2026 SDMS Annual Conference

Advanced Heart Failure: The Essential Role of Echocardiography

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Objectives

- Identify the mechanisms and progression of heart failure to support clinical understanding.
- Recognize echocardiographic findings and guideline-based protocols used in heart failure assessment.
- Describe the role of echocardiography in guiding referral and evaluation for advanced therapies, including LVADs and cardiac transplantation.

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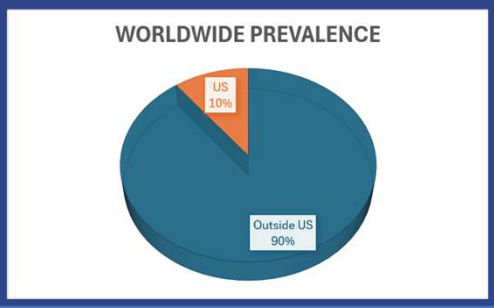
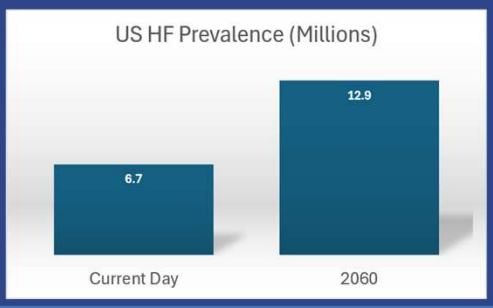
Introduction

- Epidemic
  - Increase in HF hospitalizations, increasing # HF deaths, and associated costs
- Patient's living longer
  - MI, VHD, and arrhythmias





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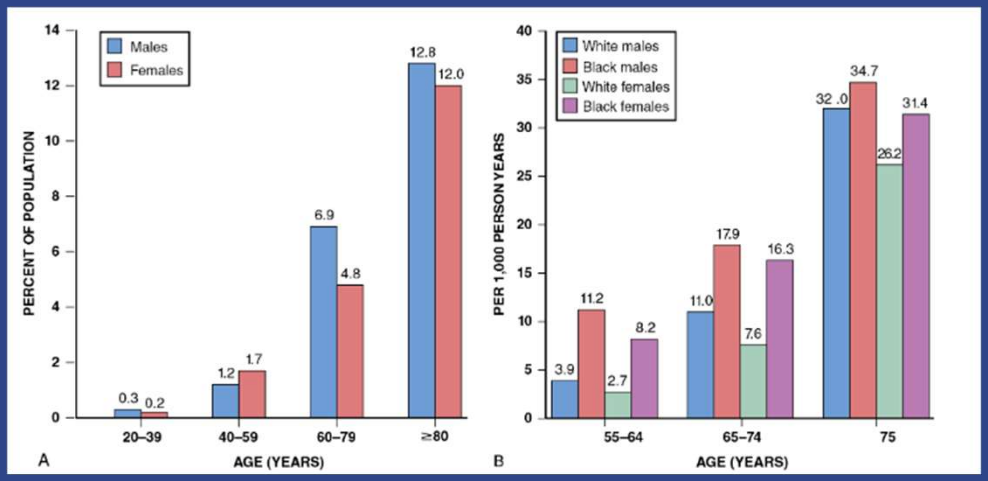
Prevalence



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Heart Failure Defined

- Complex clinical syndrome resulting from structural and functional impairment of ventricular filling or ejection
  - Pathophysiologic definition "the inability of the heart to pump blood to the body at a rate commensurate with its needs, or to do so only at the cost of high filling pressures"
- Impairment of myocardial performance
  - Normal ventricular size and function or marked dilation and reduced function
- Symptoms result from presence of elevated left or right heart filling pressures
  - Symptoms may be due to reduced cardiac output

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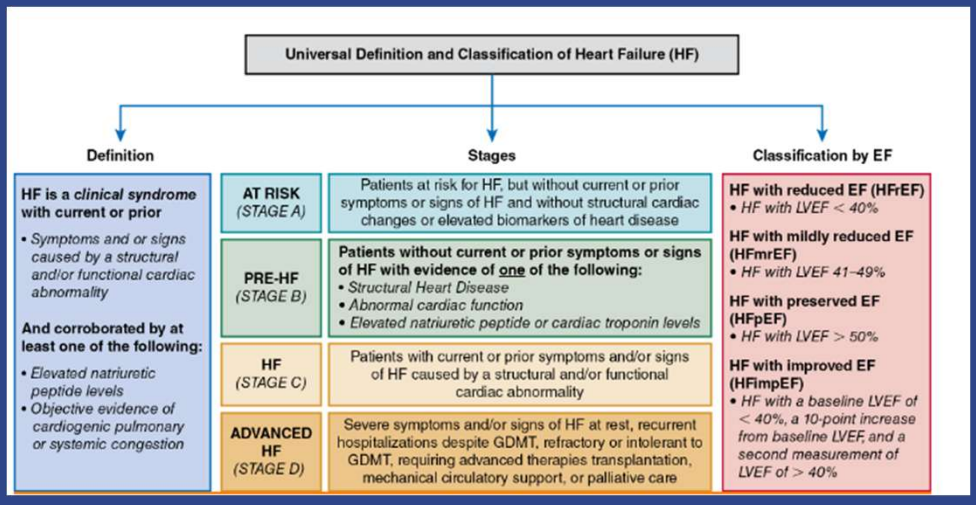
Heart Failure Defined



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Pathophysiology- Neurohormonal Activation

- When the heart starts to fail, the body activates "stress" hormones to help maintain blood flow.
- The sympathetic nervous system increases heart rate and blood pressure. This helps in the short term but can damage the heart over time.
- The renin-angiotensin-aldosterone system (RAAS) causes the body to retain salt and water, increasing workload on the heart and promoting scar tissue formation.
- Natriuretic peptides (ANP and BNP) are the body's natural defense system, helping remove excess fluid and reduce strain on the heart.

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Pathophysiology- Left ventricular remodeling

- Over time, the left ventricle changes in size, shape, and function as it tries to compensate for heart failure.
- The heart muscle may become thicker or enlarge, but these changes ultimately reduce pumping efficiency.
- Progressive scarring (fibrosis) and loss of heart muscle cells further weaken the heart.
- The failing heart also becomes less efficient at producing and using energy, contributing to worsening function.

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Pathophysiology- Summary



Heart failure progresses because the body's compensatory mechanisms, which initially help maintain circulation, eventually lead to structural damage, scarring, and worsening heart function.

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ACC/AHA & NYHA

ACC/AHA STAGES OF HEART FAILURE (HF)		NYHA FUNCTIONAL CLASSIFICATION	
A	At high risk for HF but without structural heart disease or symptoms of HF	None	
B	Structural heart disease but without signs or symptoms of HF	I	No limitation of physical activity. Ordinary physical activity does not cause symptoms of HF.
C	Structural heart disease with prior or current symptoms of HF	I	No limitation of physical activity. Ordinary physical activity does not cause symptoms of HF.
		II	Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in symptoms of HF.
		III	Marked limitation of physical activity. Comfortable at rest, but less than ordinary activity causes symptoms of HF.
		IV	Unable to carry on any physical activity without symptoms of HF, or symptoms of HF at rest.
D	Refractory HF requiring specialized interventions		

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Heart Failure



HFrEF	HFpEF
• EF ≤ 40% • Male > female • Lifetime risk 11% (male), 6% (female) • Risk factors include HTN, obesity, rheumatic HD, CAD (most common in developed countries) • Etiology unknown in 20-30% of cases	• EF ≥ 50% • Risk factors include ↑ BMI, smoking, A-fib (most common arrhythmia) • Female>Male • Mortality rates comparable or slightly ↓ than HFrEF • ↑ hospitalization rates than HFrEF



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HFpEF Echo parameters

Majority have concentric LV remodeling	↑ LA volume/LA in relation to other chambers	PASP >40mmHg	**May be asymptomatic at rest** ****Stress Echocardiography**
Quantify right heart (TAPSE, S')	Septal flattening	IVC/Hepatic	
e'	GLS		

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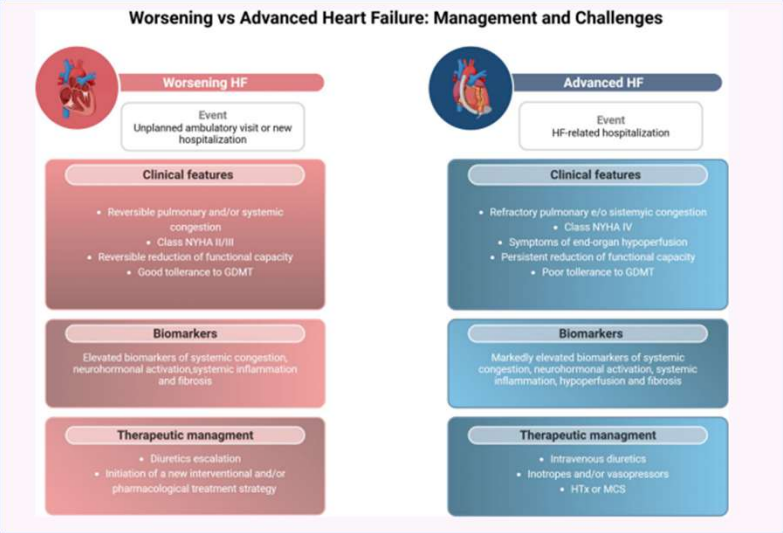
Recognizing Advanced Heart Failure



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"I Need Help"—Markers of Advanced Heart Failure

I	Inotropes	**Previous or ongoing requirement for dobutamine, milrinone, dopamine or levosimendan**
N	NYHA class/ Natriuretic peptides	Persisting NYHA Class III or IV and/or persistently high BNP or NT-pro-BNP
E	End-Organ Dysfunction	Worsening renal or liver dysfunction in the setting of heart failure
E	Ejection Fraction	Very low ejection fraction <20%
D	Defibrillator shocks	Recurrent appropriate defibrillator shocks
H	Hospitalizations	More than 1 hospitalization with heart failure in the last 12 months
E	Edema/ Escalating diuretics	Persisting fluid overload and/or Increasing diuretic requirement
L	Low blood pressure	Consistently low BP with systolic <90 to 100 mm Hg
P	Prognostic medication	Inability to up-titrate (or need to decrease/cease) ACEI, B-blockers, ARNIs or MRAs

Baumwol 2017

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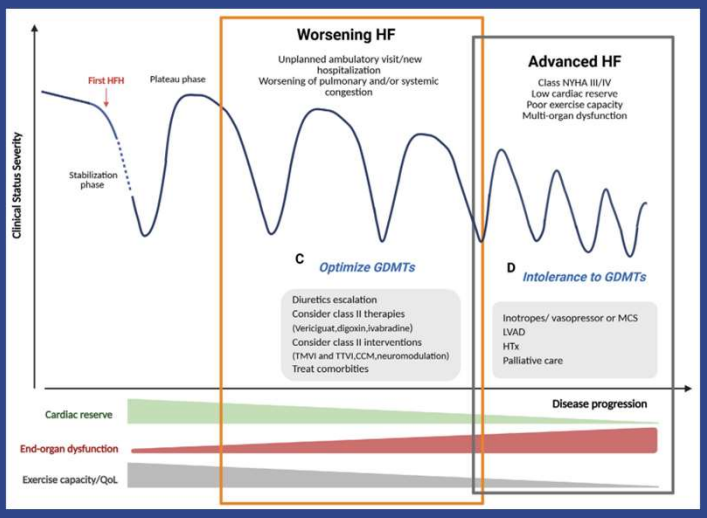
Timing of AHF Referral

- Window of opportunity
  - Risk of missing opportunity for advanced therapies once multiorgan failure begins



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Imaging to Intervention



Heart Transplant

LVAD candidacy
BTT
DT

TEER for secondary MR

CRT

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Advanced HF summary



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Transthoracic Echo

- Important for diagnosis and management of HF
- Benefits (low risk, no radiation, can be done bedside)
- Myocardial and valvular structure and function
- Intracardiac pressures and flows
- Diastolic function
- Strain

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Comprehensive Echo assessment

CASE STUDY- HF Diagnosis



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69-year-old male (current)

- 2016 (outside hospital)- witnessed cardiac arrest at home with prolonged CPR. Upon arrival to ED, VF and >10 defibrillation shocks
  - Cardiogenic shock, proximal LAD occlusion (PCI of LAD (DES)
  - Progressive slow recovery, EF 34% at discharge (increase from 27% at admission)
- 2017
  - Outpatient echo ordered for CHF. First in our health system

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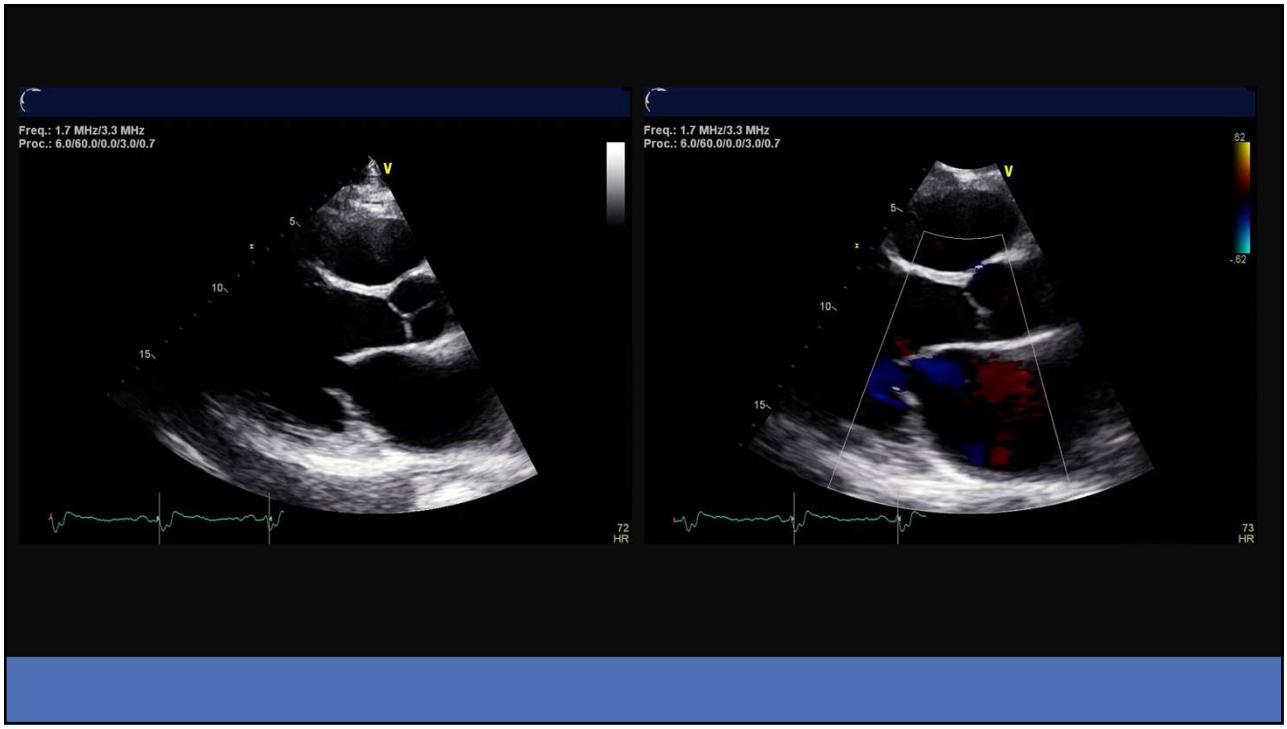

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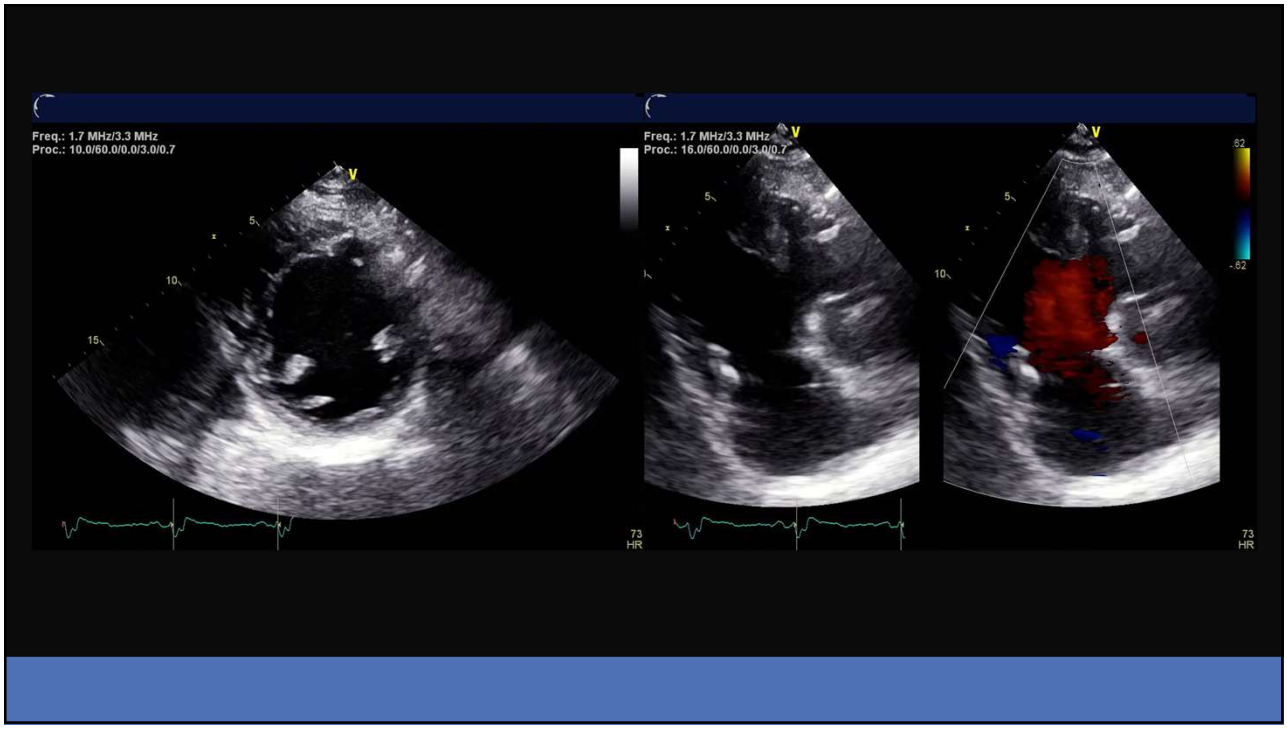

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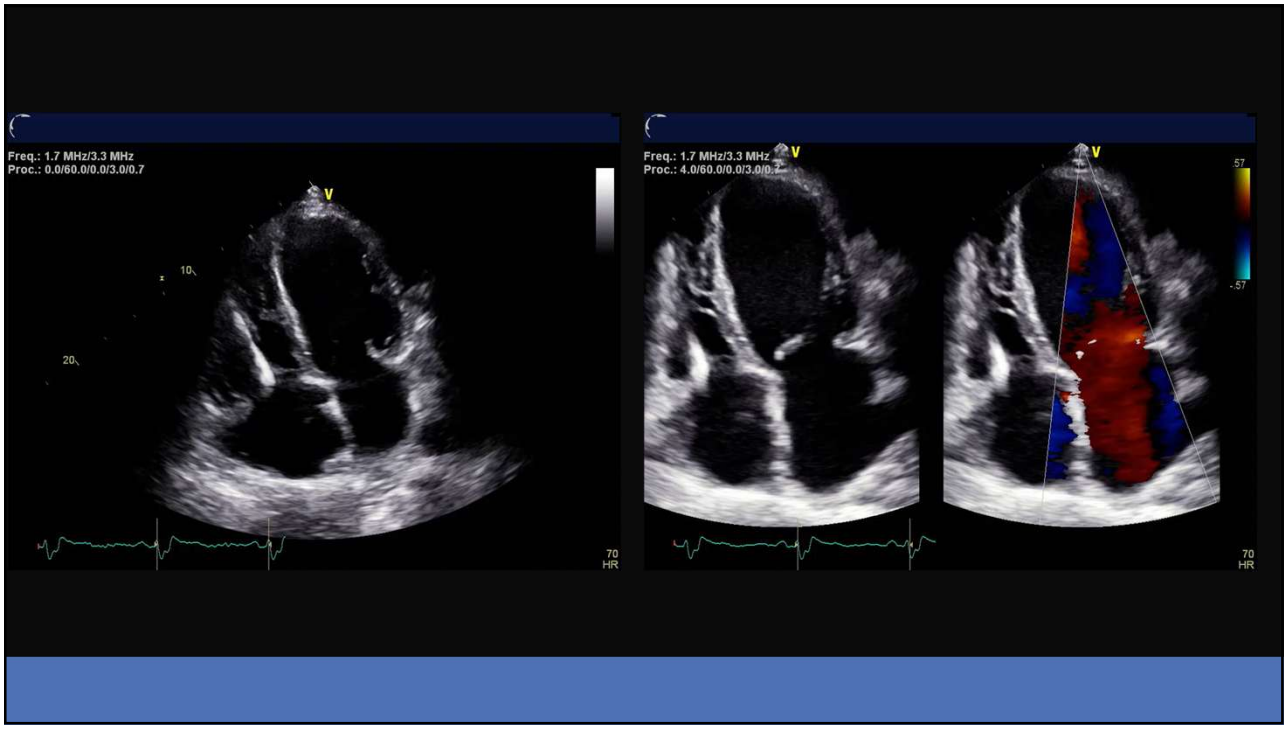

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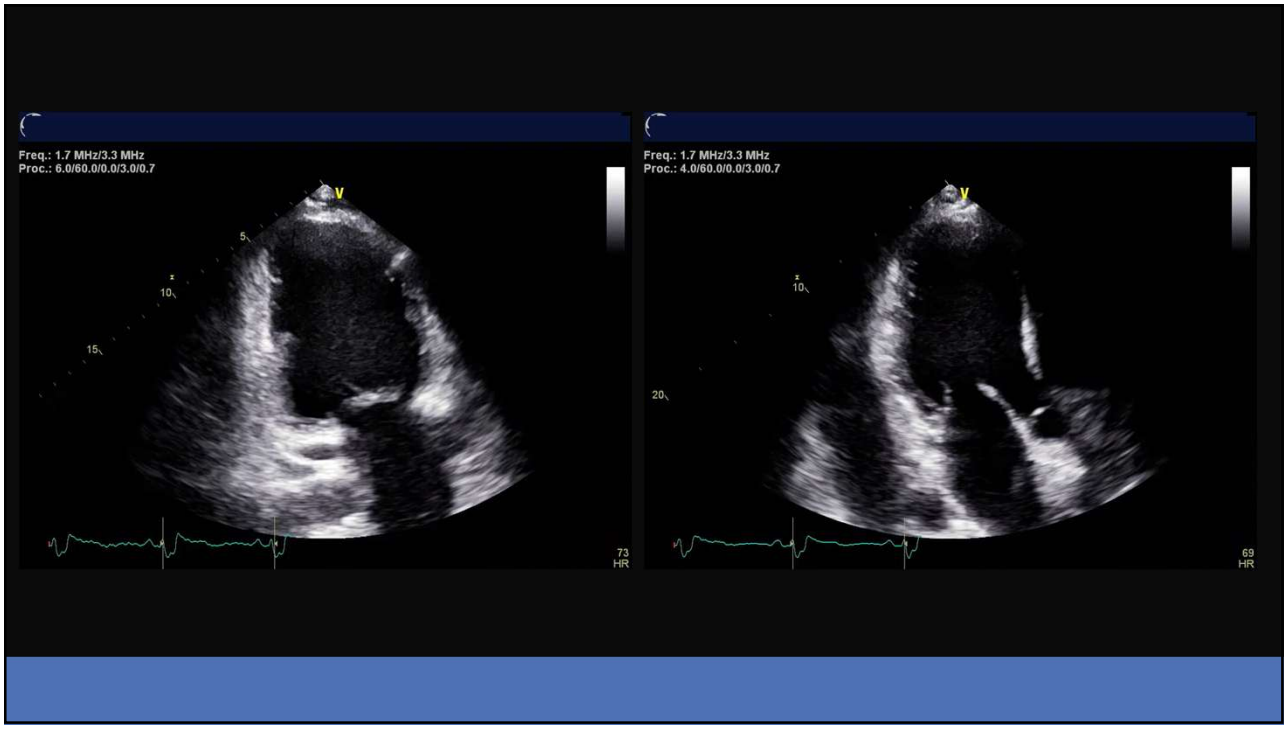

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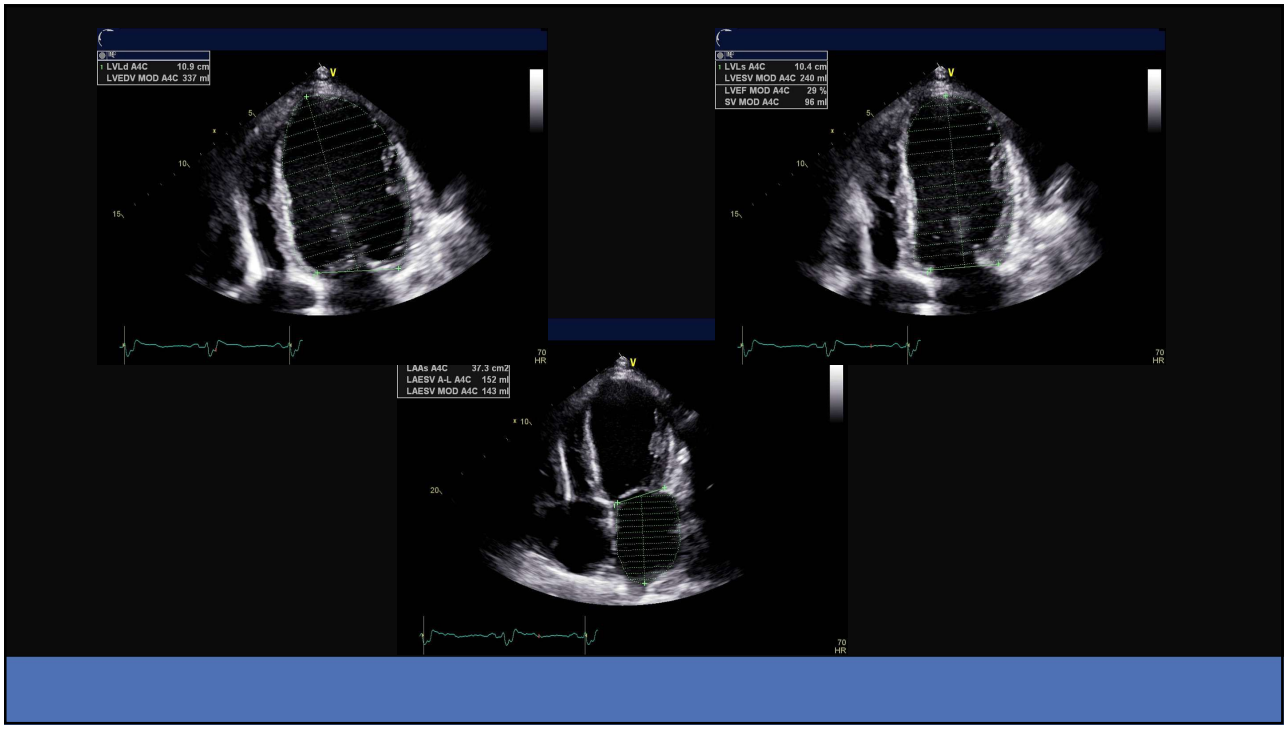

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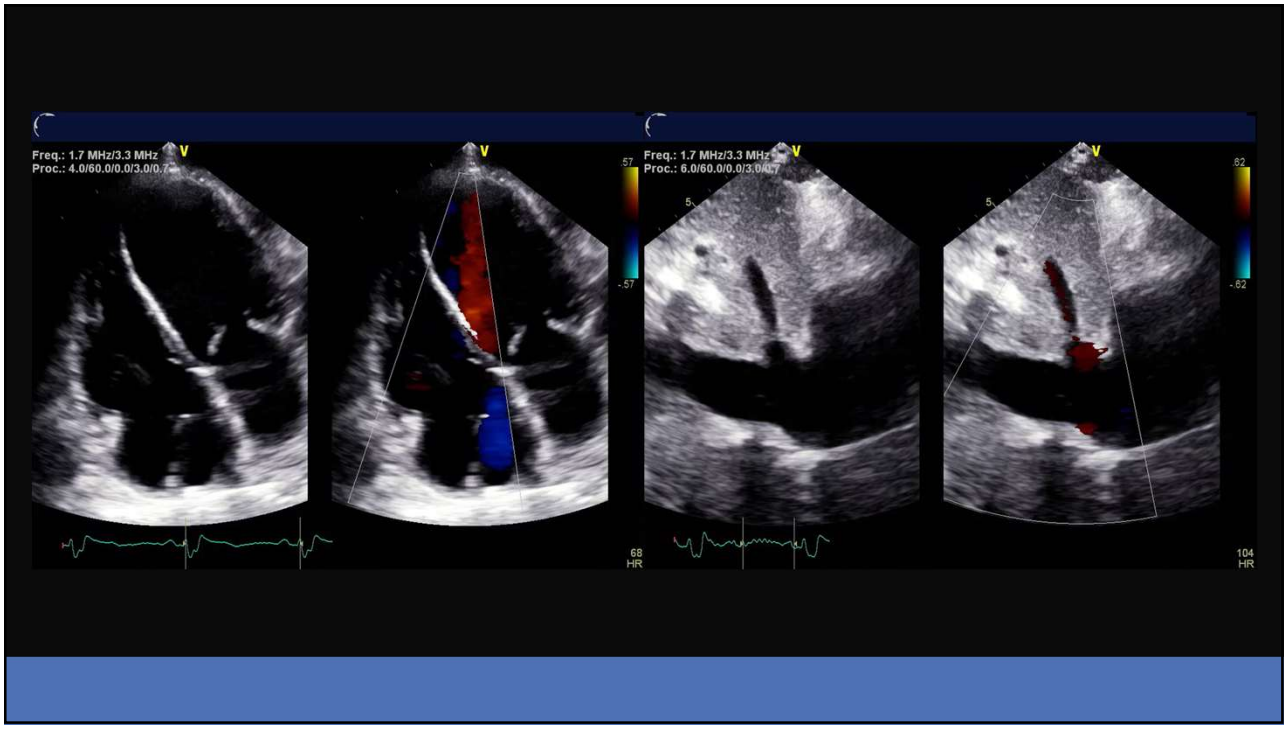

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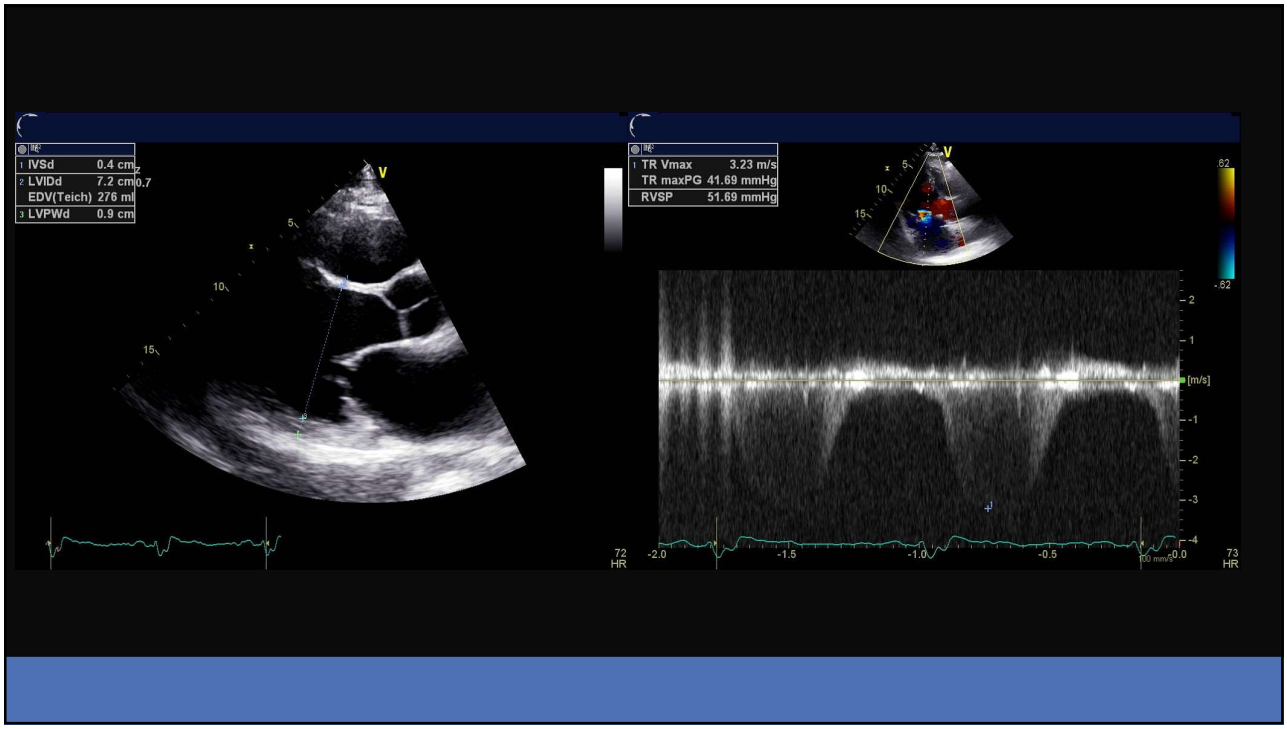

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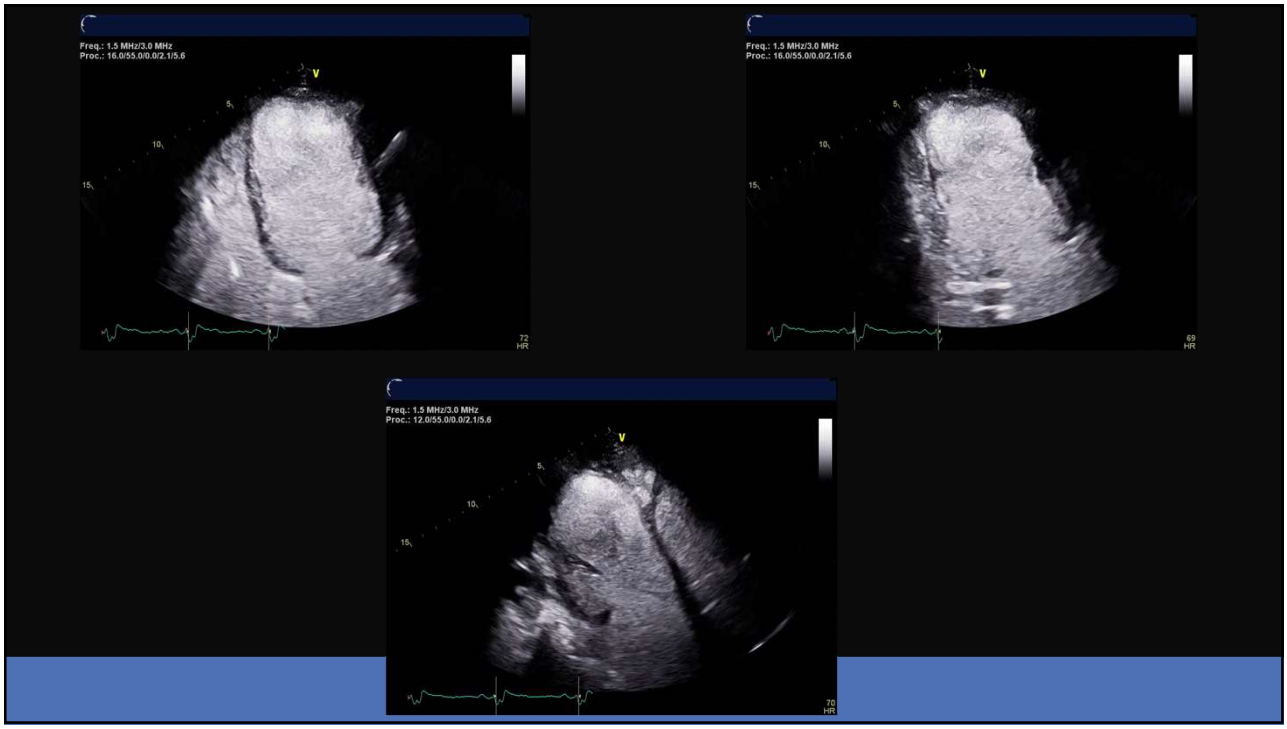

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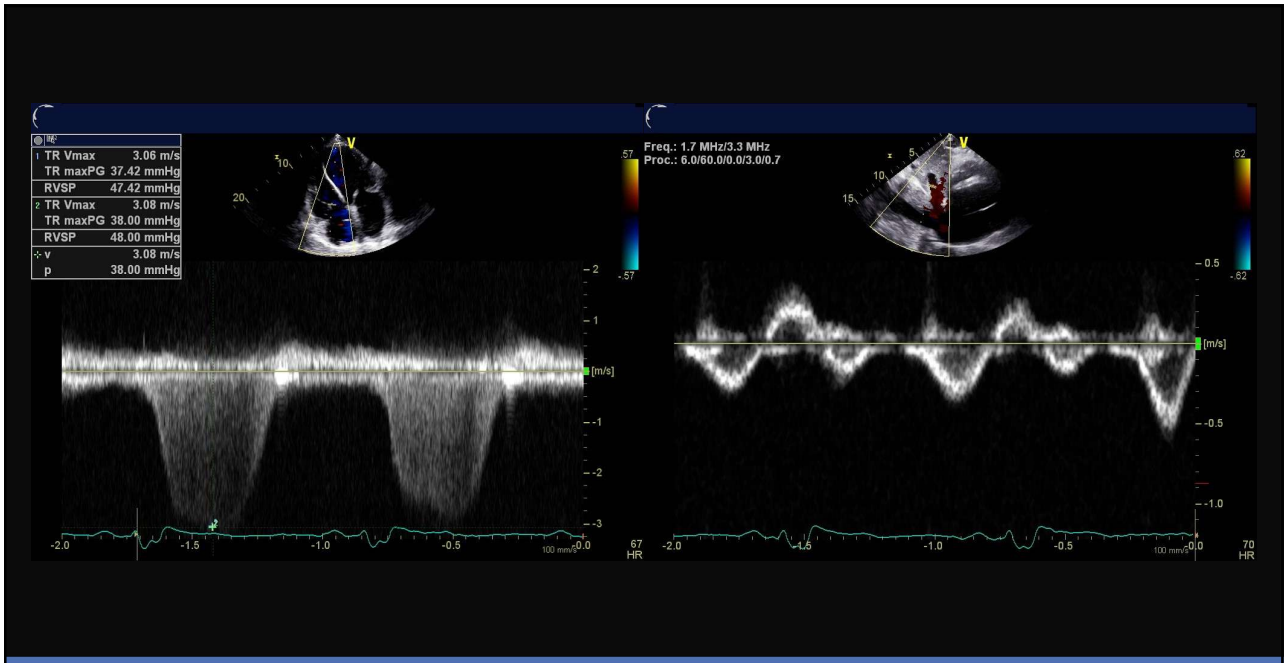

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Left Ventricular Assist Device

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Left Ventricular Assist Devices



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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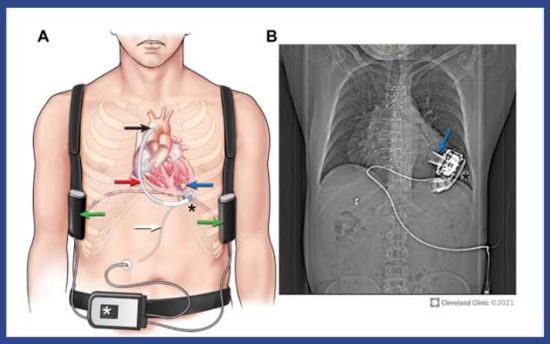
- Continuous LVAD approved by the FDA
  - Heartmate III (BTT and DT)
- Patients may still present with HMII and Heartware (HVAD)
  - Discontinued due to incidences of malfunction and stroke
- Three components of LVAD within the body
  - LV inflow
  - Mechanical Impeller
  - Outflow graft



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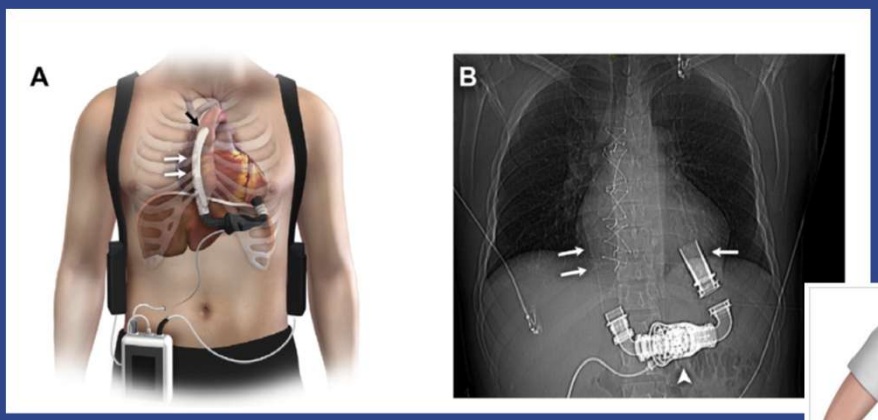

http://asecho.org/wordpress/wp-content/uploads/2015/07/2015_EchoLVAD.pdf

Heartmate II

Heartware (HVAD)



http://www.mylvad.com/content/heartware%C2%AE-lvad

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Candidate selection

Accredited Lab	Skilled sonographer	Comprehensive exam
Red flag warnings	TEE	Limited exams

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1. Pre-Implantation echocardiogram | LV

EF	LVIDd	Thrombi
• < 25% • 3D • UEA	• PLAX • ↑ Risk LV <63mm • Pre/Post LVAD unloading	• ↑ stroke • Surgeon notification • LAA (TEE) if in A-fib

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Pre-Implantation echocardiogram | RV/Shunts

RV	PFO	VSD
• Volumes • FS/TAPSE/strain • Minimum-qualitative RV assessment, TR • Bi-ventricular device may improve outcomes	• Bubble study • PFO ↑ risk of hypoxemia and embolization • Closure	• Exclusion by color Doppler • Absolute contraindication

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Pre-Implantation echocardiogram | Stenosis

MS	AS	Prosthetic
• Moderate/Severe may prevent adequate cannula inflow • Significant MS must be corrected prior to LVAD	• No impact on LVAD function • Critical AS or surgical valve closure = no forward flow if LVAD fails	• LVAD patients receive systemic anticoagulation • Mechanical valves = ↑ INR target • Recommend replacement with a bioprosthesis

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Pre-Implantation echocardiogram | AR

Critical and challenging

Blind Loop post implant

Difficult to assess with AHF

Communicate to surgeon >Mild

Bioprosthesis
Oversew valve
Coaptation stitch

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Pre-Implantation echocardiogram | Regurgitation

MR	TR	PR
• Acceptable • Improvement post-LVAD	• ≥ Moderate may indicate RV dysfunction • Consider repair	• Well tolerated if RV function is adequate

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2. Post-implant Echocardiogram/LVAD surveillance

- Performed at pump's baseline setting
- Includes LVAD specific views and Doppler flow assessments and all elements of a standard HF examination
- LVAD surveillance echocardiograms

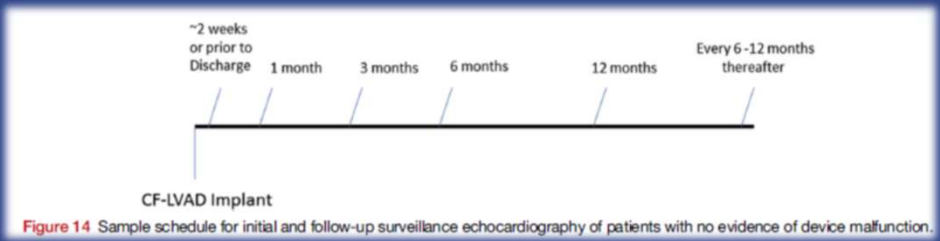

Figure 14 Sample schedule for initial and follow-up surveillance echocardiography of patients with no evidence of device malfunction.

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Post-Implant | Objectives

- Benchmarks- Individual or population
- Individual response (own controls)
- Early diagnosis native heart abnormalities (AR)
- Improved outcomes

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Post-Implant | Data Acquisition

- Annotate LVAD type/speed
- Reporting templates
- BP- No palpable pulse
- Mean arterial BP monitoring < 85 mmHG

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Post-Implant | LV/RV

LV size/systolic/diastolic function	RV size and systolic function
• LVID PLAX • EKG signal • UEA • LVIDd < LVIDs (possible) • Biplane technically challenging • Diastology not clinically useful, presumed abnormal	• Measure • Linear dimensions, RV FAC, TAPSE • Correlation of TAPSE with RV function may be weaker post-op

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Post-Implant | Aortic Valve opening

Impacted by:	Implications of not opening	Assessment
• LVAD speed • Native LV function • Volume status • PVR	• Aortic root thrombosis • LVAD associated AR	• M-mode 25–50 mm/s • Report every cardiac cycle/intermittently/remaining closed

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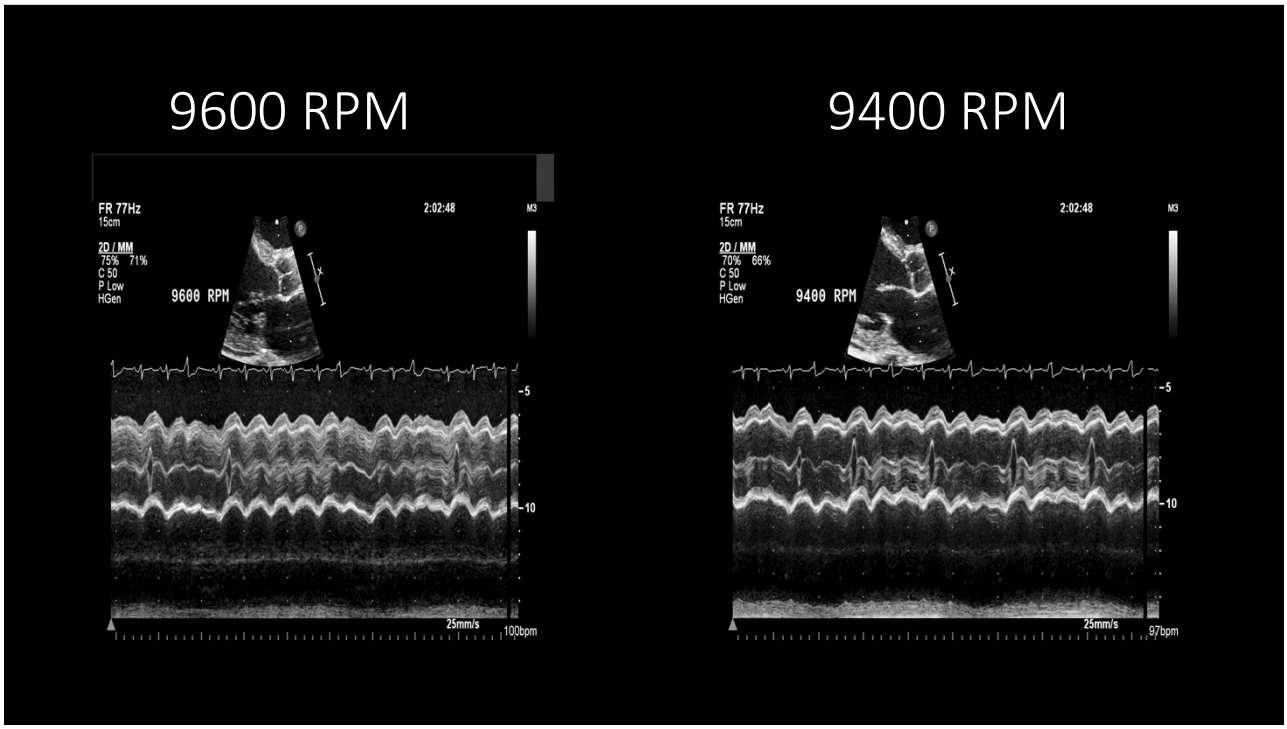

Post-Implant | Regurgitation

AR	MR	TR
• 25-33% of patients • Adverse effects • Careful assessment	• Usually ↓after implant • Persistent may = inadequate LV unloading, LVAD malposition • Quantify using standards	• Moderate or > may indicate insufficient or excessive LV unloading/↑SPAP or RV dysfunction

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Post-Implant | Ventricular septum

Leftward shift

- ↑ RV pressures
- ↓ LV preload
- Excessive speed

Rightward shift

- ↑ LV pressures
  - Inadequate setting
  - Severe AR



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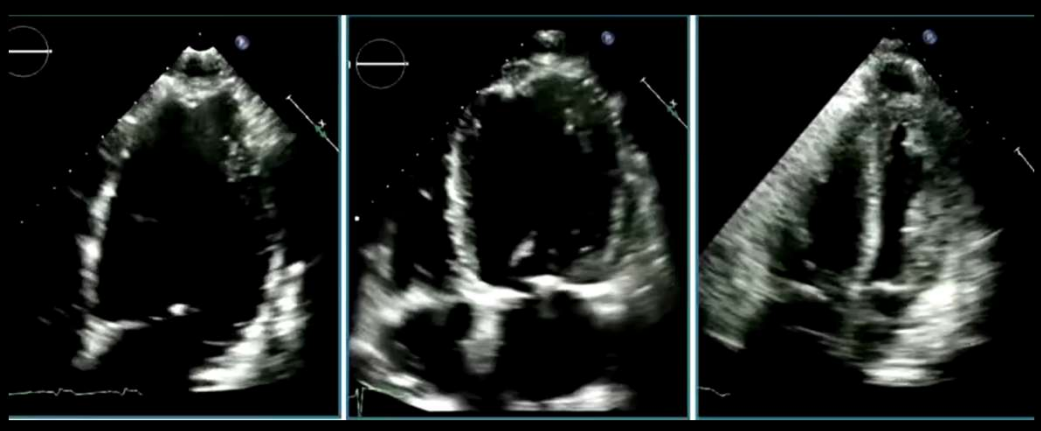

Rightward Shift

Inefficient LV unloading

Midline

Efficient LV unloading

Leftward Shift

Markedly unloaded LV

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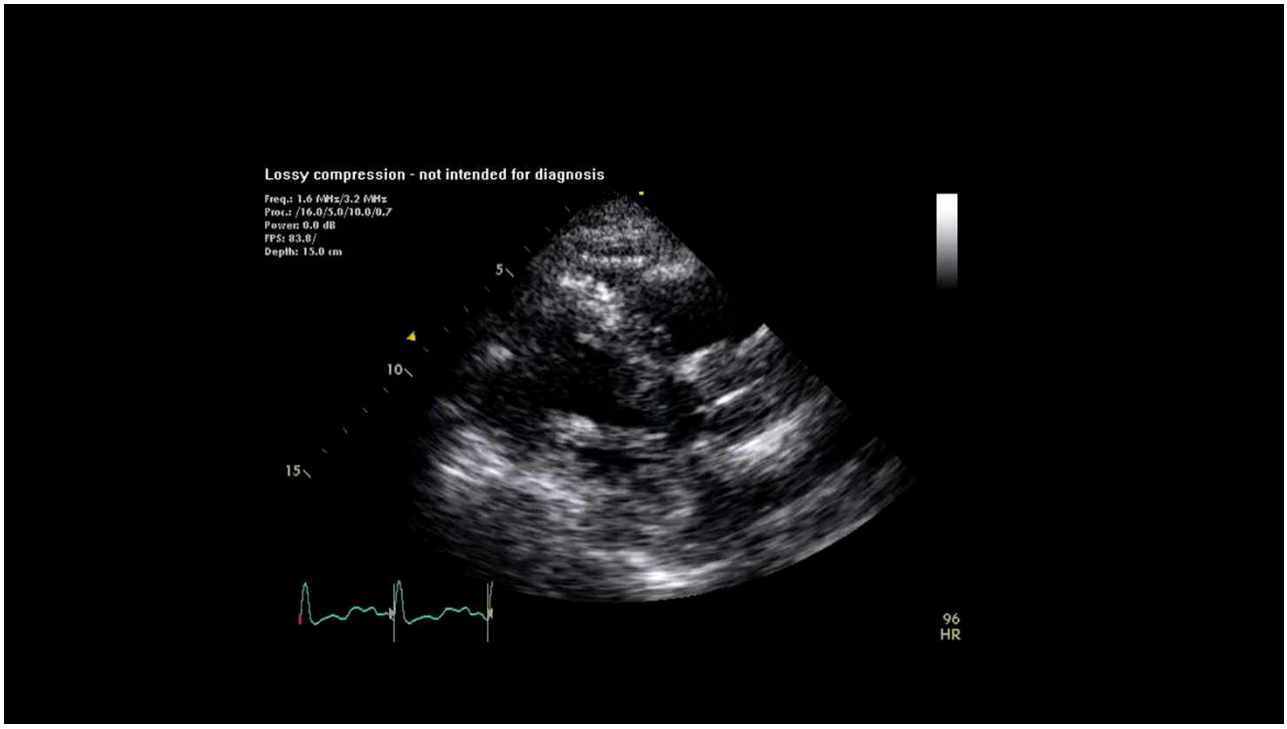

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Post-Implant | Inflow-Cannula

- Imaged in standard or modified PLAX and/or apical views
- Objective is to reveal location and orientation in relation to septum
- Color Doppler flow should be laminar, unidirectional with no evidence of regurgitation or turbulence
  - Heartware device can not be interrogated due to Doppler artifact
- PW or CW Doppler may be done off-axis
  - Flow should be <1.5 m/s
  - Flow may be pulsatile as the LV may still be contractile

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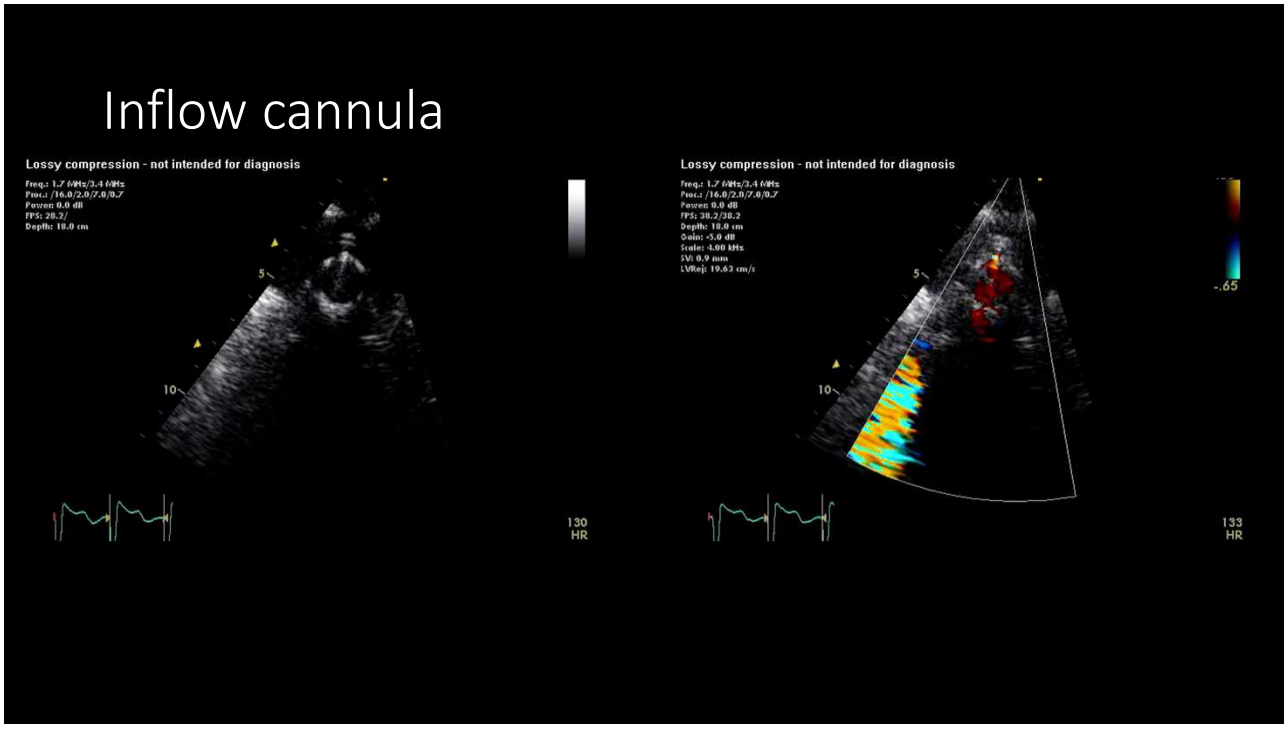
Inflow cannula



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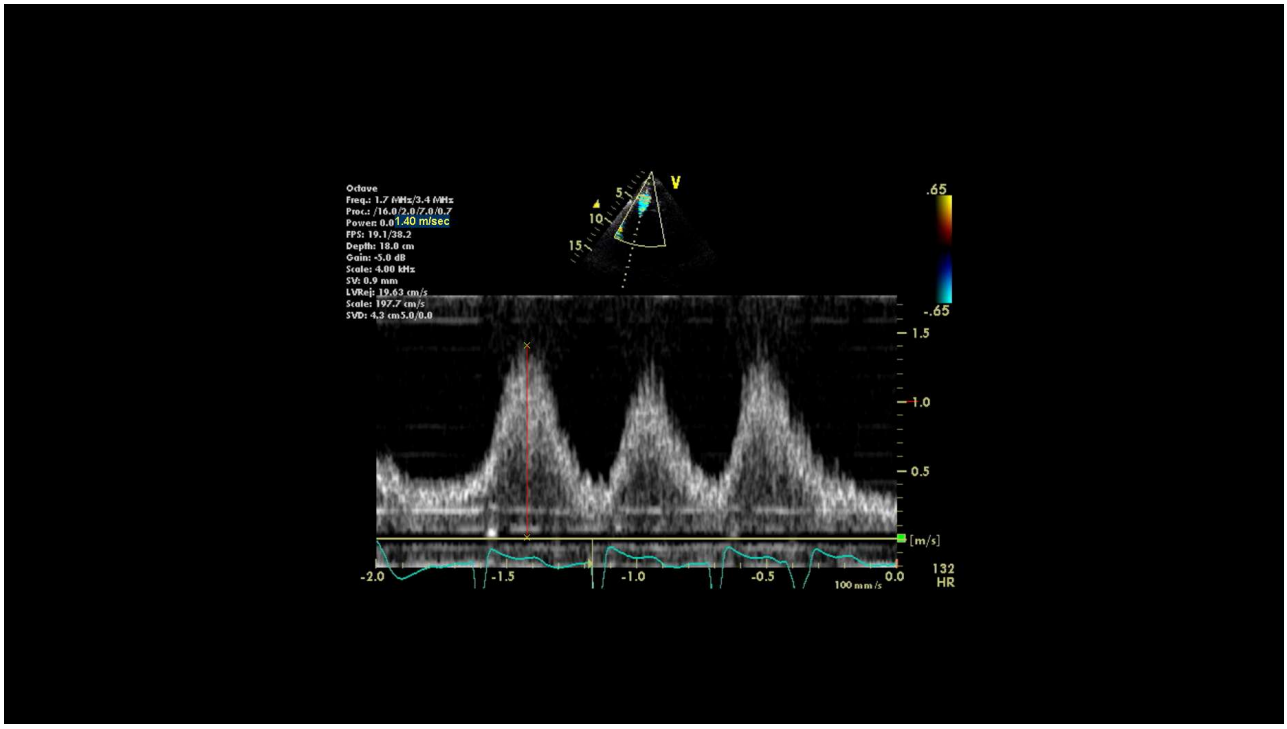

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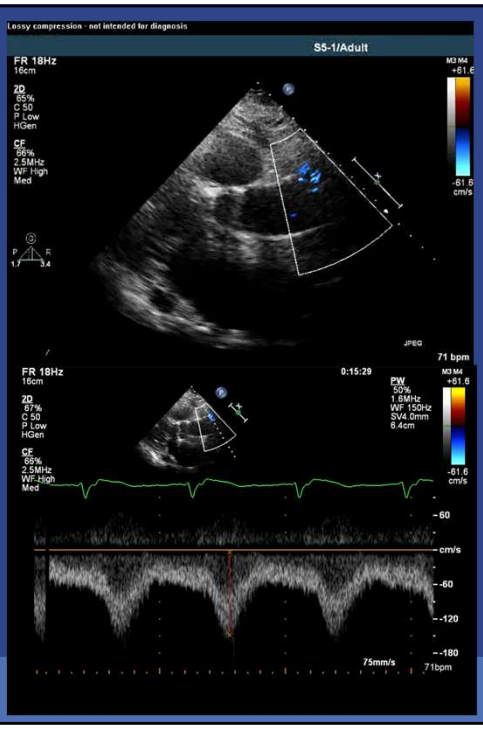
Post-Implant | Outflow Graft

- Utilize atypical views
  - Terminal portion of outflow conduit- high PLAX
  - Mid portion of the outflow graft- right parasternal view
- Outflow graft velocities > 2m/s are abnormal



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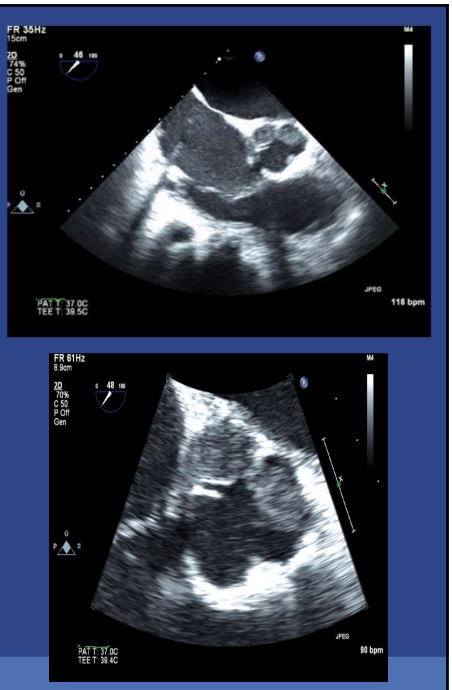
3. Post-Implant | Speed Changes

- Setting of optimization protocol or problem-focused exam (RAMP)
- Review patient's anticoagulation status before performing
  - Embolic events associated with sudden AV opening in the event of aortic root thrombus, or peripheral/pump thrombi
- Defer speed-change exams if thrombus suspected at baseline



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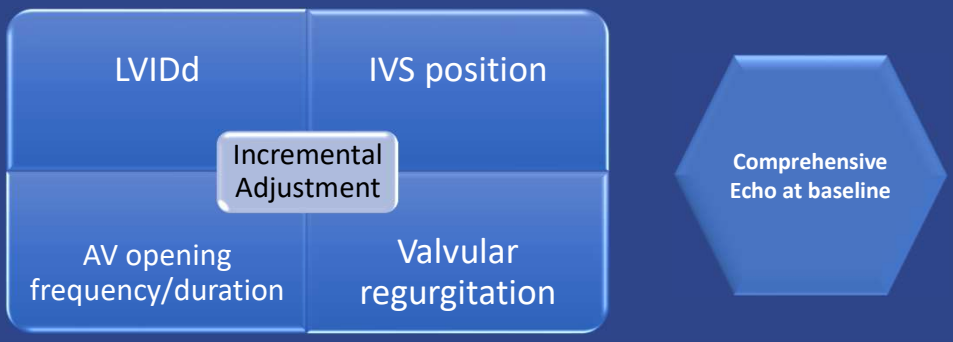
Post-Implant | LVAD Optimization protocol

- Performed in asymptomatic or minimally symptomatic patients with no device alarms or clinical indications of abnormal LVAD or cardiac function



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Post-Implant | LVAD Problem-Focused Exam

- Controller Alarm
- Abnormal serologic findings that suggest intravascular hemolysis or infection
- New or abnormally persistent symptoms
- Follow-up testing when abnormalities noted at baseline pump speed
- Other abnormal data (arrhythmias, hypotension)

? Pump Thrombosis

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Pump Alarms

Speed
RPM of impeller

Power
Pump motor voltage and current
Average over time in Watts (<10W)

Flow
Related to set speed and power



Alarm types

High Flow
Pump thrombosis, systemic arterial vasodilation, Significant AI, recovery of LV function

Low Flow (more common)
Tamponade, RV failure, hypovolemia, cannula obstruction (inflow or outflow), HTN, arrhythmias

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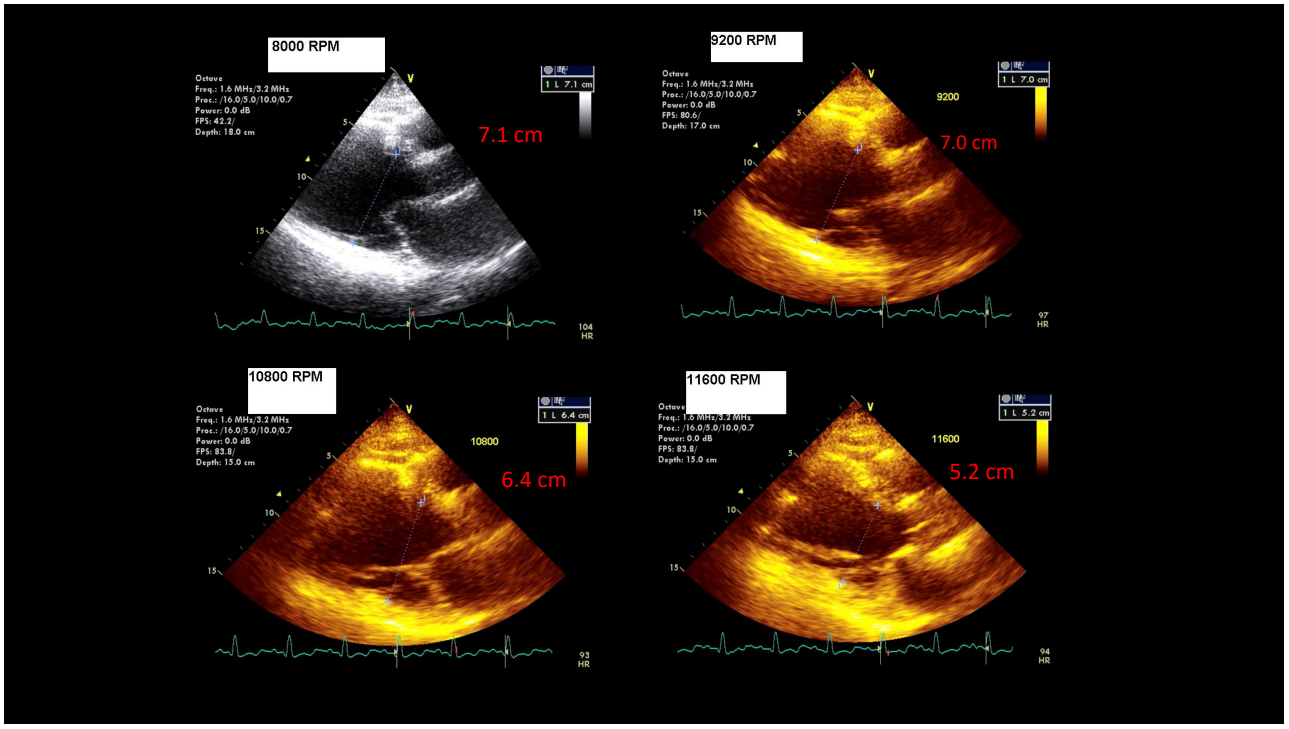

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Comprehensive Echo assessment

CASE STUDY- LVAD



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2021- Arrives in CTICU with worsening dyspnea and chest/shoulder pain, found to be in profound cardiogenic shock, EF 10%, ECMO/Impella initiated

- History CAD, ischemic cardiomyopathy, CHF, A-fib, DM2, ulcerative colitis, ICD, PCI, never smoked, no alcohol/drugs
- Transplant evaluation
- LVAD HM3 implanted

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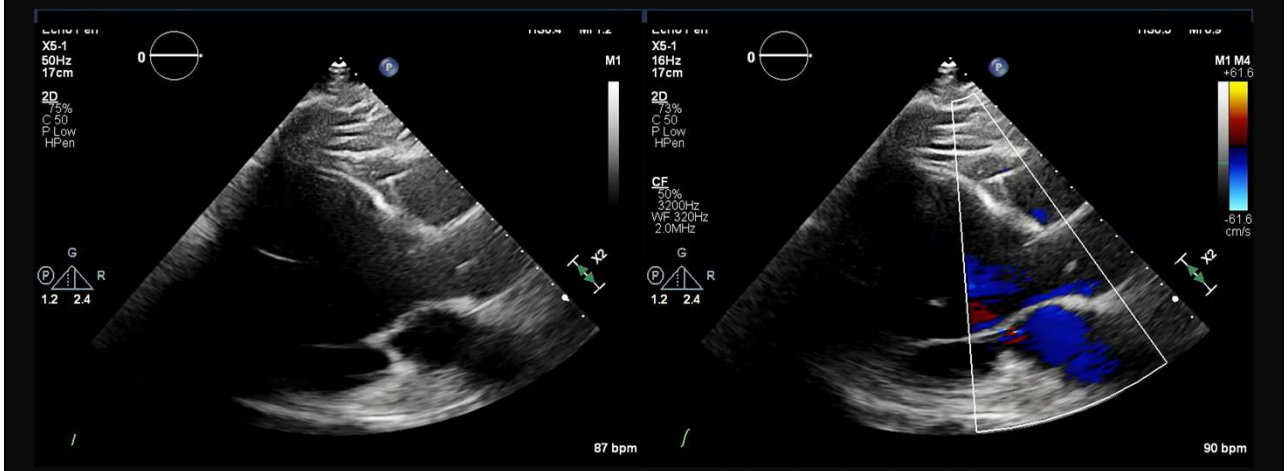
Post LVAD Exam (4-days)



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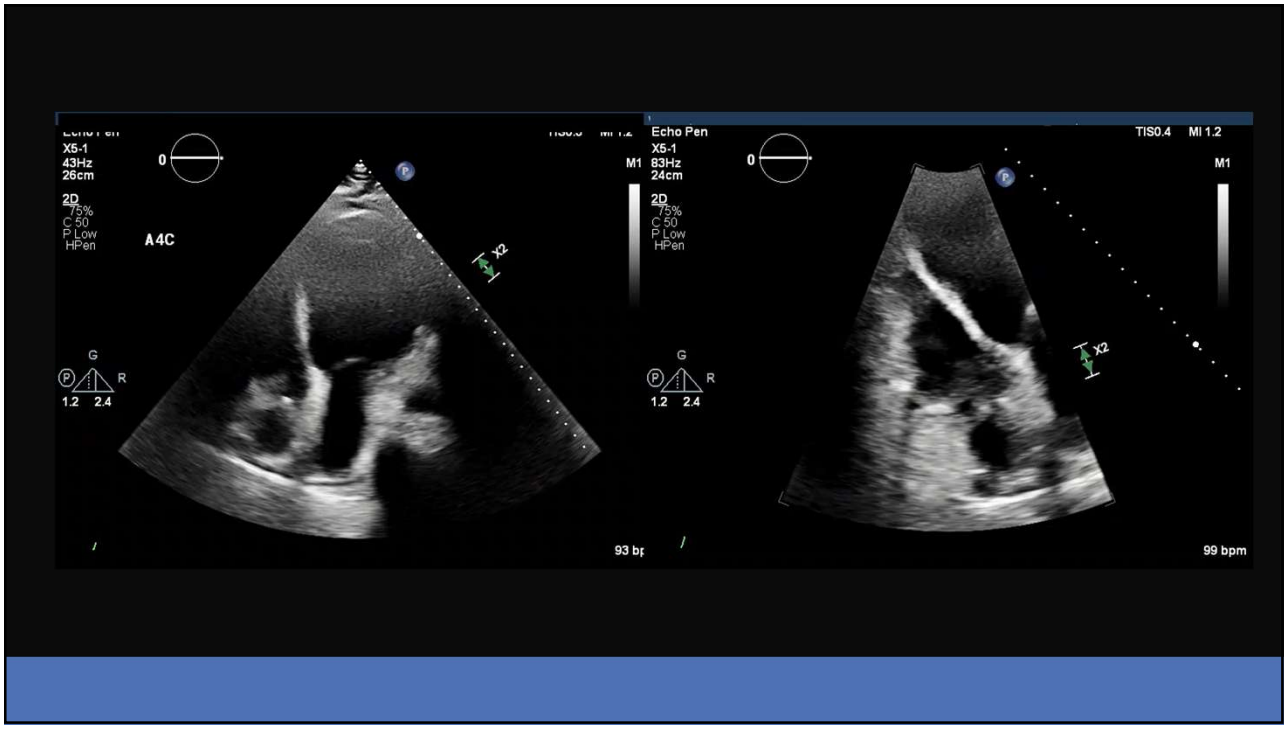

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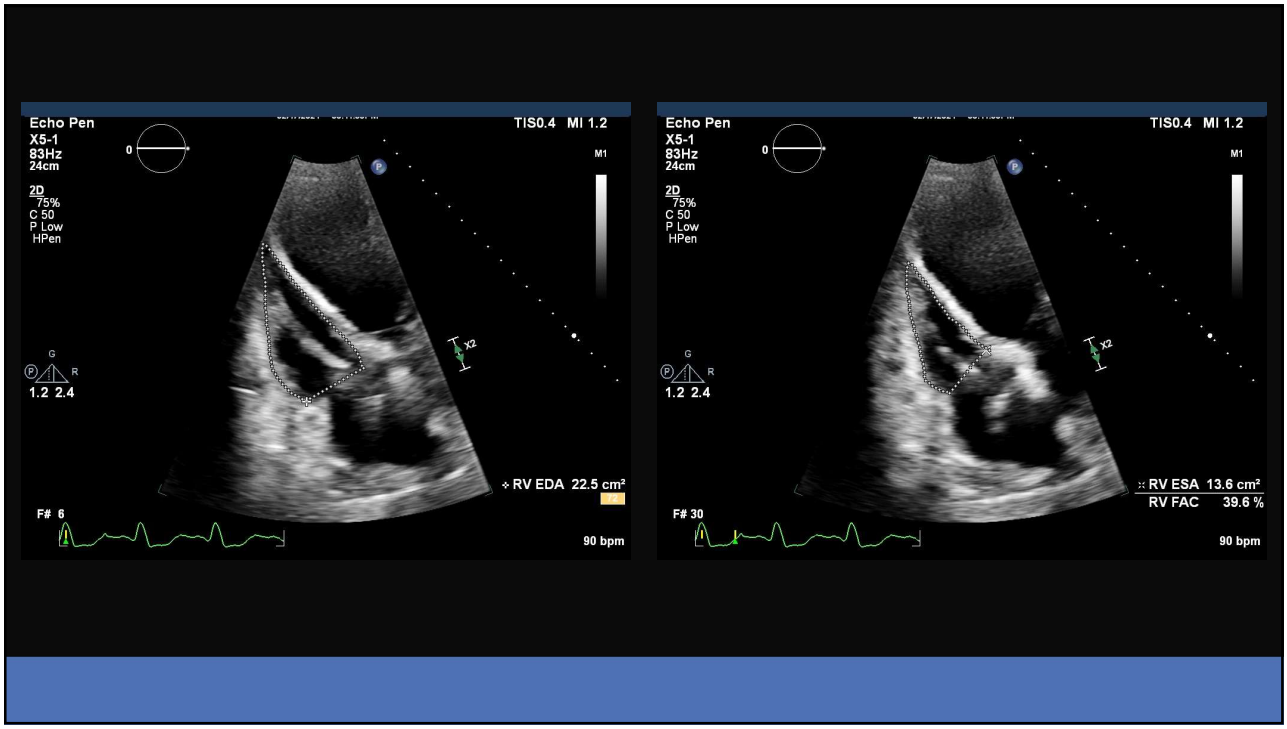

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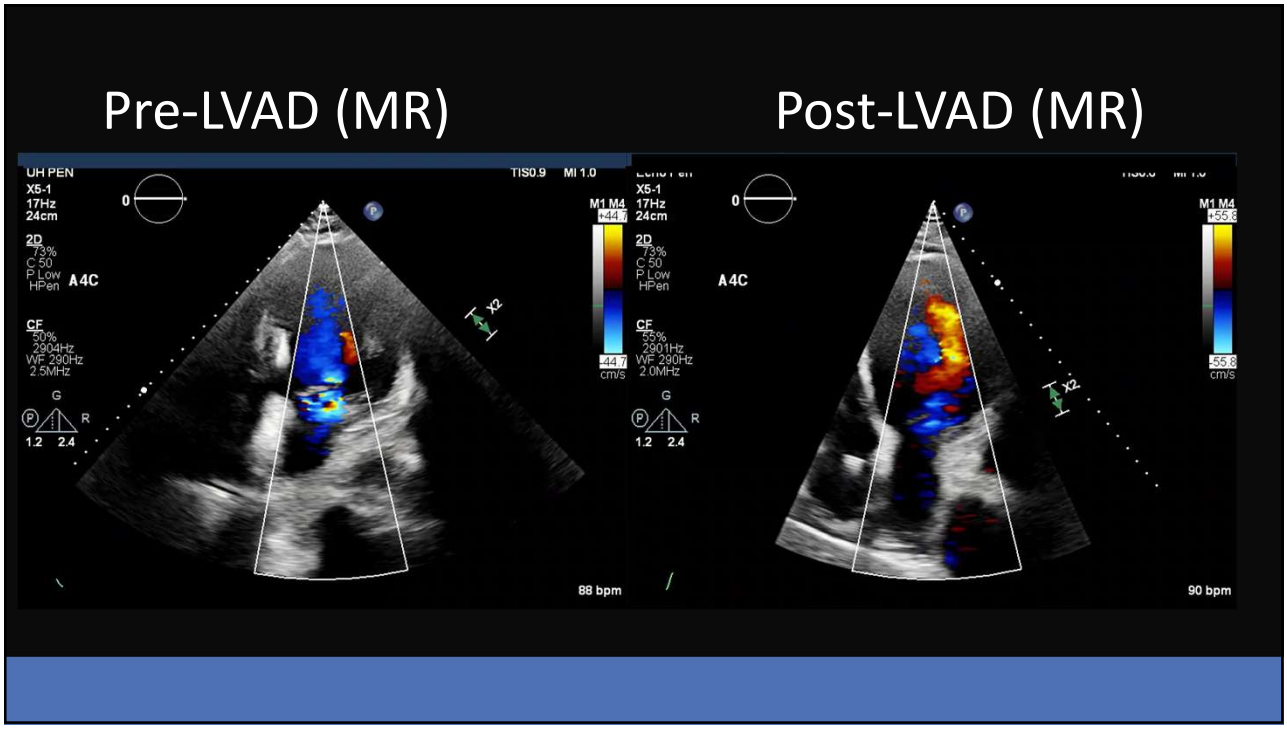

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RAMP study

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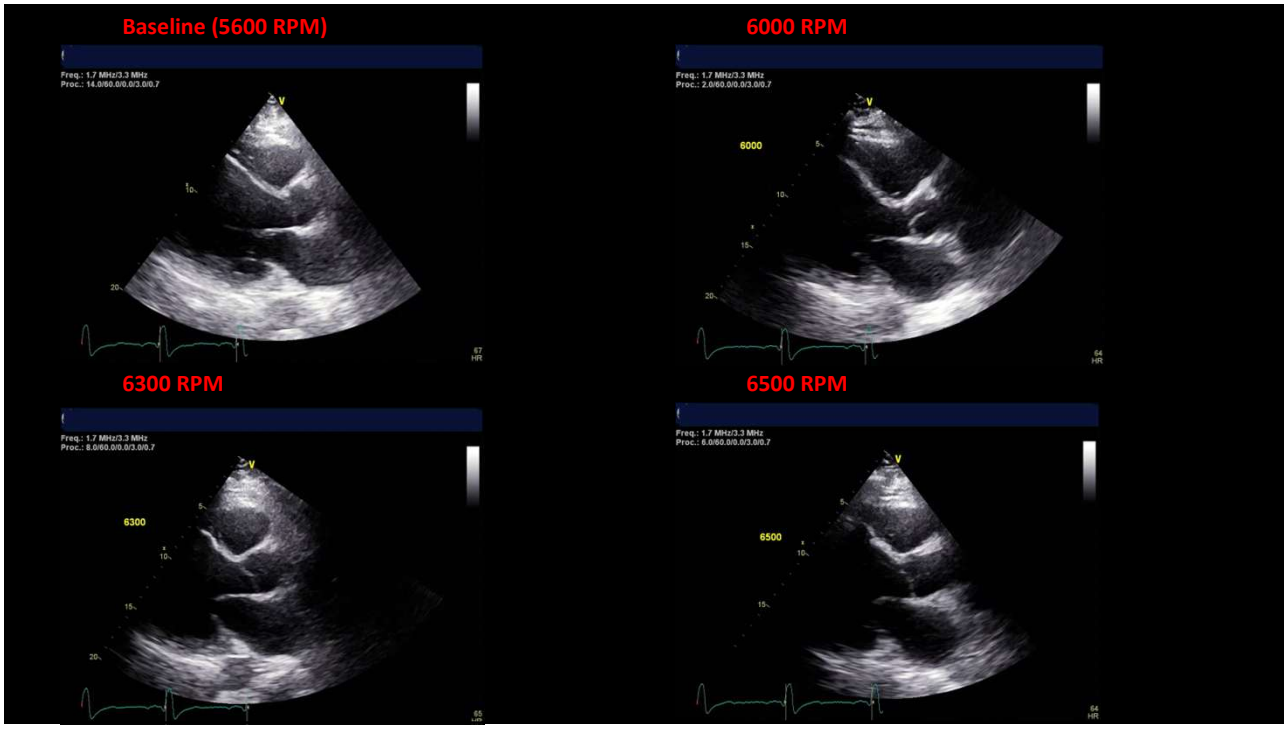

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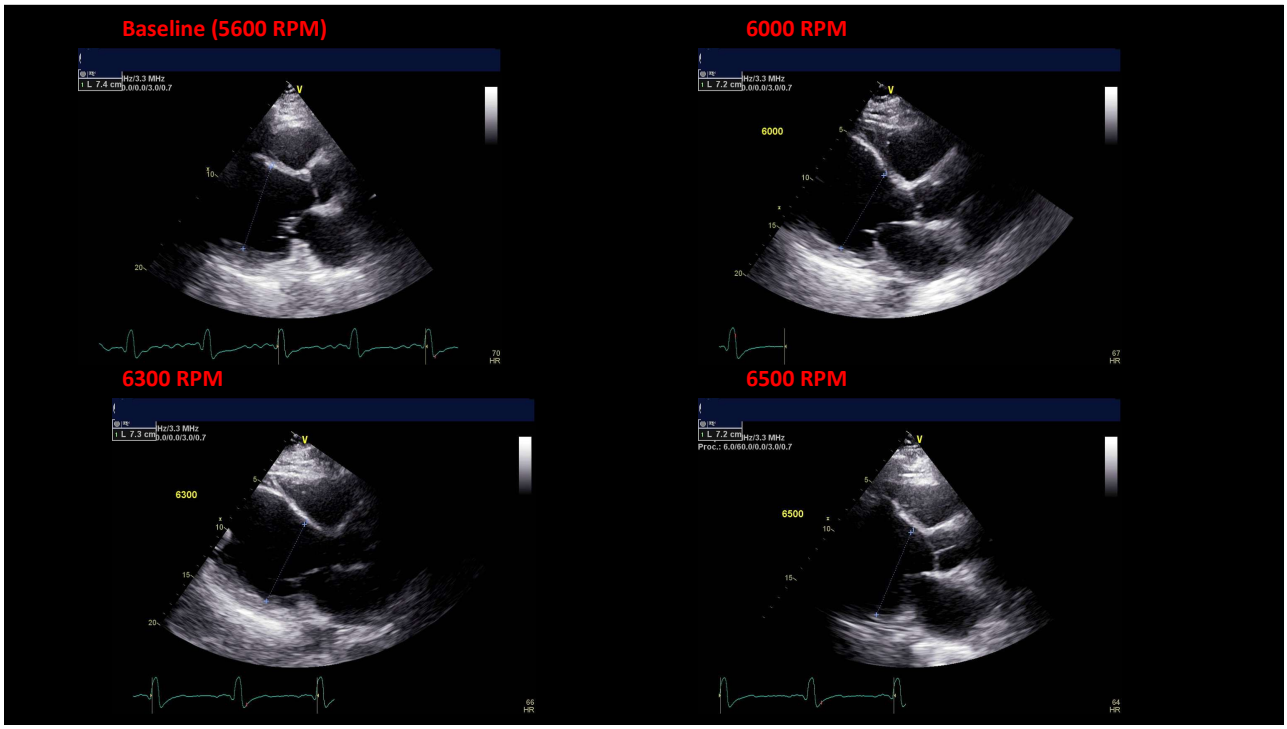

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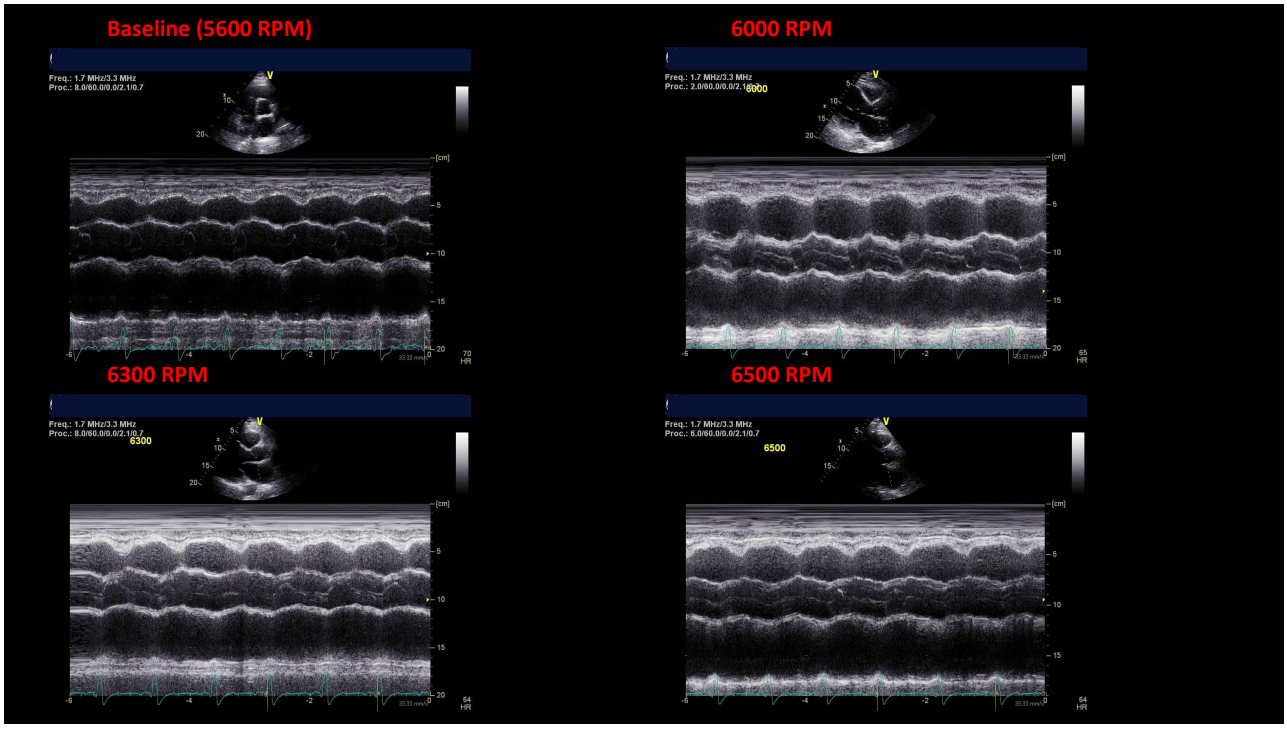

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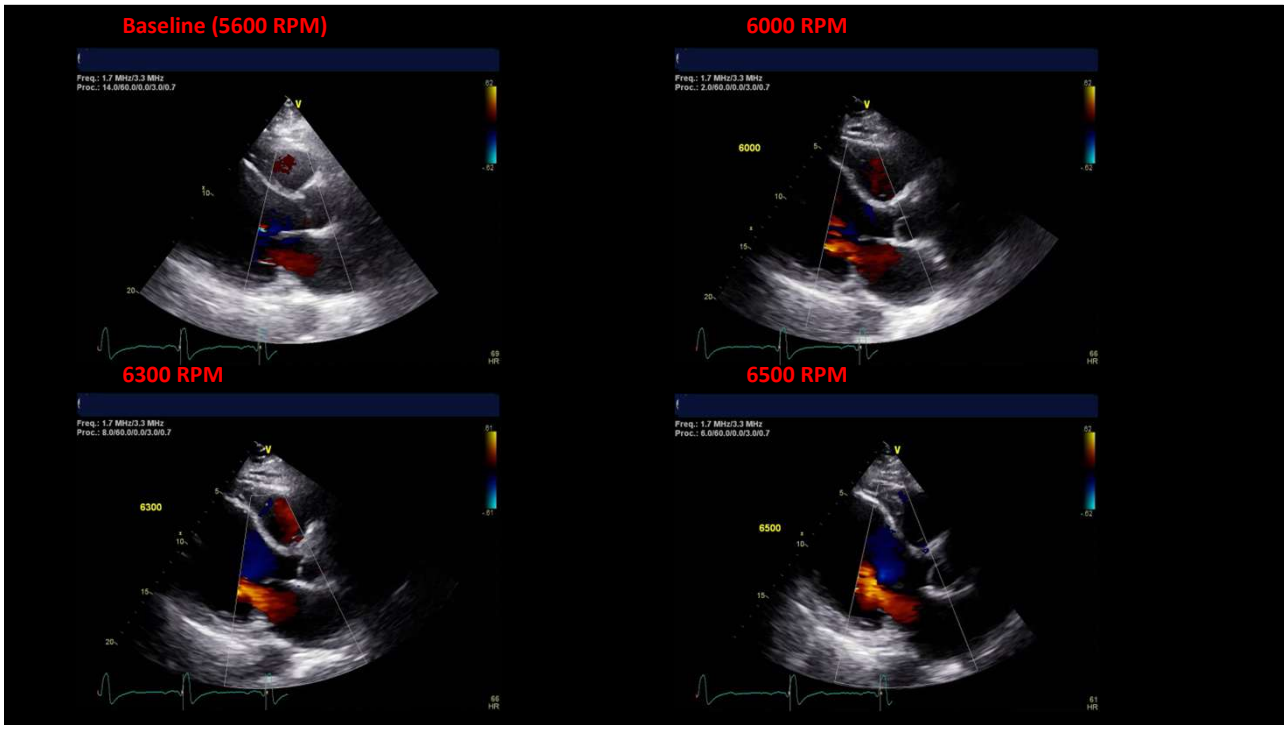

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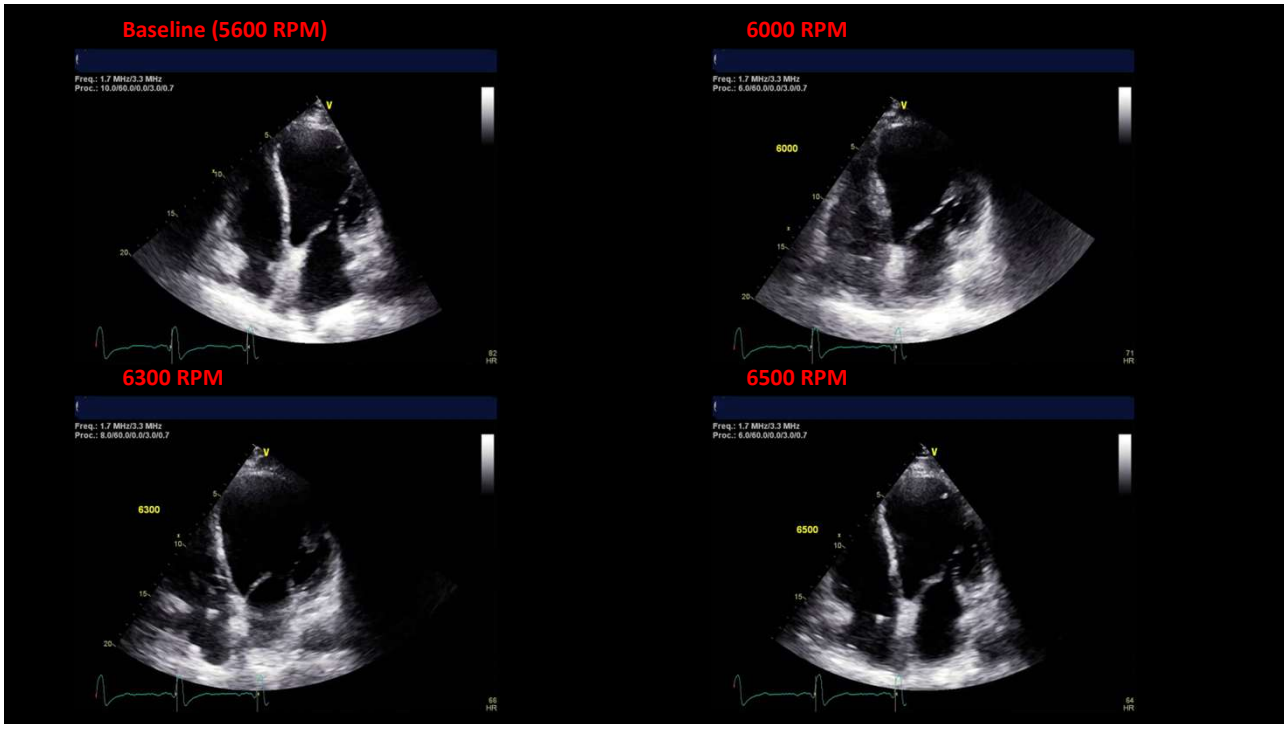

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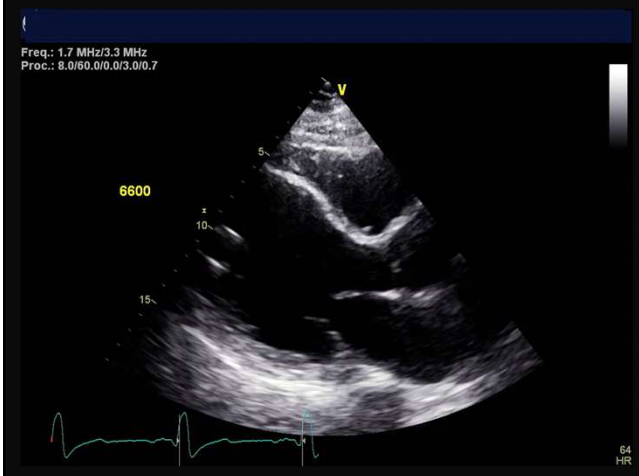
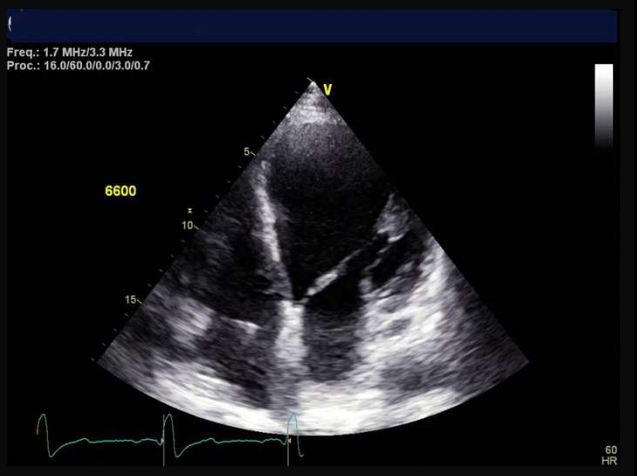
6600 RPM





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Heart Transplantation

74

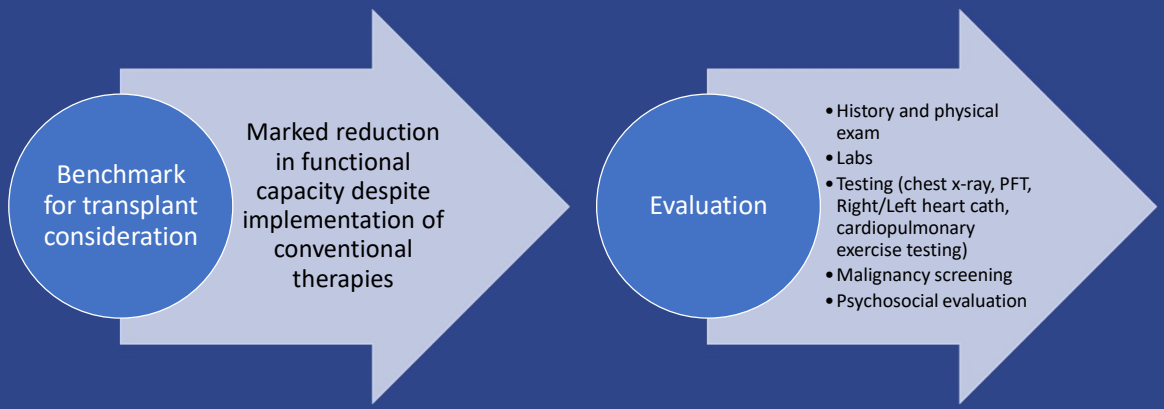
Epidemiology

- Started over 50 years ago in South Africa
  - Discontinued due to 20% one-year survival
  - Cyclosporine approved in 1984 and transplants began to rise
- Performed internationally including >140 centers in the US
- In 2022, 4,111 heart transplants were performed in the US (17% increase since 2018, 43% increase since 2010)
  - Successful treatment of Hepatitis C (antiviral agents)
  - Opiate crises

Starling 2026

75

Transplant consideration and evaluation



Starling 2026

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Transplant Serial monitoring

- Rejection
  - The transplanted heart is identified as foreign and attacked by the recipient's immune system leading to graft dysfunction or failure
  - Acute or chronic
  - Fatigue, shortness of breath, signs of heart failure typical
- Evaluation
  - Labs (biomarkers, CBC, metabolic panel, Serologic testing)
  - Imaging (Echo, CMR, nuclear)
  - **Endomyocardial biopsy (gold standard)**

Heart 2024

77

Endomyocardial biopsy

- Gold standard for monitoring rejection
- Biopsy taken from the interventricular septum (right side)
- 6% complication rate
  - RBBB
  - Tricuspid regurgitation (90% of HT patients have TR)
  - Right ventricular perforation
    - Results in pericardial effusion



Olymbios 2018

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Rejection





Acute

- T-cell mediated inflammatory response
  - Macrophage and lymphocyte infiltrates
  - Edema
  - Myocyte necrosis
  - Most common in first 6-months
  - 24% of patients may experience one instance within first 12-months

Chronic

- Often manifests as Cardiac Allograft Vasculopathy
  - Immunologic response against vascular endothelium
    - Diffuse, impacts coronaries and microvasculature
  - Leading cause of death after 3-years post-transplant
  - 29% at 5-years, 47% at 10-years
  - Difficult to treat, retransplant usually only option

Olymbios 2018

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Post Transplant | Echocardiography

- Important information relating to morphology and function
- Intraoperative and post-operative to identify early graft dysfunction
- First month: ↑ LV mass and wall thickness (edema), resolves in 3-months
  - If persists, caused by persistent tachycardia, HTN d/t immunosuppression drugs, & repeated episodes of rejection
- ↓ LVEF within year one of transplant predictor for rejection (Acute/Cardiac allograft vasculopathy (CAV))
- RWMA prognostic for adverse outcomes
- TDI <10 cm/s indicates high likelihood of CAV
- Diastolic function changes first with acute rejection
  - Edema and fibrosis stiffens the ventricles and impairs relaxation

Olymbios 2018

80

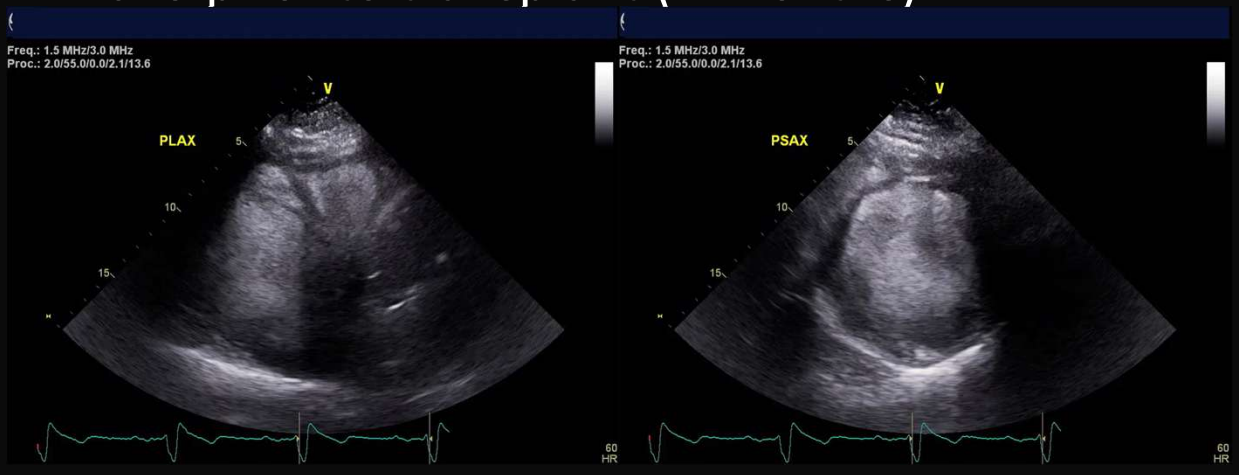
Comprehensive Echo assessment

CASE STUDY- Heart Transplant



81

Echo prior to transplant (7-months)



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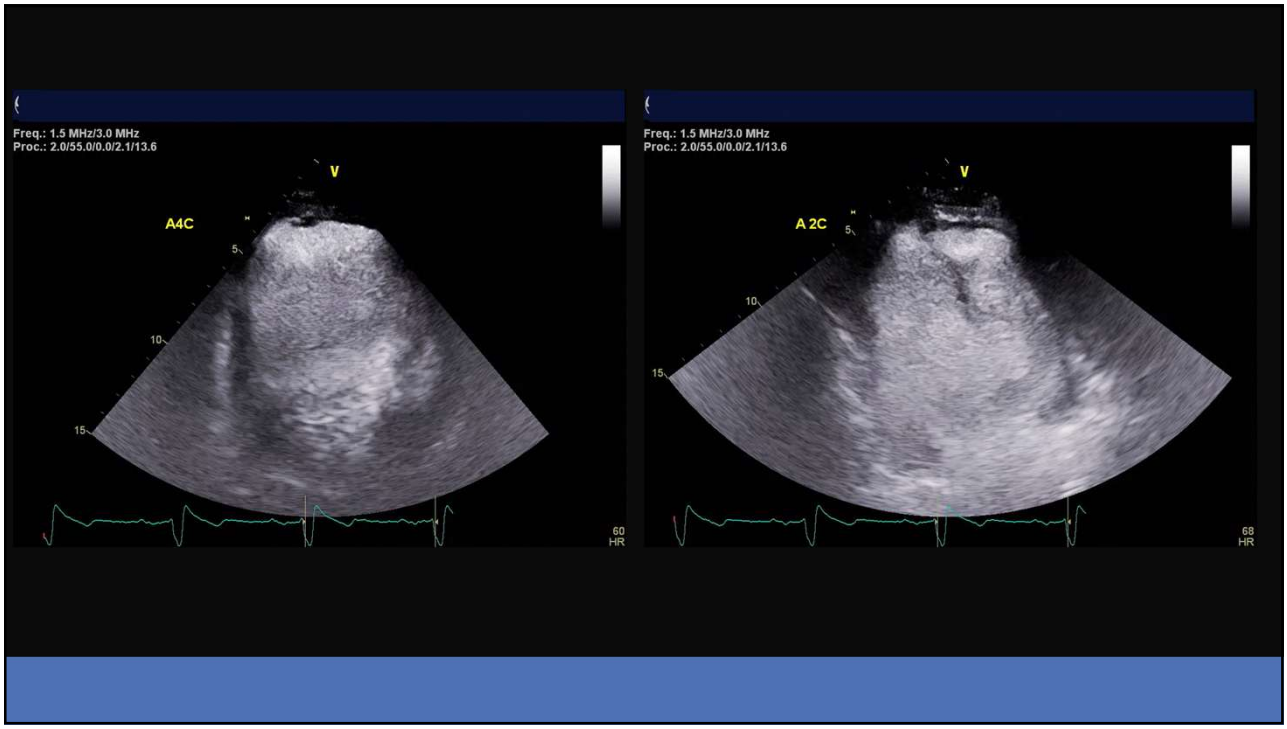
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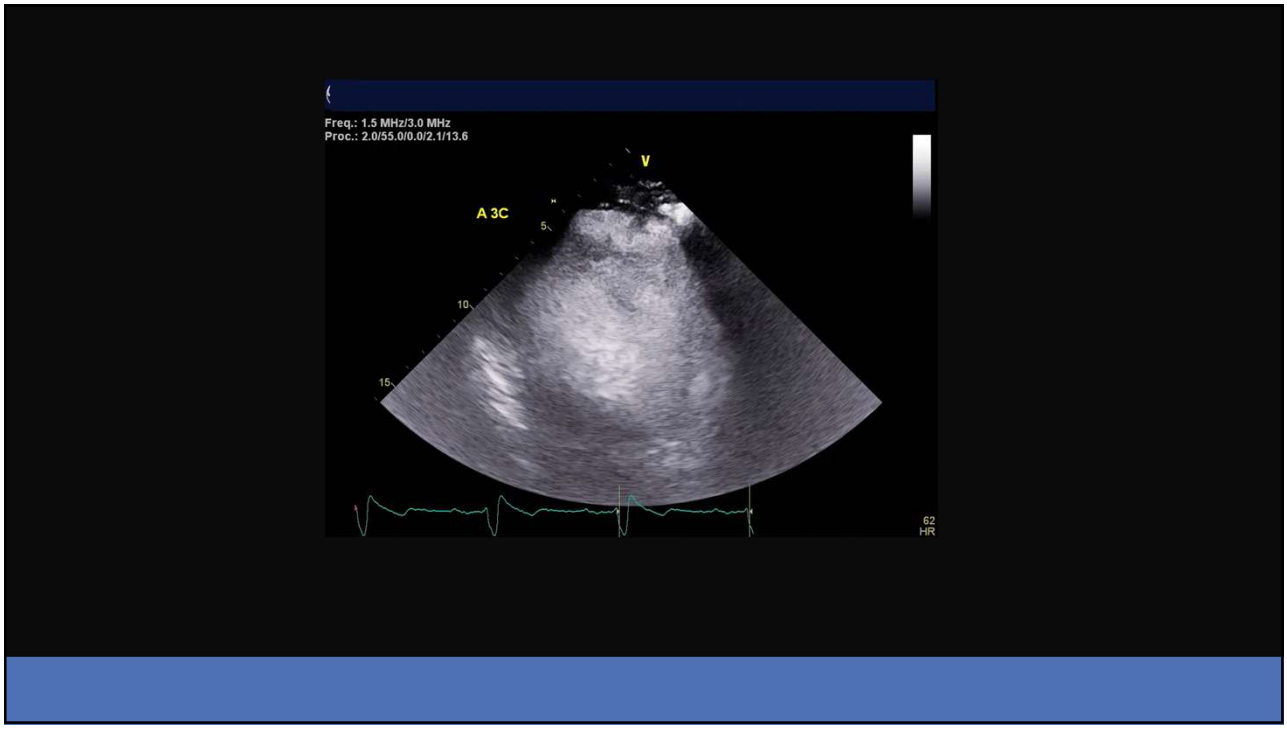
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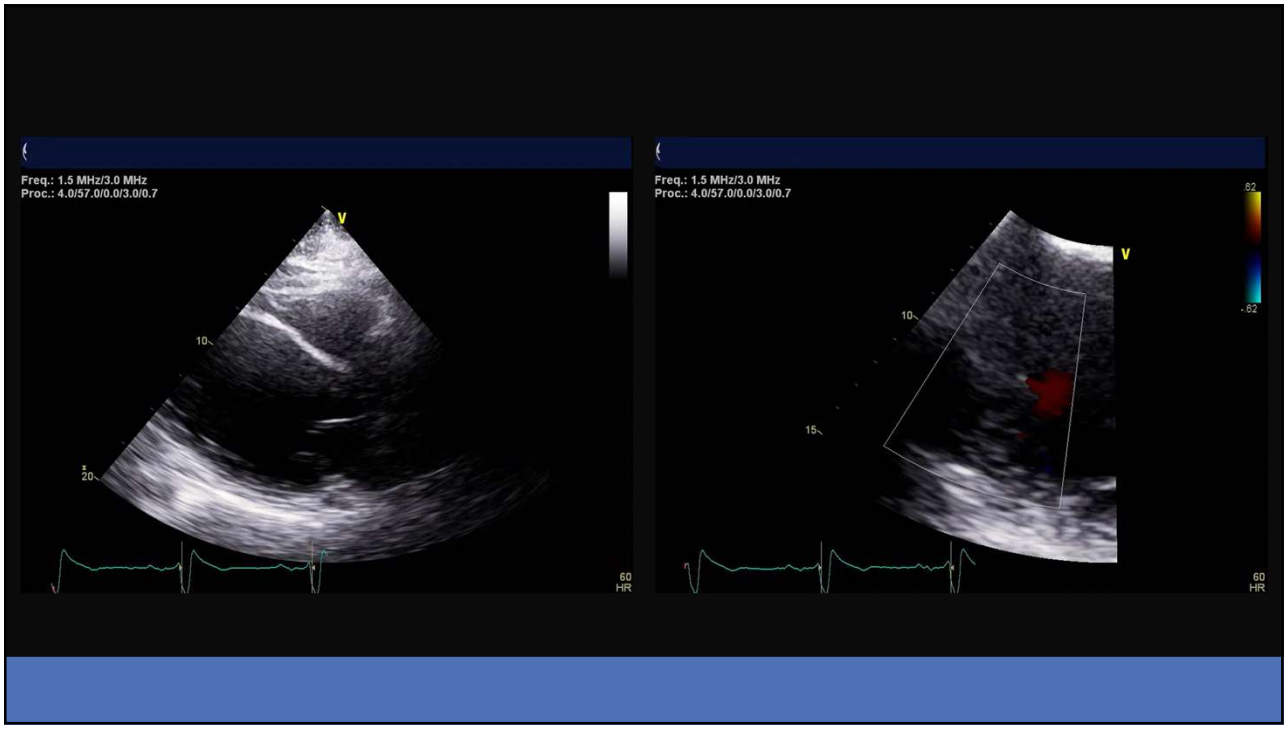

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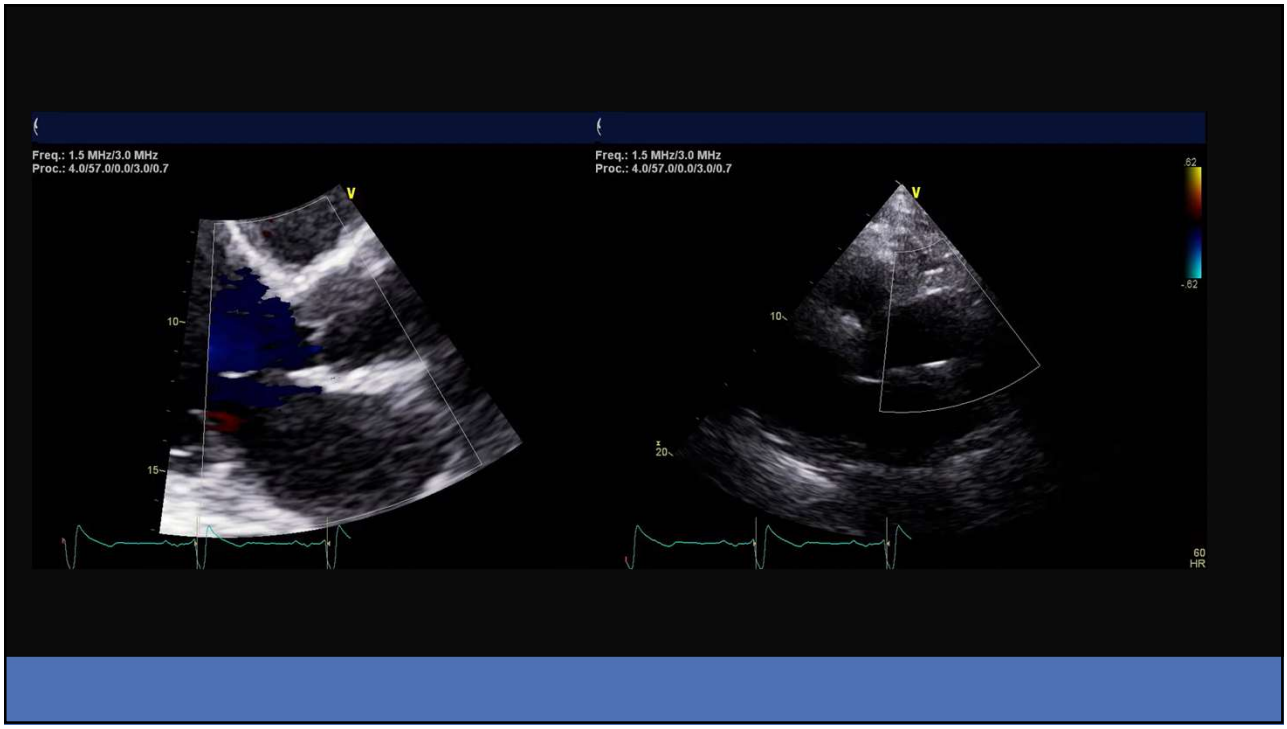

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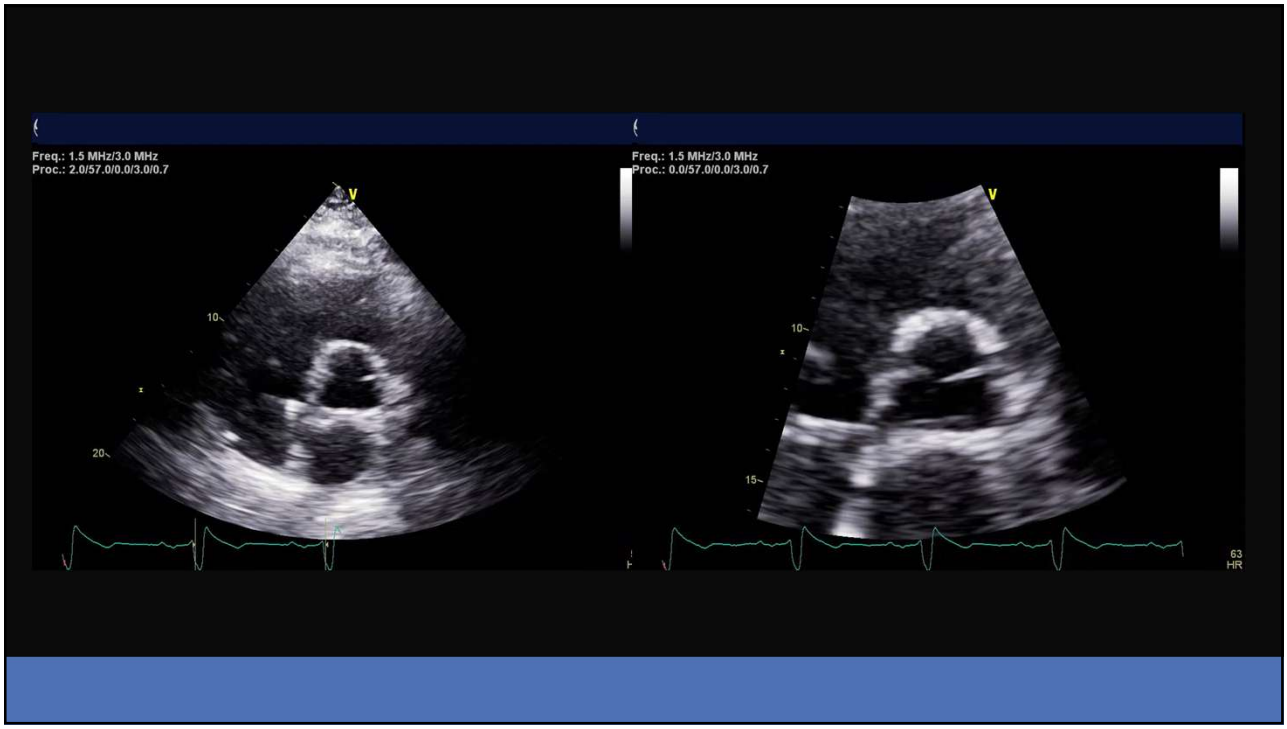

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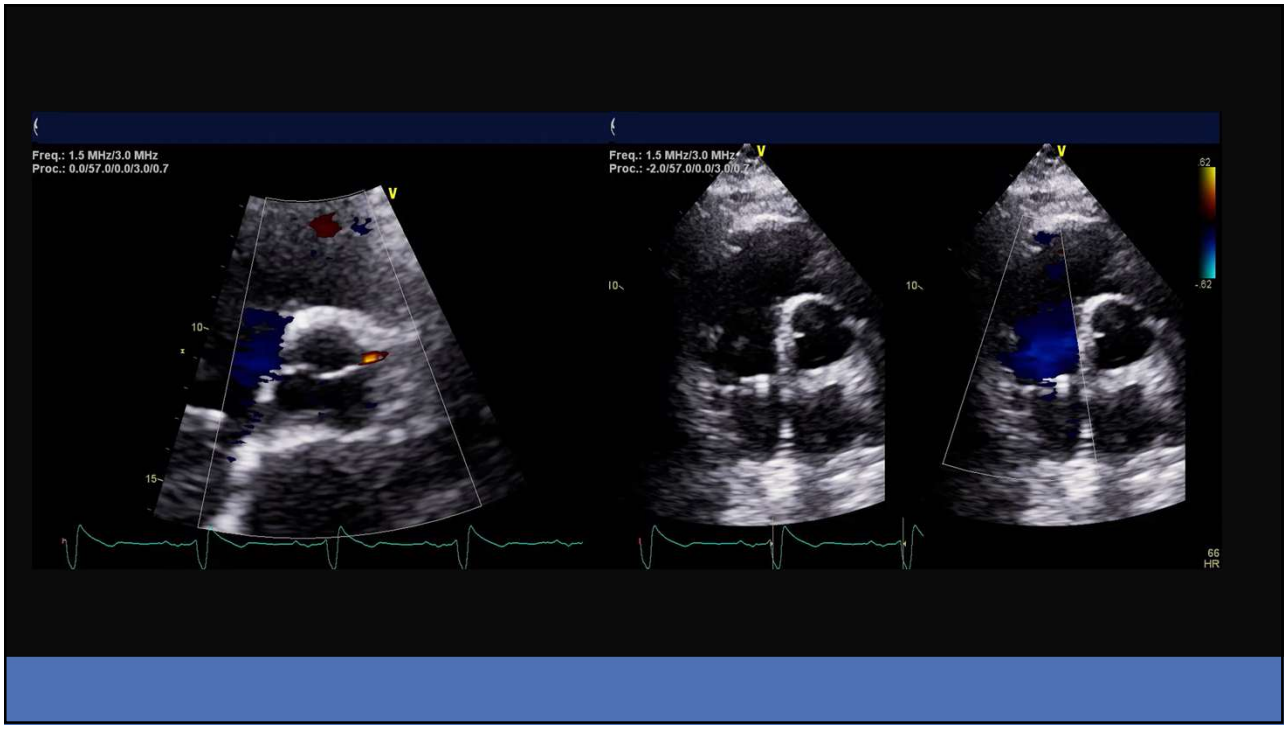

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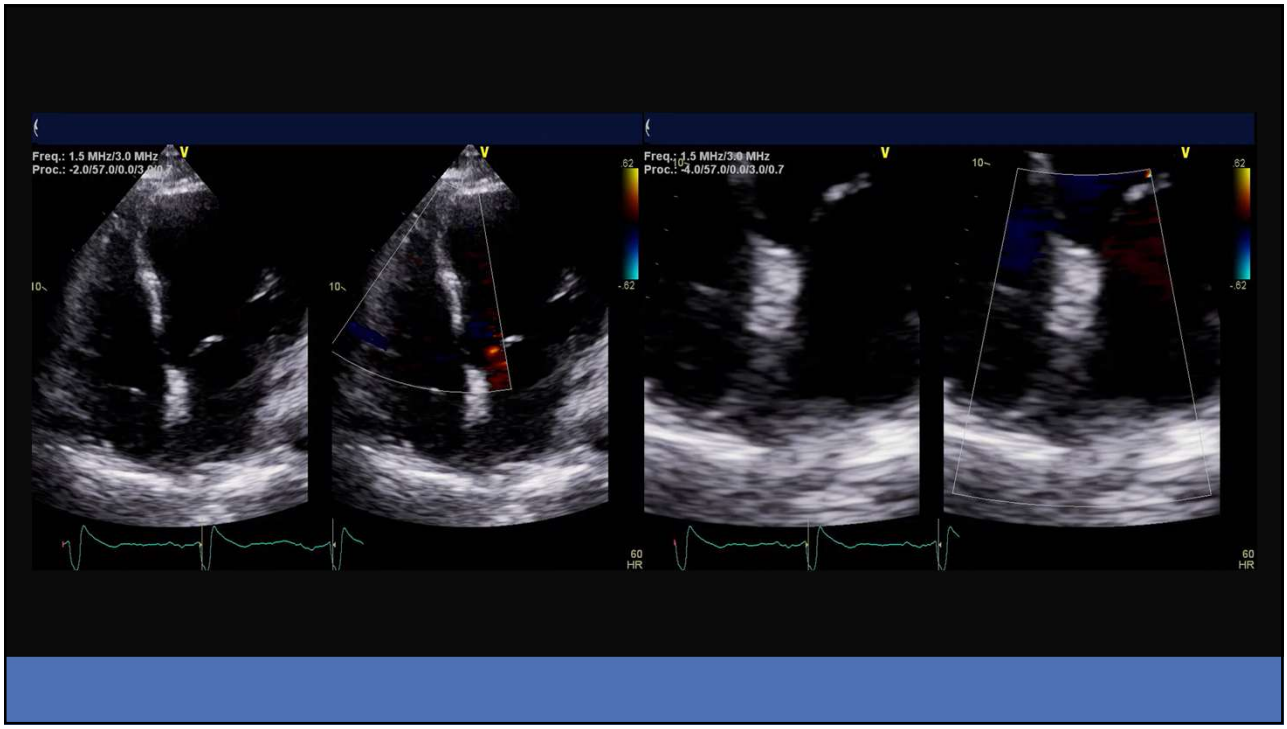

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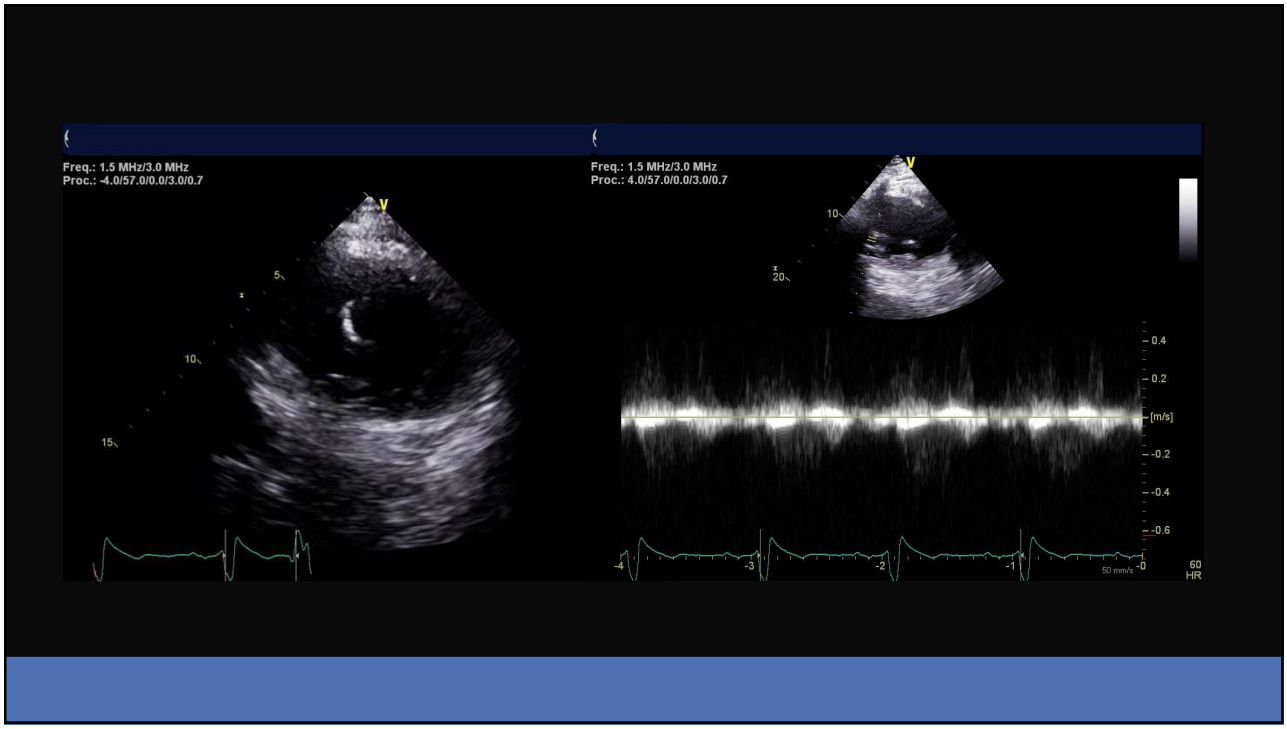

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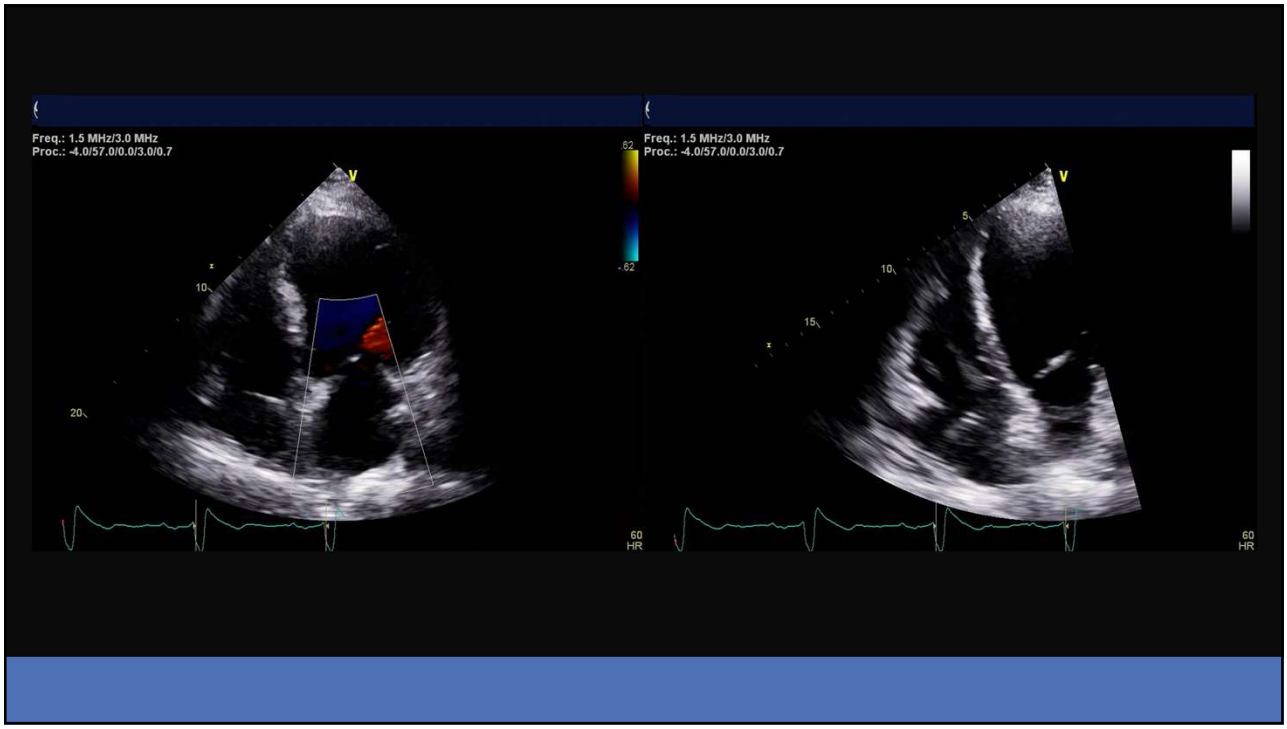

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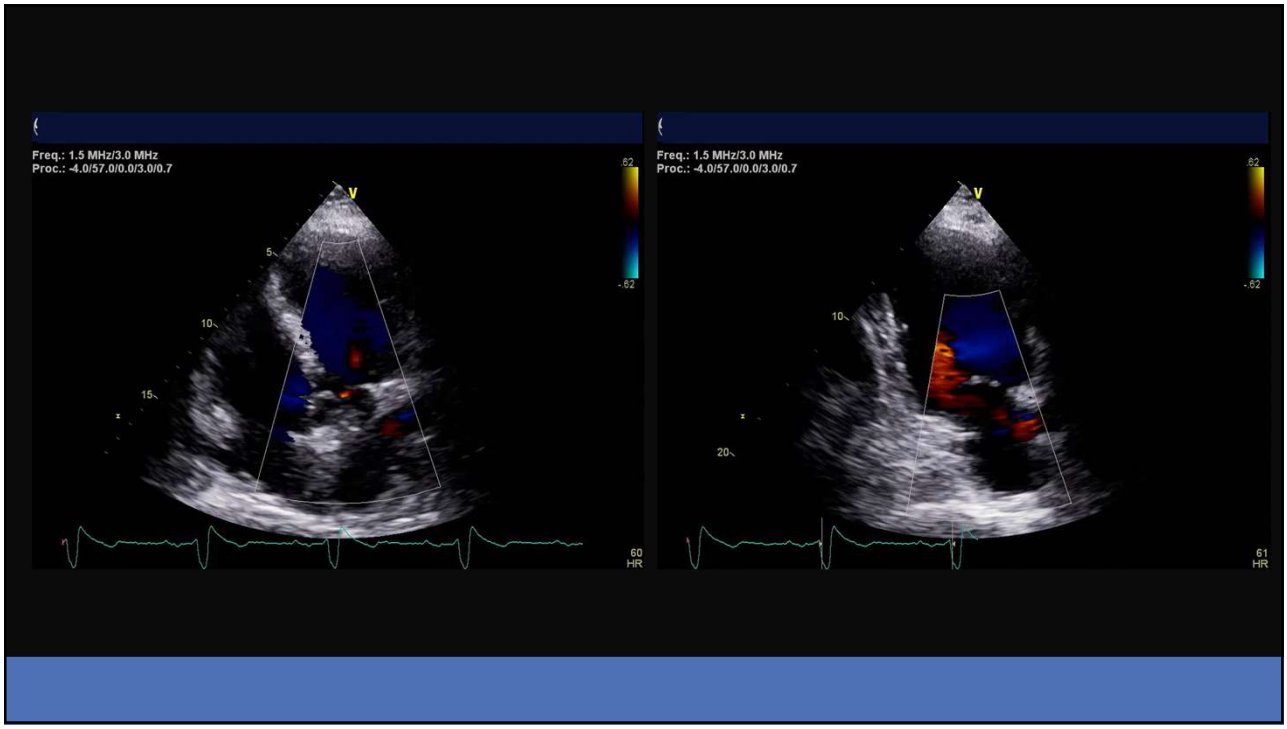

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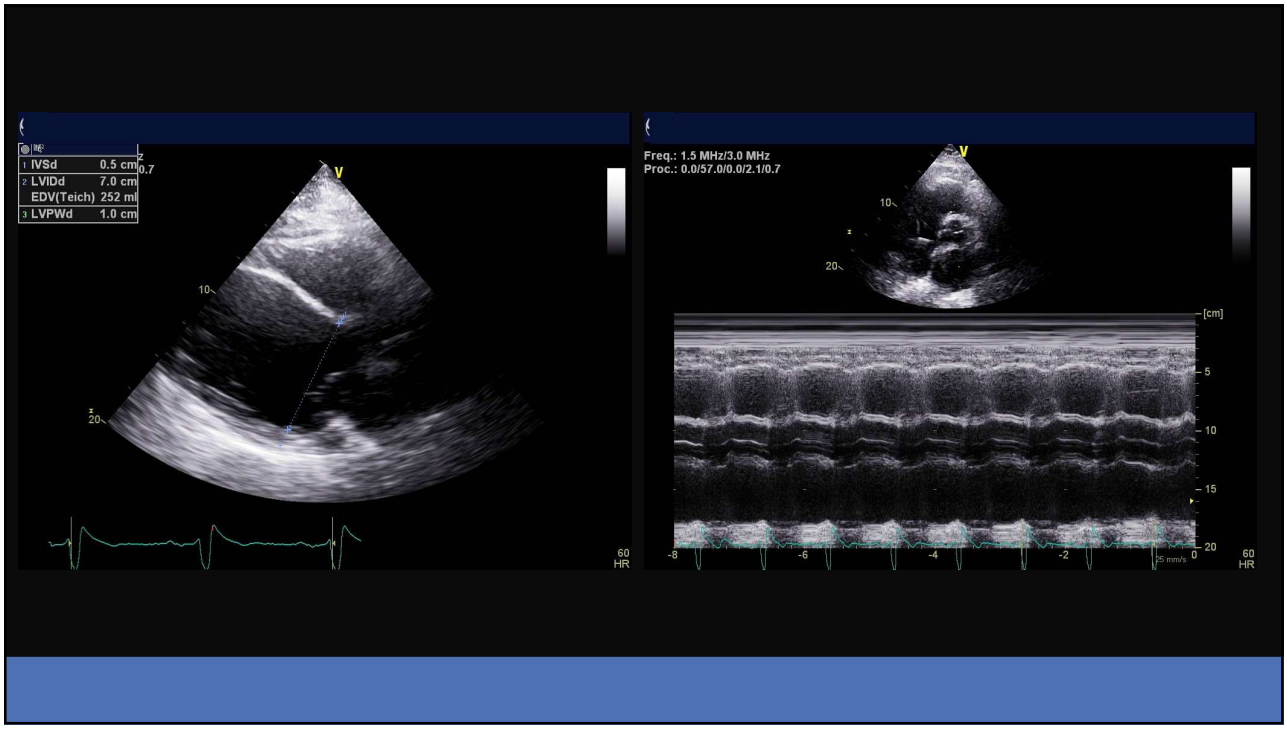

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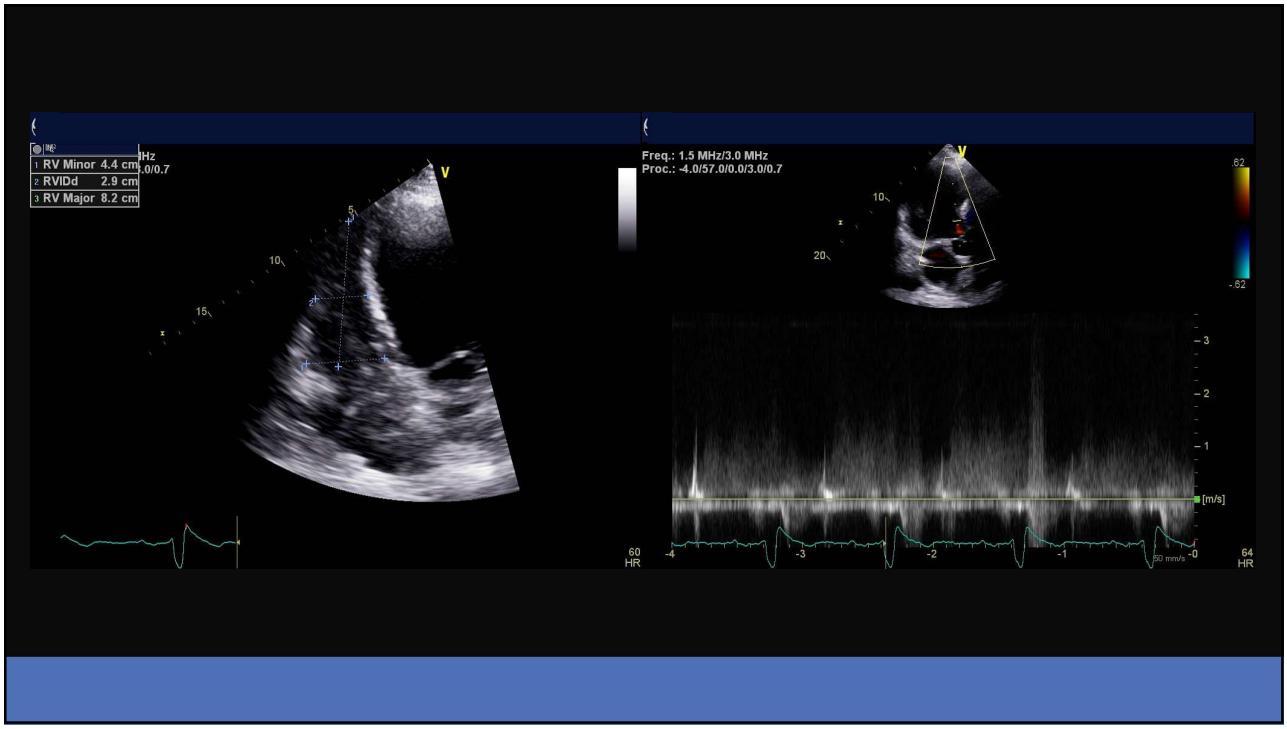

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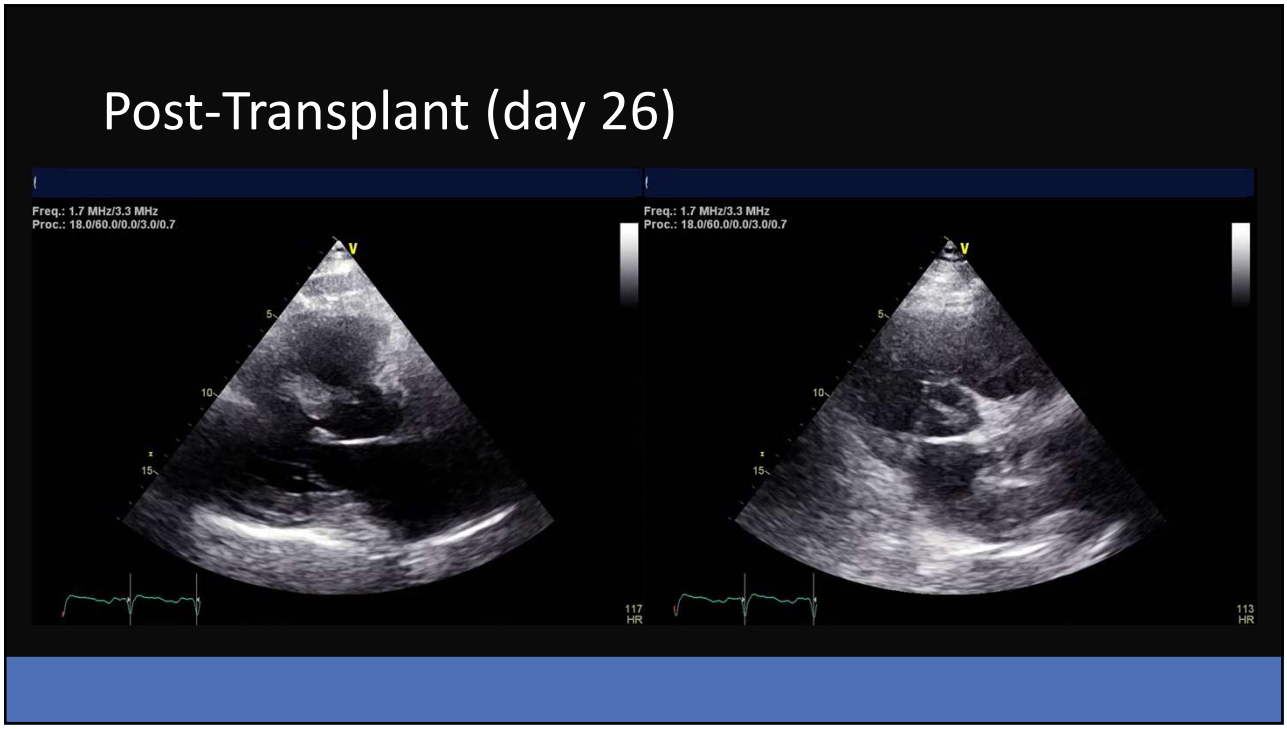

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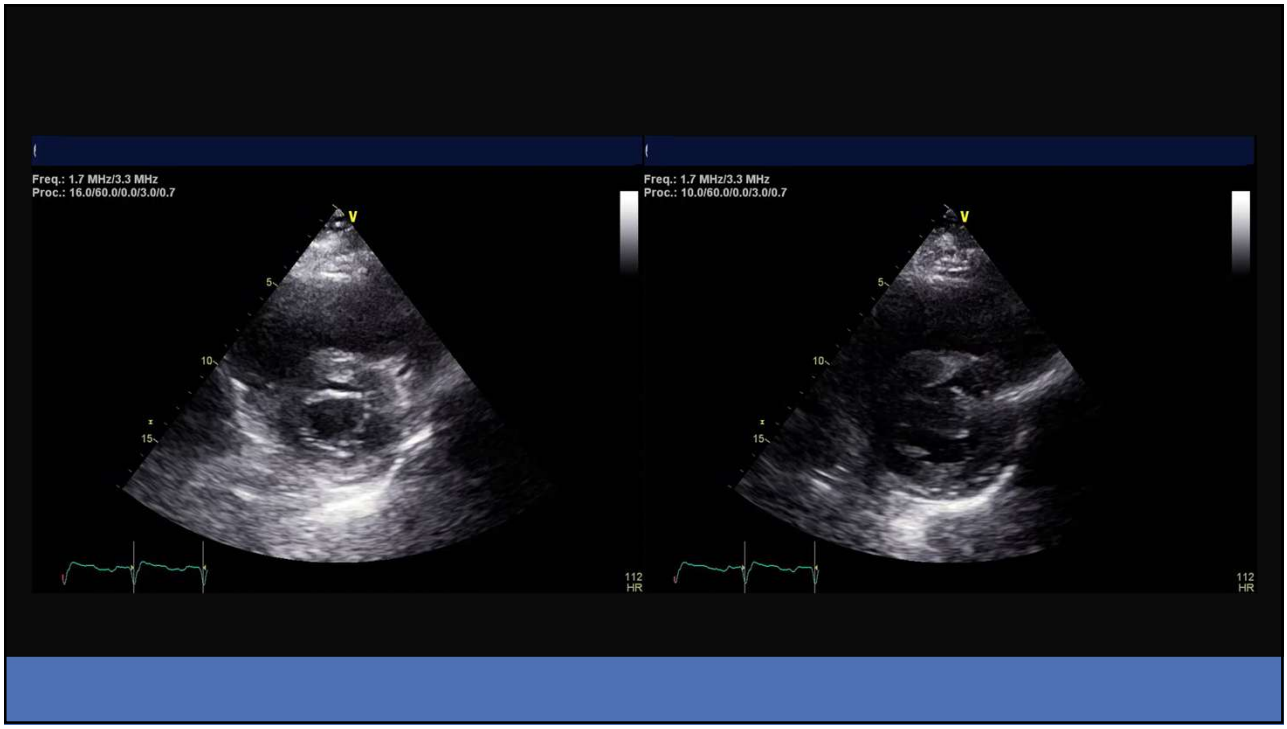

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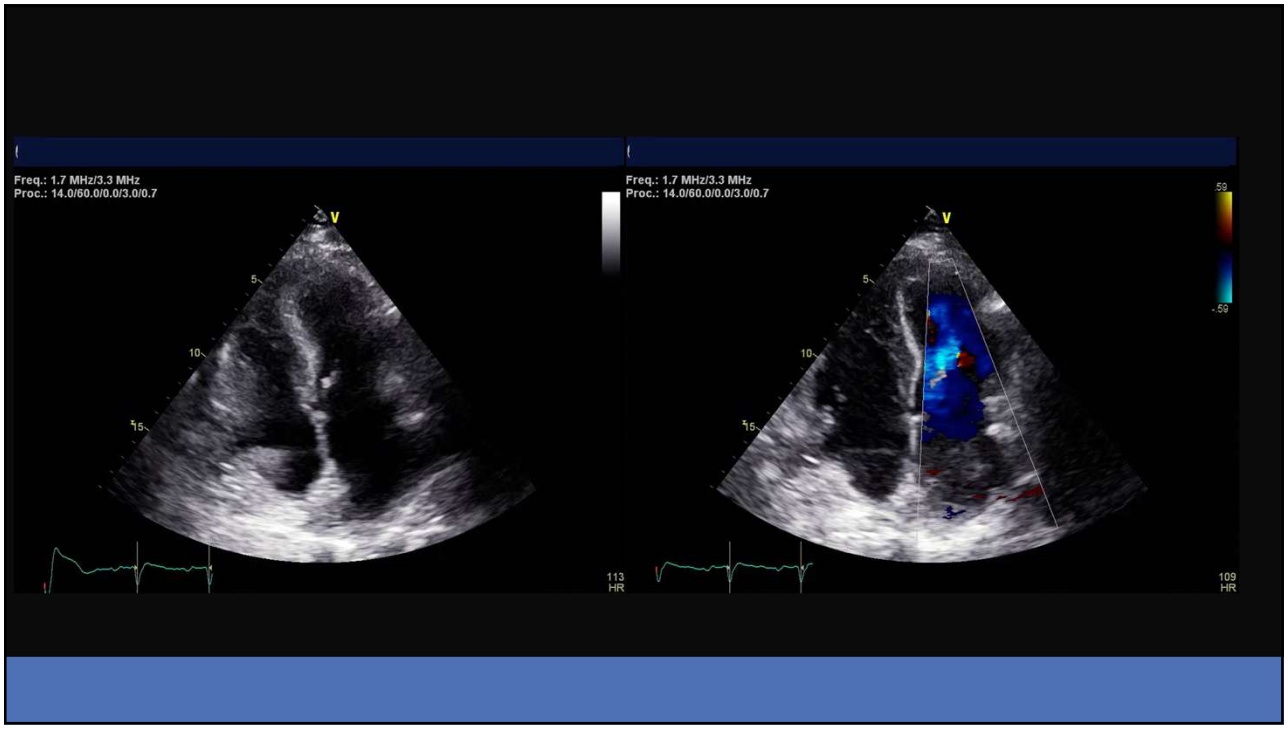

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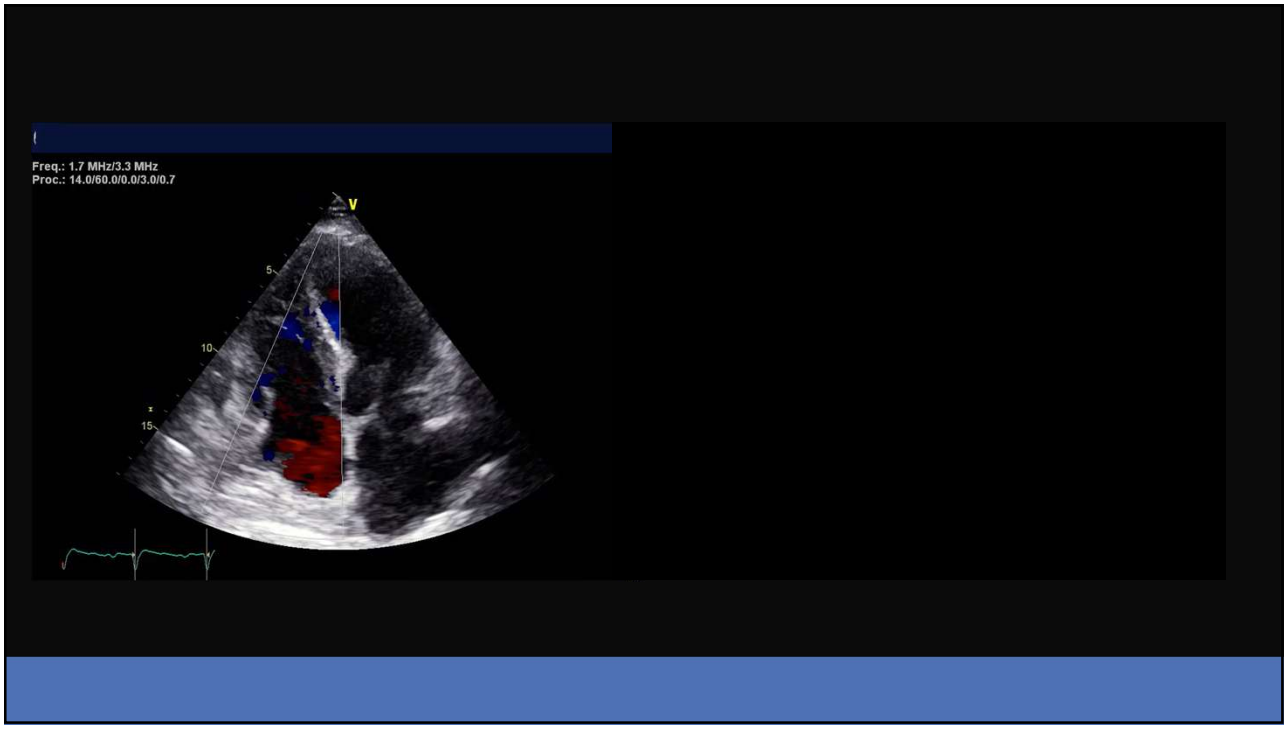

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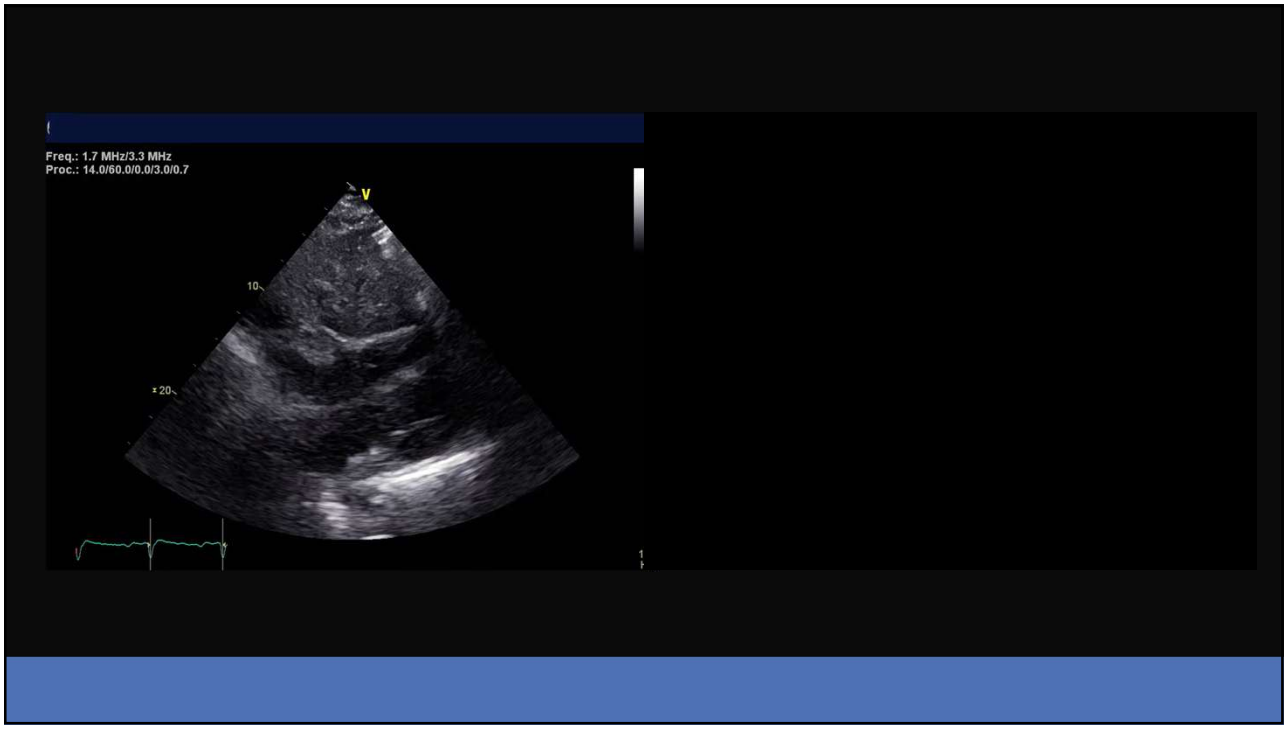
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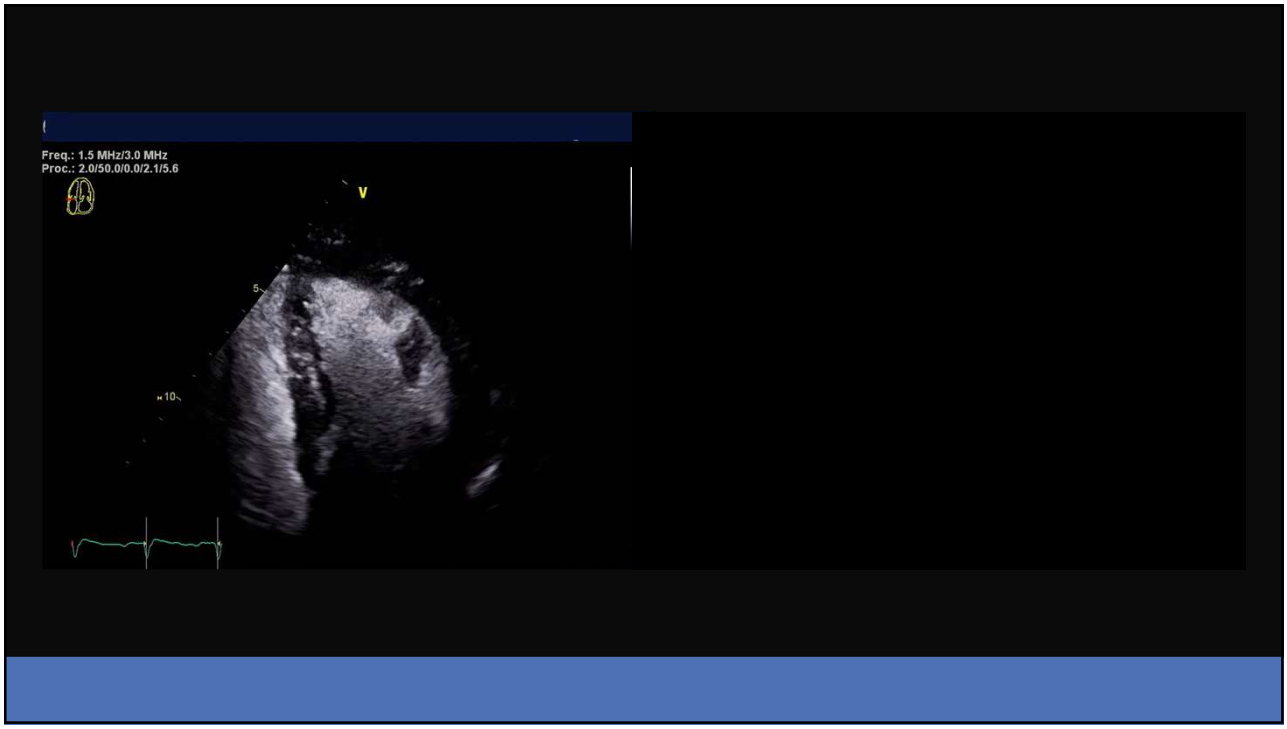
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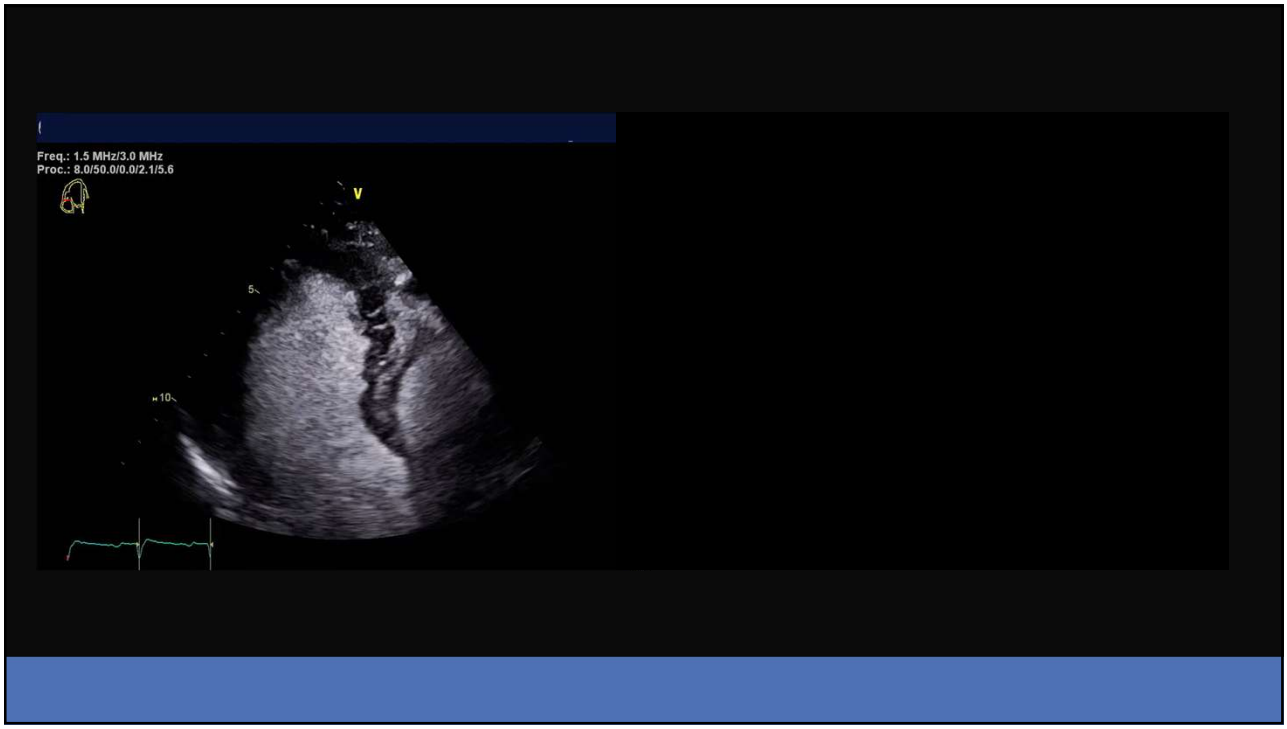

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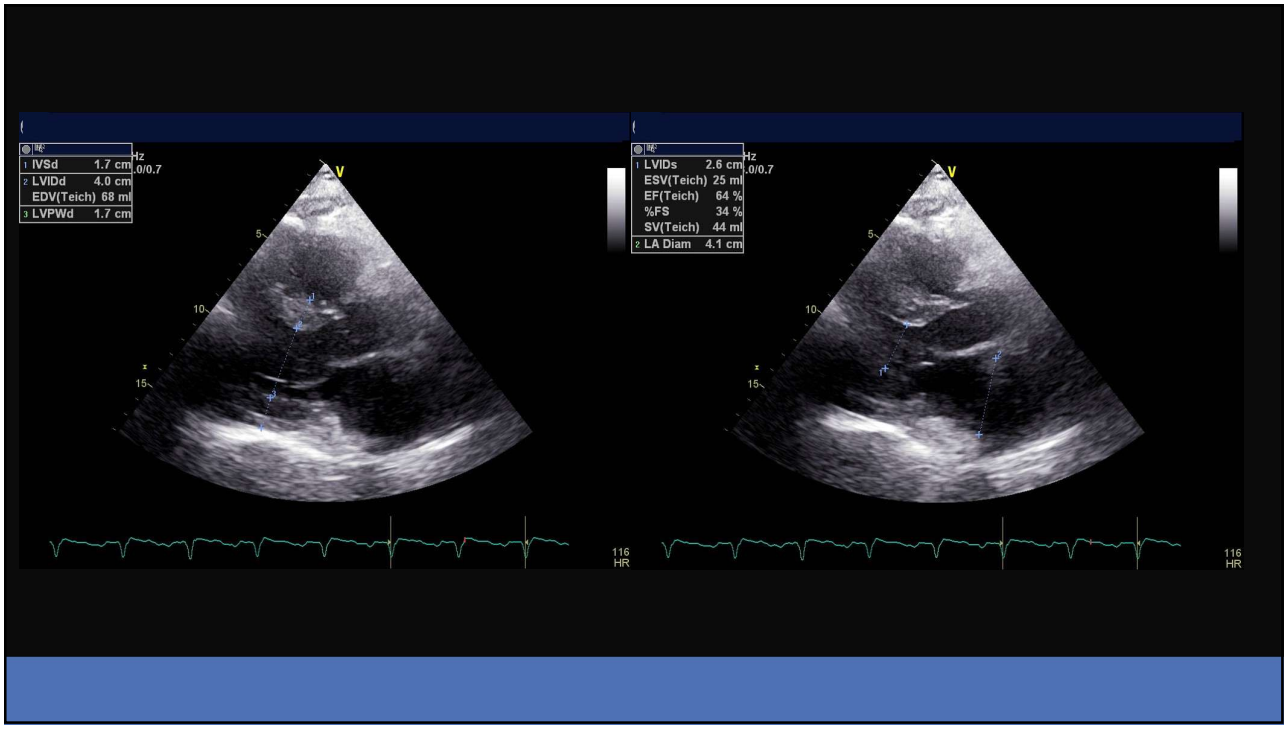

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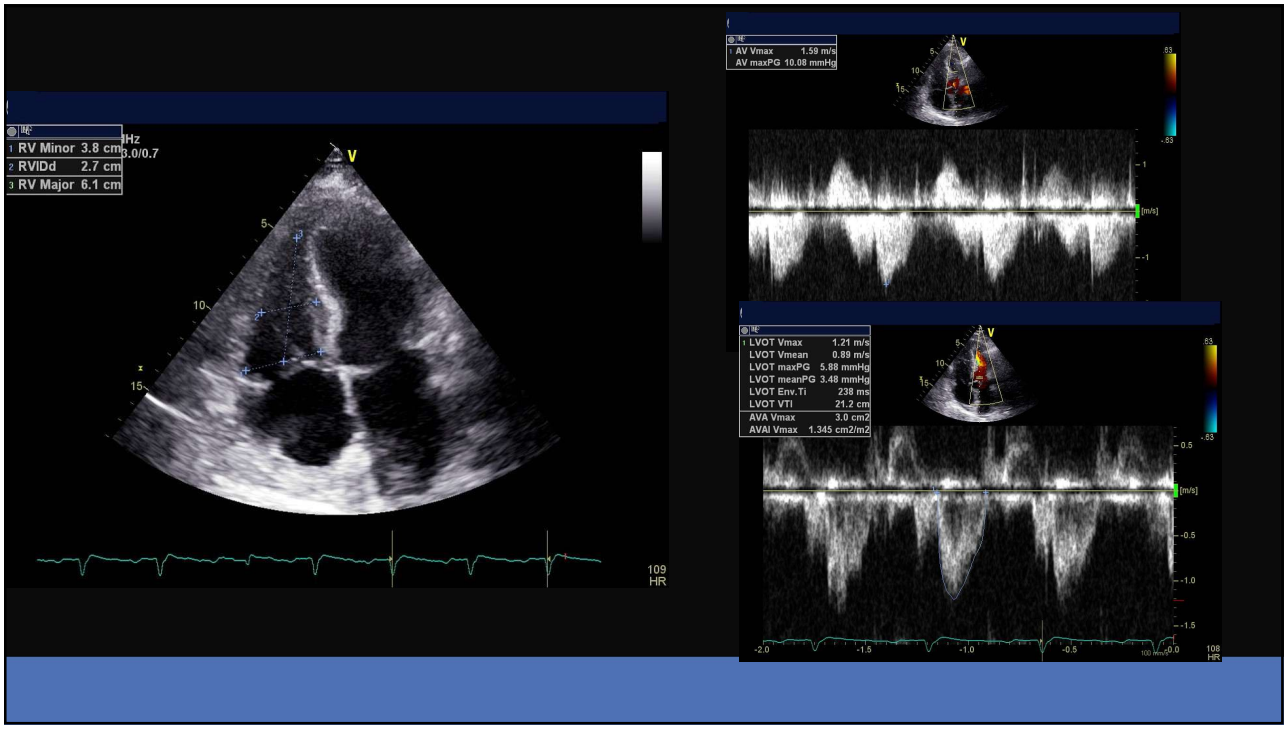

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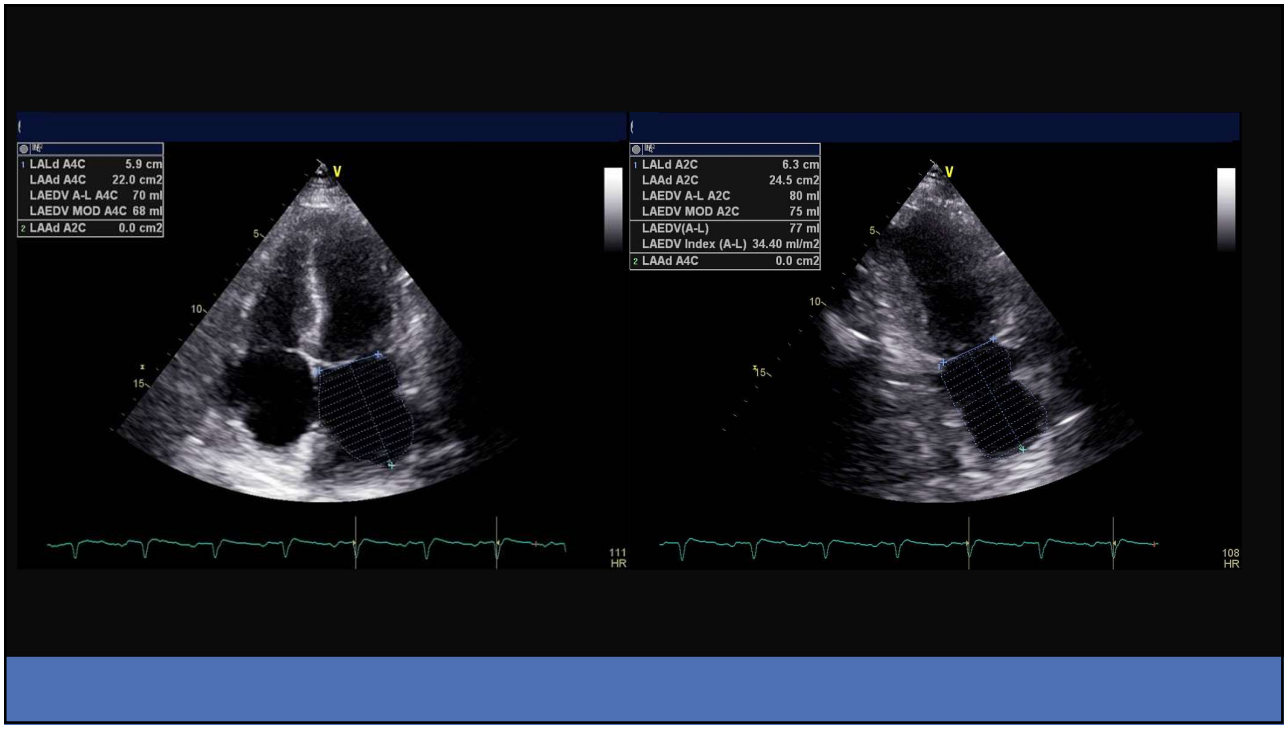

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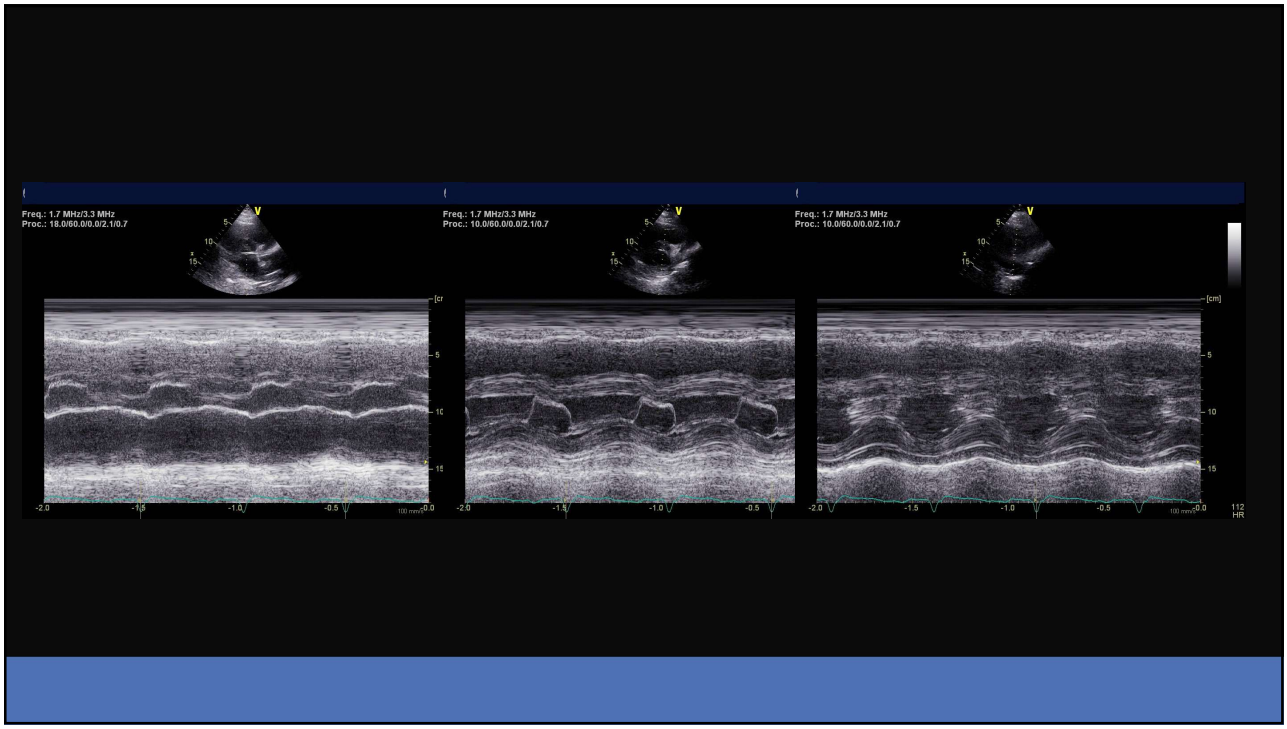

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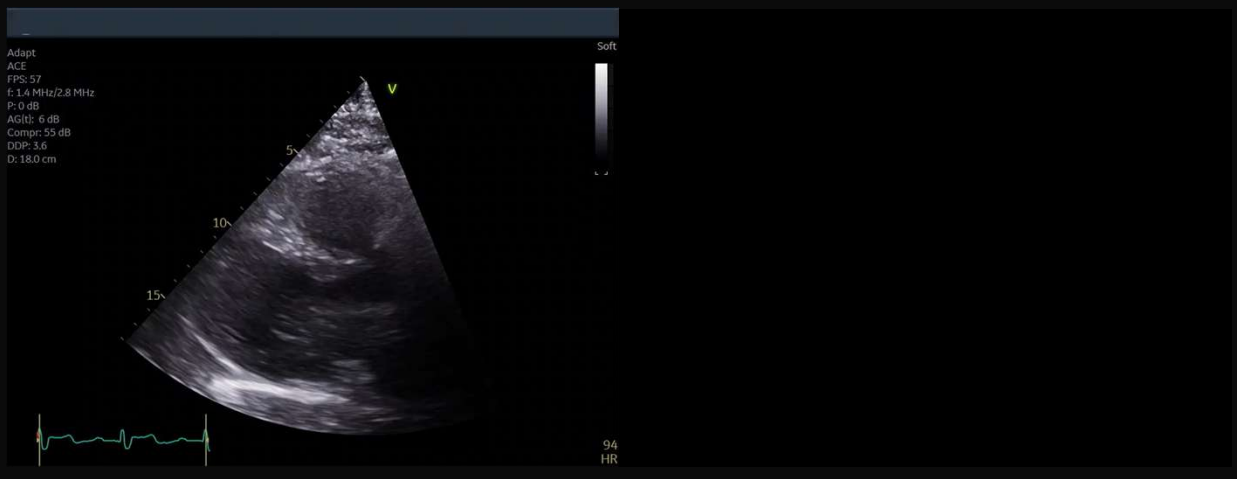
Recent Echo



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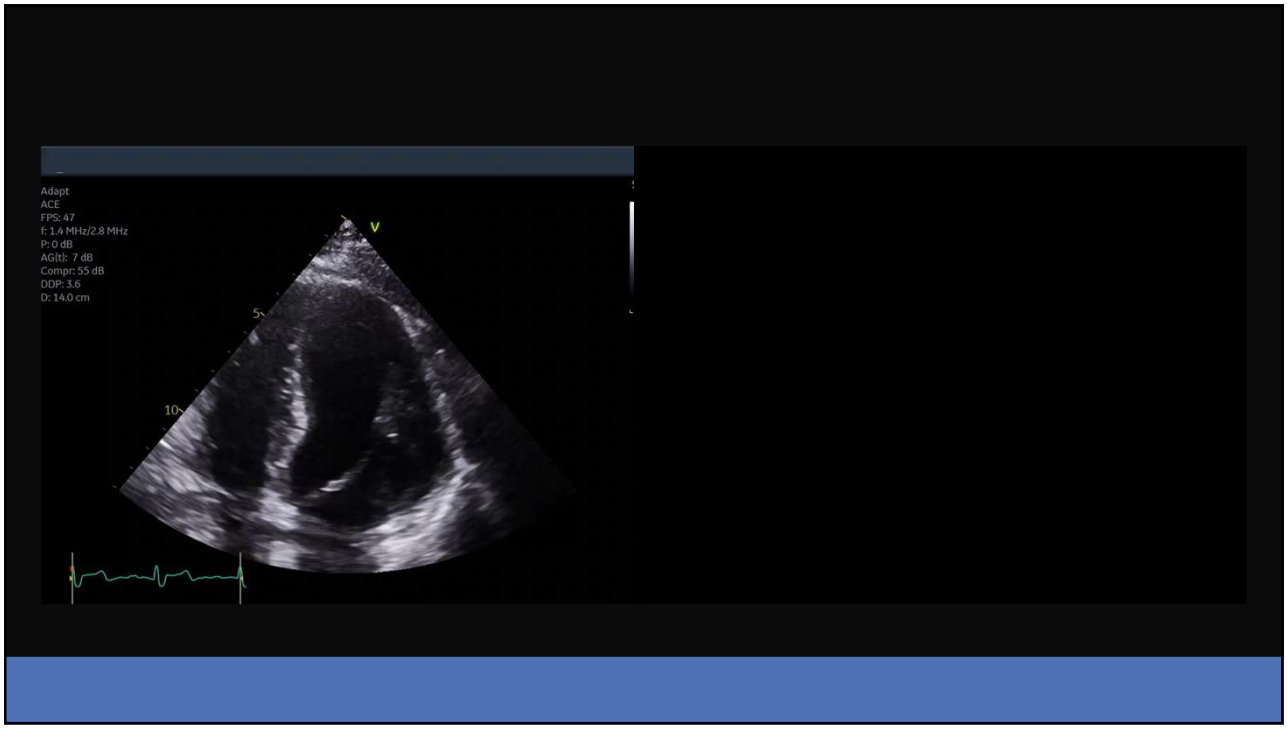

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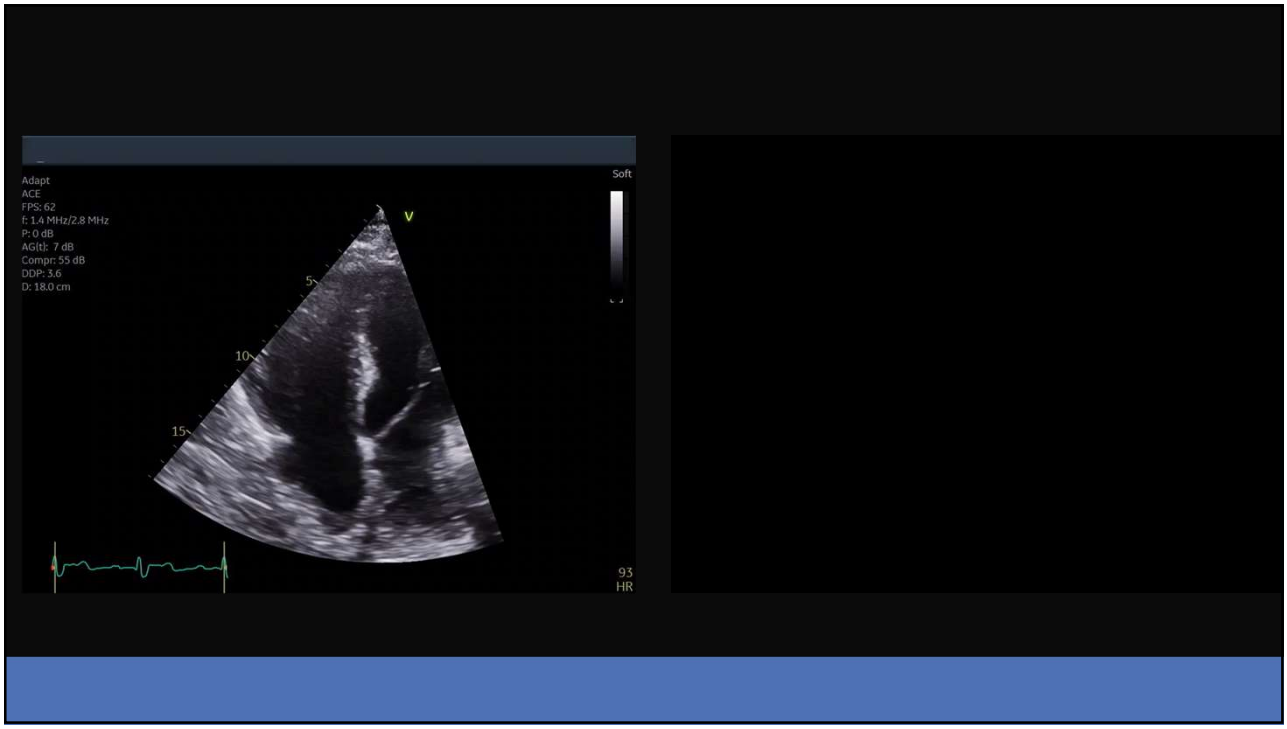

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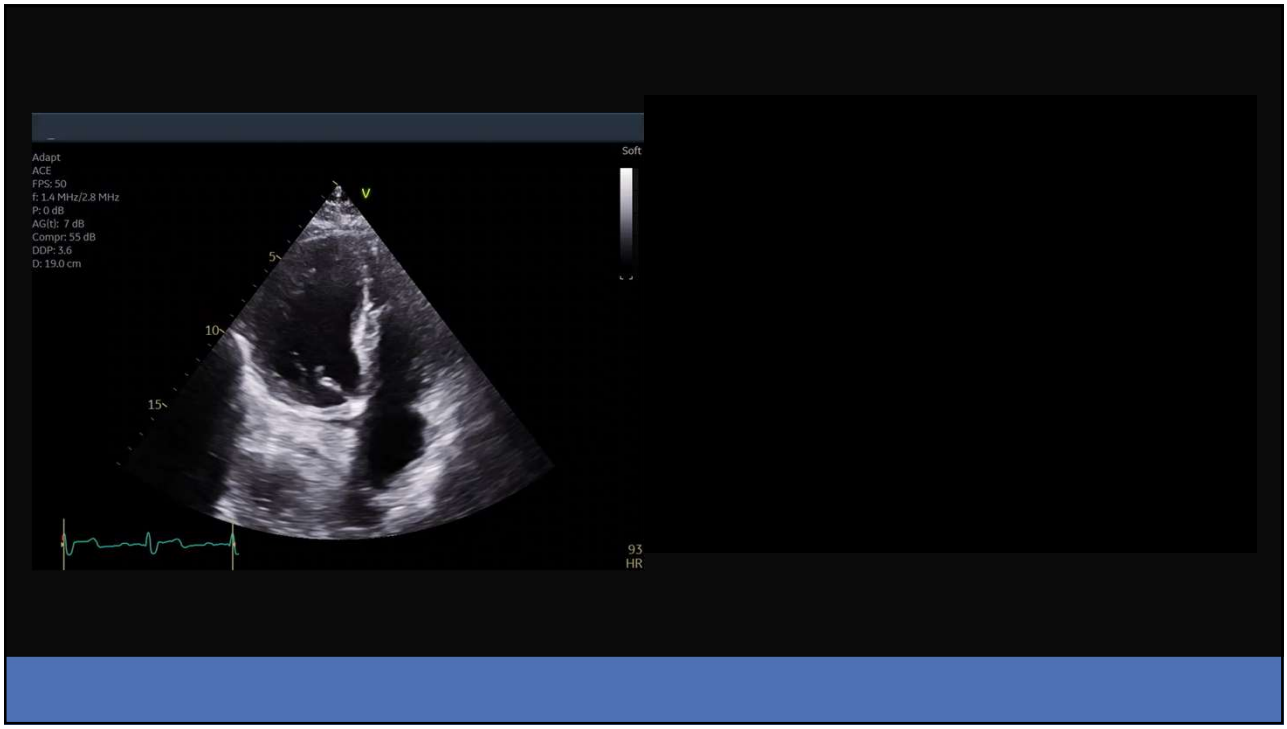

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- Post-op course complicated by transient complete heart block, AKI on CKD, hypomagnesemia, glossitis with dysphagia, steroid/TPN induced hyperglycemia, and post-operative ileus
- Patient doing well with no evidence of allograft dysfunction, rejection, or opportunistic infections

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In closing

- Remember the "I NEED HELP" Concept
  - Recognize clinical deterioration early
  - Refer before irreversible decline occurs
  - Engage multidisciplinary teams
  - Individualize therapy selection
  - Balance longevity with quality of life
- Final Message
  - **Advanced heart failure is not the end of therapy. It is often the beginning of the conversation about the most effective therapy.**

Resources

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