD, PhD, Raymond F. Stainback, MD, FASE, and Bo Xu, MD, FASE, *Weston, Florida; Durham, North Carolina; Minneapolis, Minnesota; Houston, Texas; Stanford, California; Detroit, Michigan; Atlanta, Georgia; Cleveland, Ohio; Boston, Massachusetts; Chicago, Illinois; Seattle, Washington; and Ann Arbor, Michigan*

Keywords: Echocardiography, Left ventricular assist devices, HeartMate 3, Temporary mechanical circulatory support, Comprehensive examination

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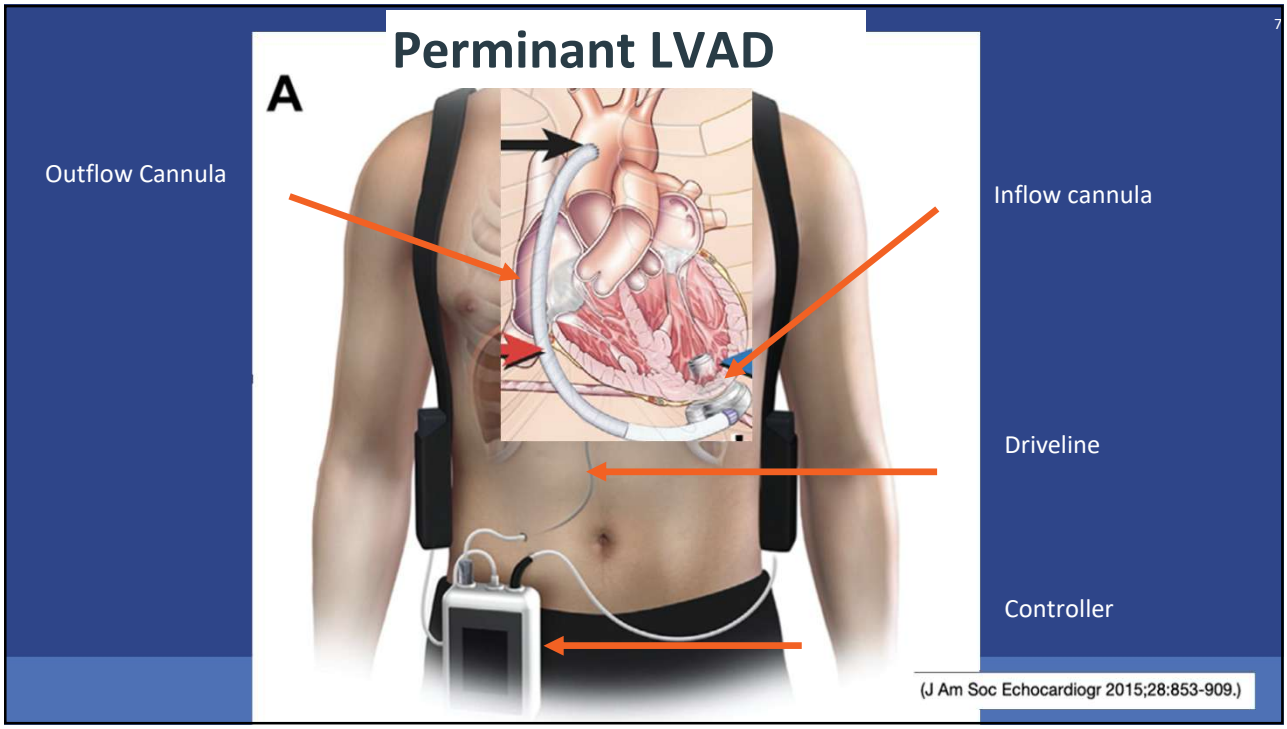

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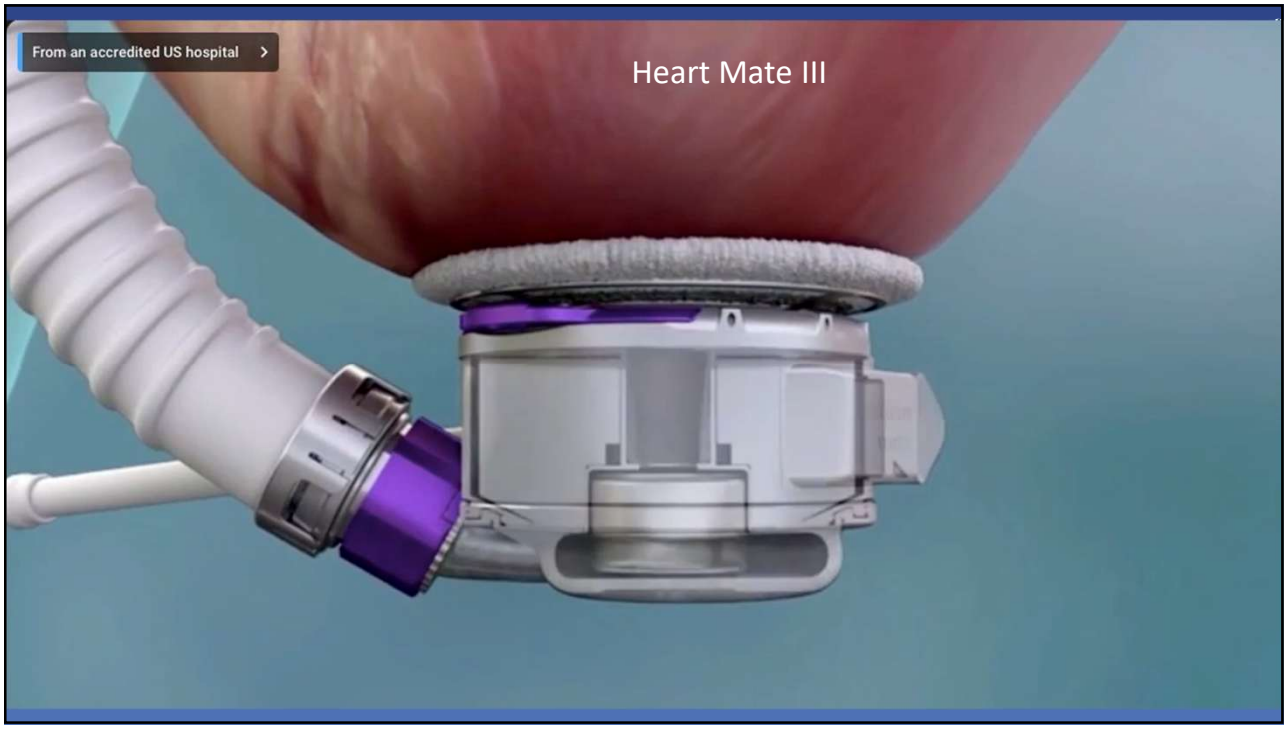

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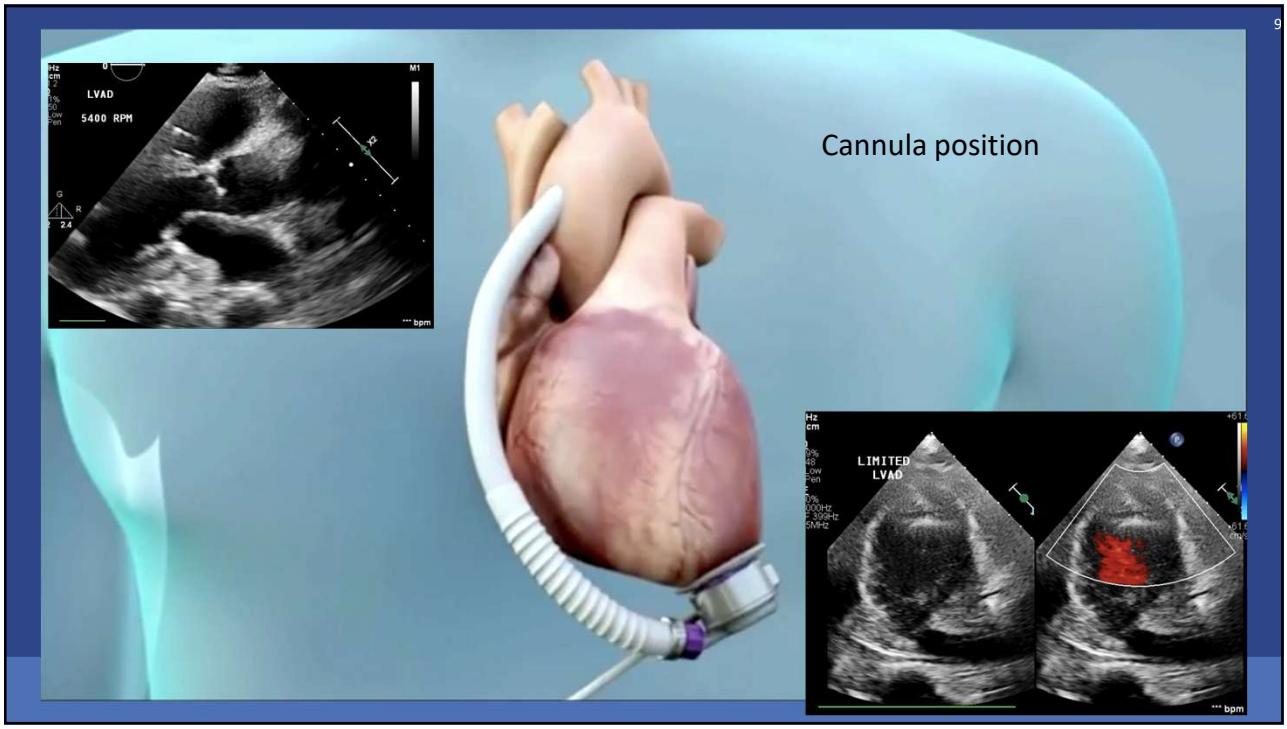

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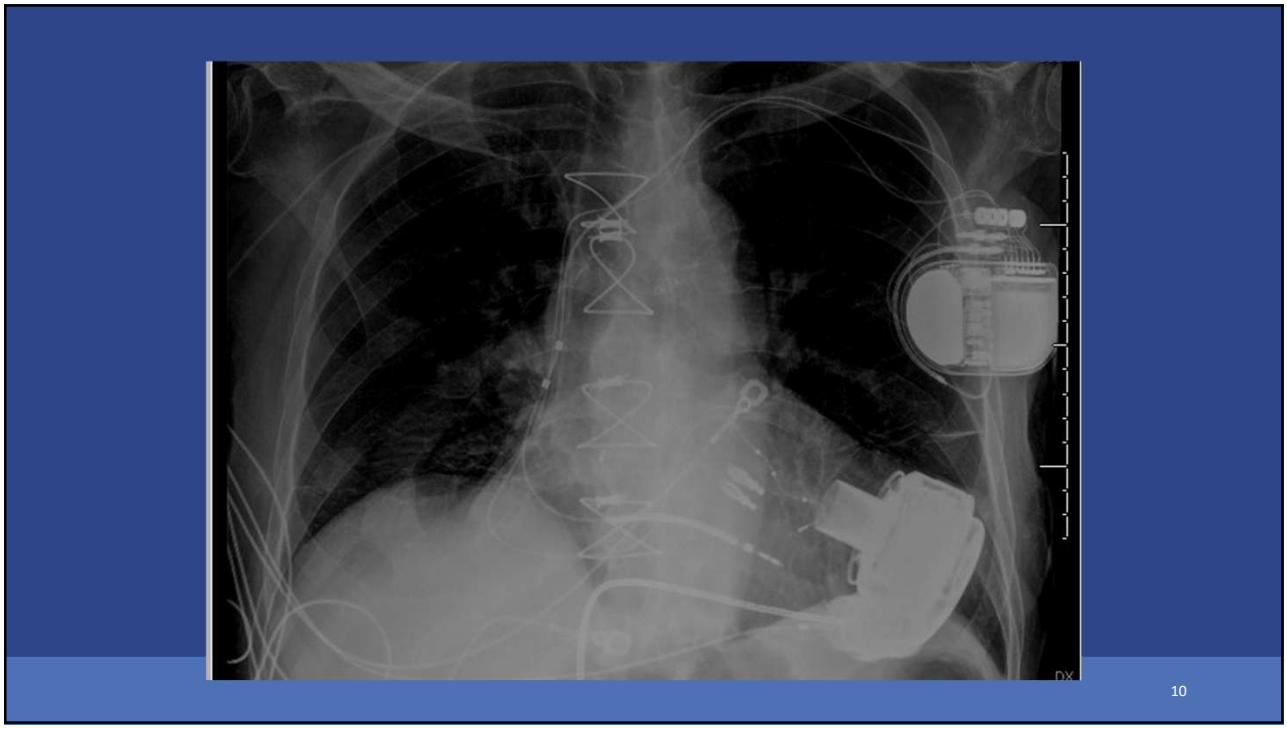

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Complications

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Complications and Red Flags

Complications

TTE and/or TEE (first line)

- Cardiac tamponade
- Early or late RV failure
- Residual or acquired left sided HF***
- TIA or CVA related to thromboembolic events^^
- Low flow alarm troubleshooting#
- Pump dysfunction (ramp testing needed)
- Infection (outflow graft anastomosis, CIED leads, or native or prosthetic valve related)

Gated CCT and/or CTA (second line*)

- Cardiac tamponade
- RV failure (early or late)
- TIA or CVA due to thromboembolic events (aortic root clot, inflow cannula clot, outflow graft thrombus intra-luminal)
- Low flow alarm troubleshooting^
- Outflow cannula twist or kink or extra-luminal obstruction due to thrombus or biodebris
- Pump dysfunction due to inflow/outflow graft

Table 1 Preimplantation TTE/TEE "*red-flag*" findings

Left Ventricle and Interventricular Septum
Small LV size, particularly with increased LV trabeculation
LV thrombus
LV apical aneurysm
Ventricular septal defect
Right Ventricle
RV dilatation
RV systolic dysfunction
Atria, Interatrial Septum, and Inferior Vena Cava
Left atrial appendage thrombus
PFO or atrial septal defect
Valvular Abnormalities
Any prosthetic valve (especially mechanical AV or MV)
> mild AR
≥ moderate MS
≥ moderate TR or > mild TS
> mild PS; ≥ moderate PR
Other
Any congenital heart disease
Aortic pathology: aneurysm, dissection, atheroma, coarctation
Mobile mass lesion
Other shunts: patent ductus arteriosus, intrapulmonary

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(J Am Soc Echocardiogr 2015;28:853-909.)

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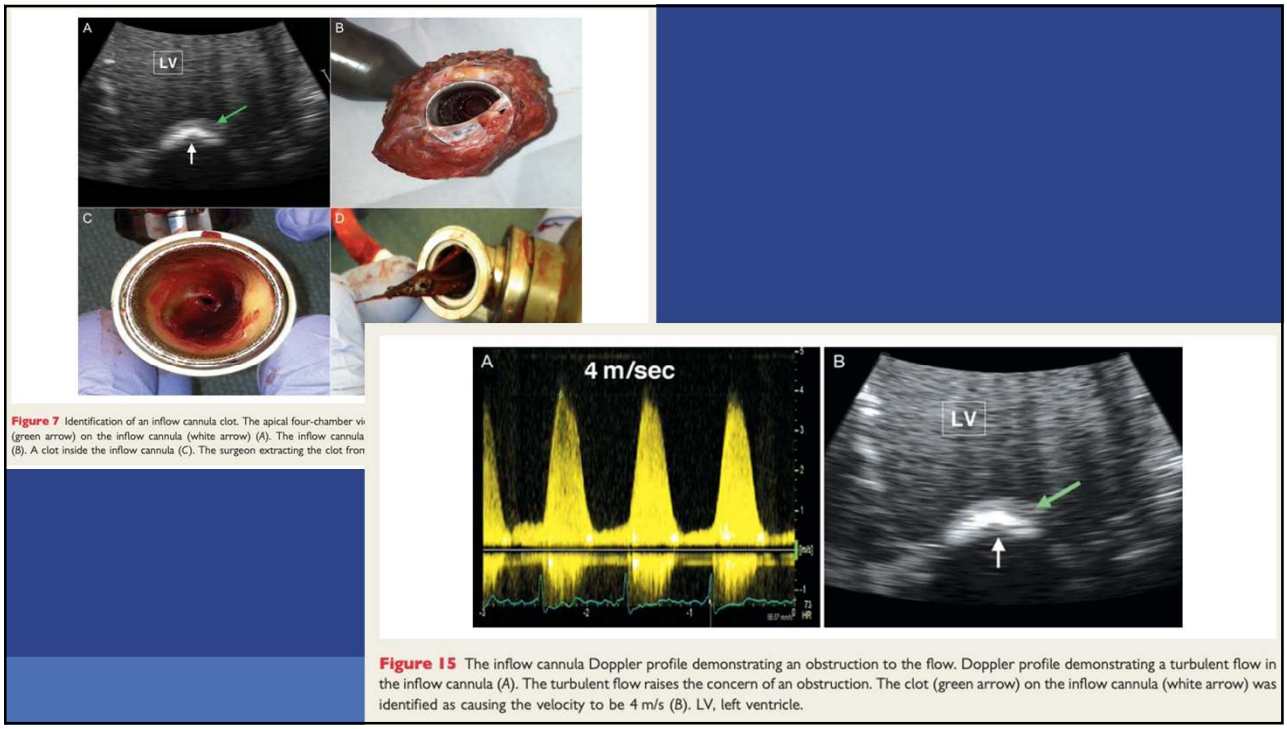

Figure 7 Identification of an inflow cannula clot. The apical four-chamber vi (green arrow) on the inflow cannula (white arrow) (*A*). The inflow cannula (*B*). A clot inside the inflow cannula (*C*). The surgeon extracting the clot fron

Figure 15 The inflow cannula Doppler profile demonstrating an obstruction to the flow. Doppler profile demonstrating a turbulent flow in the inflow cannula (*A*). The turbulent flow raises the concern of an obstruction. The clot (green arrow) on the inflow cannula (white arrow) was identified as causing the velocity to be 4 m/s (*B*). LV, left ventricle.

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Important Echo Considerations: Pre Implant

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Important Echo Assessments

- EF should be < 25%, with strong consideration to use both contrast and volume measures.
- Establish baseline LVIDd measurement for repeat evaluation. Small LV cavities have a higher incidence of 30 day morbidity and mortality (< 5.5 cm).
- ***Full RV function assessment should be performed on all LVAD patients, especially in the screening process***.
- RV measures such as RV strain (<-9.6%) and RV/LV end diastolic ratio > 0.75 were strong independent predictors of post operative RV dysfunction

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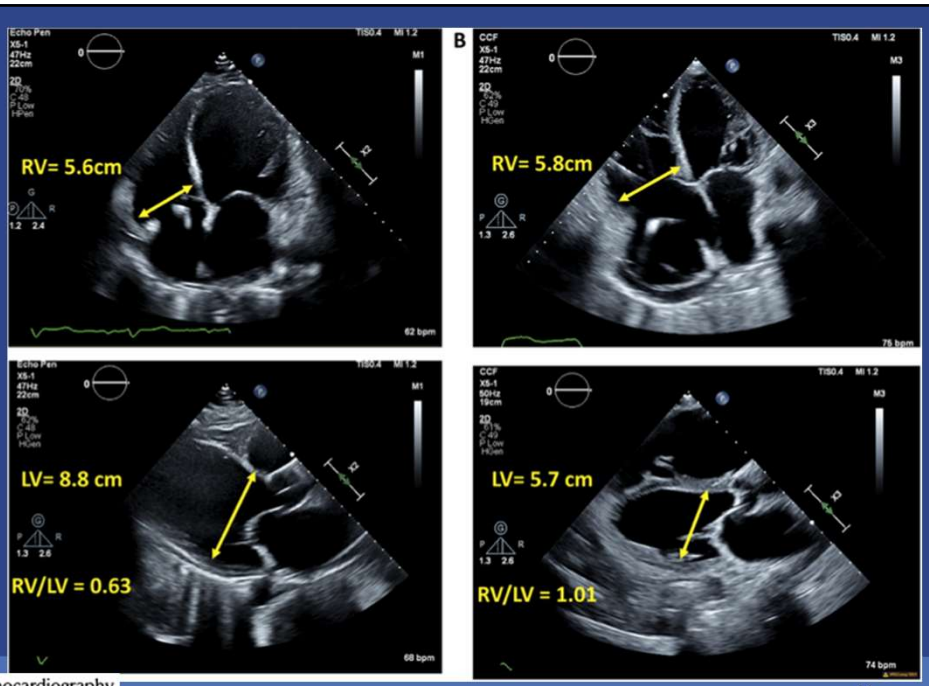
RV/LV Ratio



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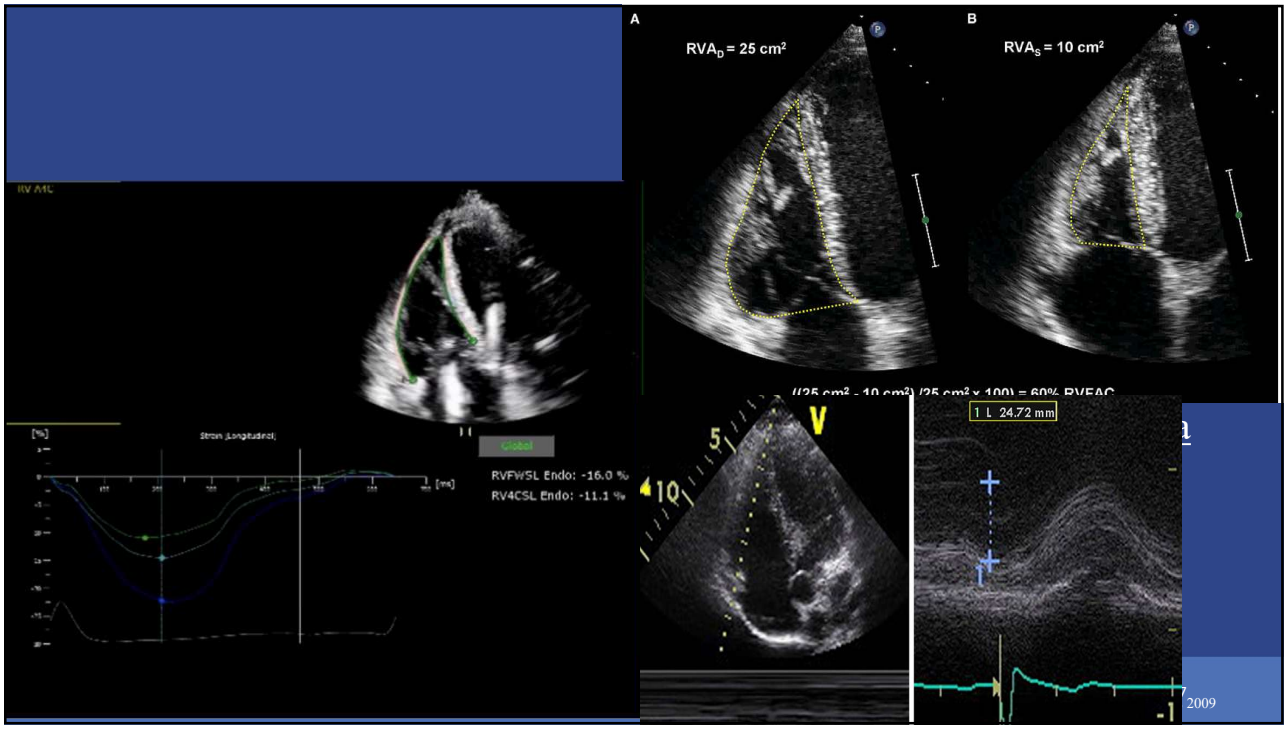

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RV to PA Coupling

•Optimal ventriculo-arterial coupling takes place when there is maximal transference of potential energy from one elastic chamber (the ventricle) to another (the arterial system), and this occurs if both elastances are matched.

•The ratio TAPSE/PASP can therefore be used as an index of ventriculo-arterial coupling.

• Normal Range for TAPSE/PASP is 0.7-0.5 mm/mmhg

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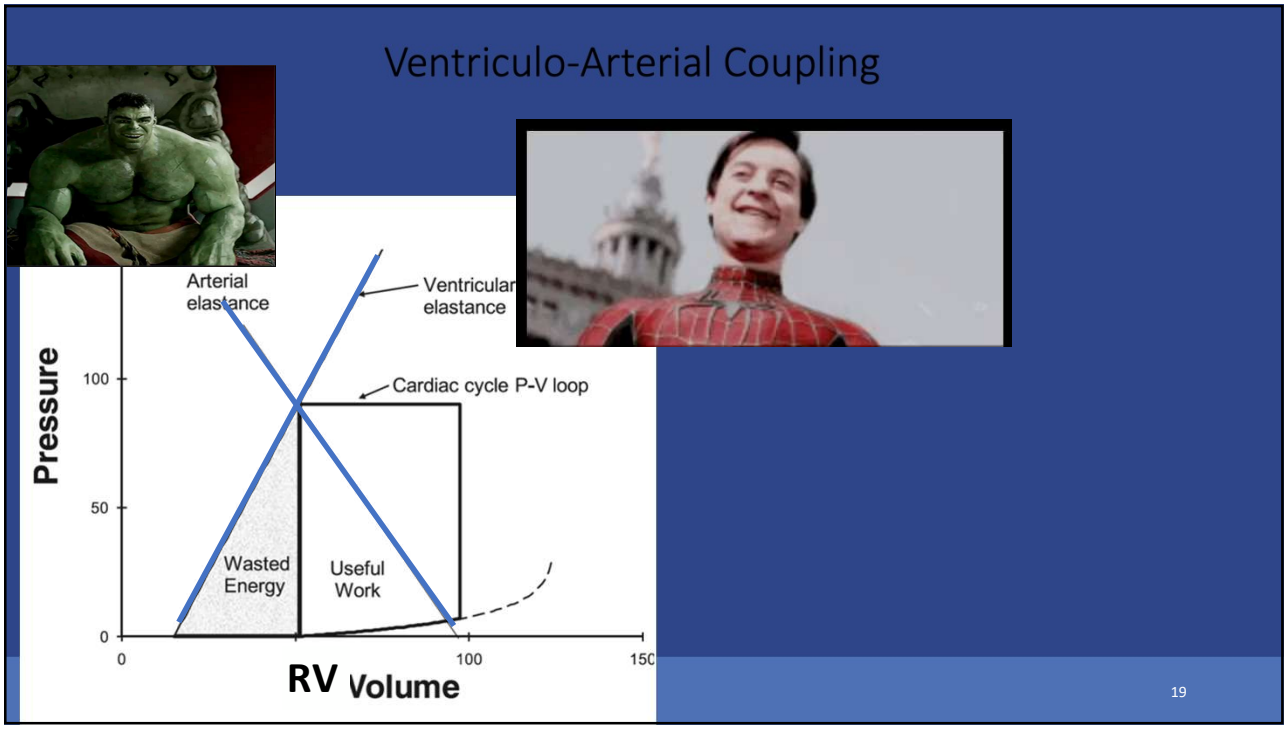

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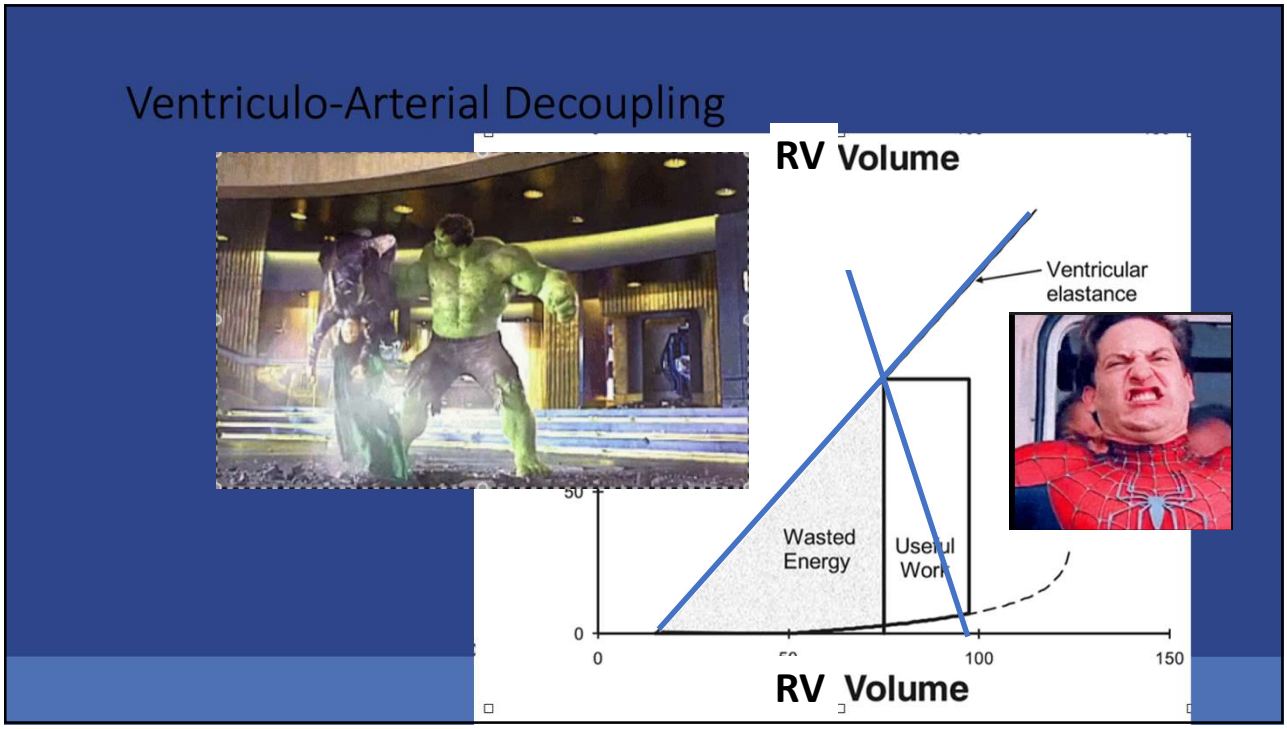

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15 mm / 54 mmhg= 0.27 mm/mmhg…….Uncoupled

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Valve Disease: MR, MS, and TR

- Moderate to severe mitral stenosis can limit LAVD flow
- Mitral regurgitation can resolve with LVAD, however severe MR is red flag
- Tricuspid regurgitation is a red flag due to the association with RV dysfunction
- Mechanical valves should be replaced pre implantation (high PT INR) with bio prosthetics

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Warning: Aortic Regurgitation

- Estimation of Aortic regurgitation is essential as the retrograde aorta to LV gradient is increased
- Significant regurgitation can create “futile” cycles
- Some correction method are replacement of the valve (most common with TAVR), Park stitch, or complete oversewing (least prevalent).

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Imaging

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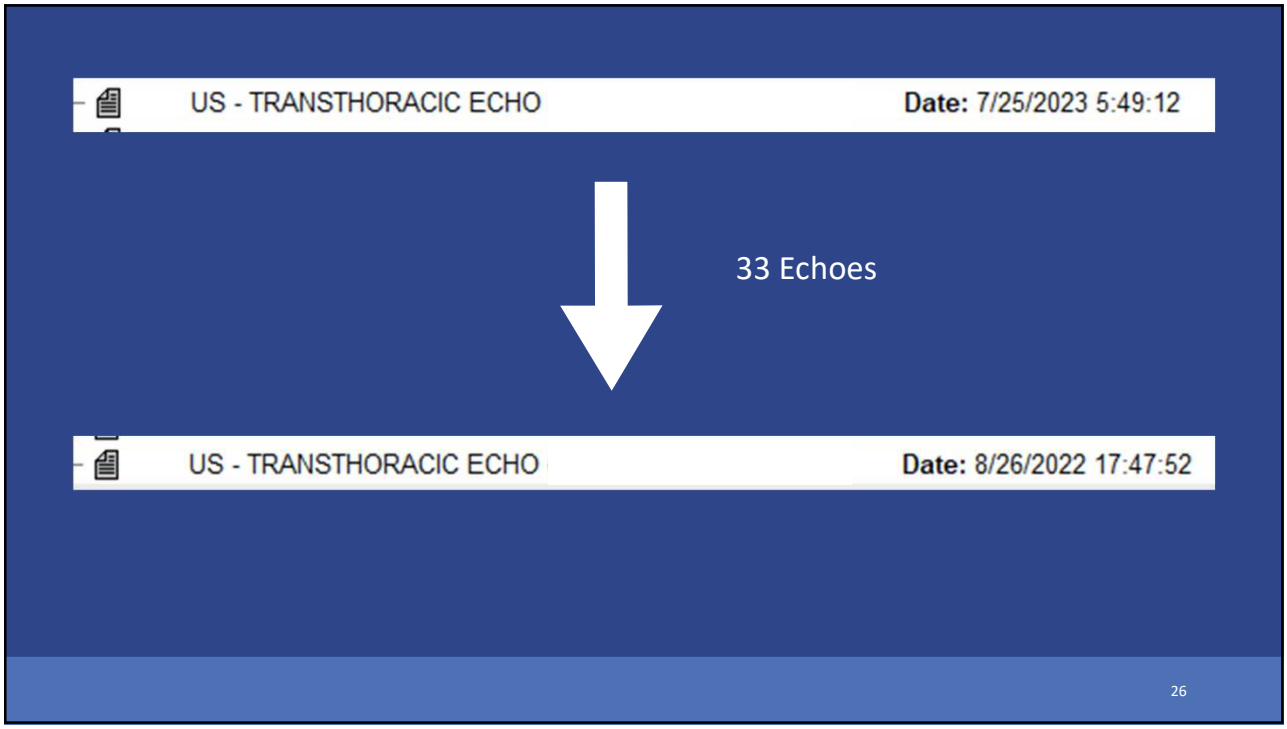

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Imaging Protocol Post Implant

- Pericardial effusion
- Aortic valve opening frequency
- Position of the IVS
- Visualization of inflow and outflow cannula (if applicable)
- Velocities and position of each cannula (if applicable)
- RV FX
- IVC diameter (if applicable)

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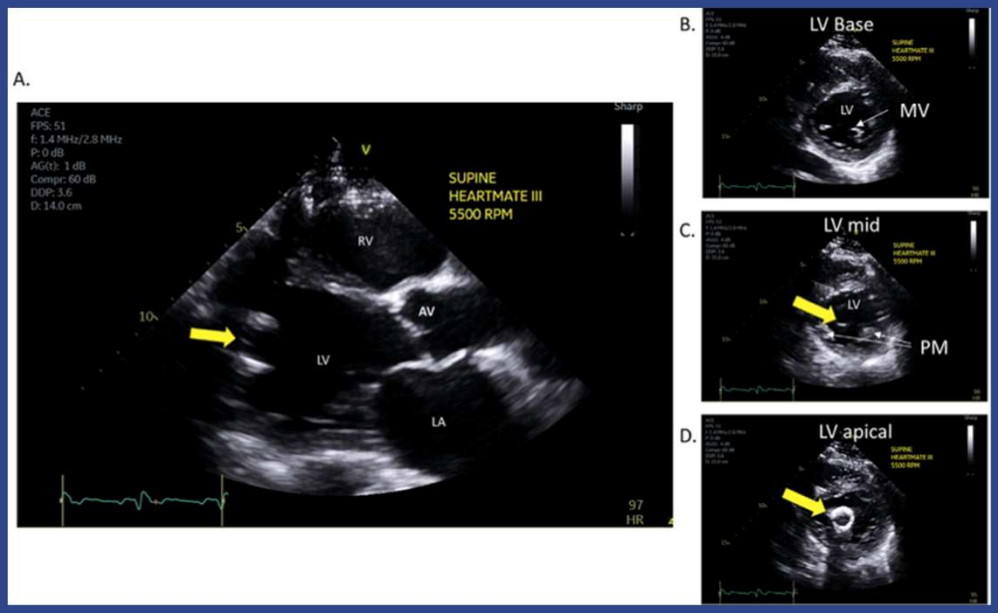
Inflow:

Normal position



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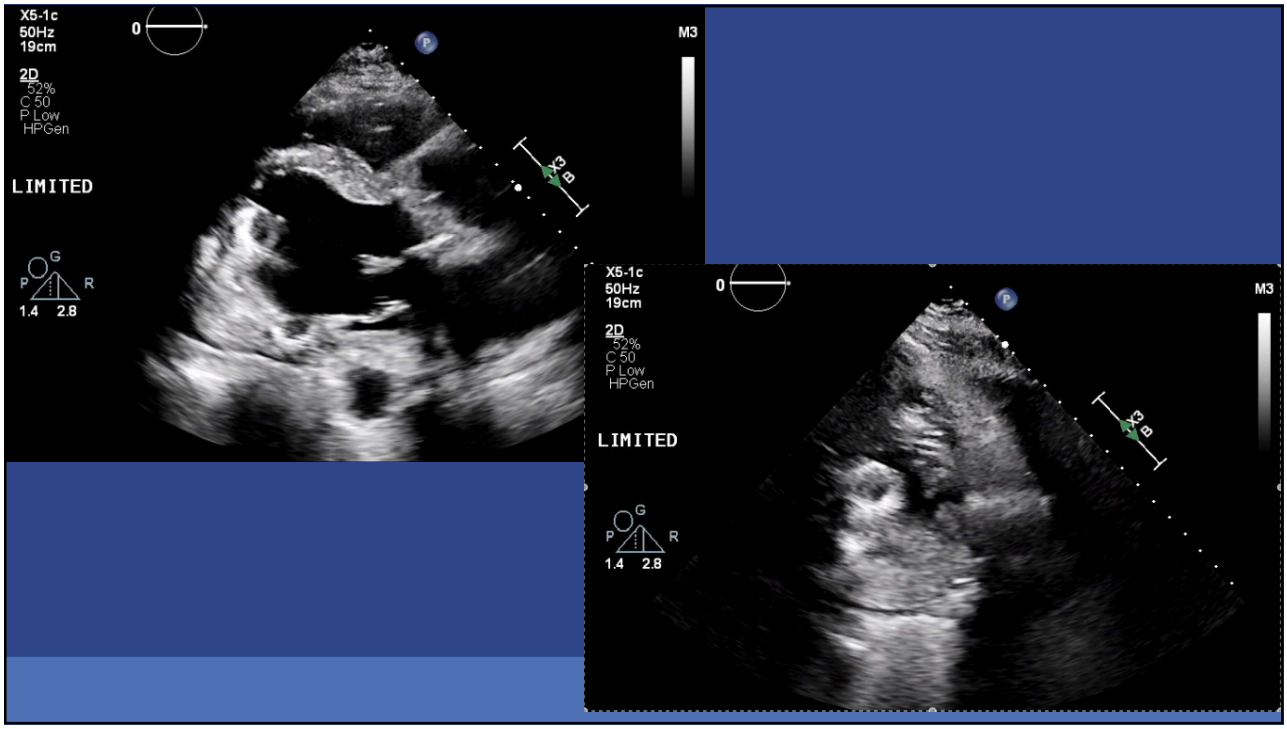

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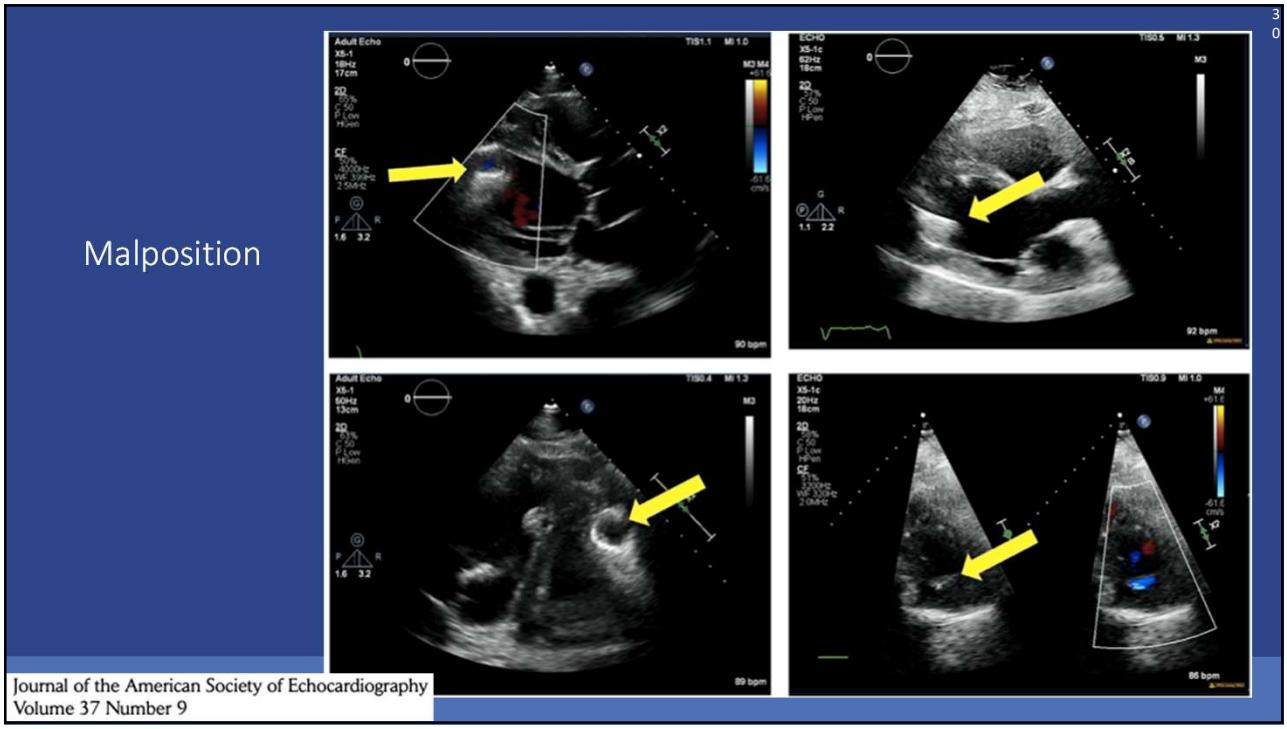

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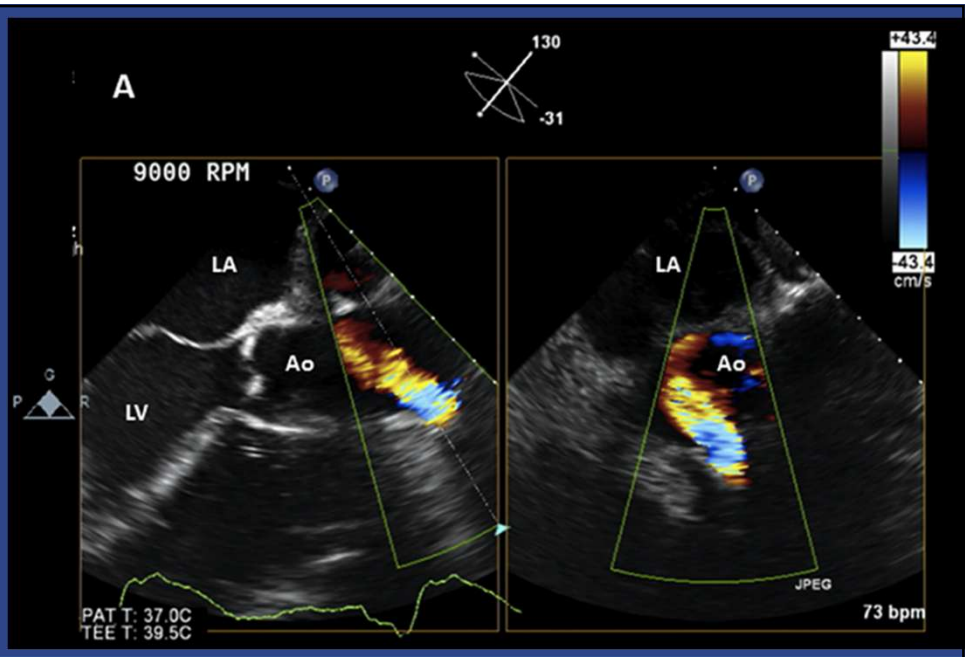
Outflow:

Normal position



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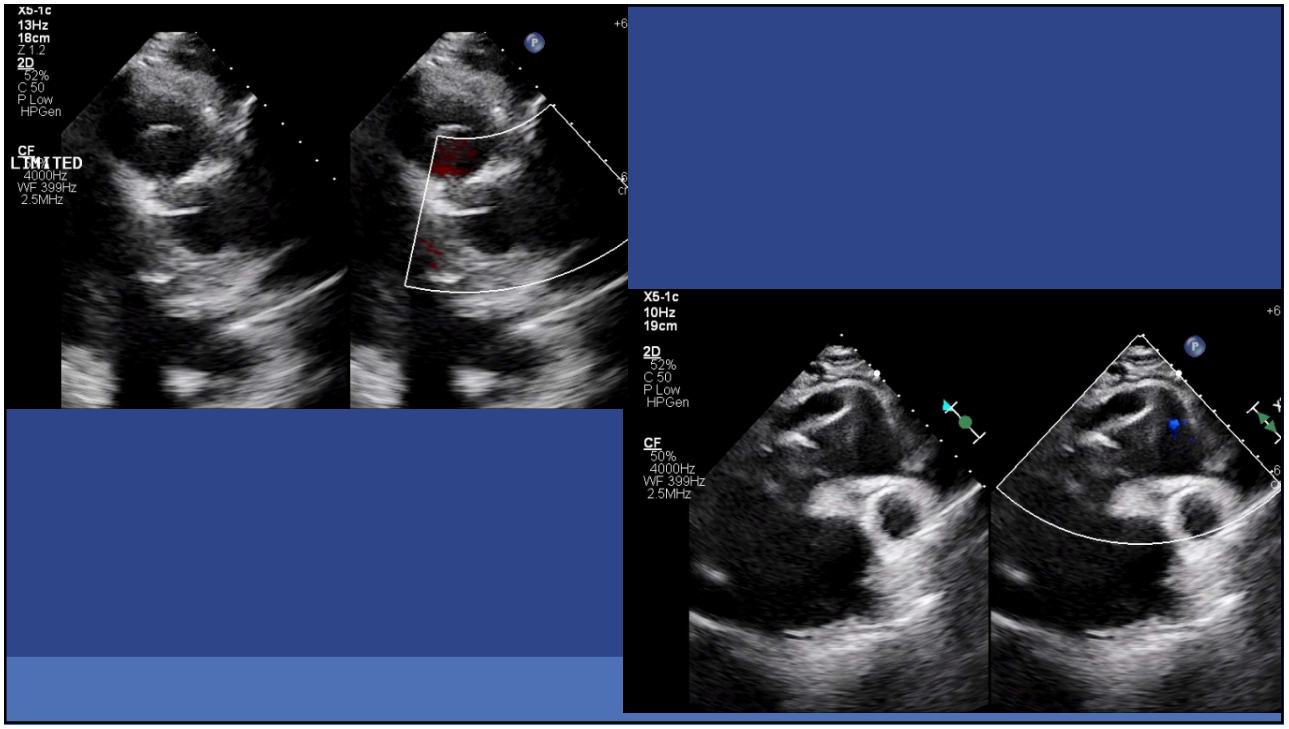

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Performing the Echo with LVAD

- CW of the inflow cannula is primary way to determine velocities
- PW of outflow cannula can occur from high left parasternal, SSN, or subcostal views
- Be sure to always note pump speed on the screen for reference
- M-mode is ***extremely helpful*** (at sweep speeds of 25-50 ms) to determine frequency of AOV opening and inter ventricular position.
- Inflow velocities should be < 1.5-2 m/sec

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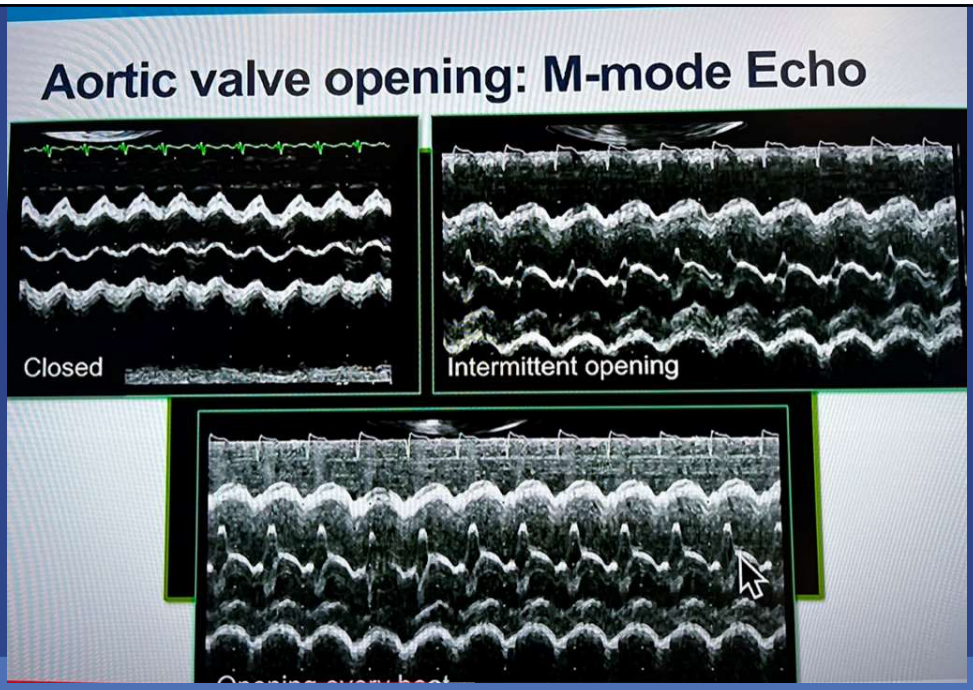

Image:Mayo Clinic Board Review 2022 LVAD lecture

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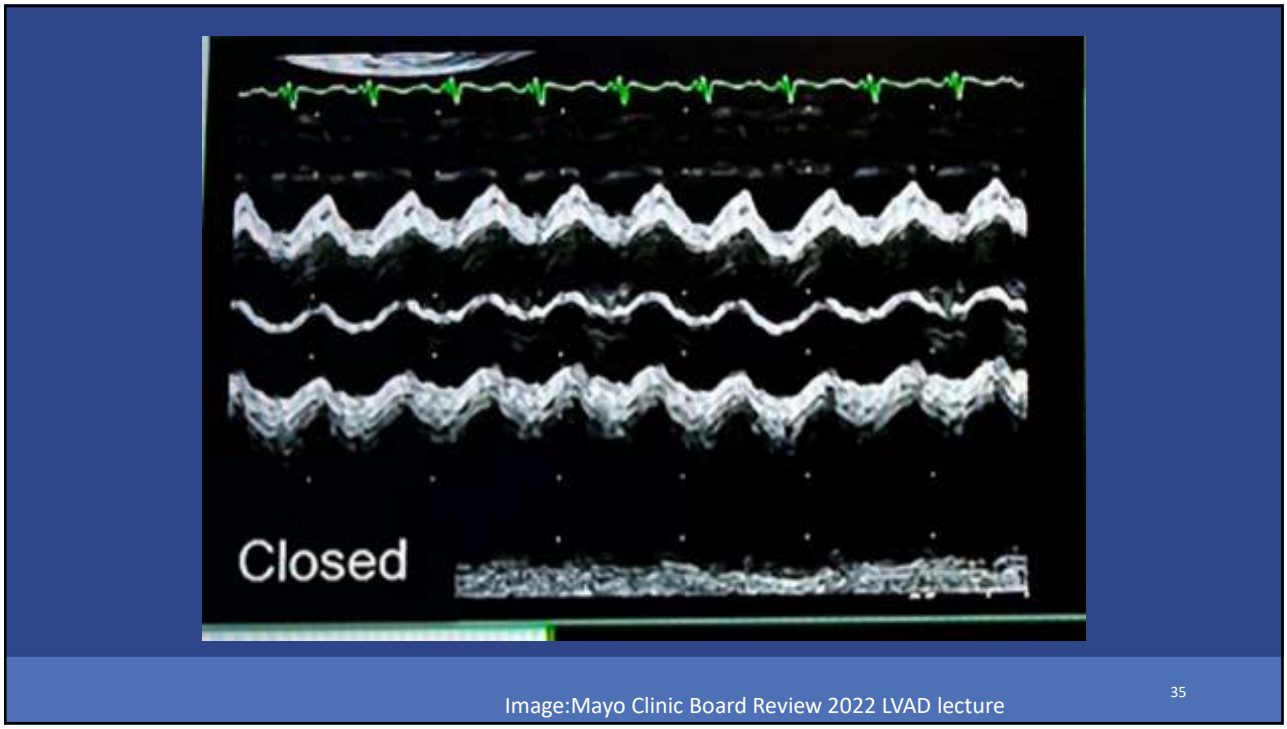

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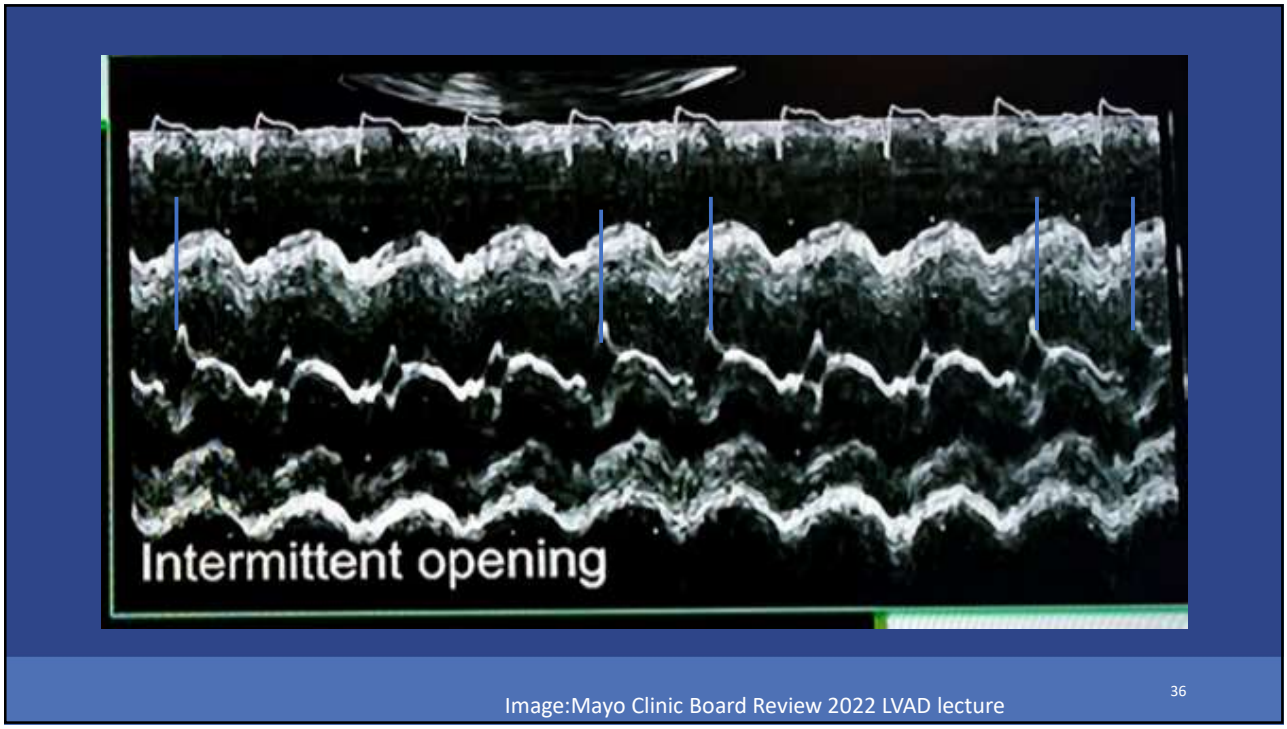

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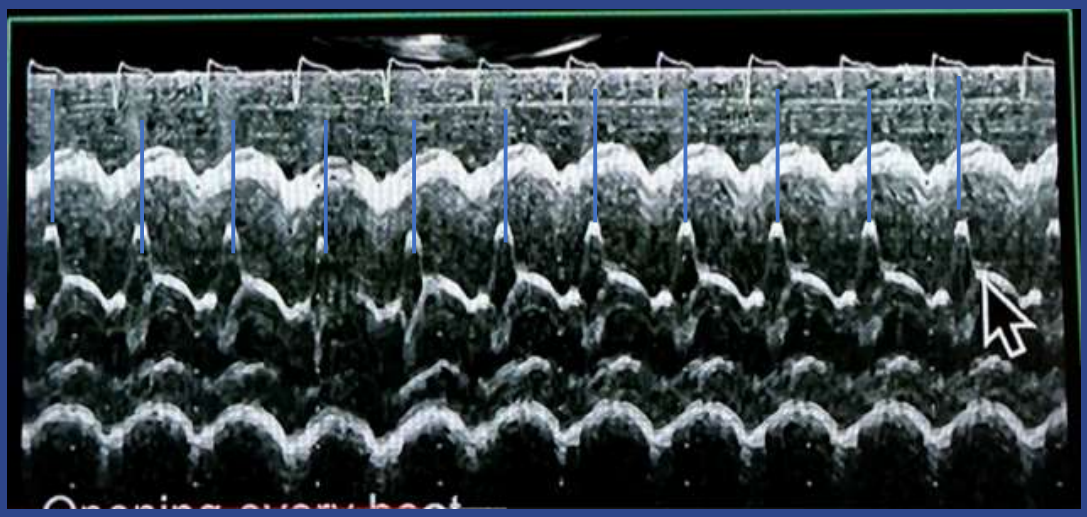

Image:Mayo Clinic Board Review 2022 LVAD lecture

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LVAD Flow considerations

- 3 things to keep in mind with LVAD
  1. How well are we unloading the LV- Diastolic diameter
  2. How well is the RV tolerating the preload- RV size and function
  3. How well are we maintaining cardiac output

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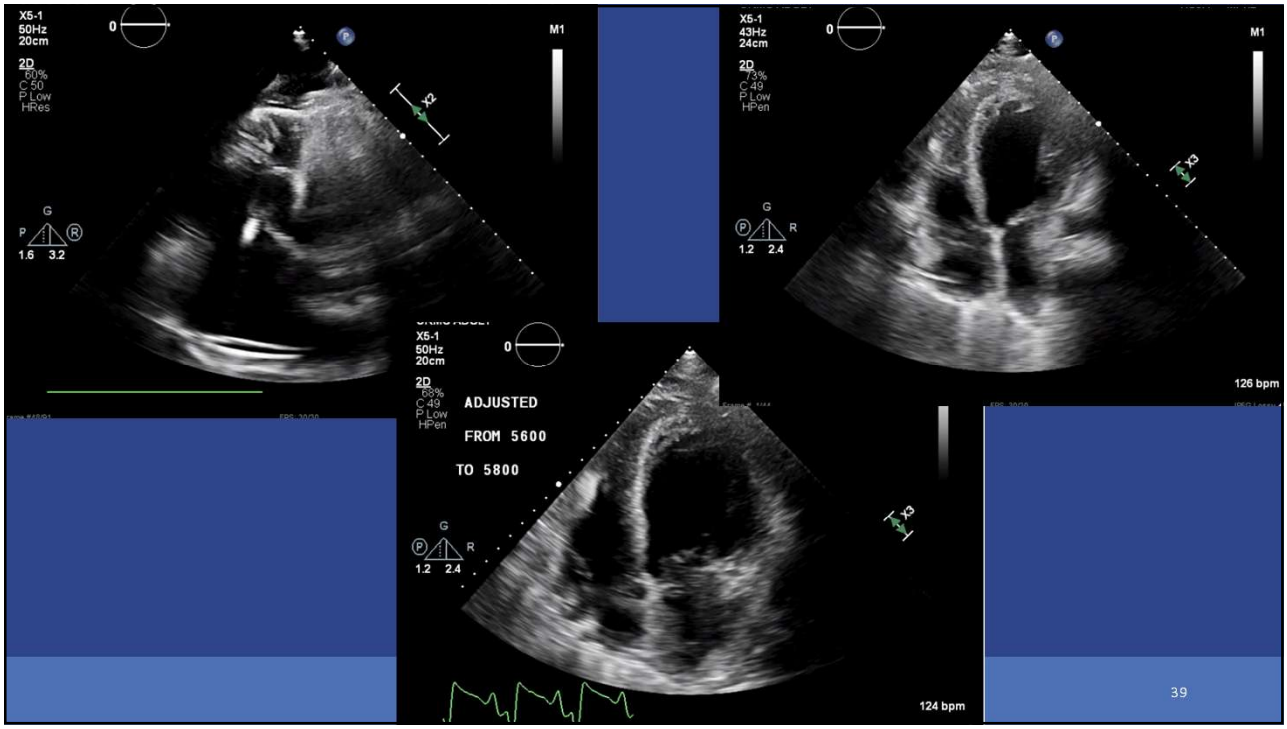

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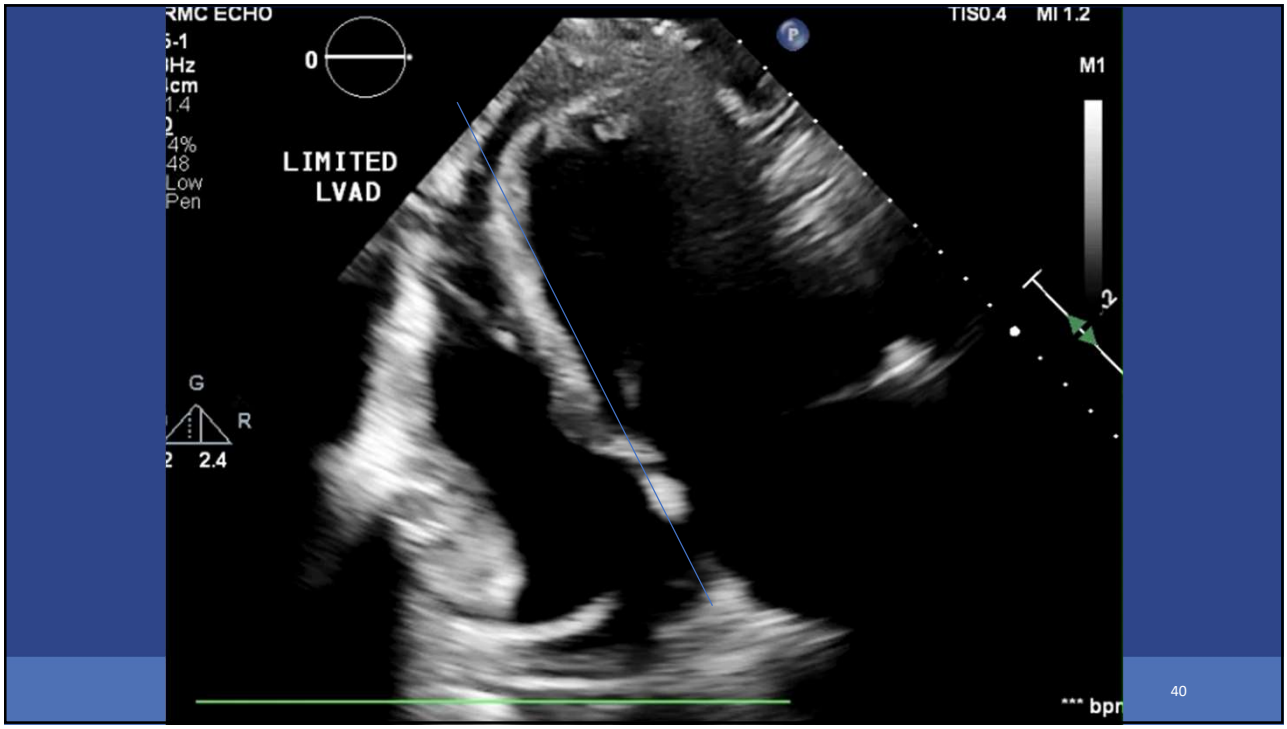

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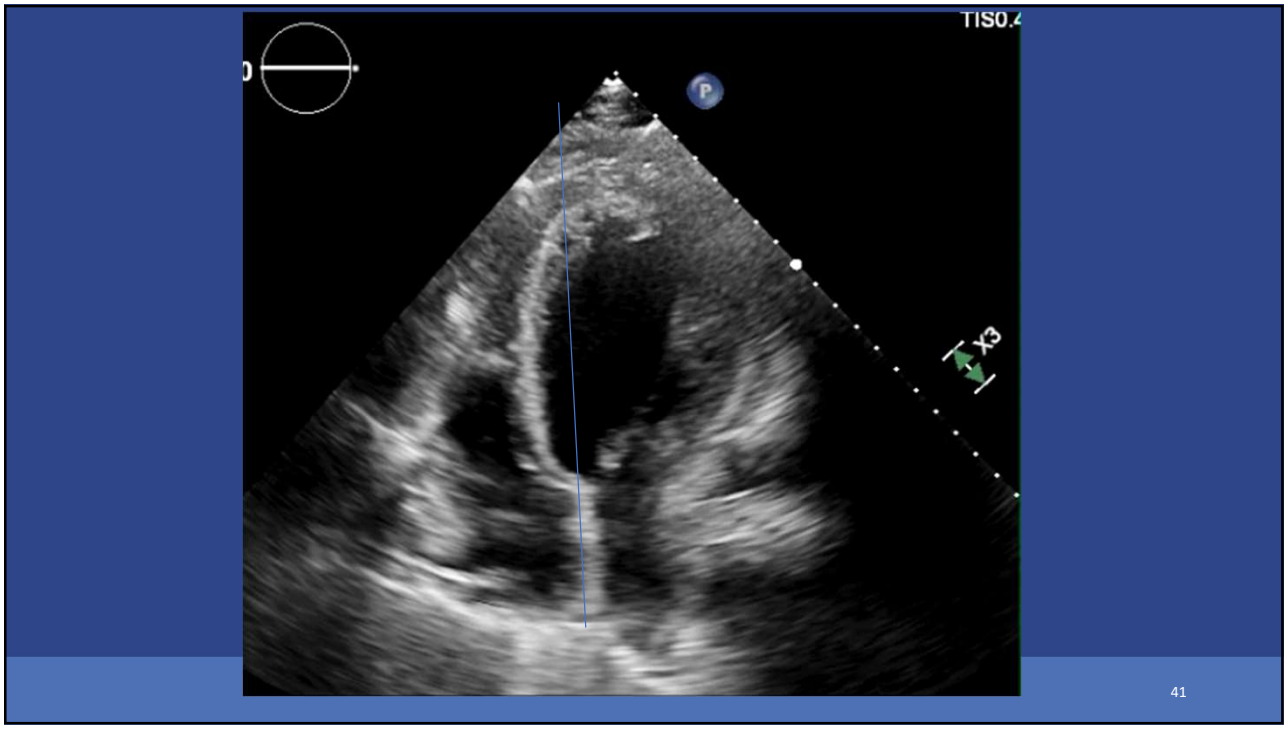

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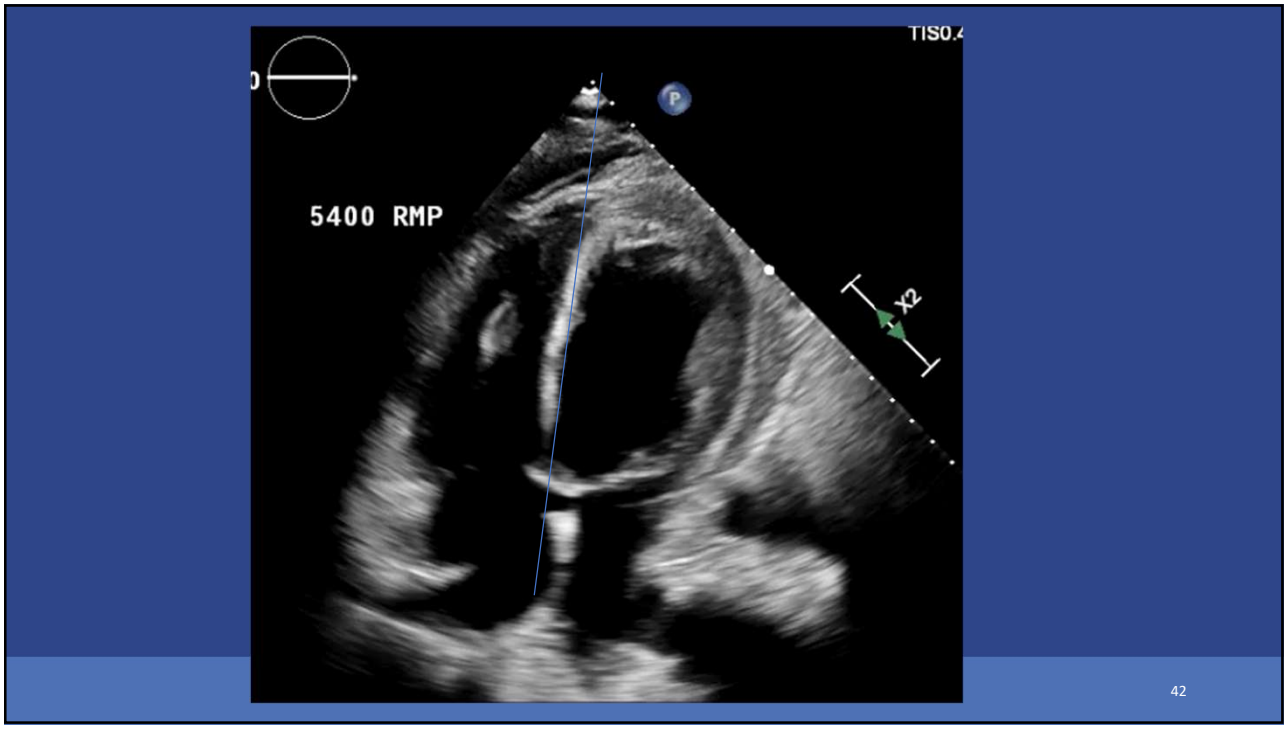

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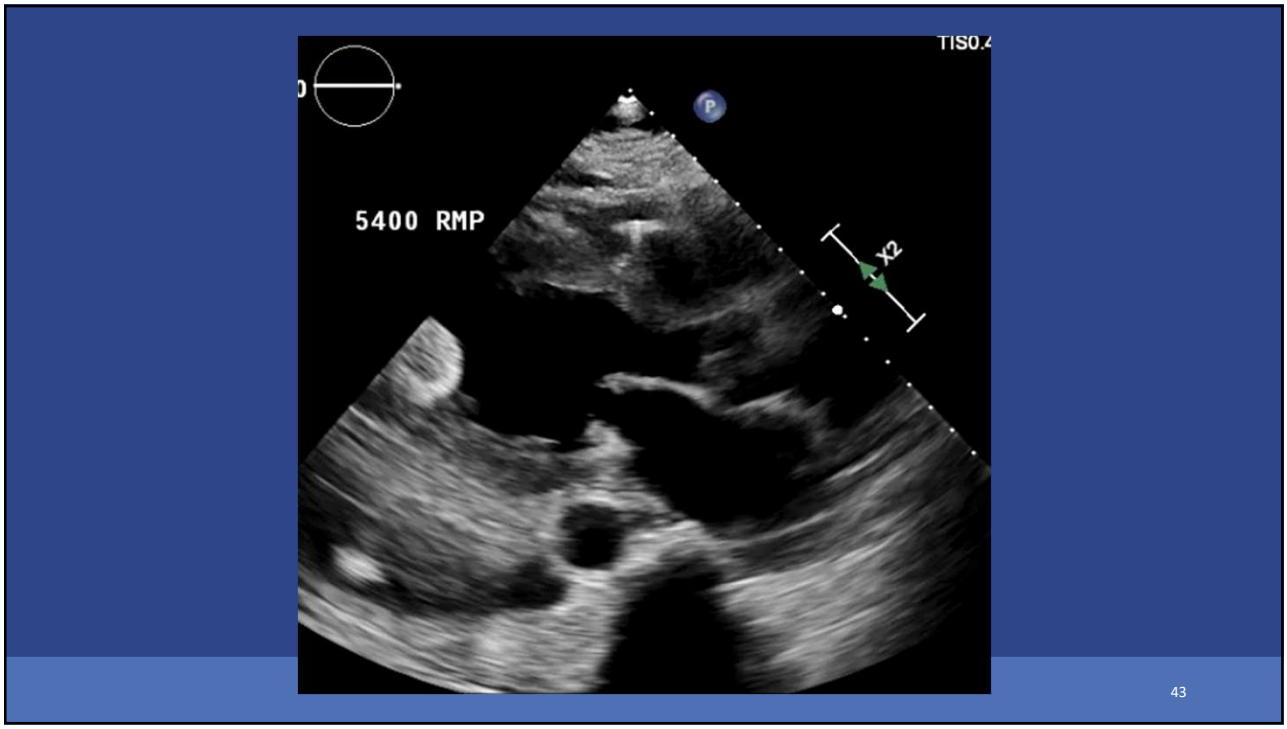

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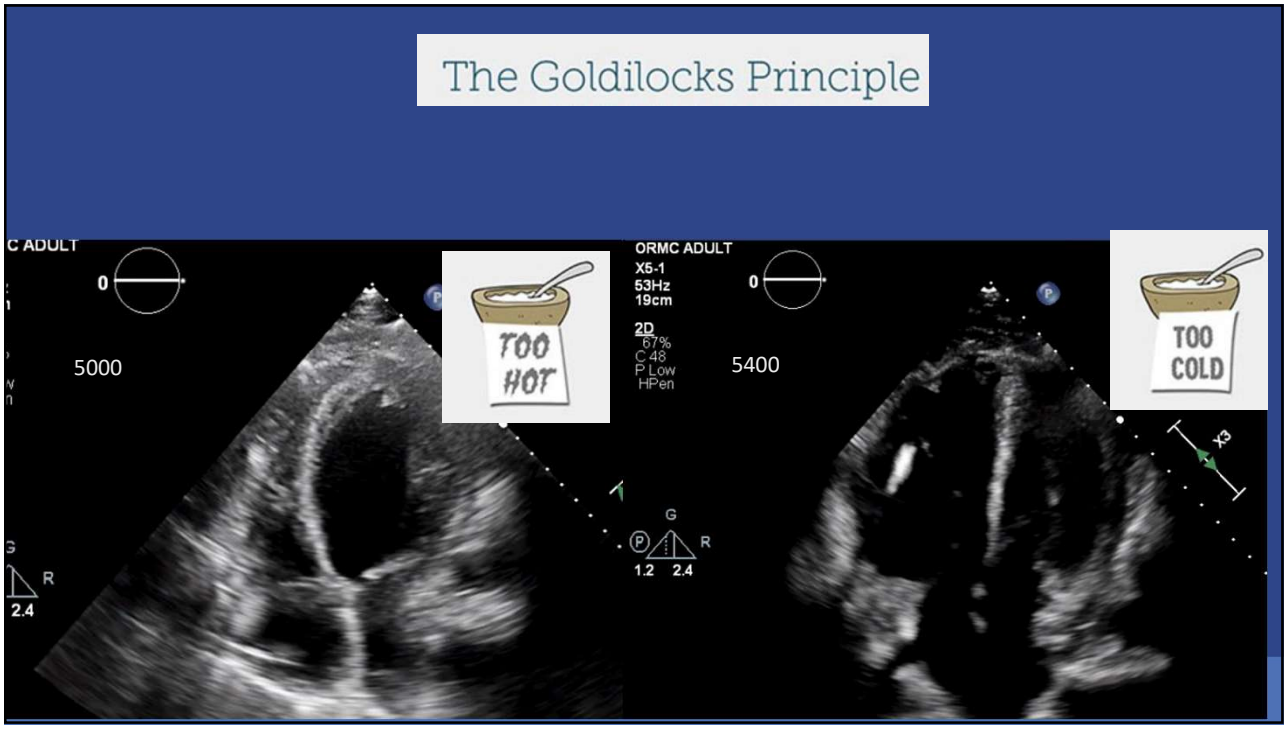

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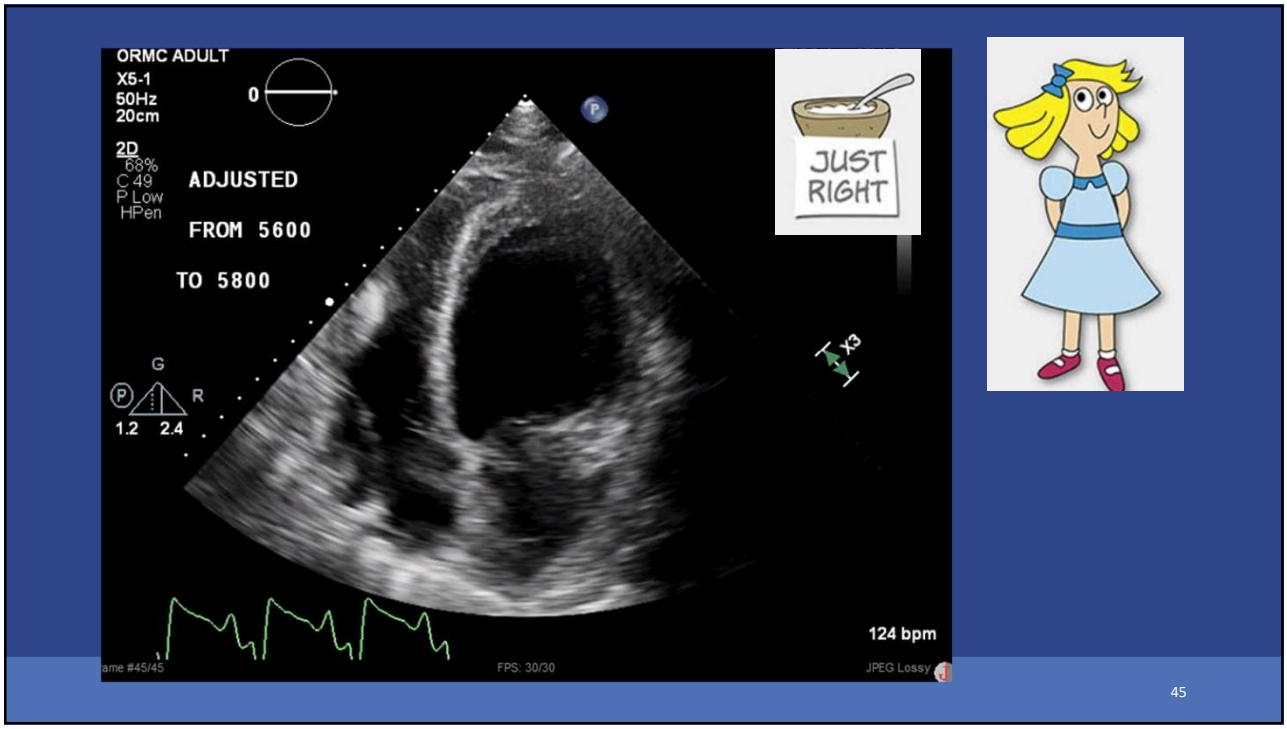

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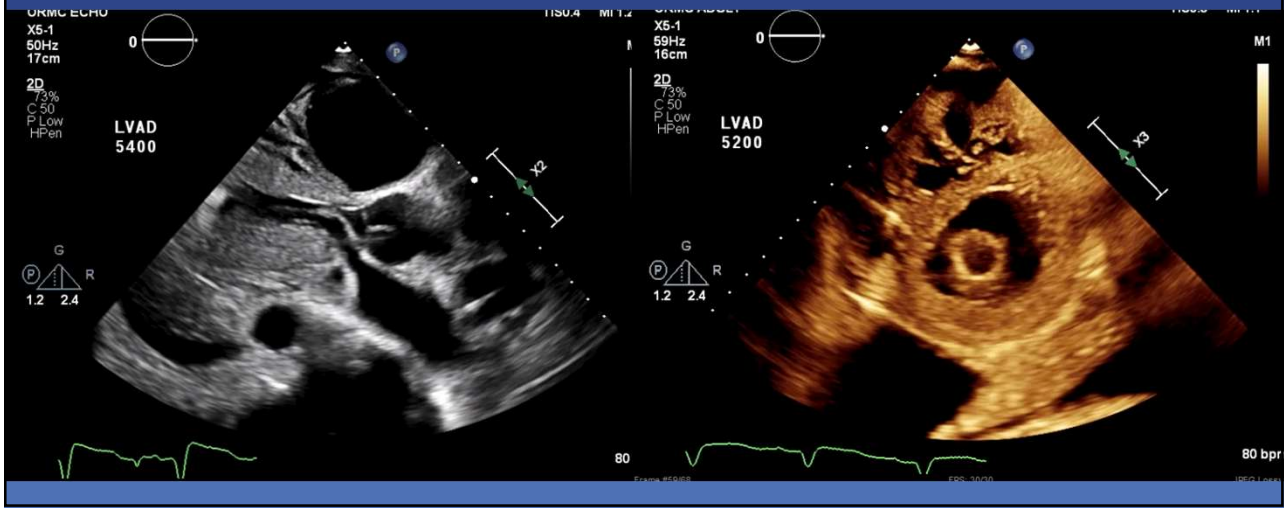
Too much



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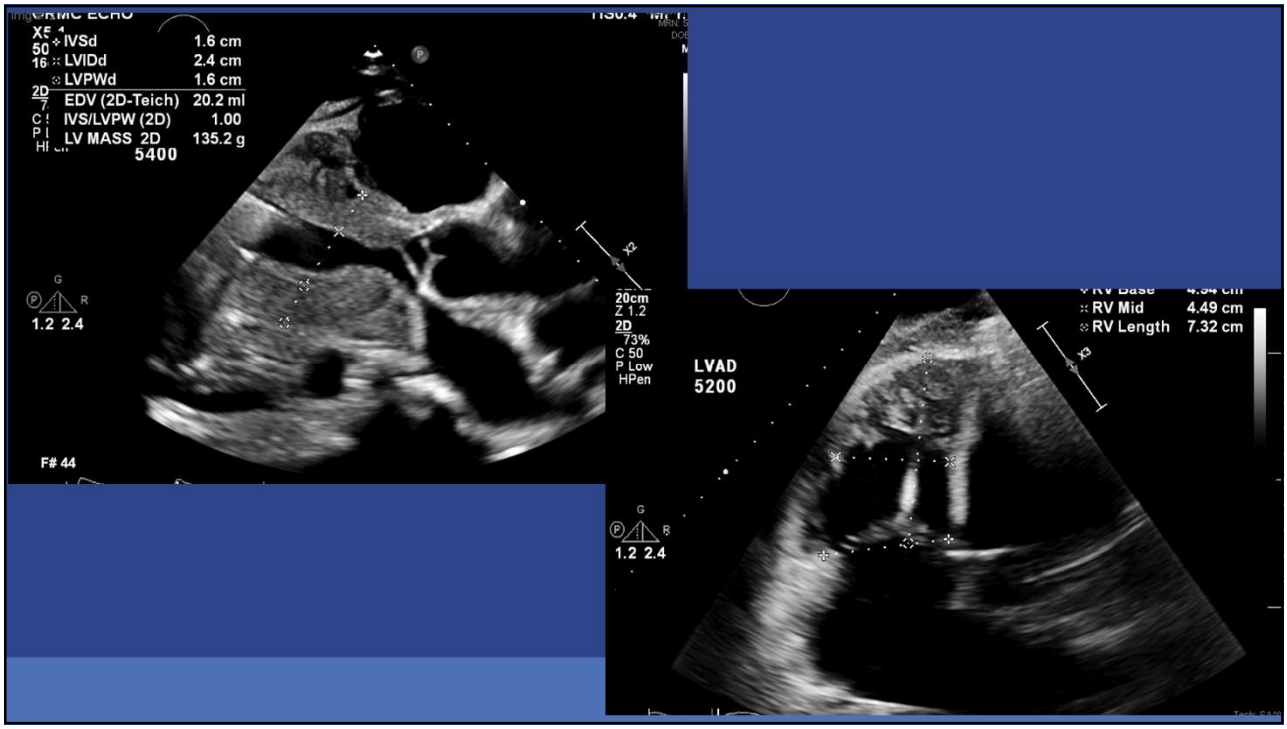

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LVAD Cases

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1) Pre-Implant LVAD Right Side

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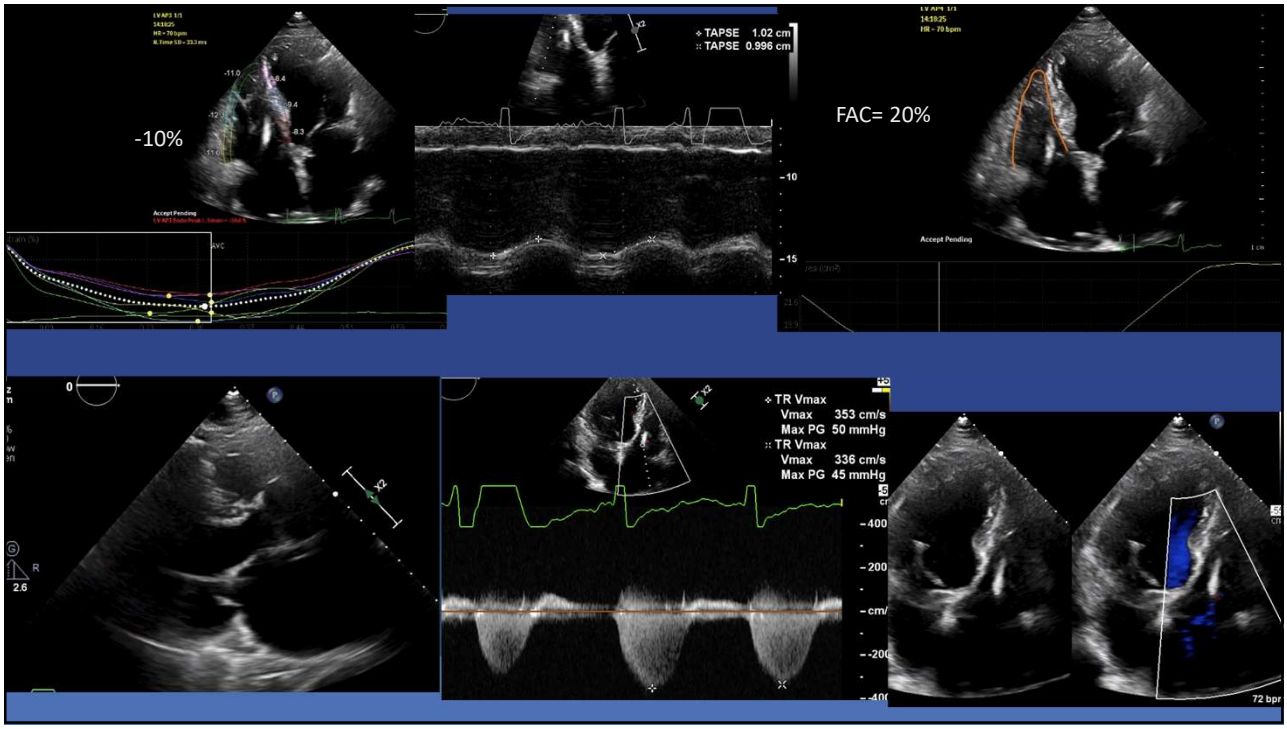

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Post LVAD TTE

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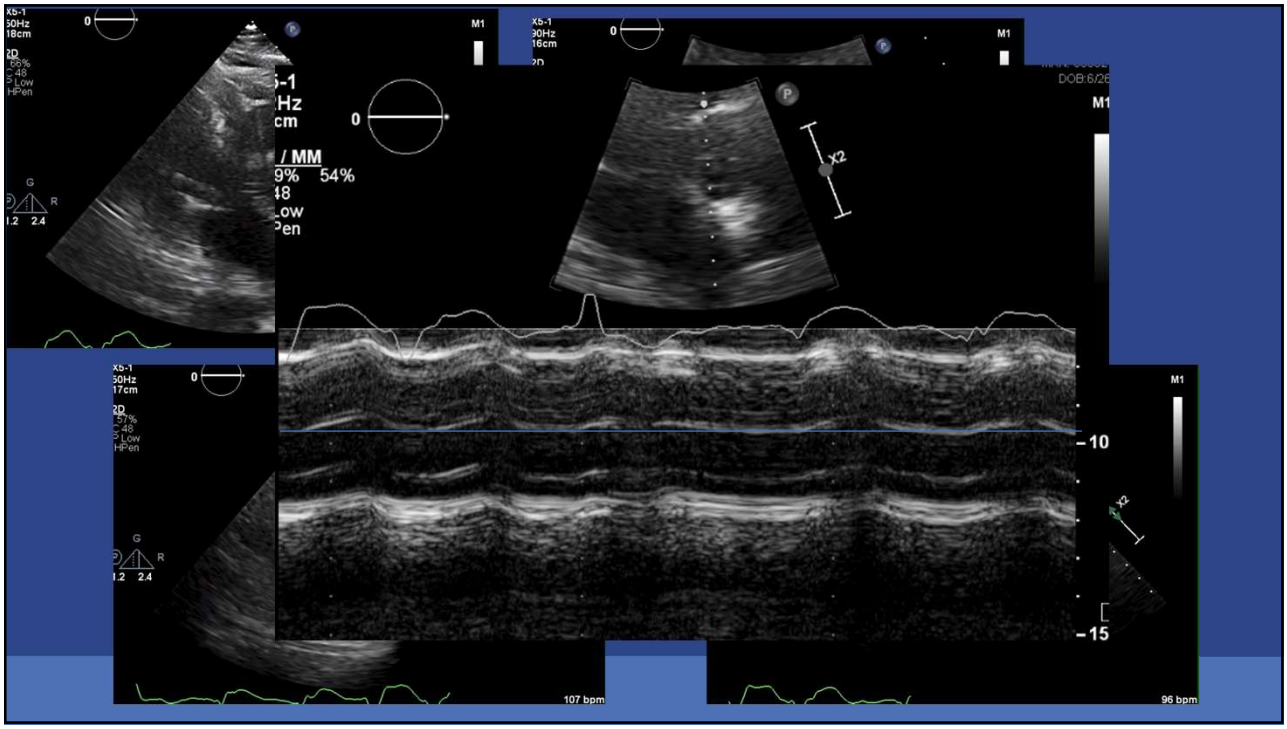

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Post LVAD TEE

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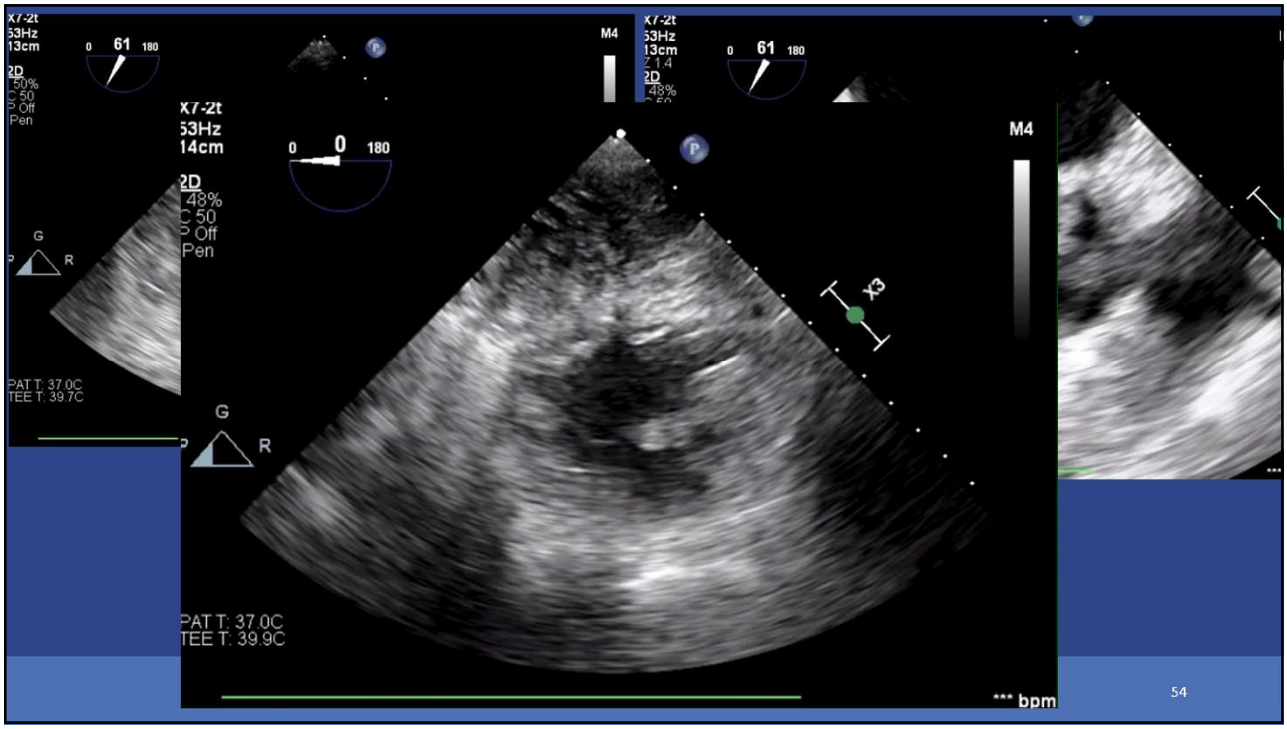

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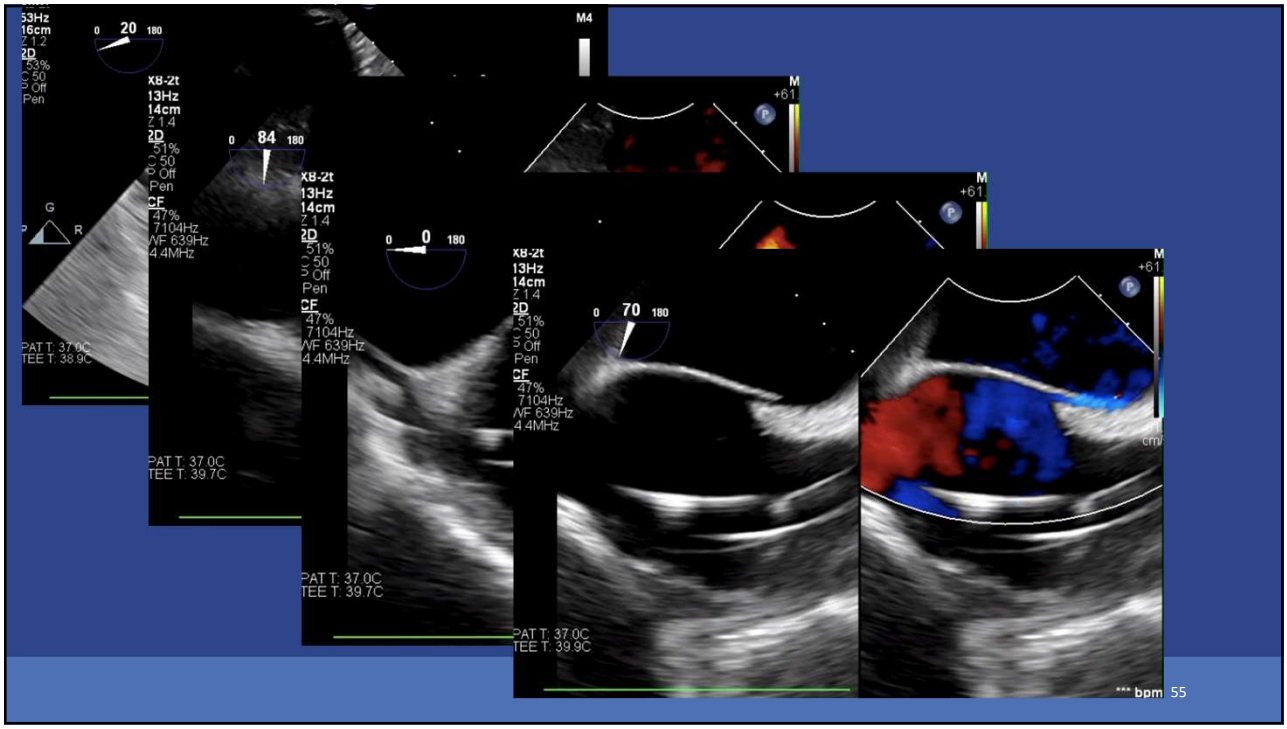

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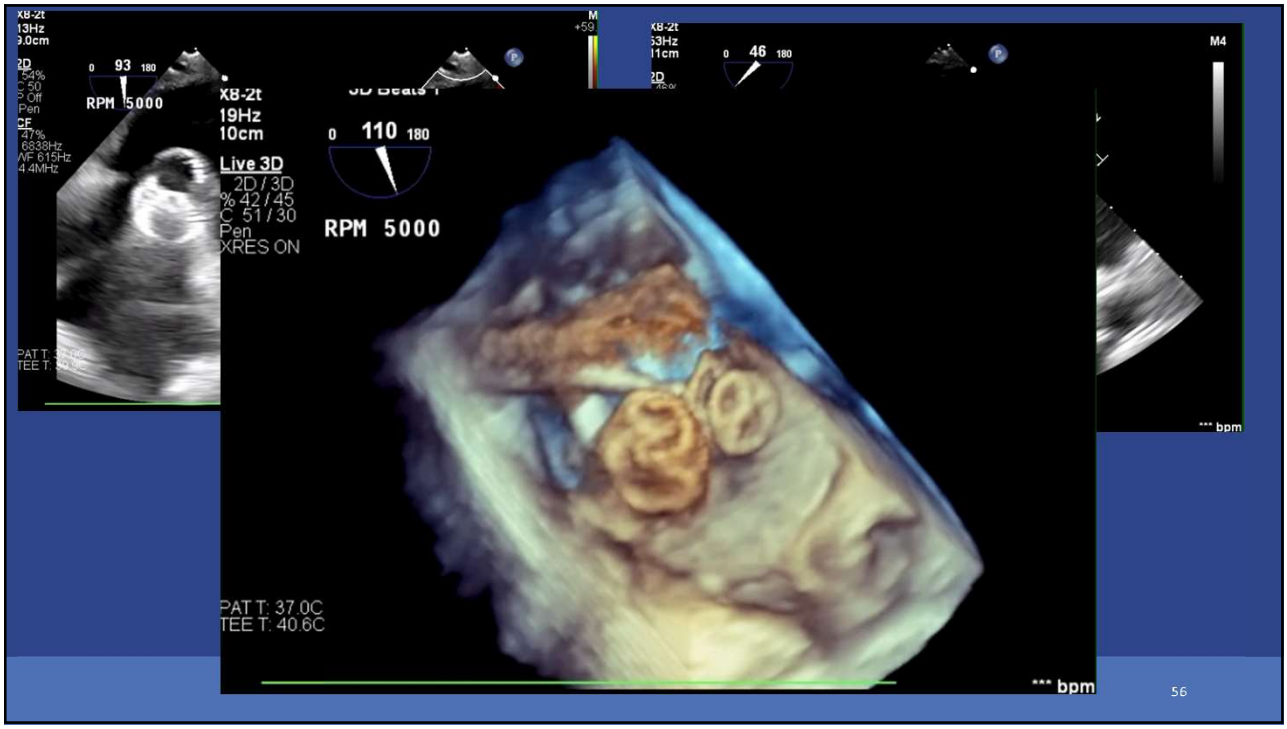

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2) Pre LVAD Echo Assessment

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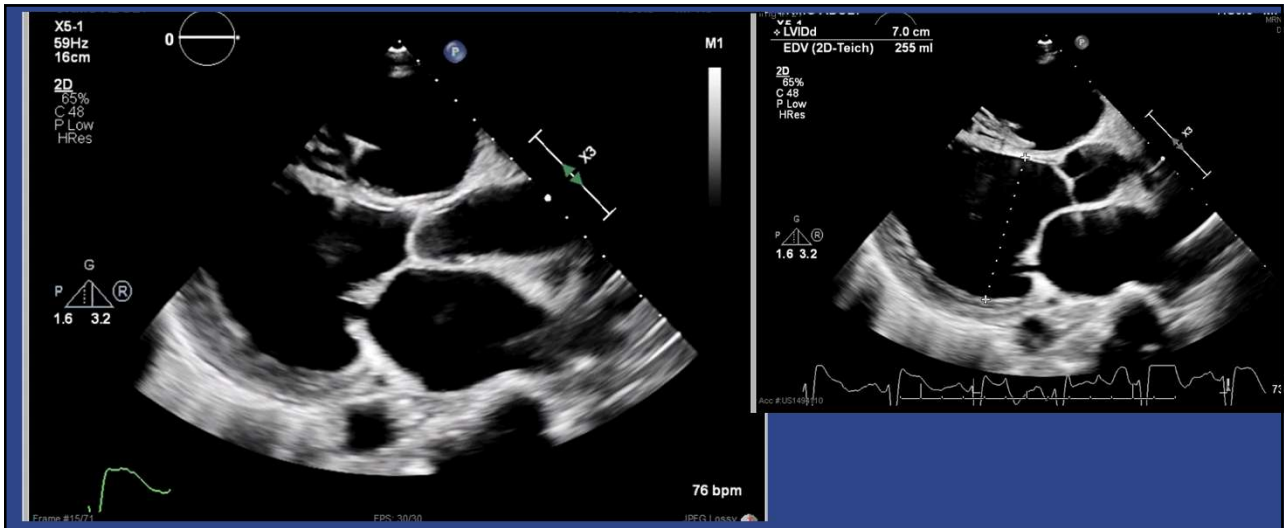

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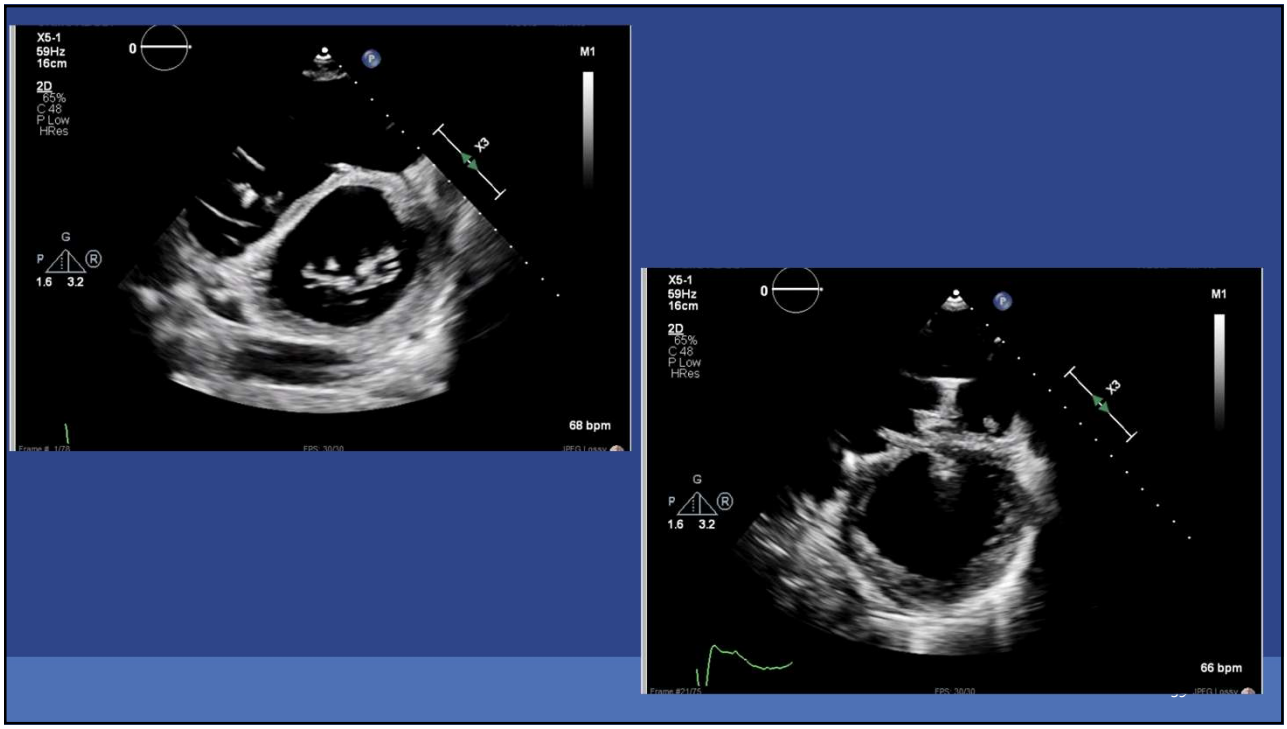

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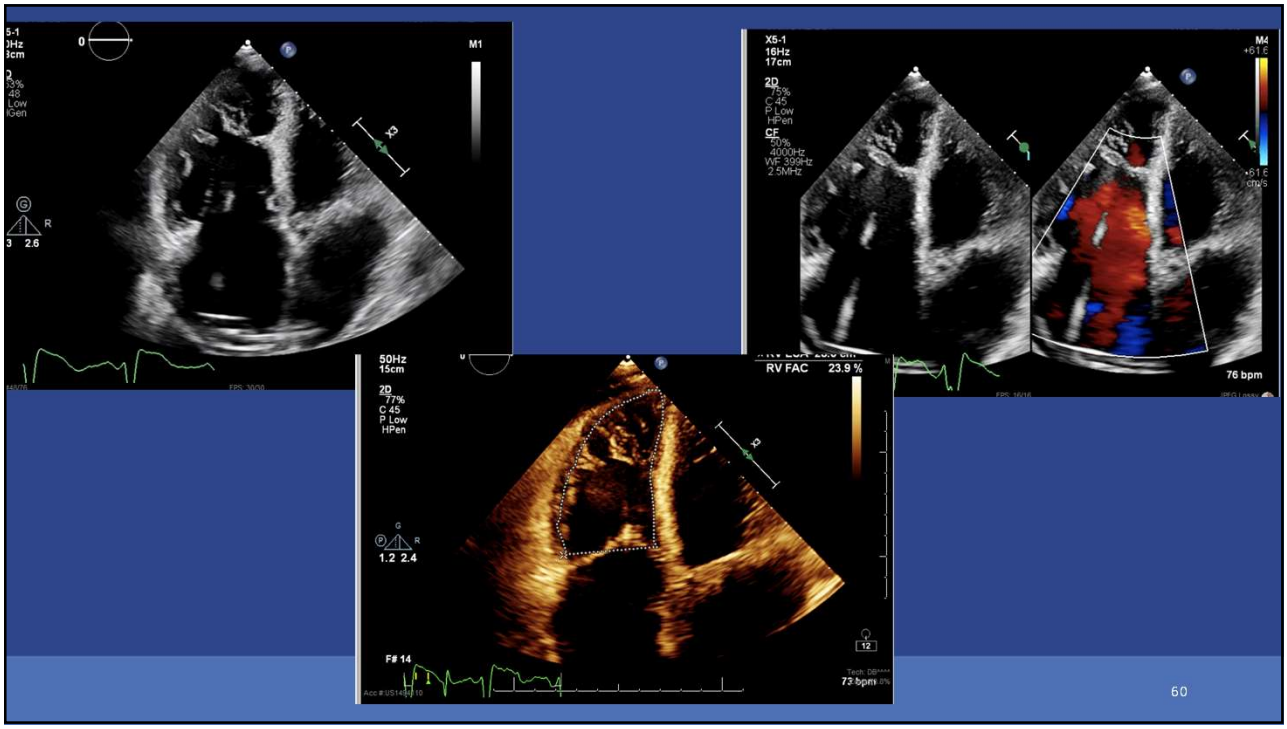

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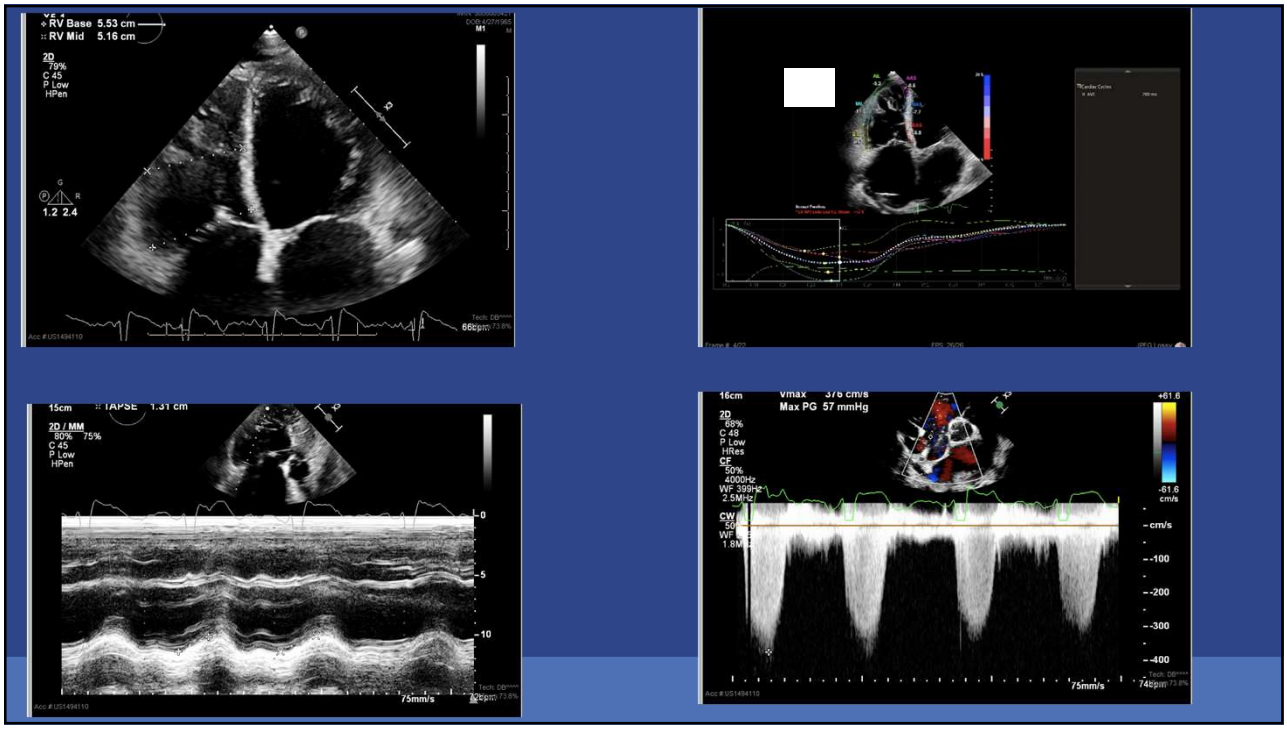

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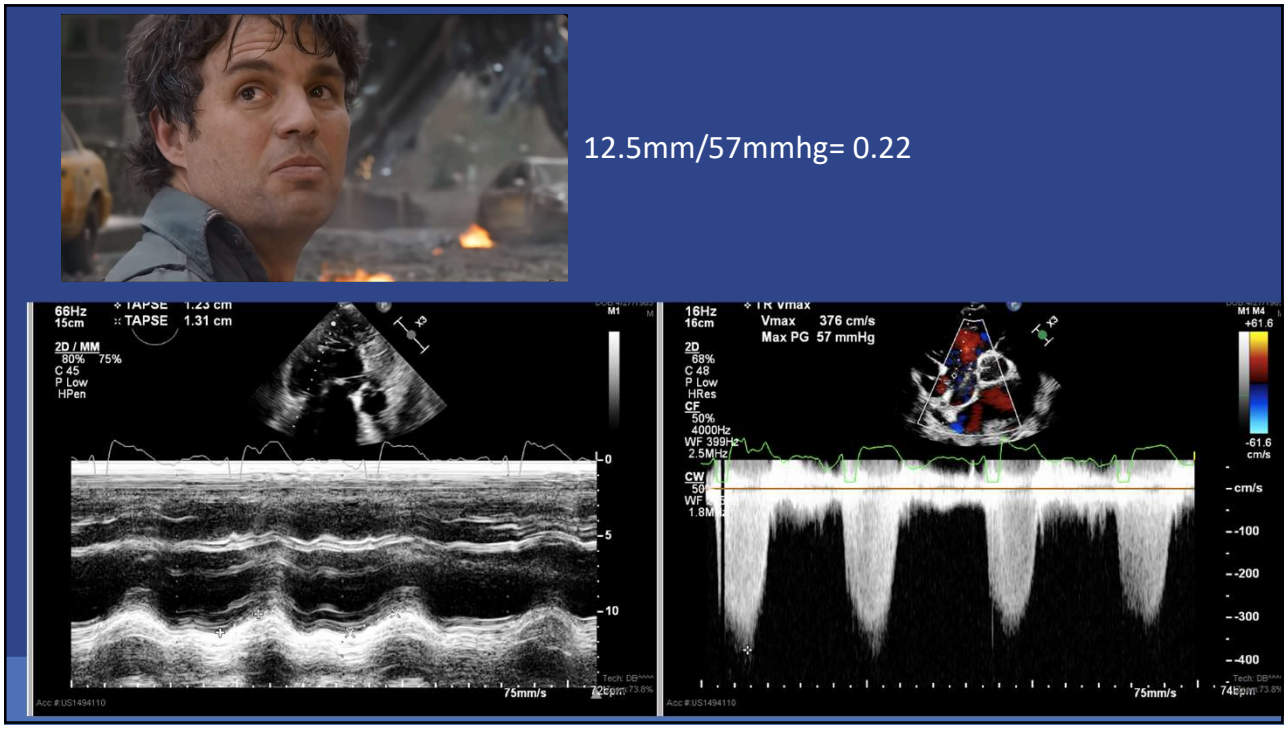

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Post Implantation

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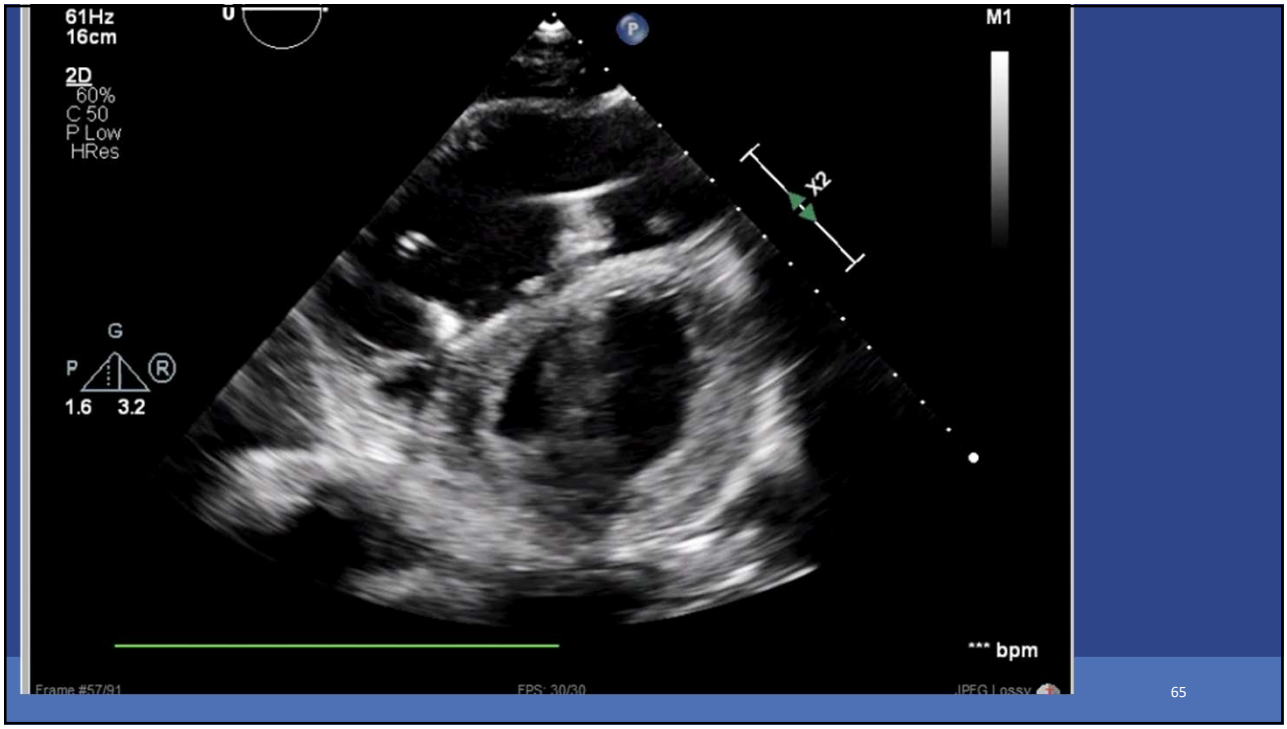

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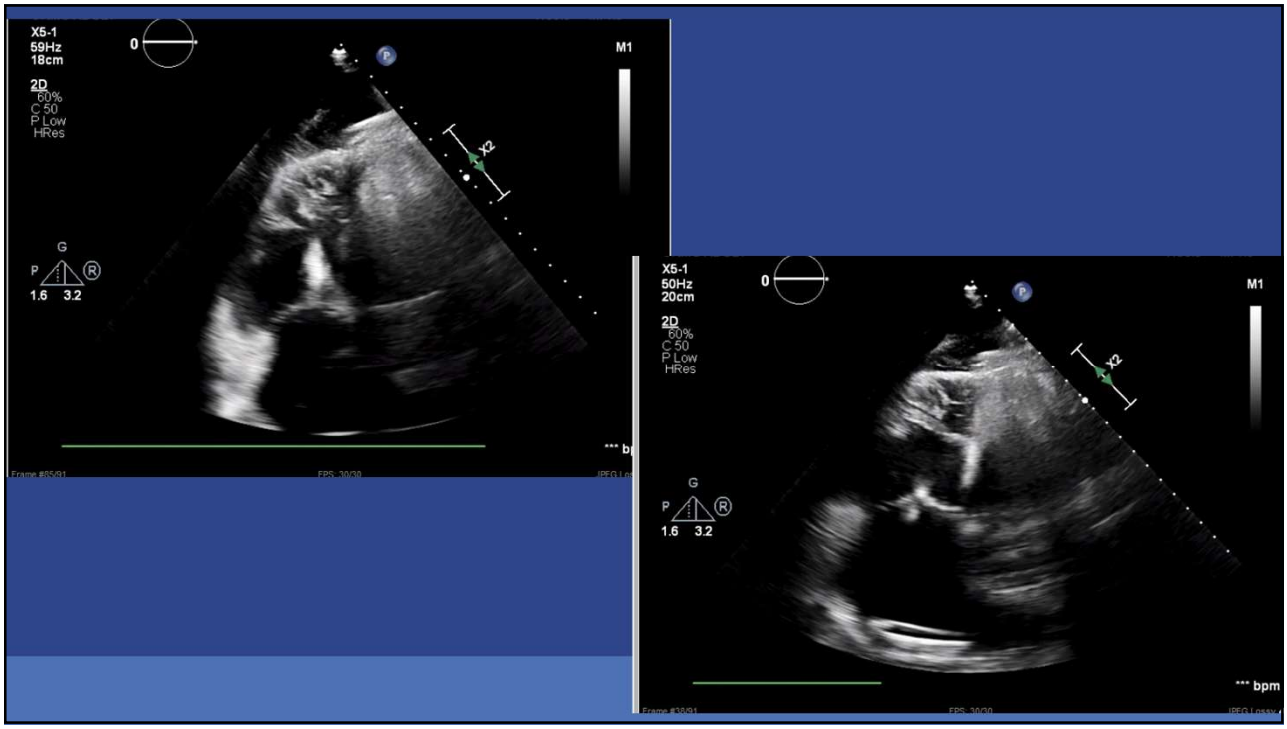

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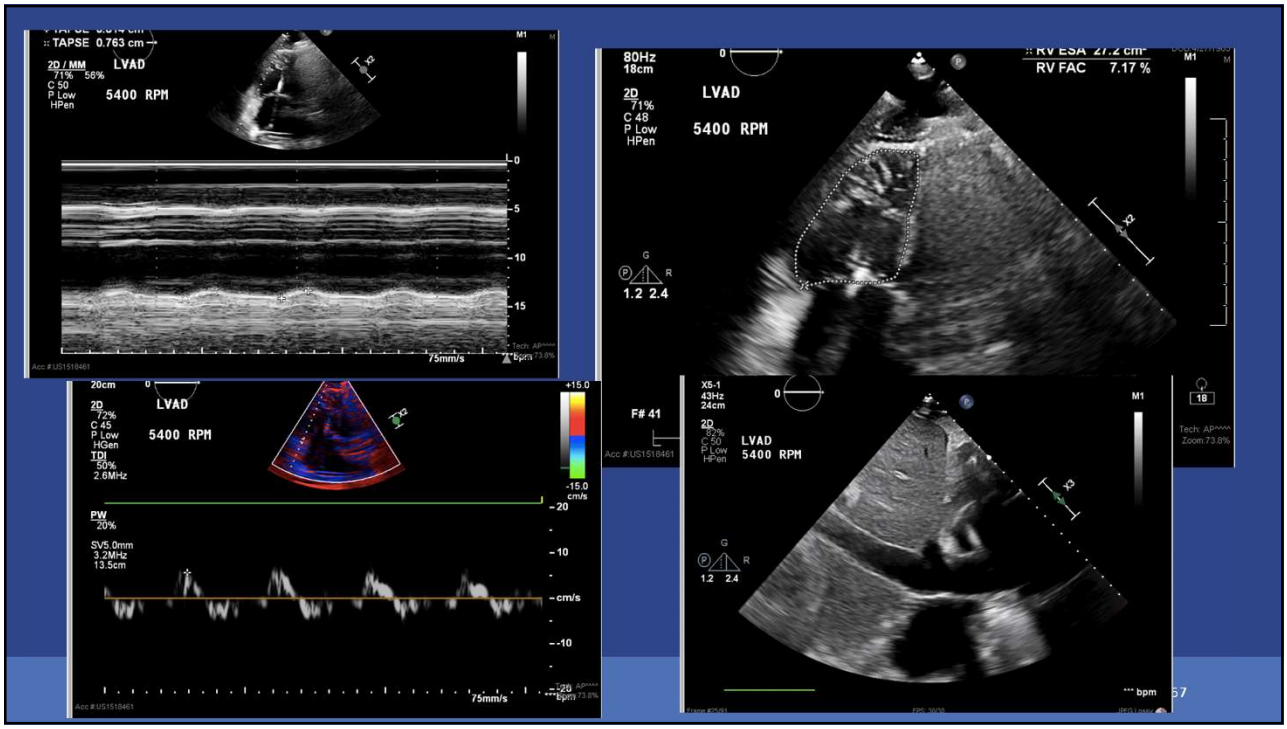

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3) Valve Disease

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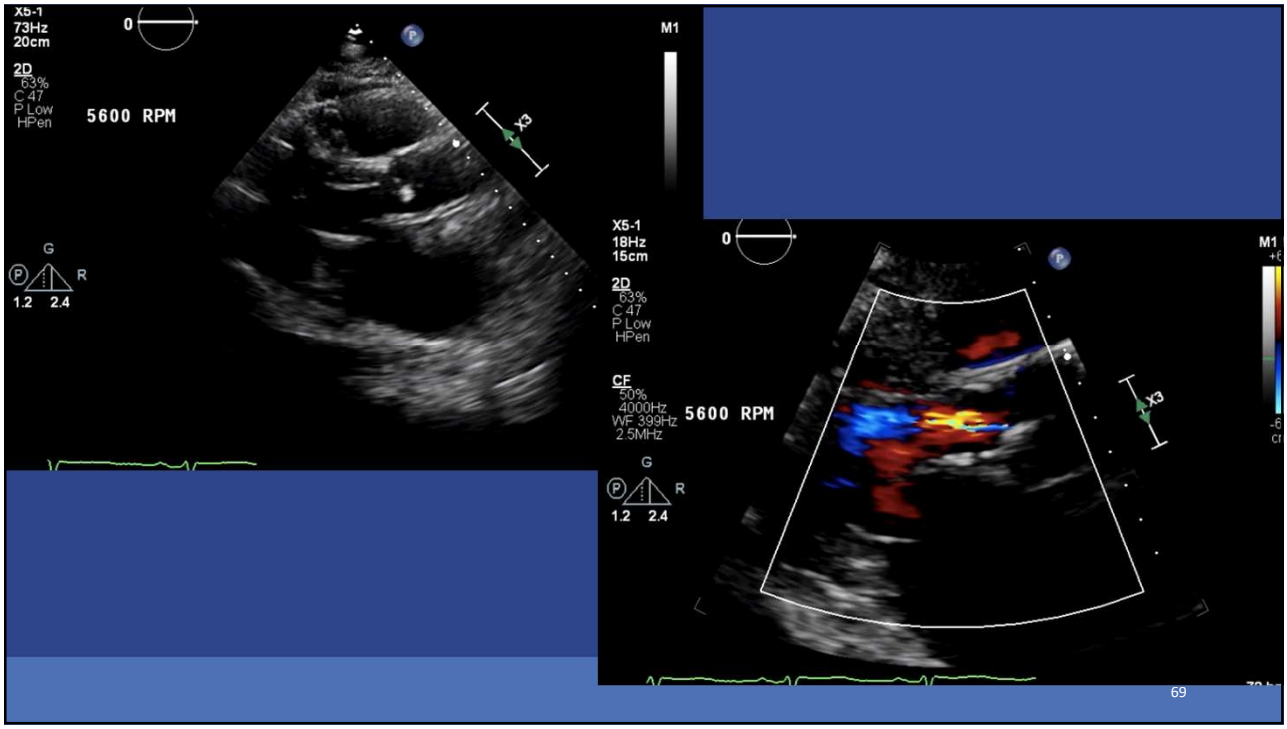

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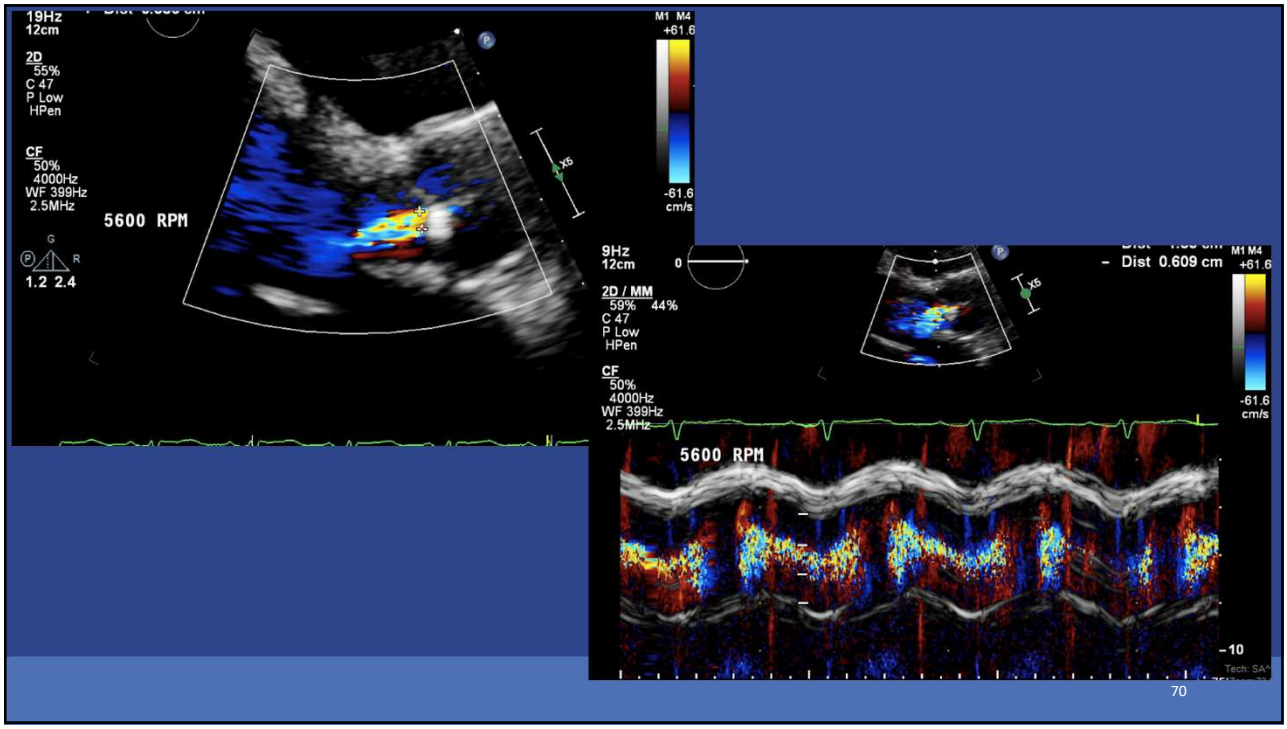

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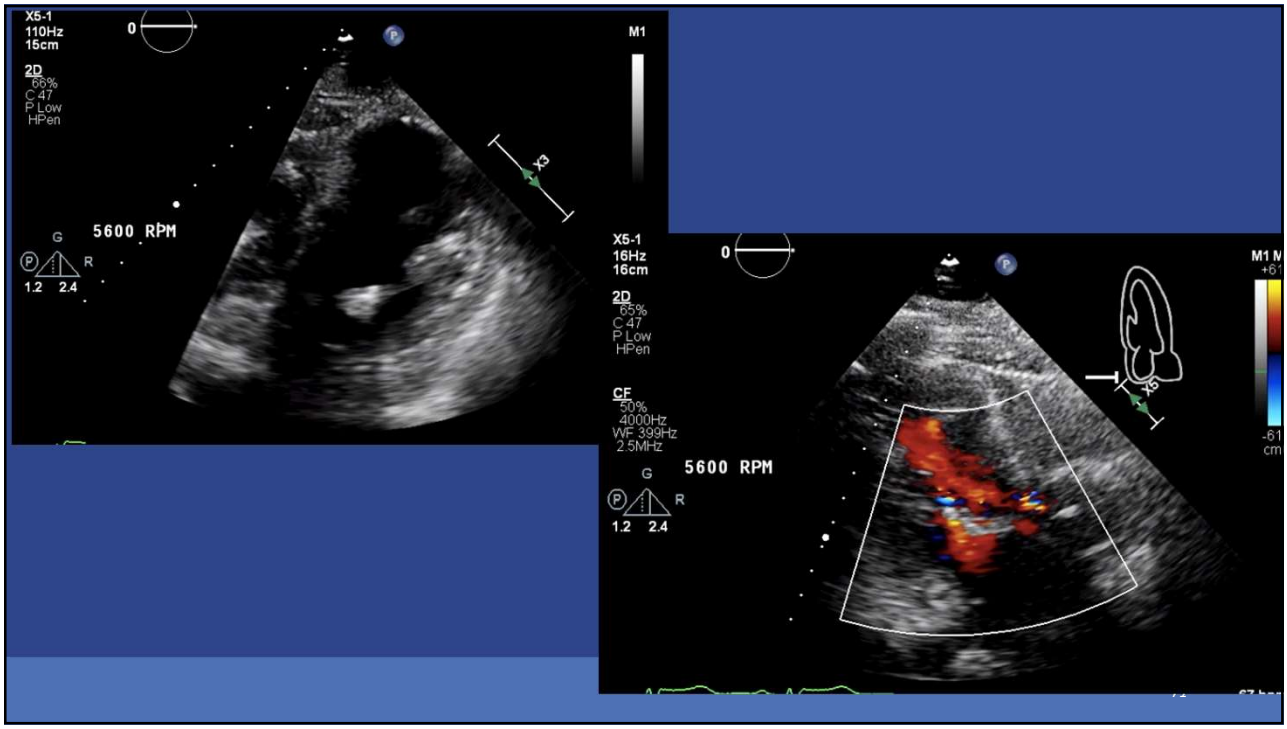

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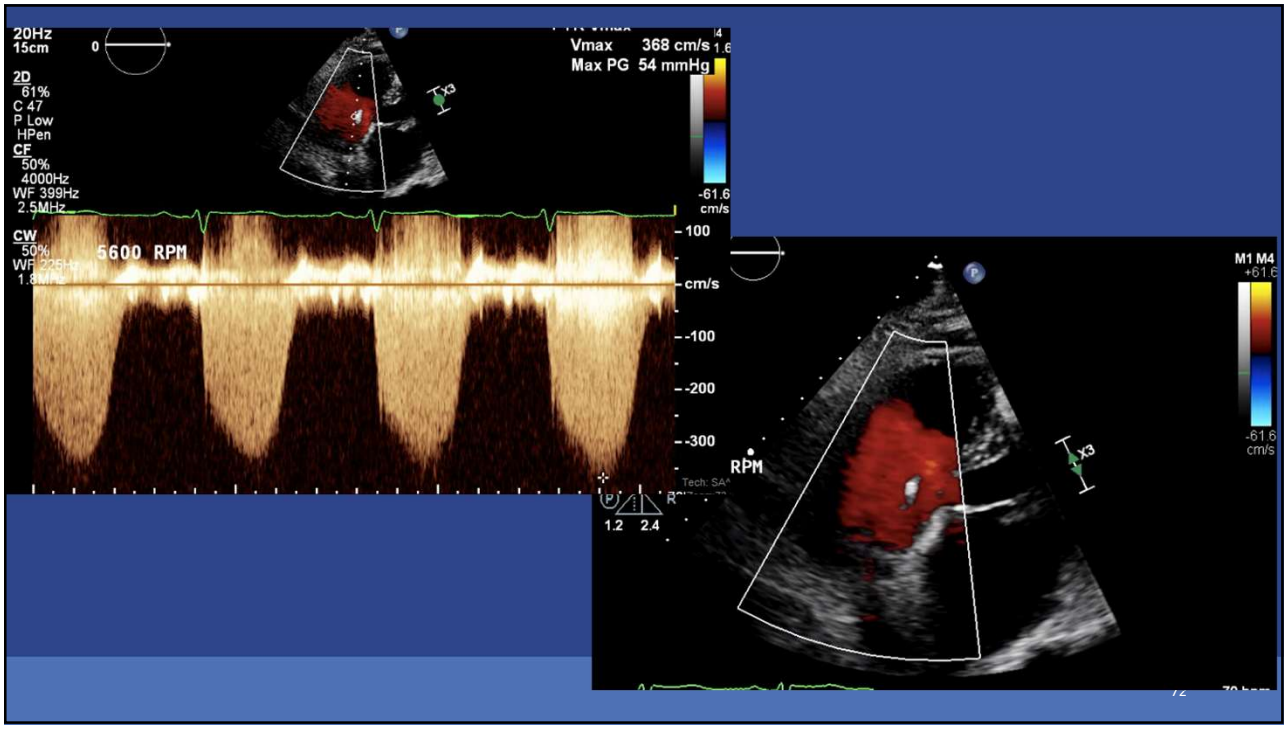

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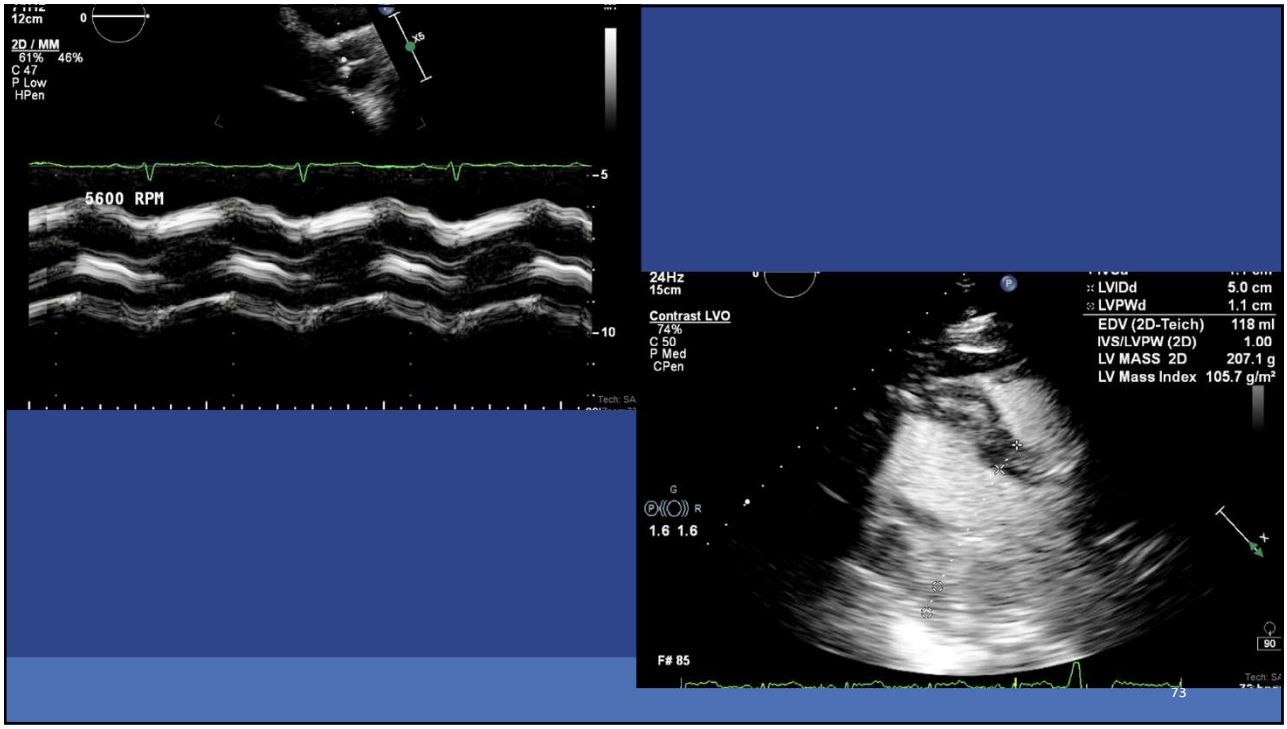

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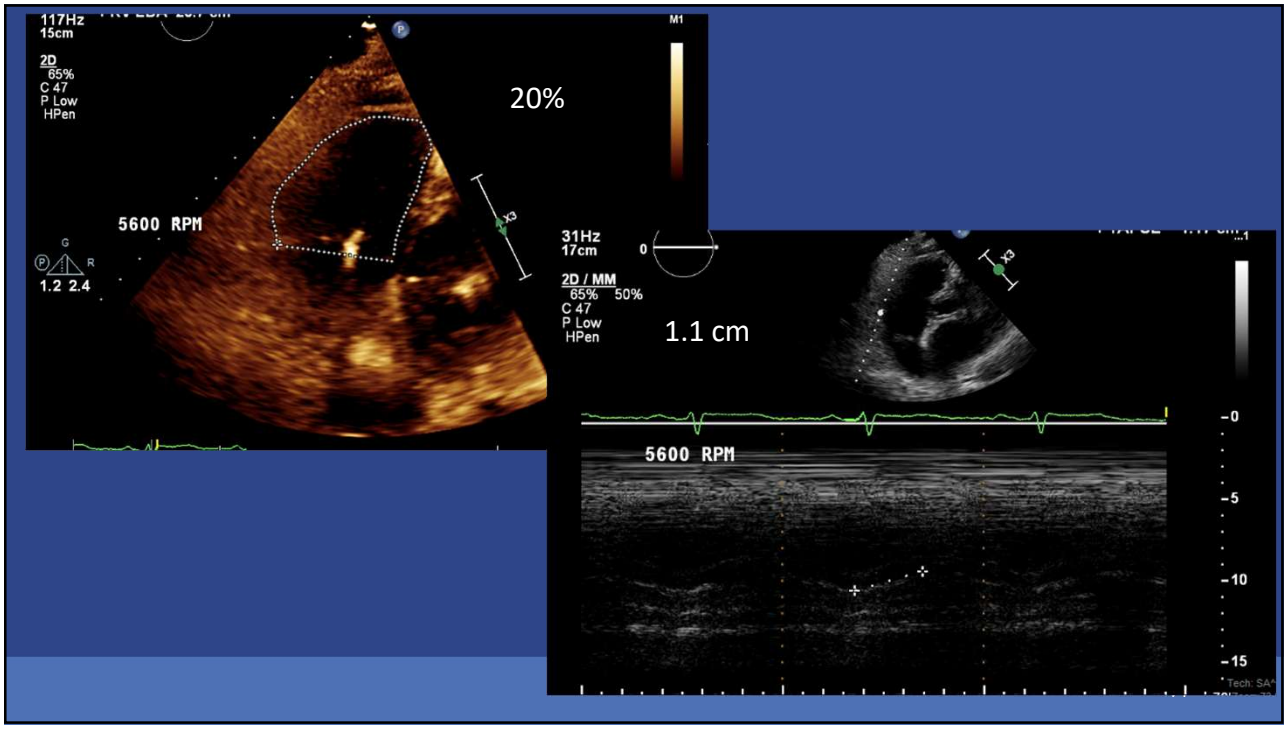

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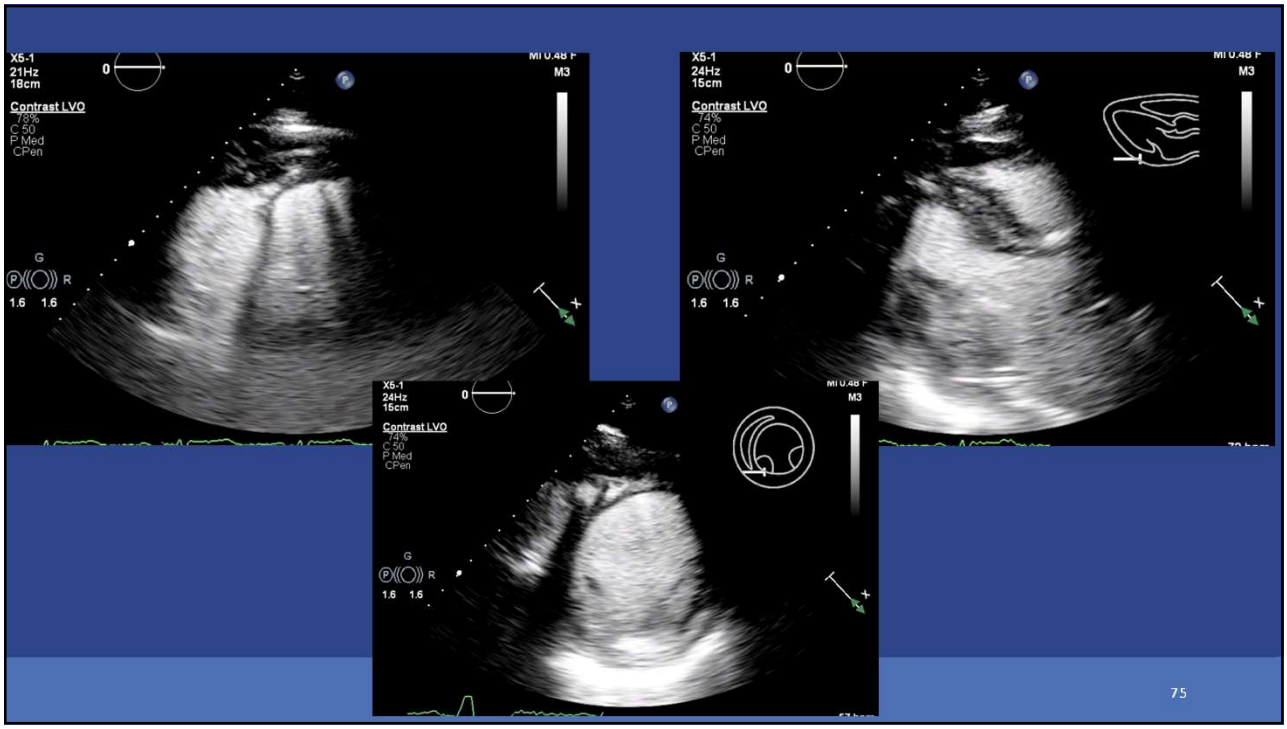

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Imaging protocol for LVAD maintenance: Summary

- Annotation on the screen- MAP, pump speed, & LVAD brand.
- Visualization of both inflow and outflow cannulas
- CW of inflow cannula (AP 2 or 4) and PW of outflow cannula (R parasternal or high left PLAX)
- Frequency of AOV opening (using M-mode)
- Septal Position

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Temporary Support Devices

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Table 1 Temporary mechanical circulatory support device types and clinical applications

	Inflow/outflow/pump placement	Clinical applications and characteristics
IABP	Percutaneous or surgical cut-down (Femoral, subclavian, or axillary artery)	LV support Diastolic inflation: improves cerebral and coronary perfusion Systolic deflation: increases LV unloading, decreases LV wall stress and myocardial oxygen consumption
TandemHeart (Tandem Life)	Centrifugal extracorporeal LA-to-femoral/axillary artery Percutaneous or surgical cutdown	LV support Placed under fluoroscopic and echocardiographic guidance Requires transseptal puncture
ProtekDuo (Tandem Life)	Centrifugal extracorporeal Inlet: SVC-RA junction Outlet: PA Percutaneous (right IJ vein)	RV support Can be combined with an external membrane oxygenator for respiratory support Spectrum Medical dual lumen coaxial cannula for RV support is similar to ProtekDuo with an additional drainage port in the RV
Impella CP (Abiomed) Impella 5.5	Microaxial intracorporeal LV-to-ascending aorta Impella CP: percutaneous (femoral artery) Impella 5.5: surgical cutdown (axillary artery) or direct aortic	LV support Hemodynamic benefits: Increased cardiac output Unloading of the LV: lower LV filling volume and pressure, decreased wall stress and myocardial consumption
Impella RP	Microaxial intracorporeal Inlet: IVC-RA junction Outlet: PA Percutaneous (femoral vein)	RV support Pulls blood from the RA and pumps it into the PA
Impella RP Flex	Microaxial intracorporeal Inlet: SVC- RA junction Outlet: PA Percutaneous (right IJ vein)	RV support Pulls blood from the RA and pumps it into the PA
Surgically implanted TMCS: Centrimag (Thoratec Corporation) Rotaflow (Maquet Getinge Group) Bio-Pump (Medtronic)	Extracorporeal centrifugal LV support: LA/LV-to-ascending aorta RV support: RA/RV-to-PA Surgical sternotomy or thoracotomy	LV, RV, or biventricular support Possible biventricular support configurations: Durable LVAD and surgically implanted RV TMCS Surgically implanted LV and RV TMCS
VA ECMO	Extracorporeal centrifugal with membrane oxygenator RA-to-ascending aorta/descending aorta Central: sternotomy or thoracotomy Peripheral: percutaneous and/or surgical cutdown	LV, RV, or biventricular support additional configurations VVA: third venous cannula for improved venous drainage Veno-arterial-venous: oxygenated blood is returned to both the ascending aorta and the RA Veno-arterial-arterial : 2 separate cannulas return oxygenated blood to the arterial system (e.g., descending aorta and axillary artery)
VV ECMO	Extracorporeal centrifugal with membrane oxygenator Dual vein cannulation: drainage from the IVC (via femoral vein) with return in the RA (via femoral vein and IVC or right IJ and SVC) Single vein cannulation: dual lumen single cannula with drainage from SVC and IVC and return in the RA	Respiratory support: VV ECMO does not provide direct circulatory support, may improve RV function through respiratory support

Temporary Support Devices

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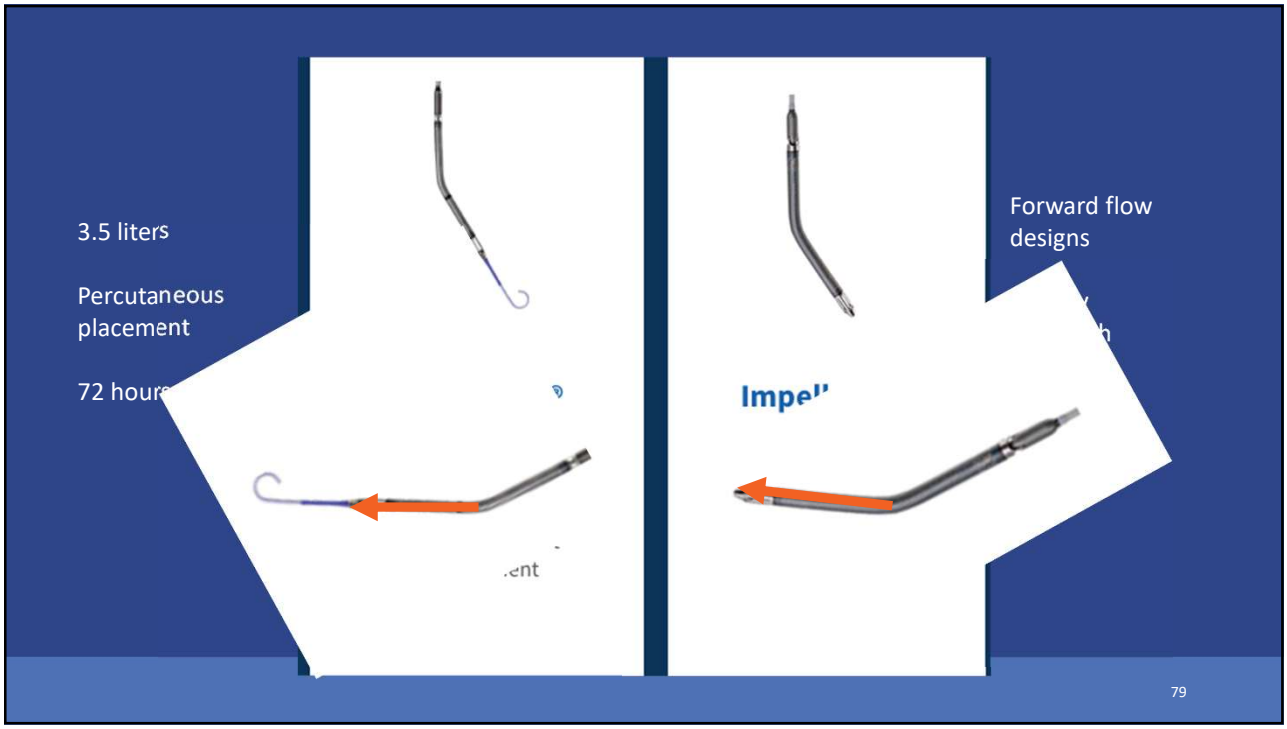

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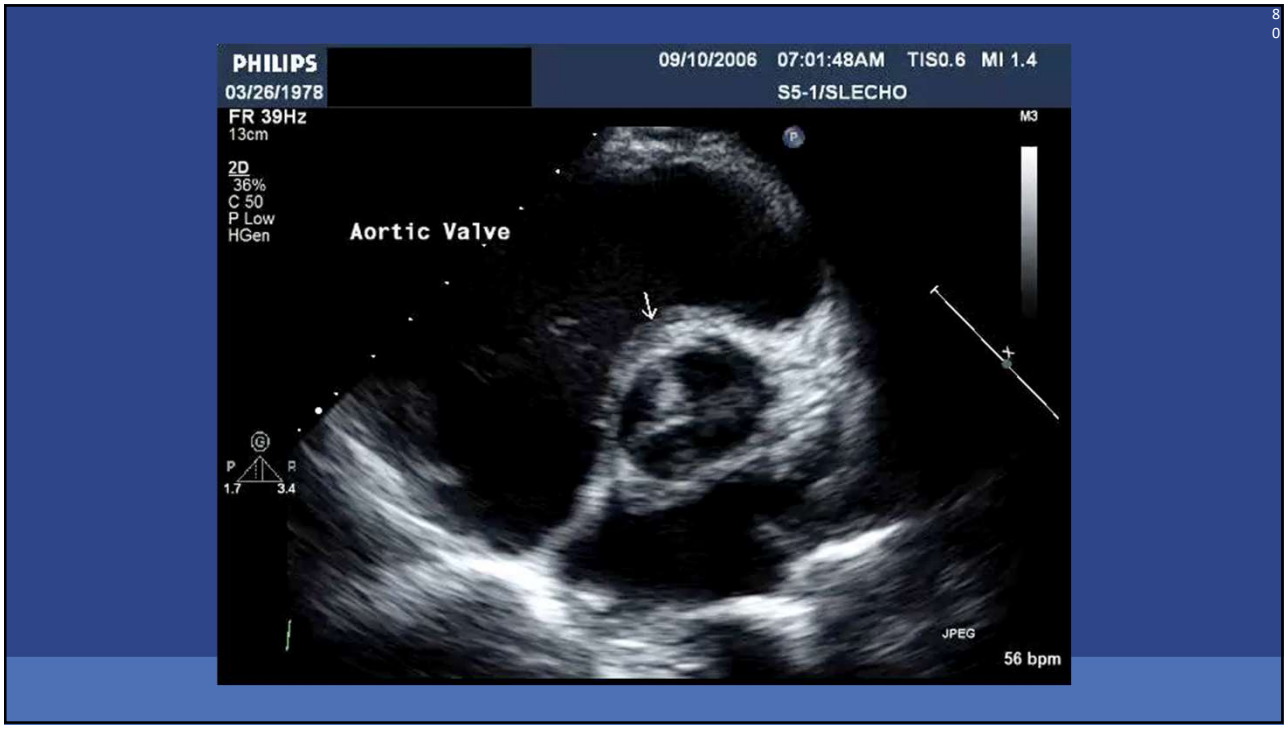

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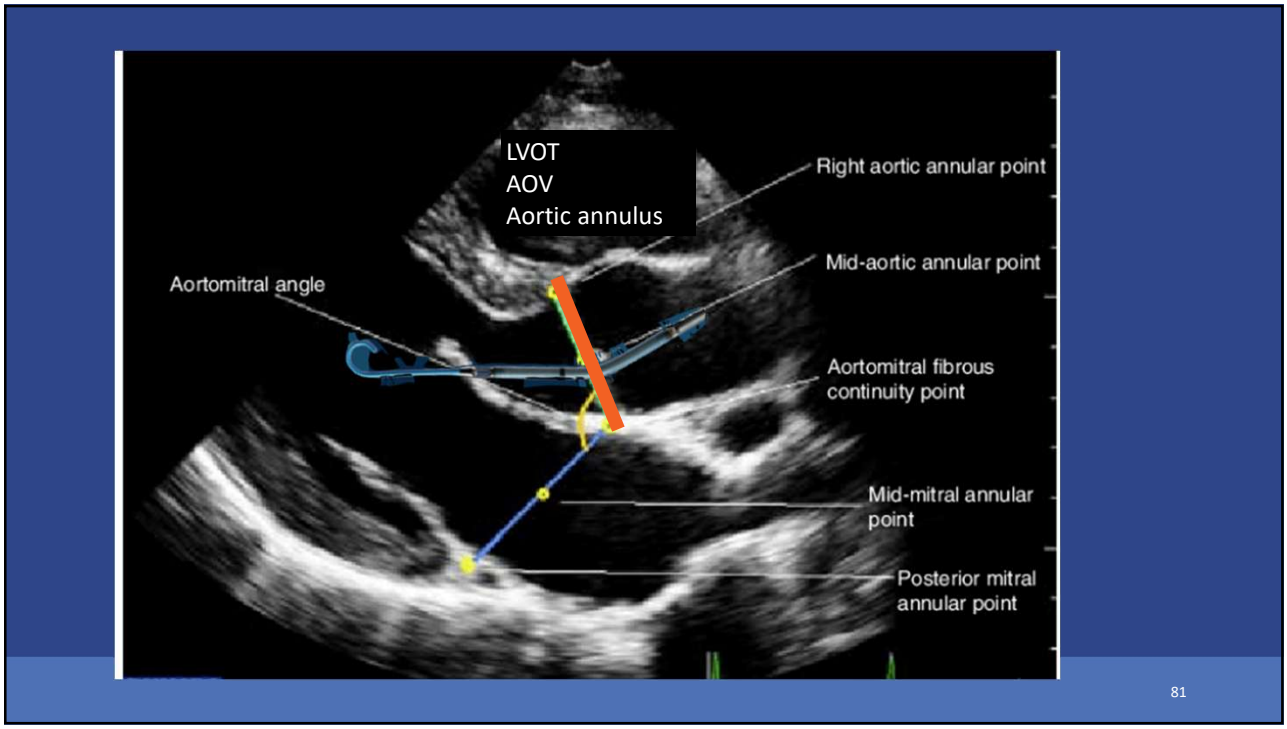

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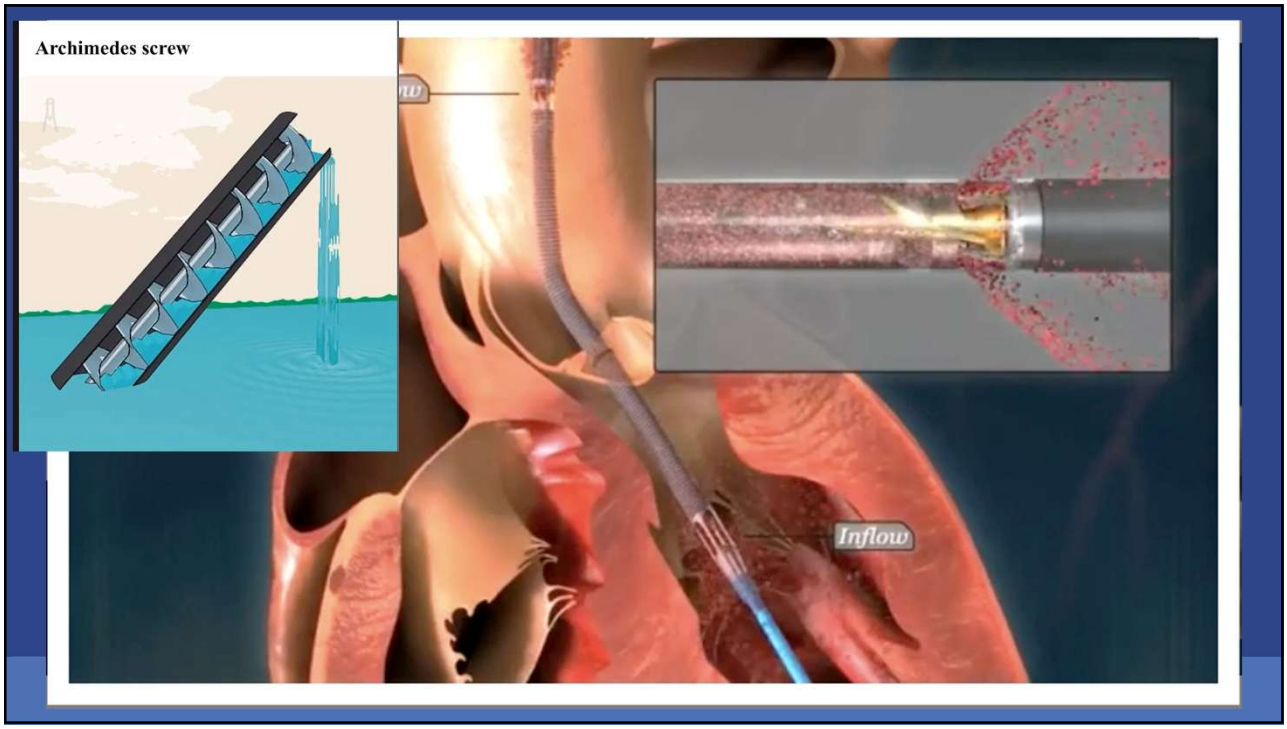

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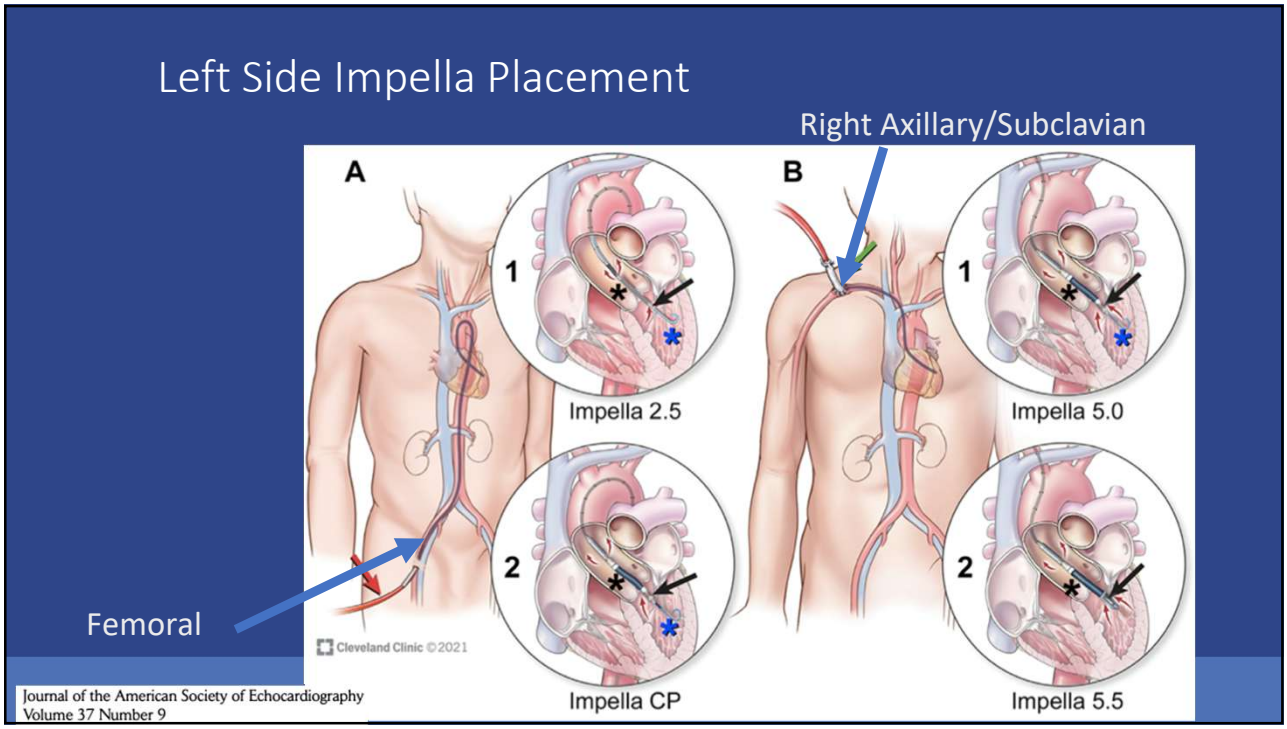
Left Side Impella Placement



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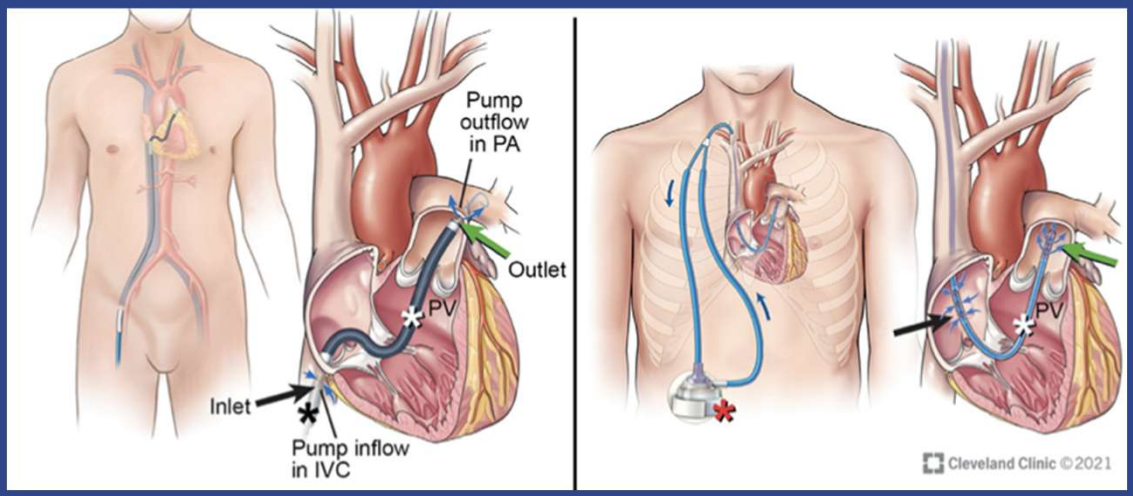
Right Side Impella



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Right and Left Impella Red Flags

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Left Side

- LV, LA, RV
  - VSD
  - ASD
  - LV thrombus (see adjacent Figure B, *red arrow*)
  - LA thrombus
  - LV rupture
  - Small LV
  - Narrow LVOT
  - Significant RV dysfunction
- Valvular abnormalities
  - ≥moderate MS
  - Significant myxomatous MV disease
  - ≥moderate AR
  - Mechanical aortic prosthetic valve
  - Severe AS with AV area ≤0.6 cm^2
- Other
  - Aortic dissection
  - Cardiac tamponade
  - Significant atheromatous disease
  - Other aortic pathology (coarctation, aneurysm)
  - Any congenital heart disease

Right Side

- RA, RV, PA
  - IVC or SVC strictures or thrombi
  - Congenital abnormalities (interrupted IVC, absent right SVC, prominent Chiari network)
  - IVC filters
  - RA, RV, or PA thrombi or masses (see adjacent Figure D, *red arrow*)
- Valvular abnormalities
  - Mechanical prosthetic TV
  - Mechanical prosthetic PV
  - ≥moderate TV or PV stenosis
  - ≥moderate PR
- Other
  - Significant uncorrected left heart disease (LV dysfunction, valvular abnormalities)
  - Severe pulmonary hypertension

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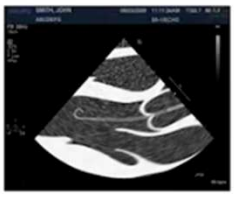
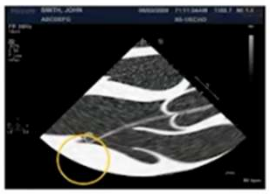
IMPELLA POSITIONING



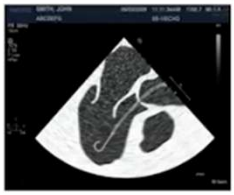
Correctly positioned Impella (TTE)

Best views:

Parasternal long axis transthoracic echocardiogram (TTE)

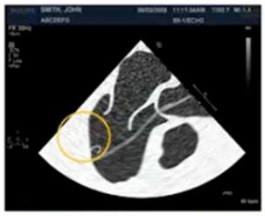


Impella in papillary muscle (TTE)



Correctly positioned Impella (TEE)

Long axis transesophageal echocardiogram (TEE)



Impella in papillary muscle (TEE)

INOVA HEART & VASCULAR

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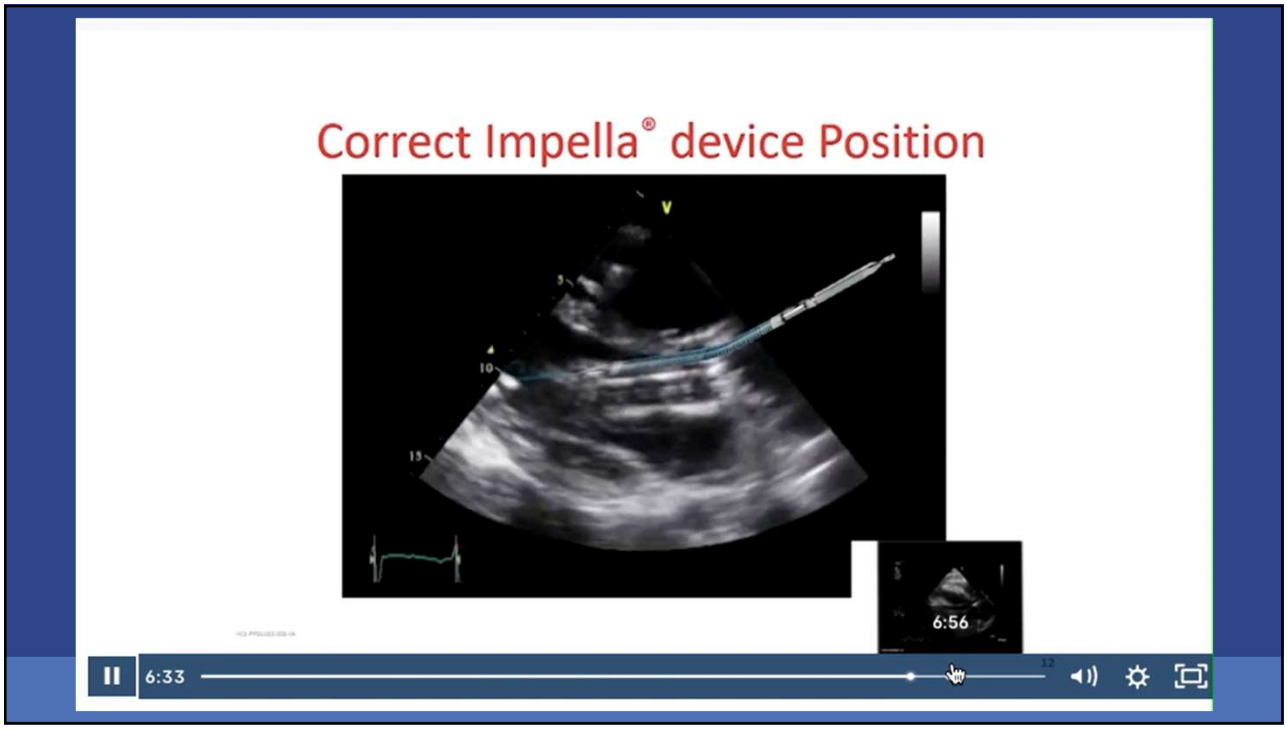

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Measurements:
Left Side CP Device

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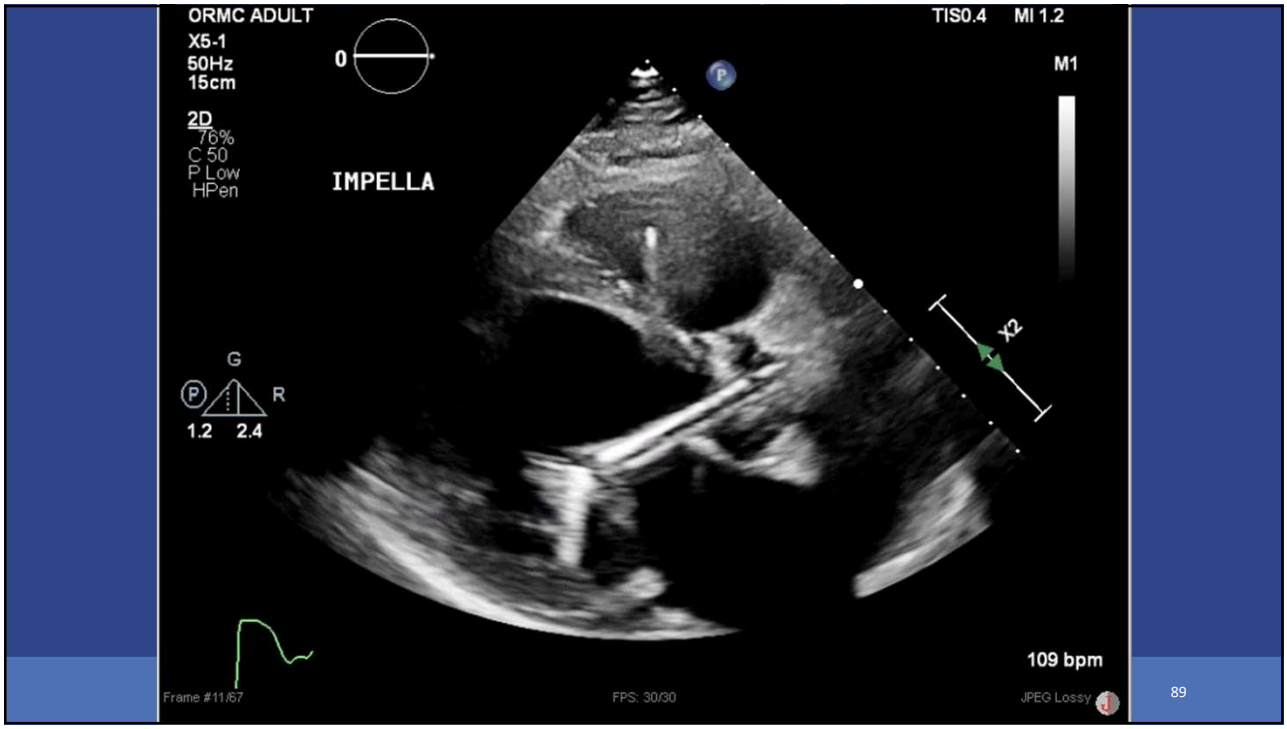

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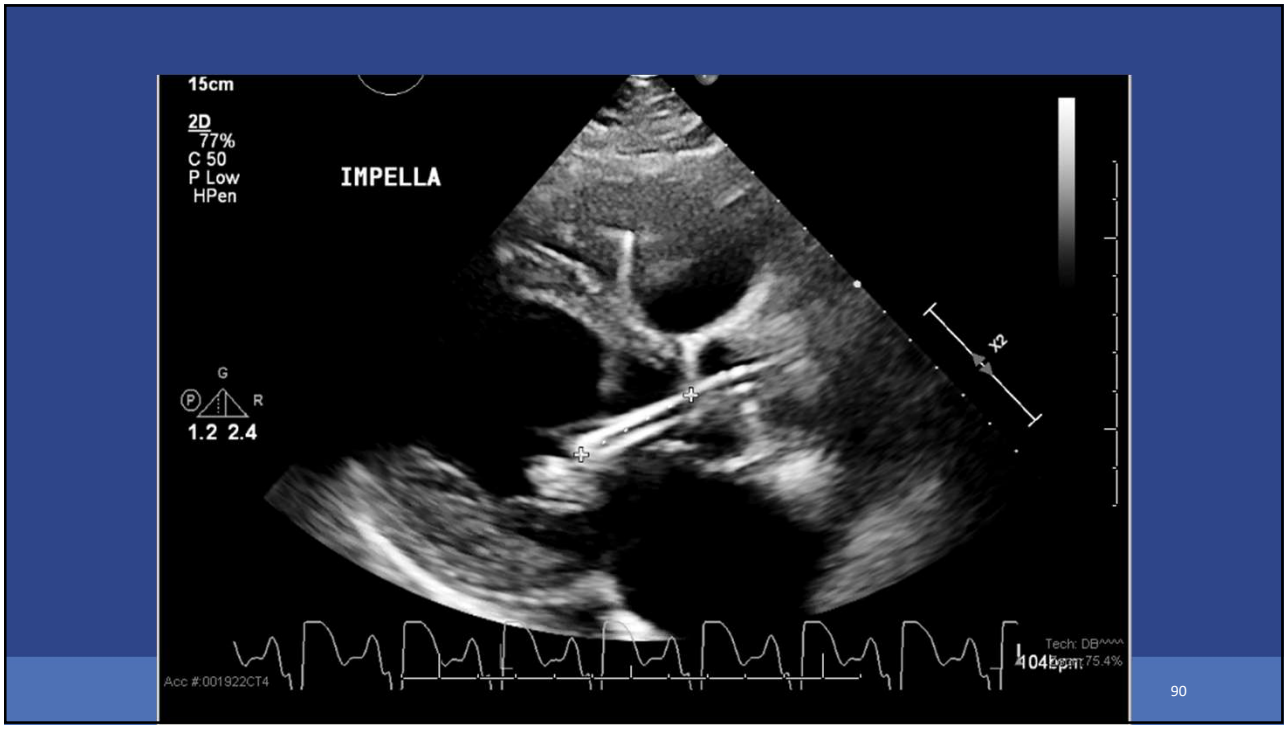

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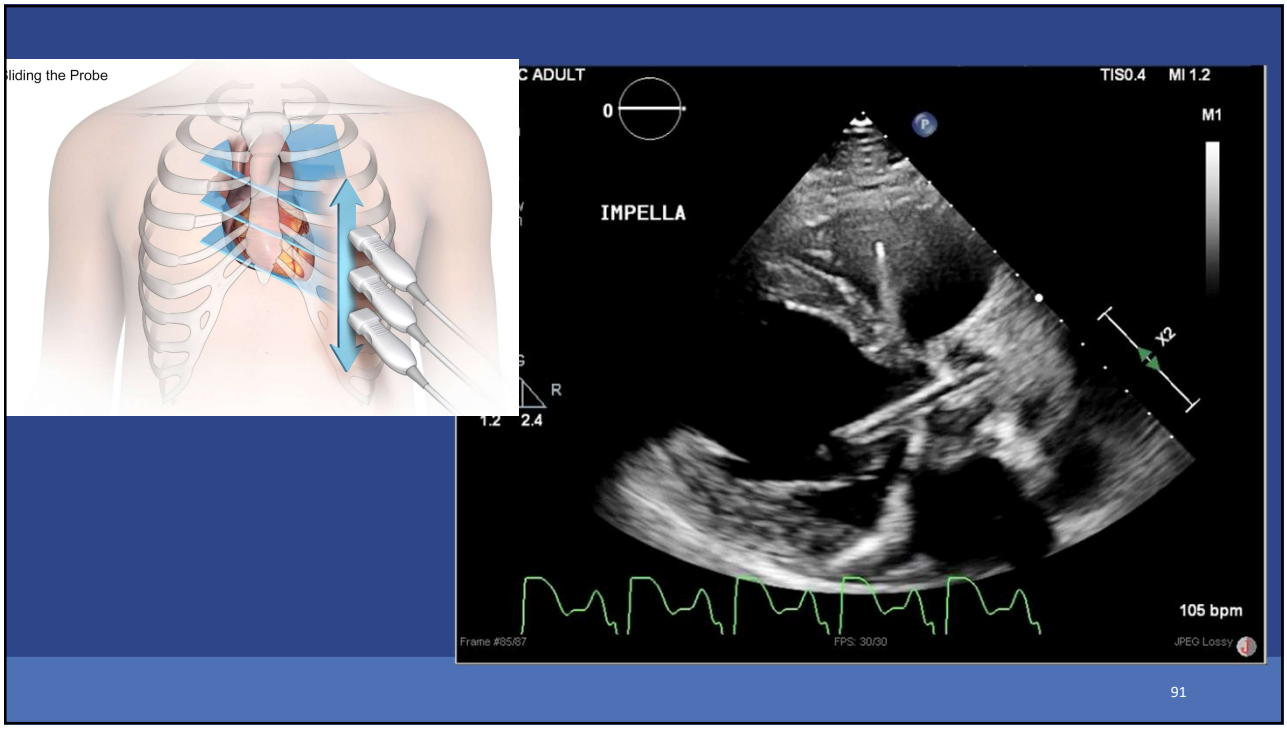

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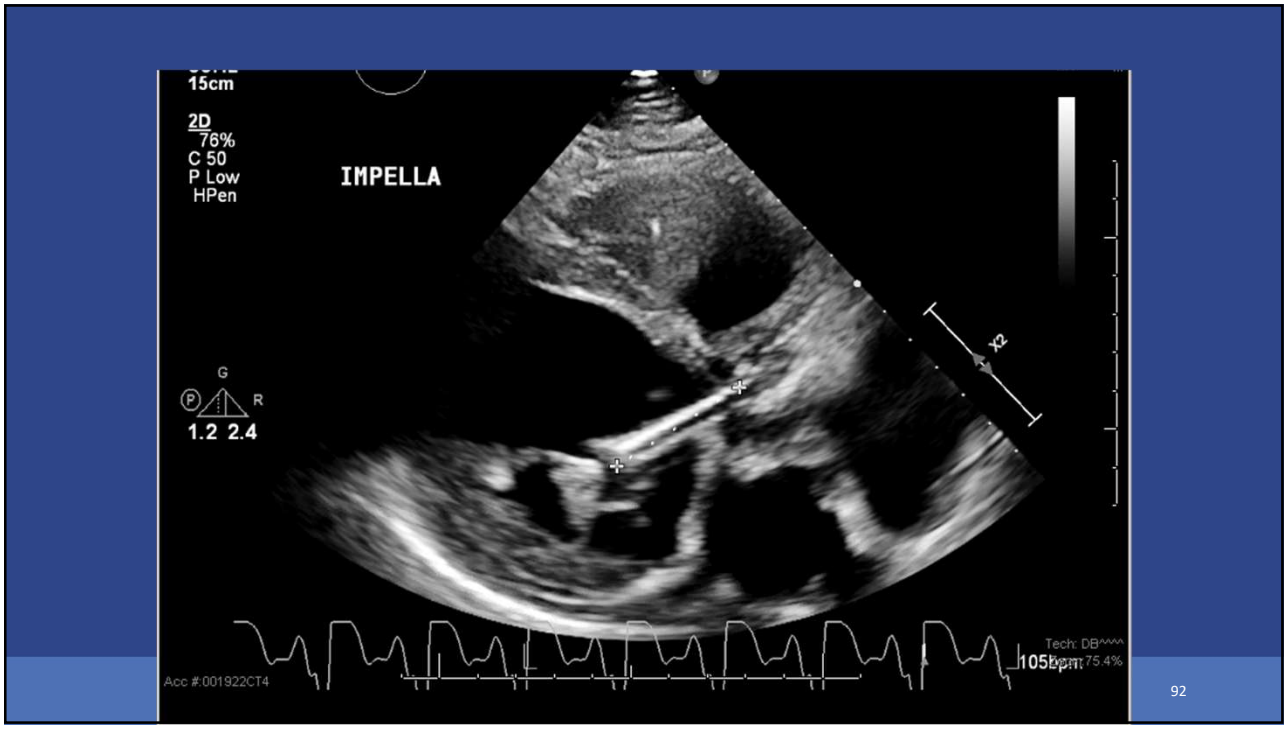

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Measurements
Left Side 5.5 Device

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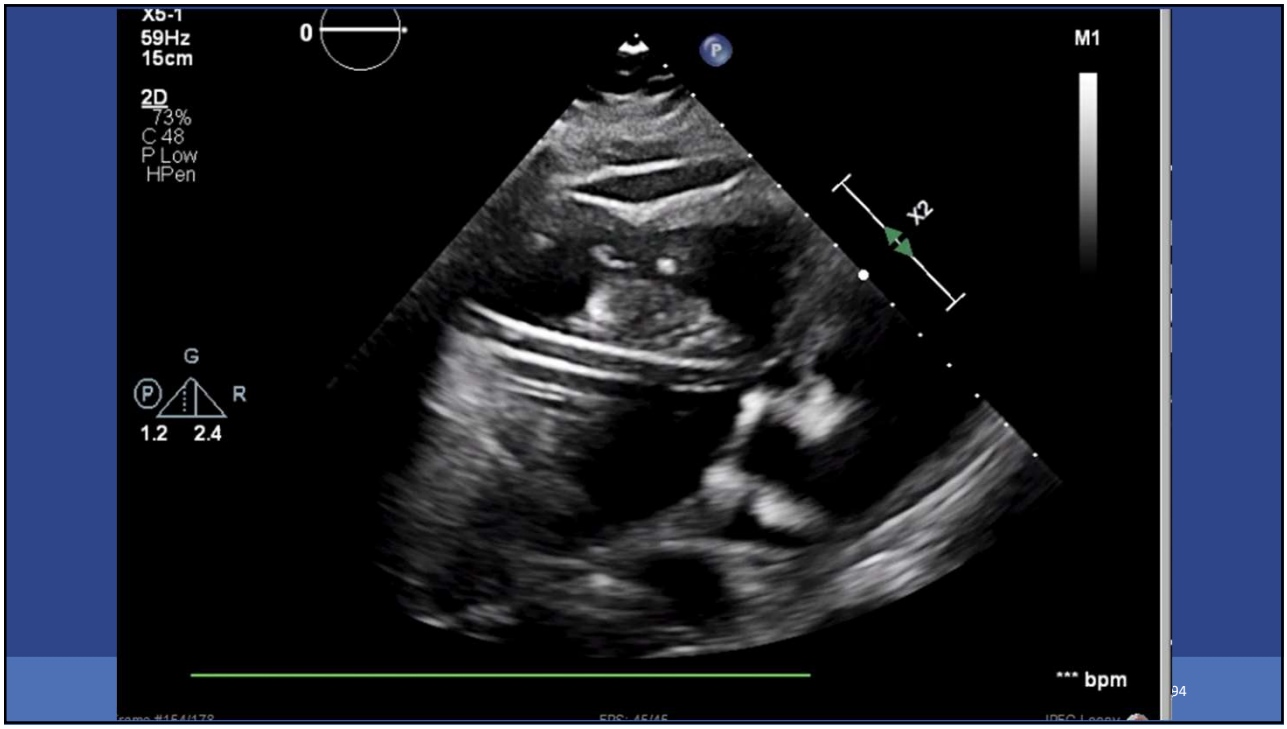

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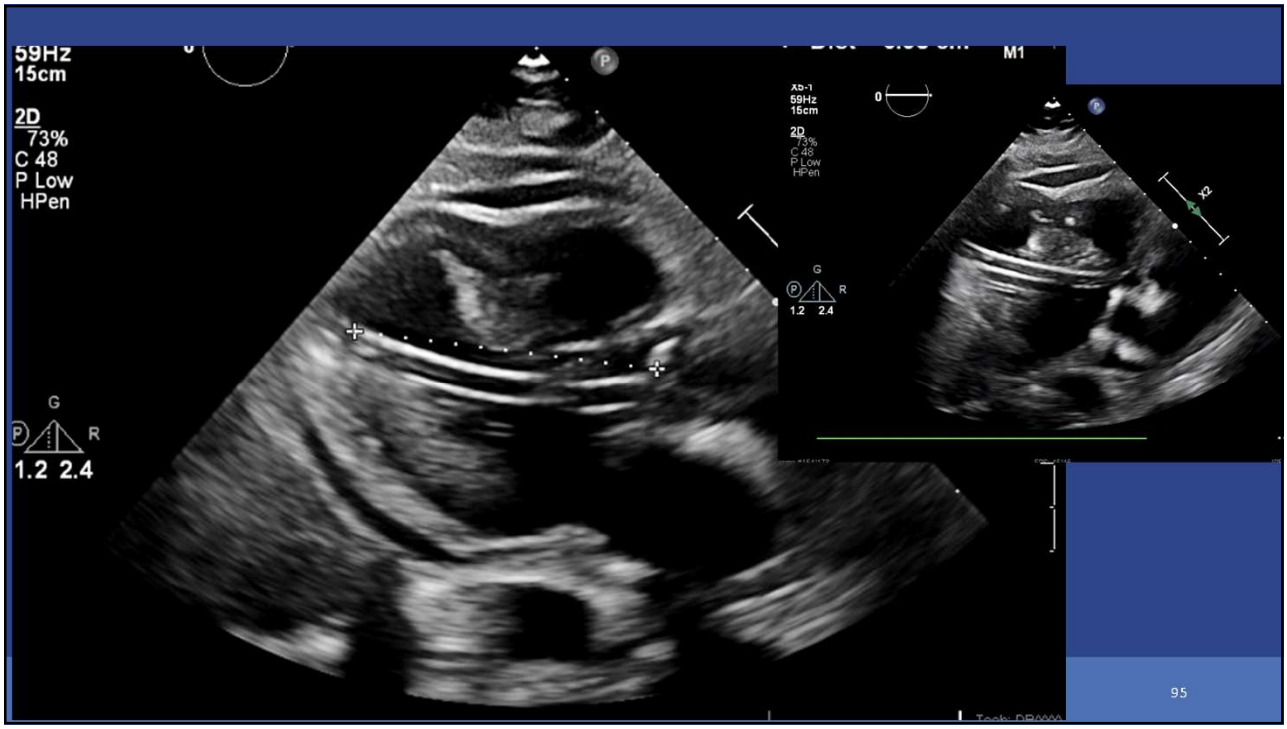

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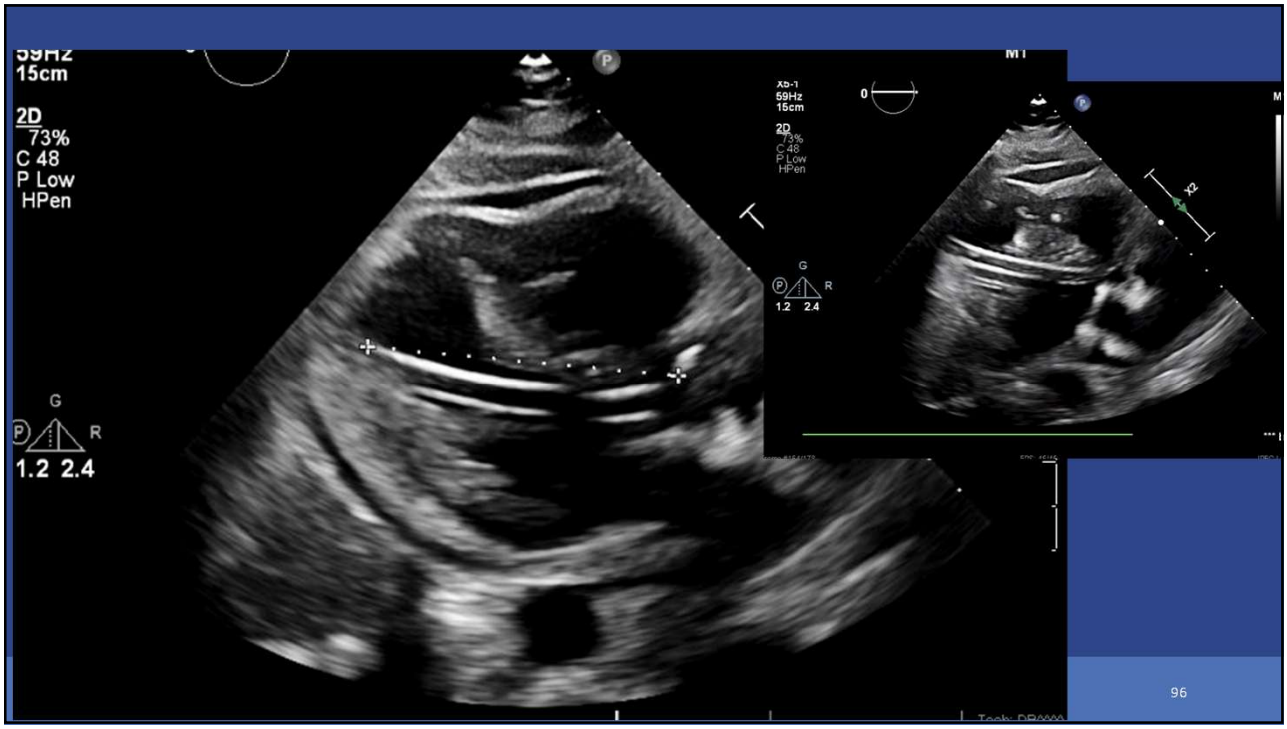

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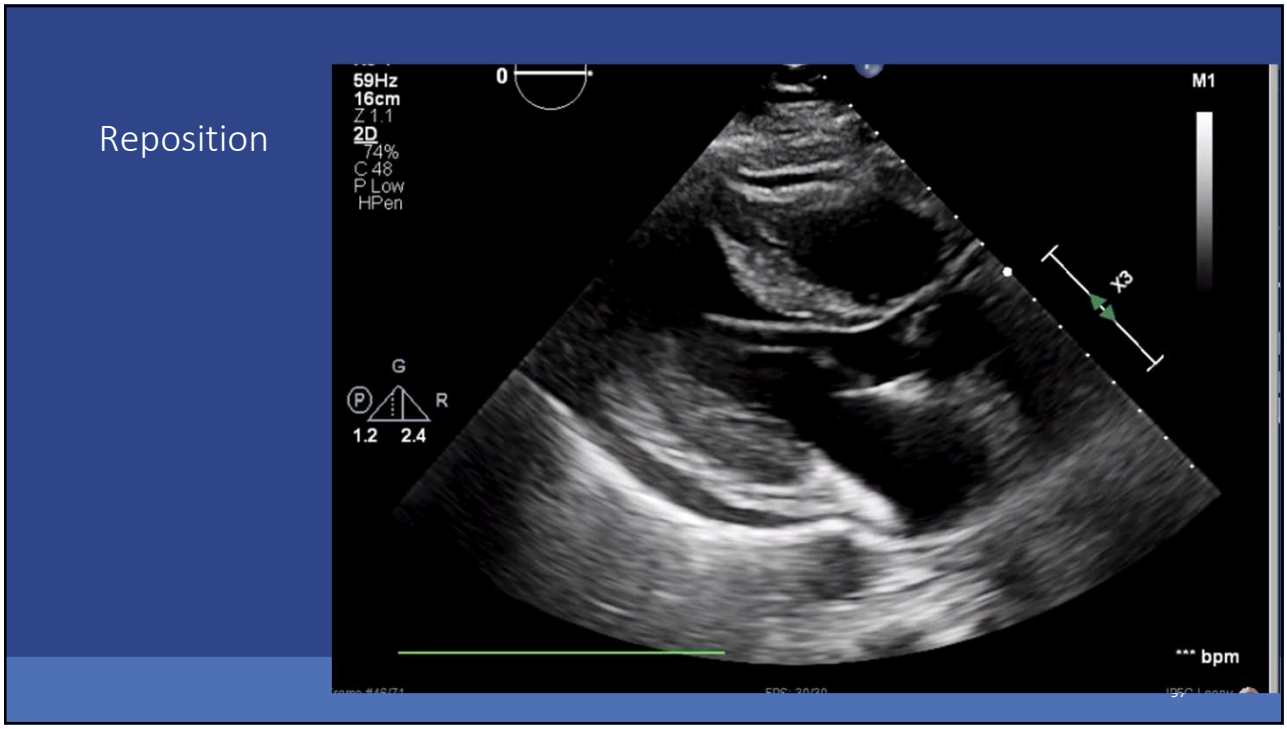

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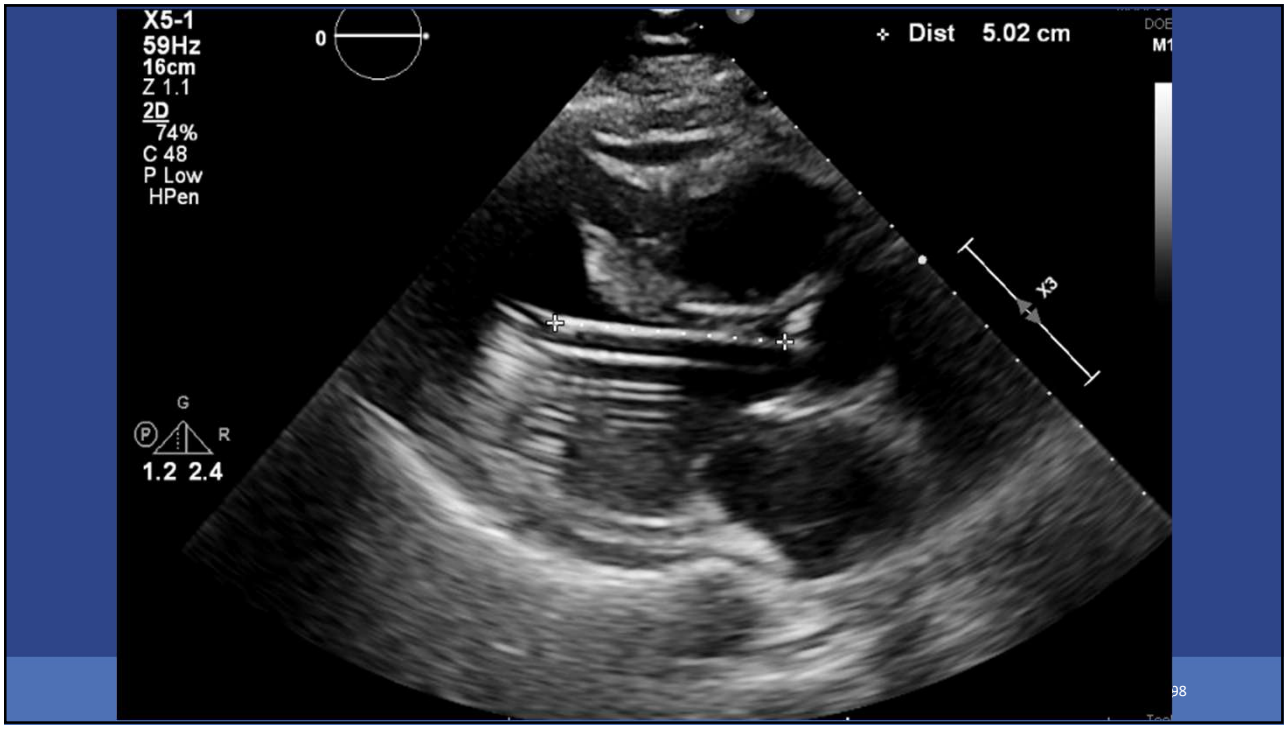

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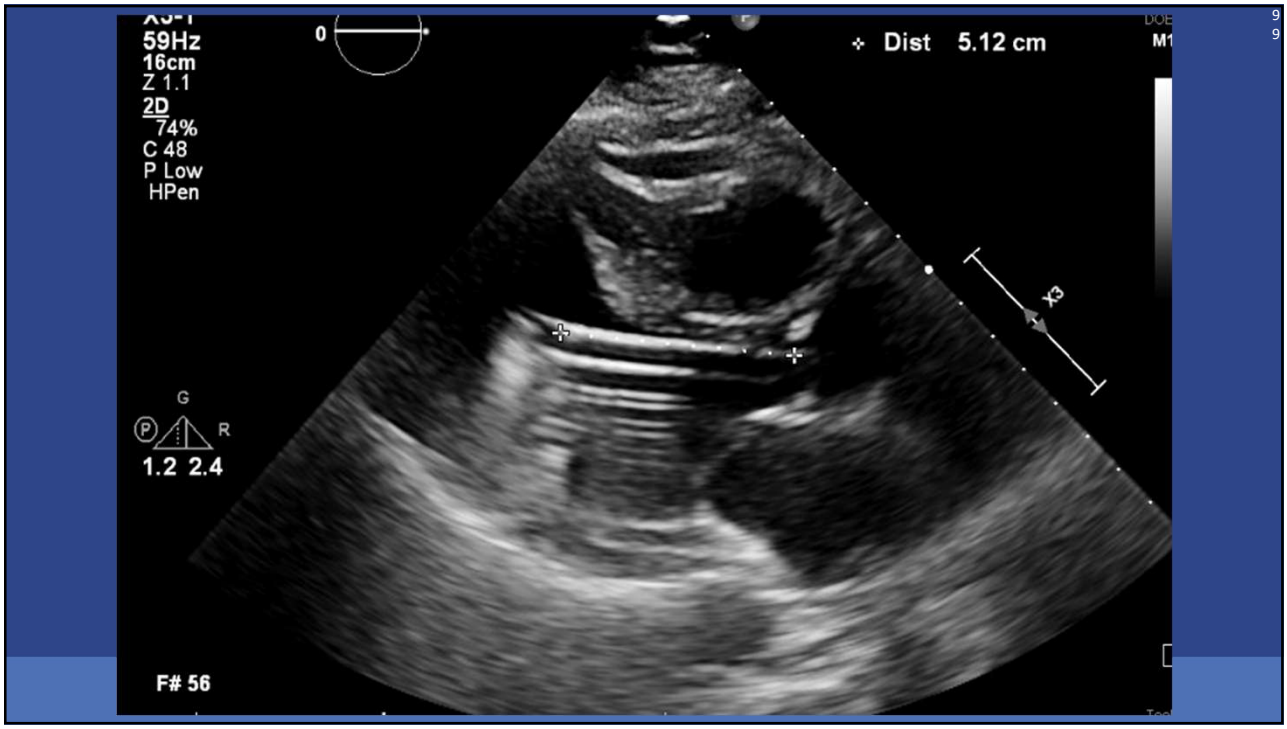

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Measurements: Left Side CP

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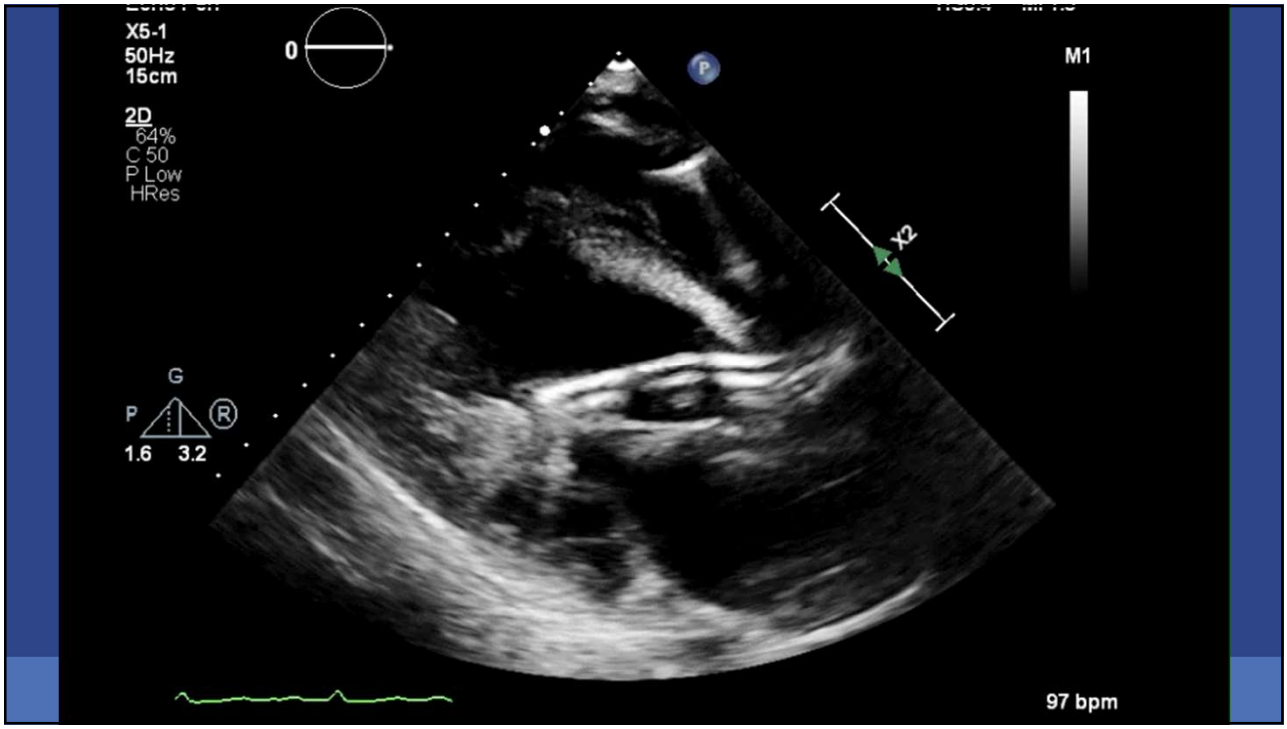

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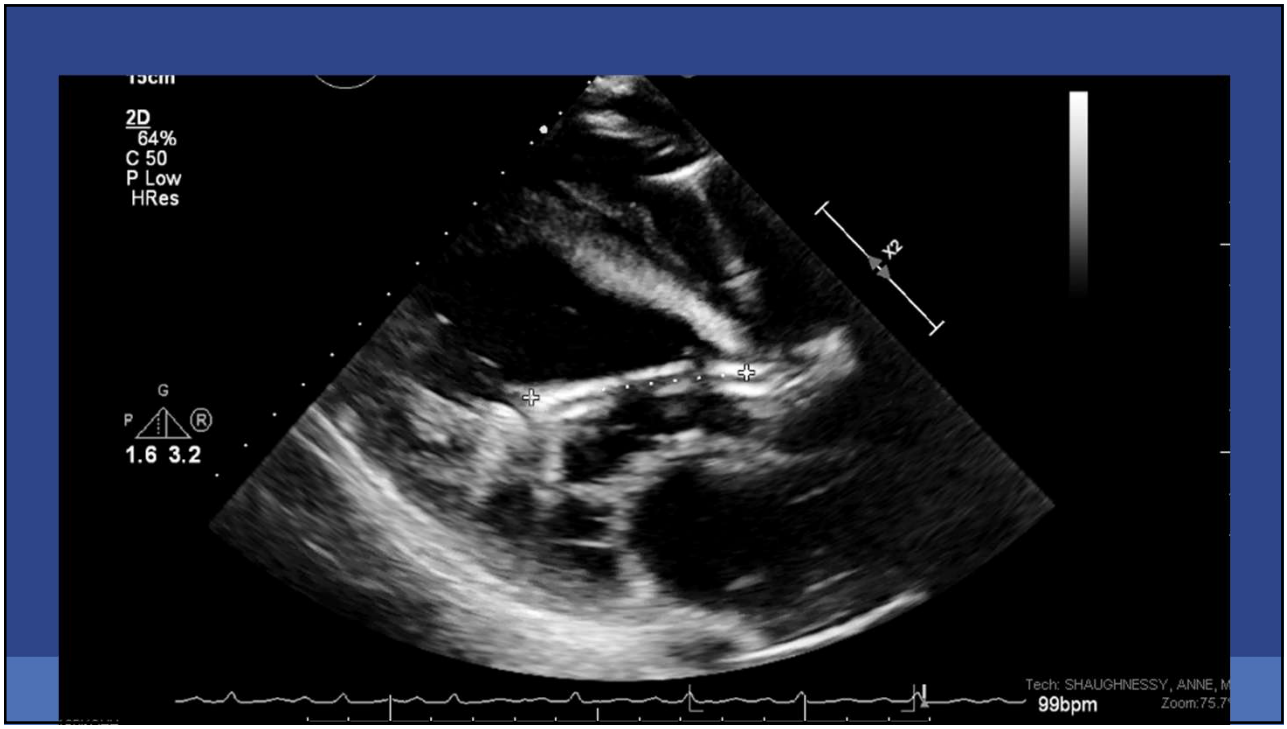

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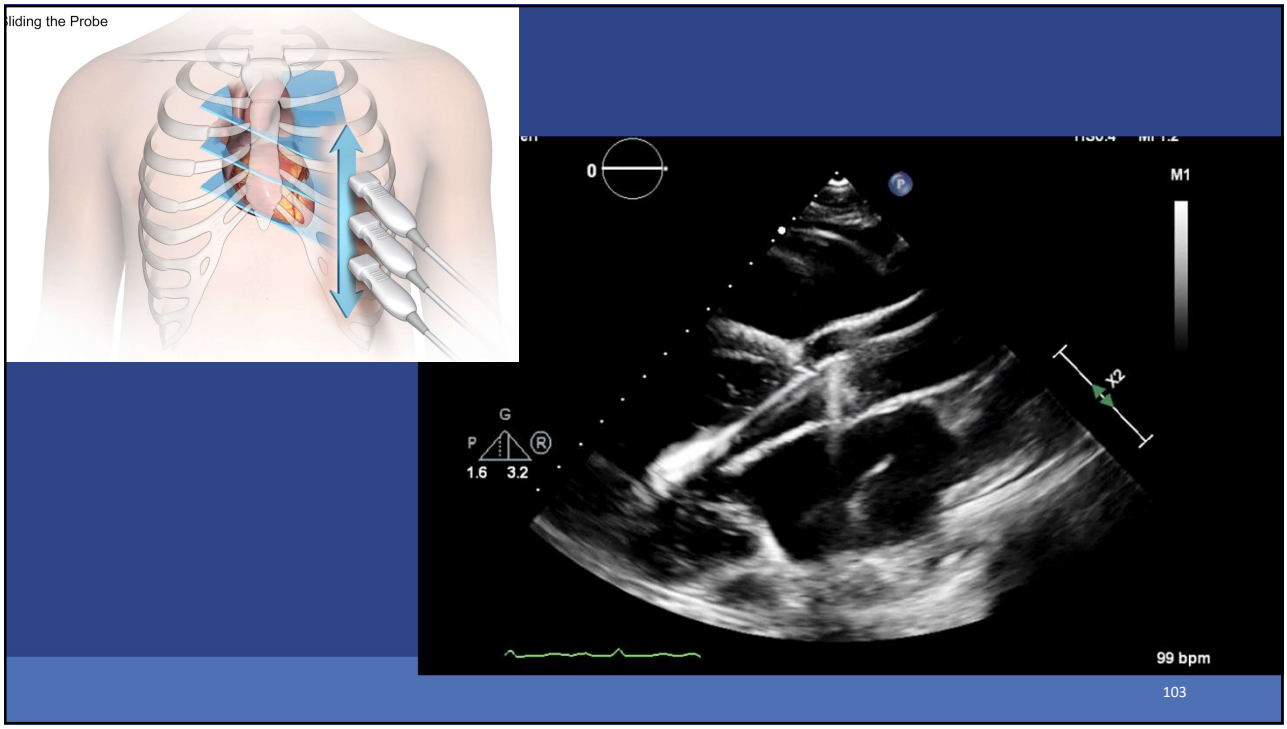

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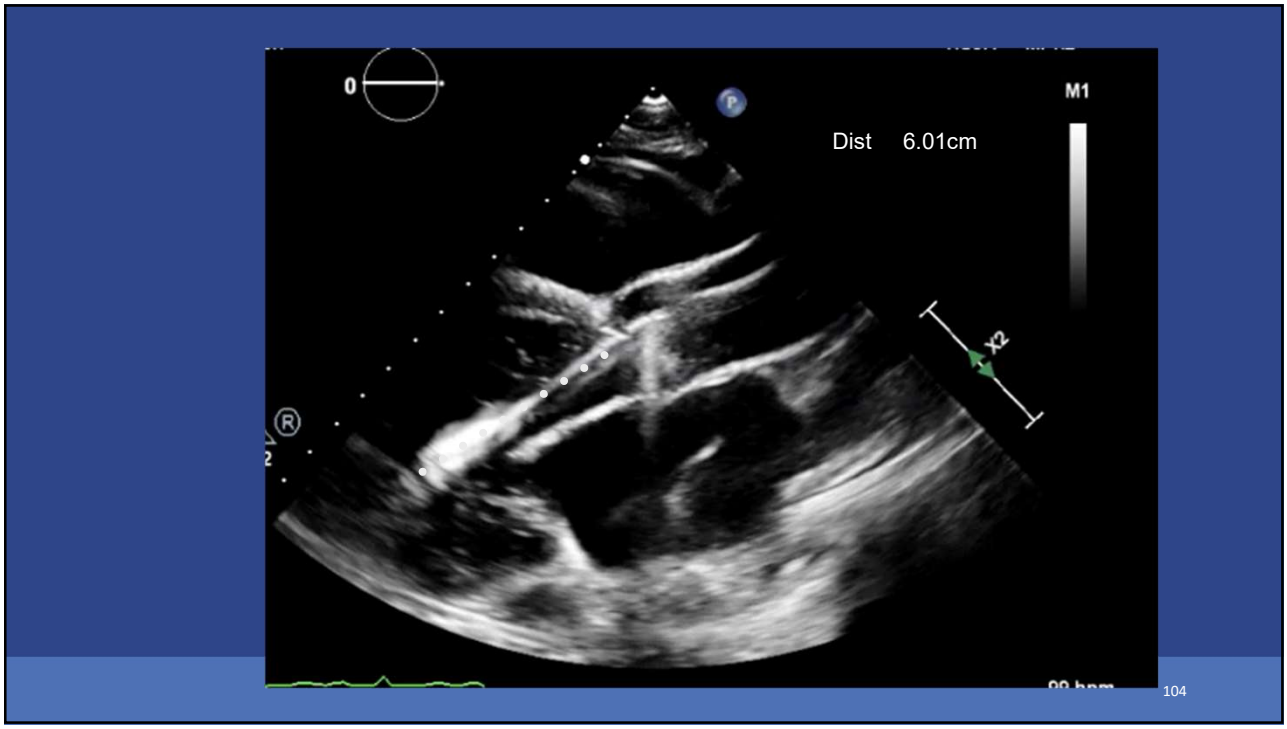

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31 YO female with giant cell myocarditis:
Left side CP device, Right side Flex

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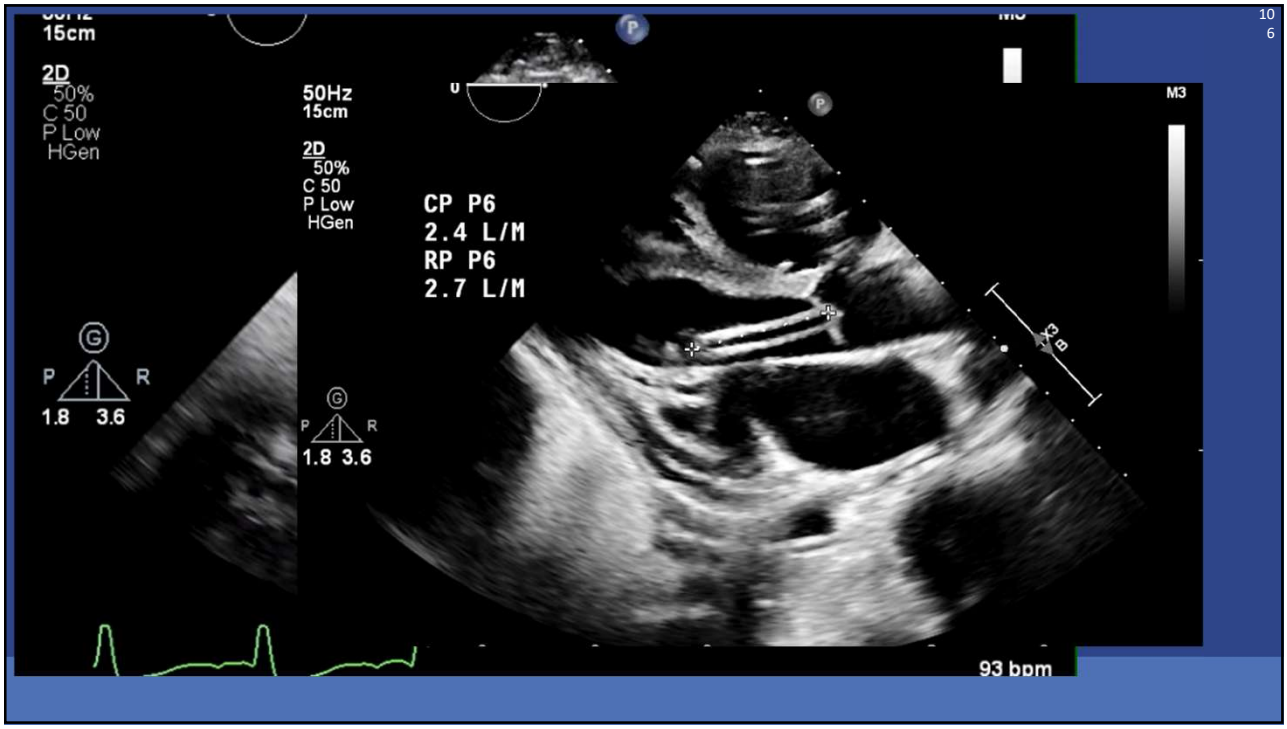

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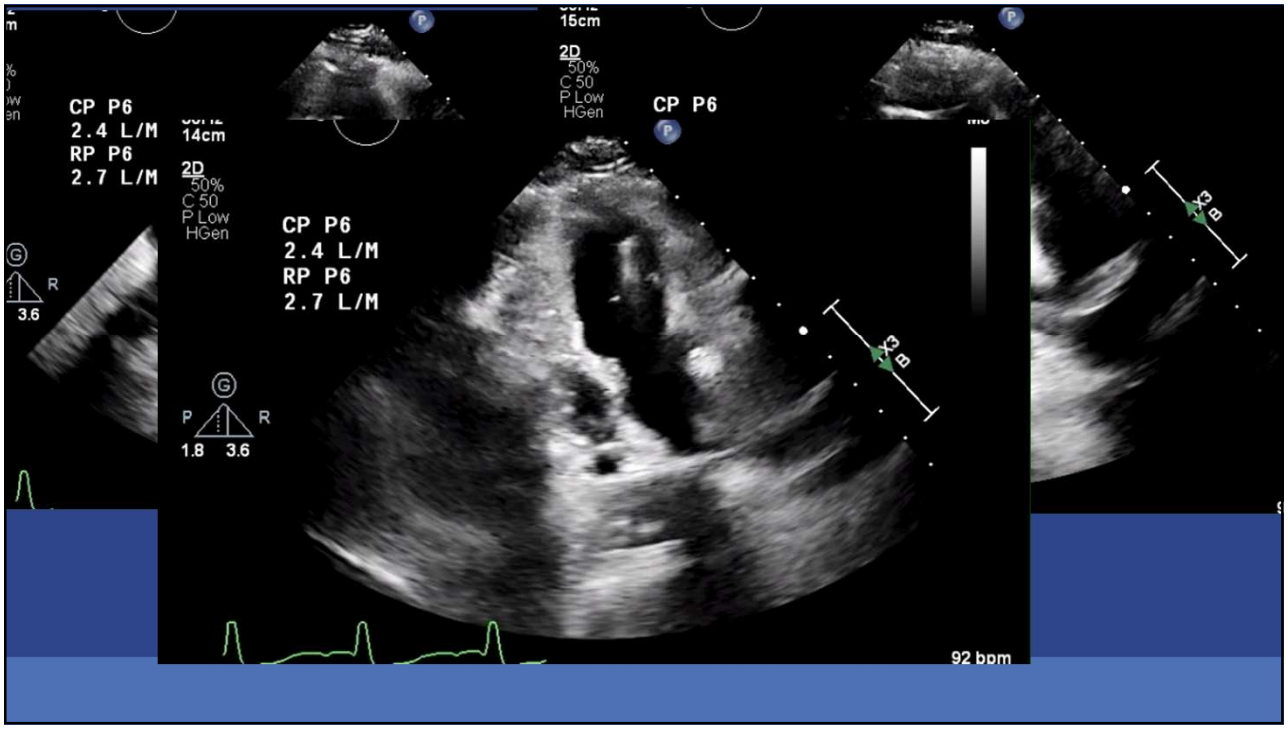

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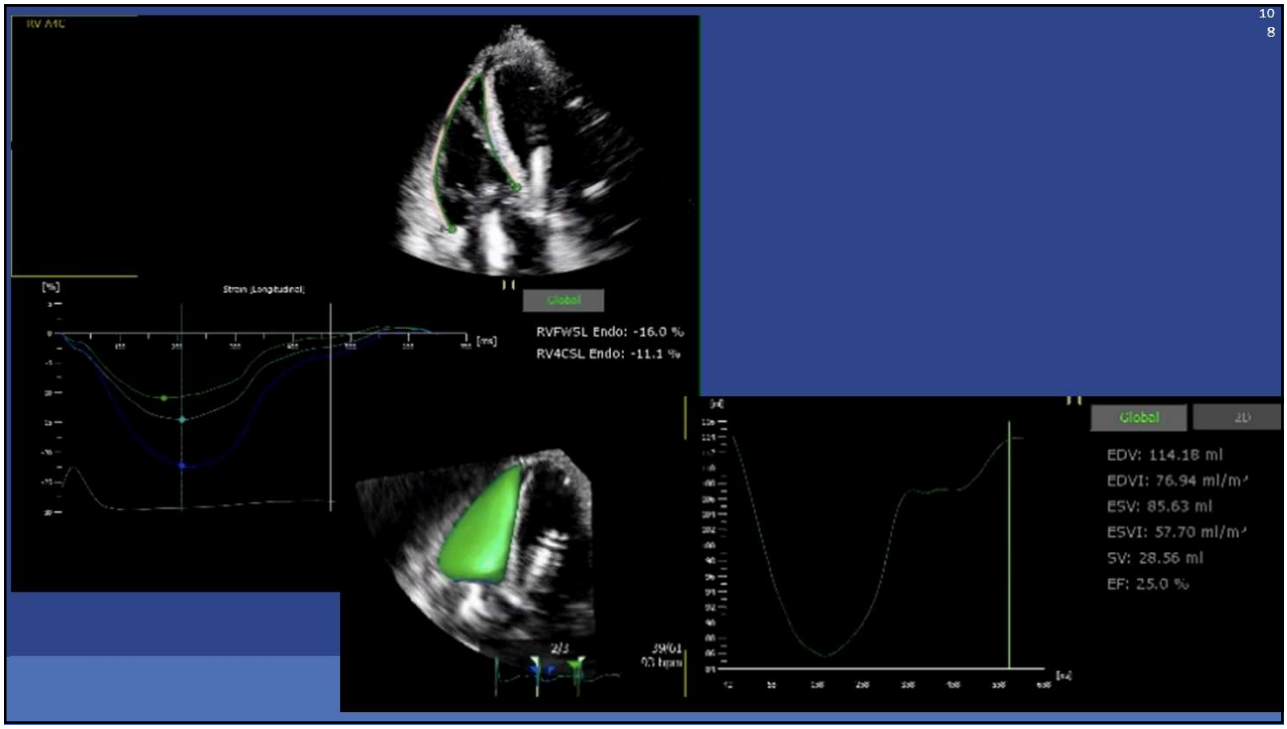

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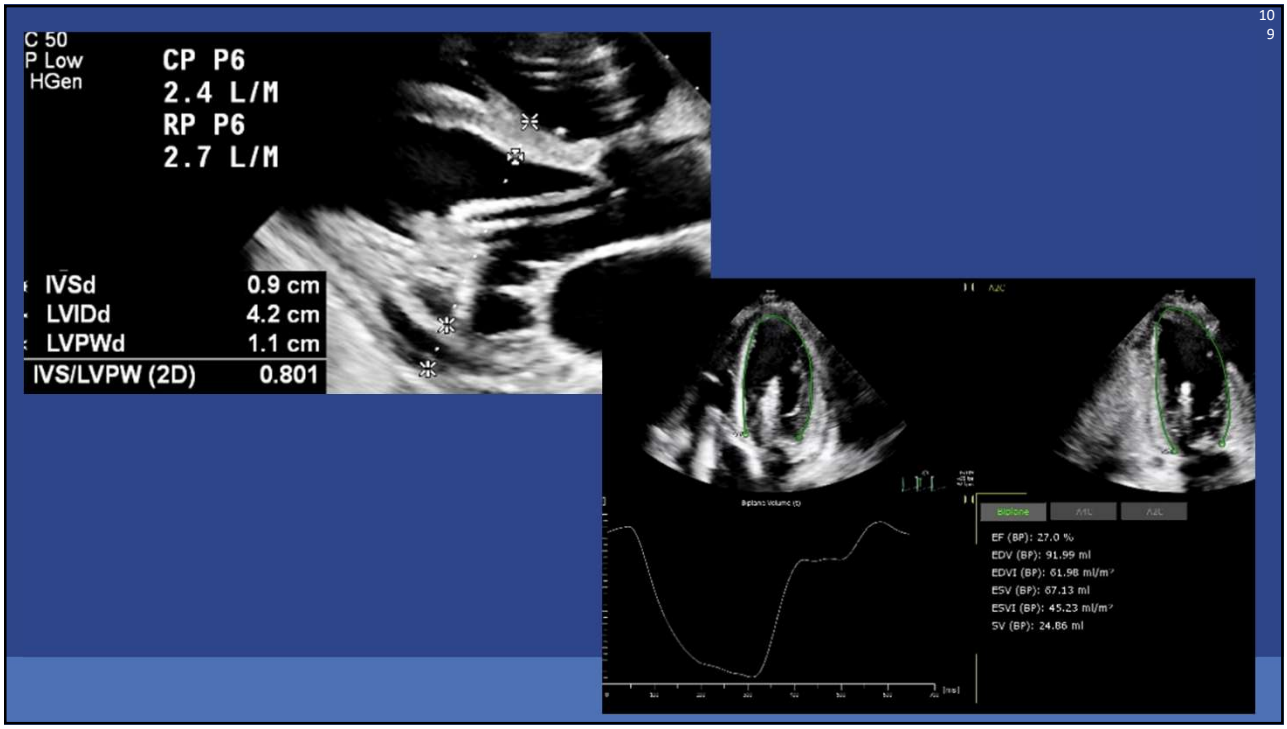

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Summary

- Pay attention to the visual presentations for LVAD (septal position, chamber dilatation)
- Importance of pre assessment for patient selection
- Understand limitations of imaging
- On axis views for measurements with Impella
- Remember 5.5= 5 3.5/CP= 3.5

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