Exploration Echocardiographique des LVADs

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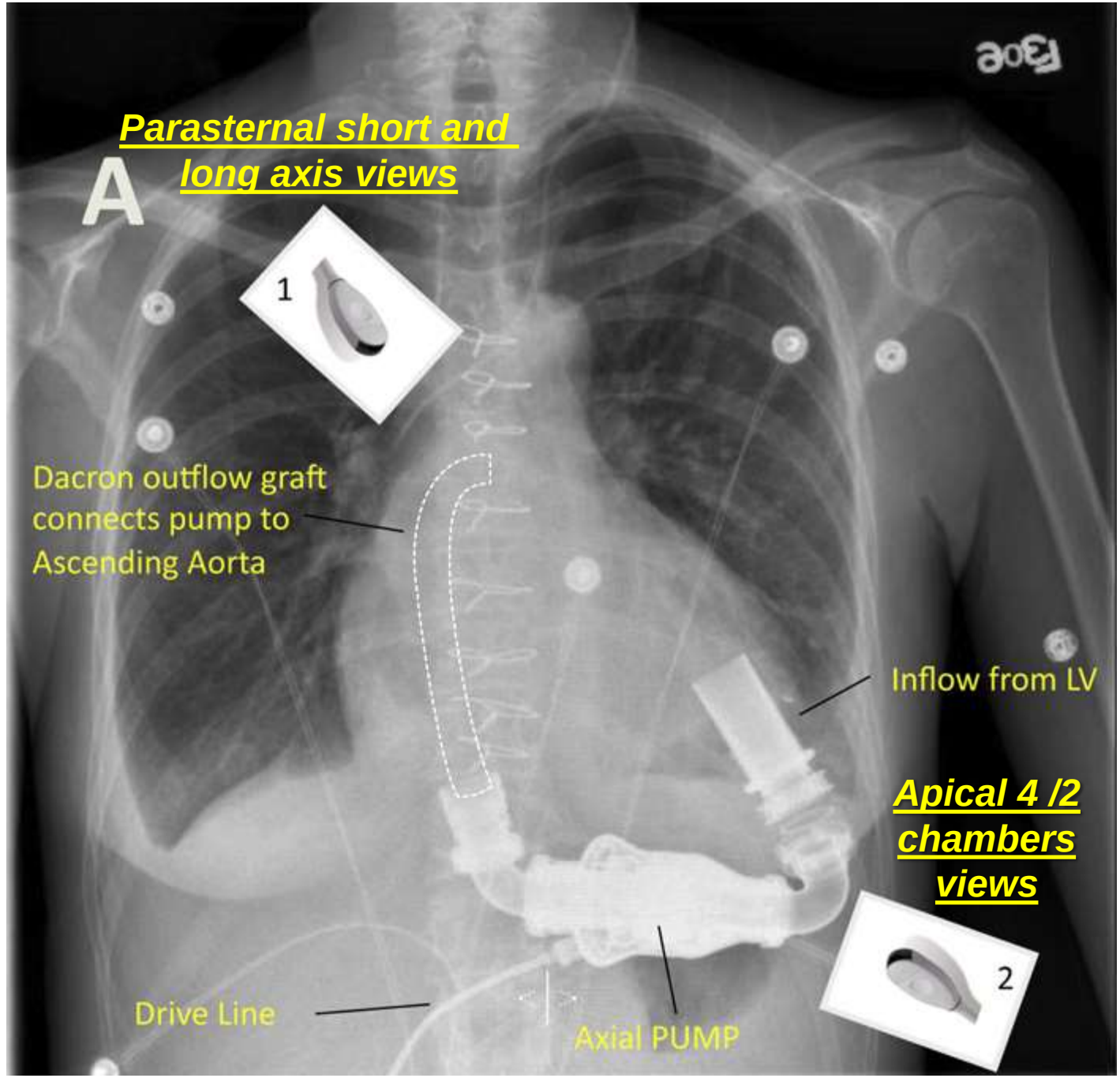
Normal LVAD cannula Doppler findings

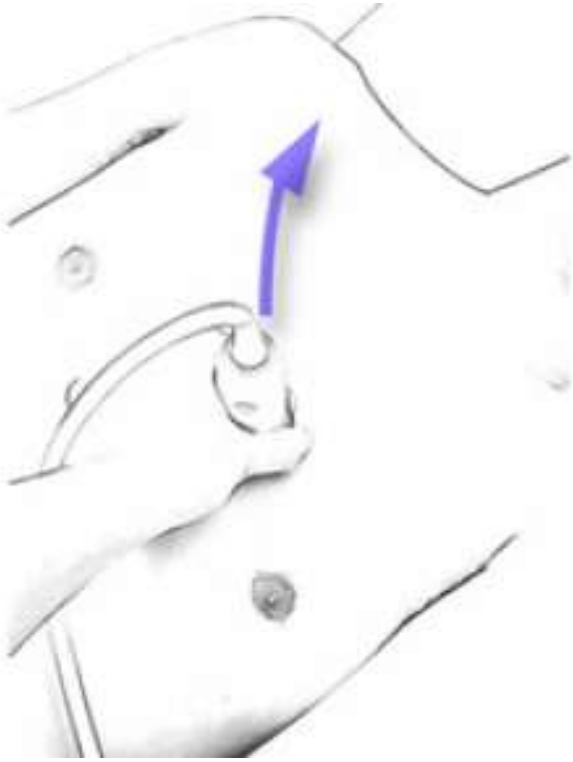
Normal cannula flows

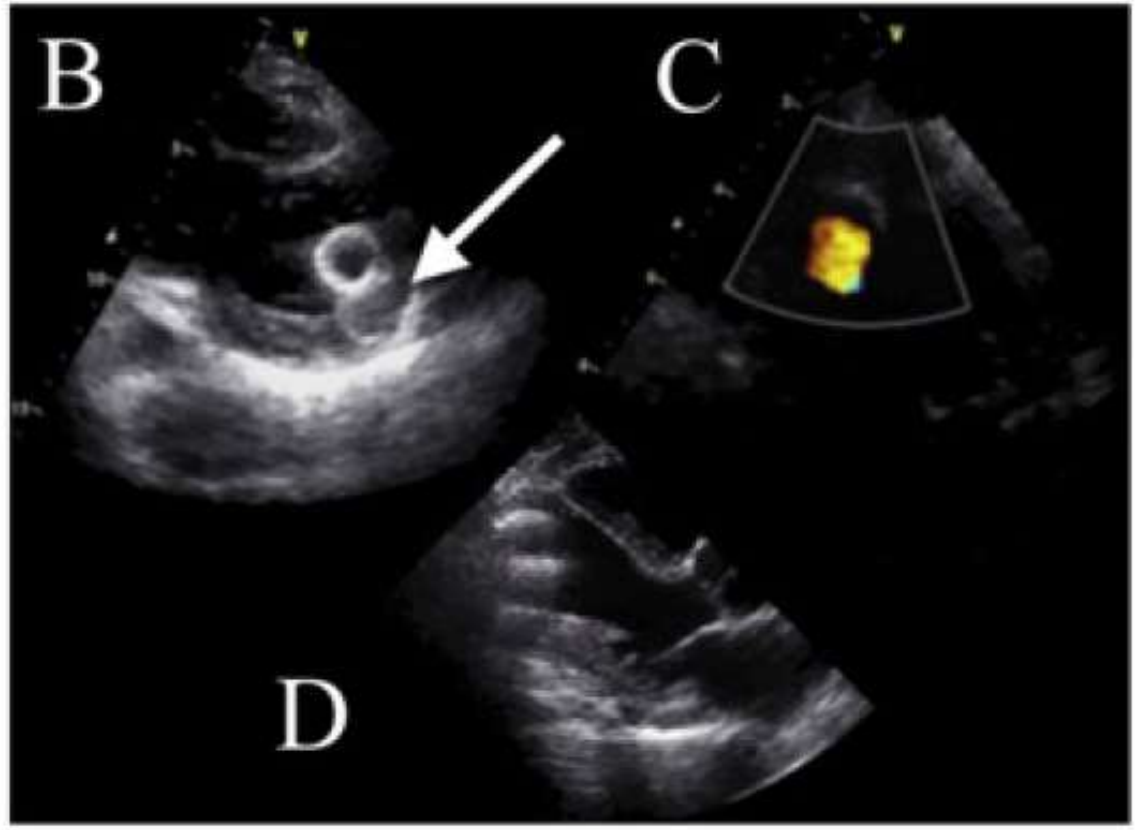
- Continuous-flow LVADs have
  - Phasic, slightly pulsatile
  - Low-velocity inflow and outflow patterns,
  - With peak velocities <2.0 m/s and typically <1.5 m/s
- Normal apical inflow appears as nonturbulent flow toward the apical transthoracic transducer
  - However, with off-axis imaging, apparent direction of normal flow relative to the transducer may vary


A
Parasternal short and long axis views
1
Dacron outflow graft connects pump to Ascending Aorta
Inflow from LV
Apical 4 /2 chambers views
2
Drive Line
Axial PUMP

- The **mid-ventricular parasternal short-axis view** offers an *en face* view of the inlet cannula (B). A mirror image artifact is seen adjacent to the true cannula (white arrow).
- Color Doppler shows uniform color indicating laminar flow in normal LVAD function (C).
- From the **parasternal long-axis** view, **tilt the imaging plane towards the apex** (blue arrow) to image the inlet cannula at the left ventricular apex and its relationship to the mitral valve. (D).

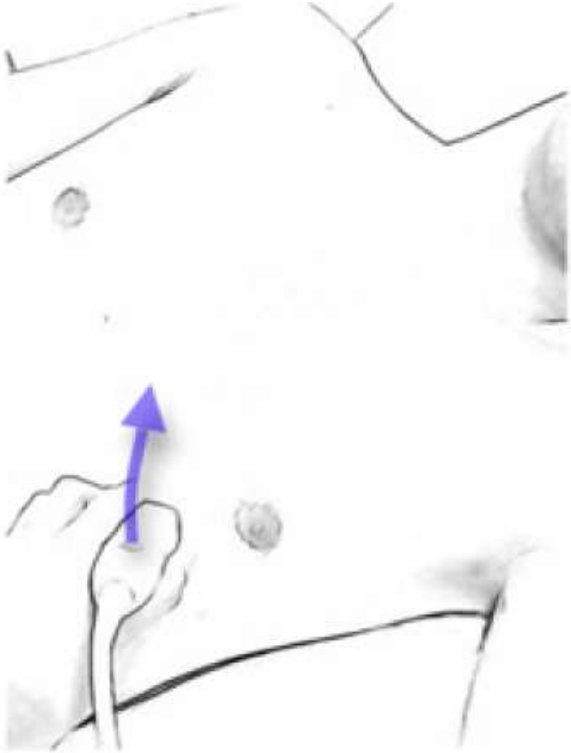
Inflow Cannula

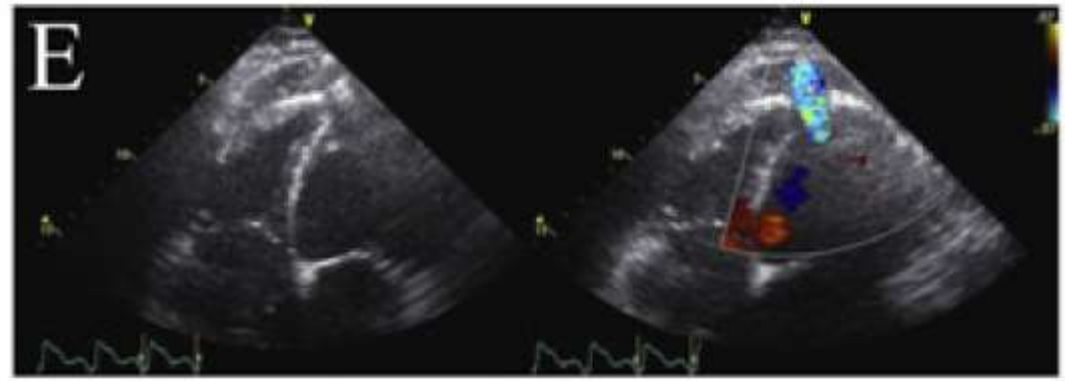


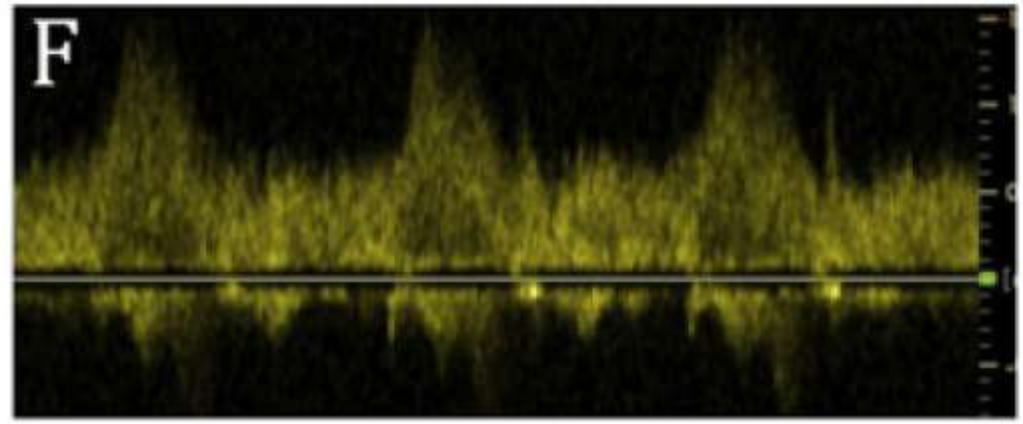


- Tilting the imaging plane **inferiorly from a standard apical 4-chamber view** typically provides the best visualization and highest inlet cannula velocities as flow is most parallel to the ultrasound beam.
- **Off-axis views** facilitate imaging of intrapericardial devices such as the HVAD (E)
- Pulsed wave Doppler of inlet cannula from an apical approach (F)

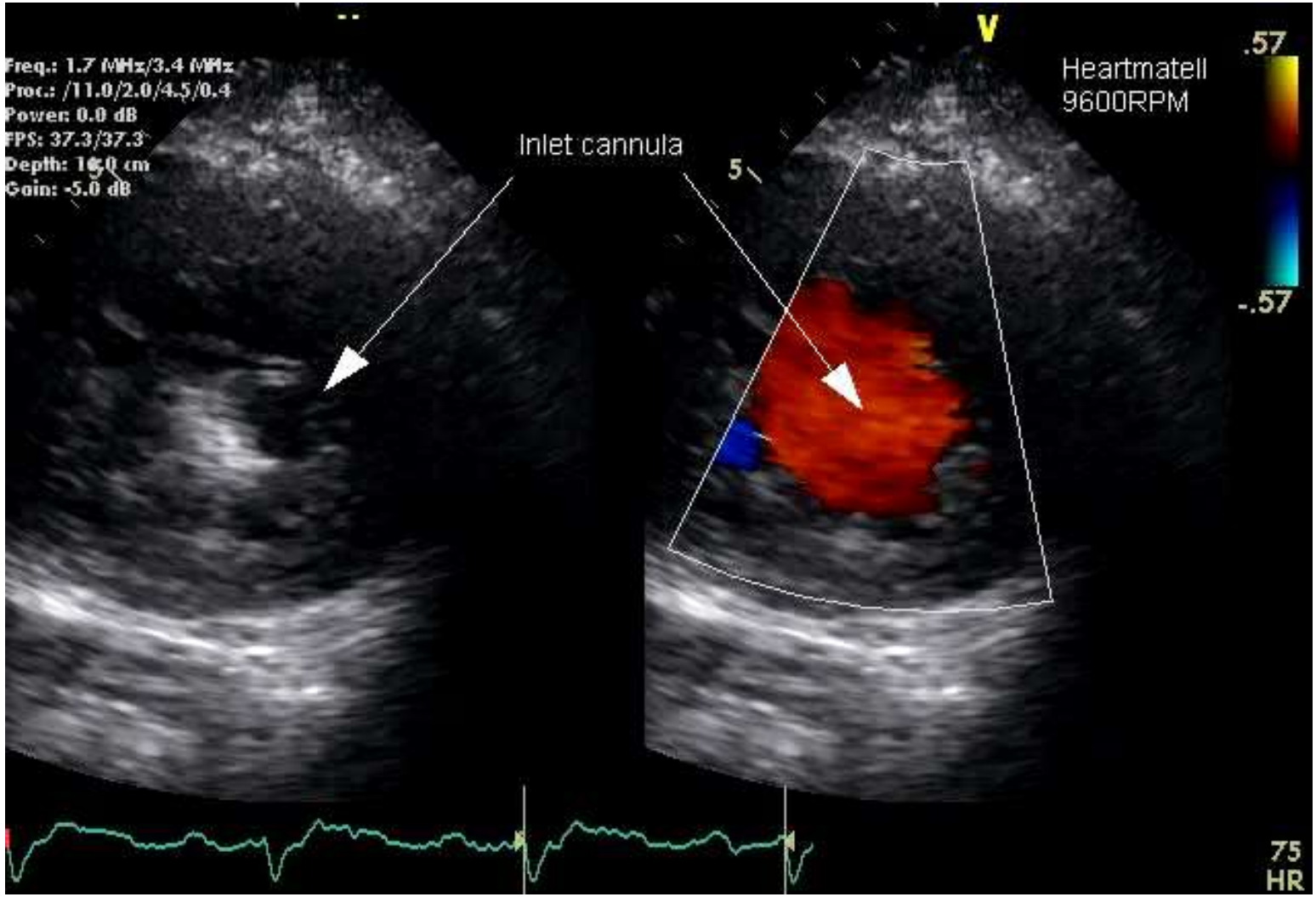
Inflow Cannula



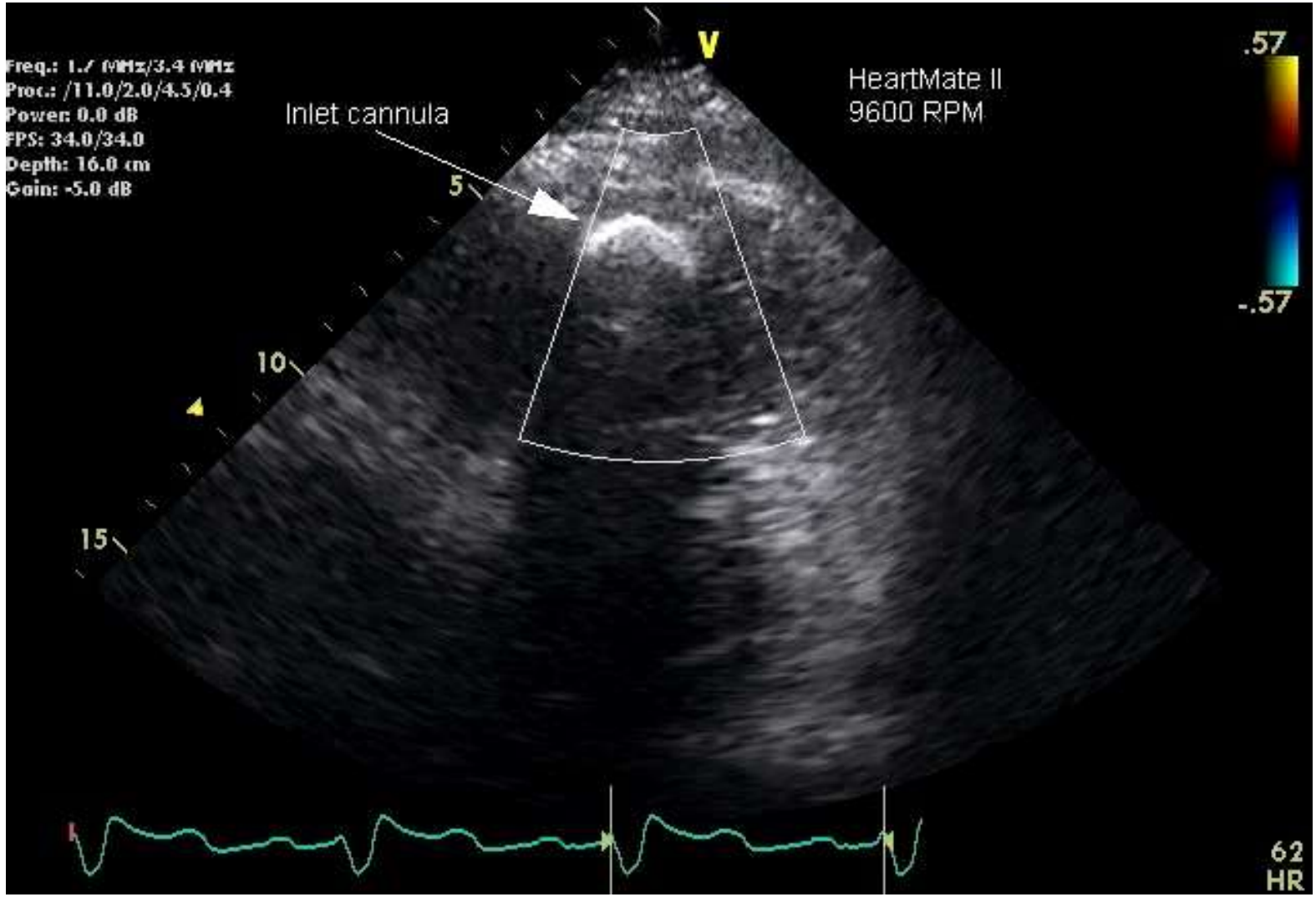


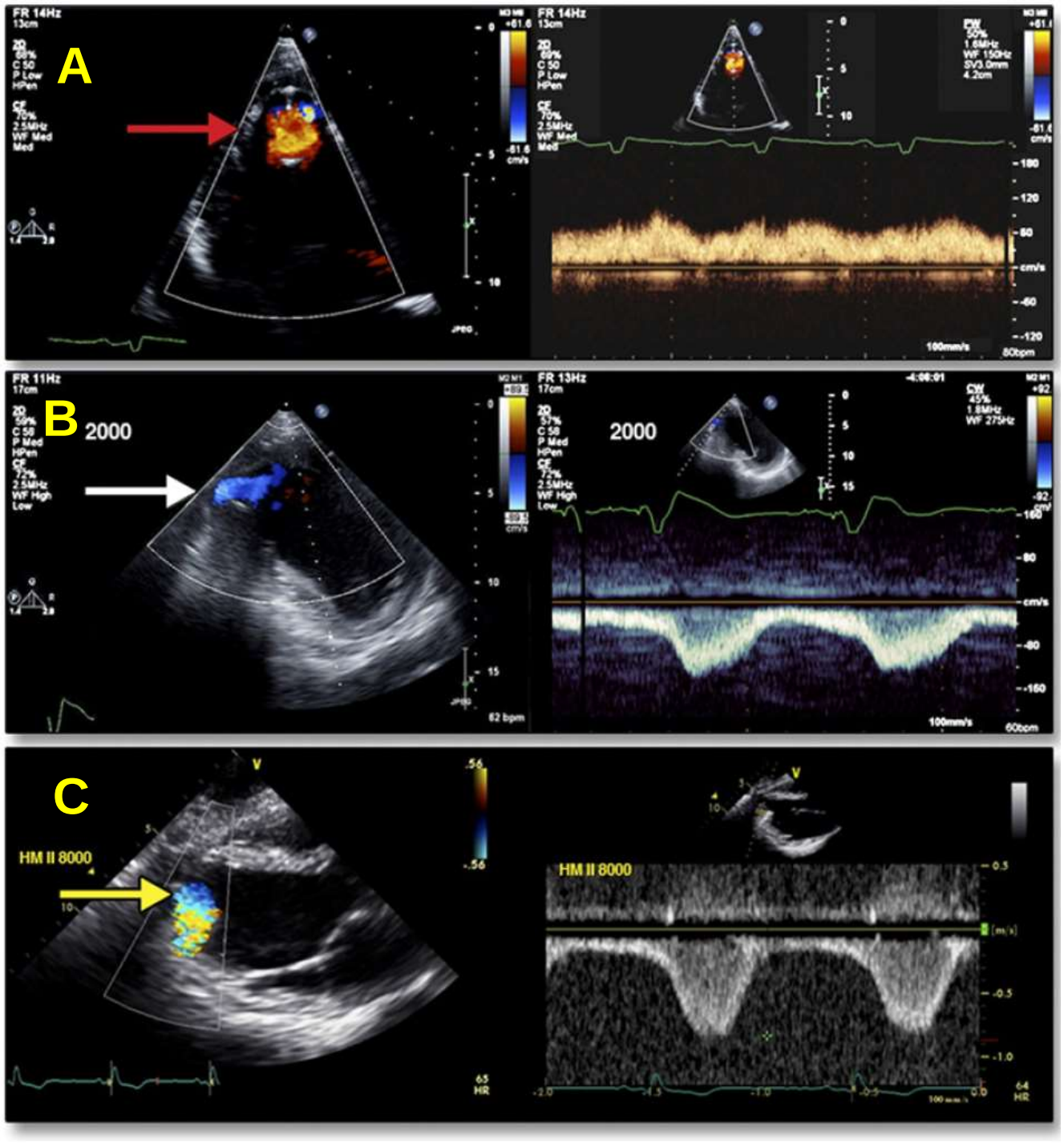


Mid-Ventricular parasternal short axis view



Apical 4-chamber view



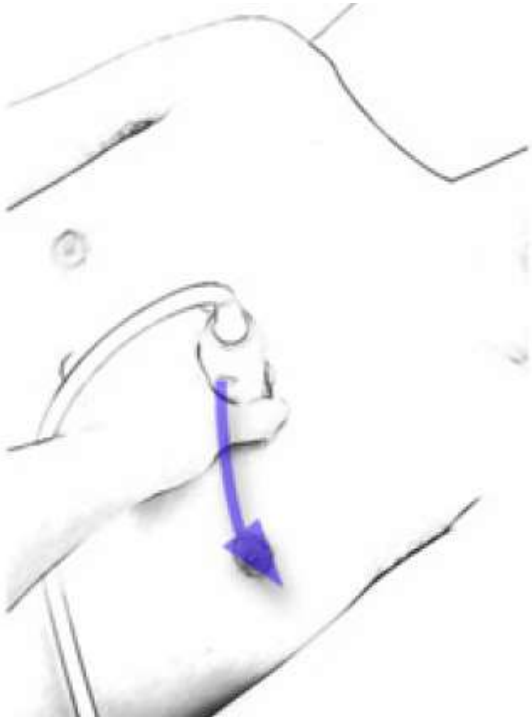


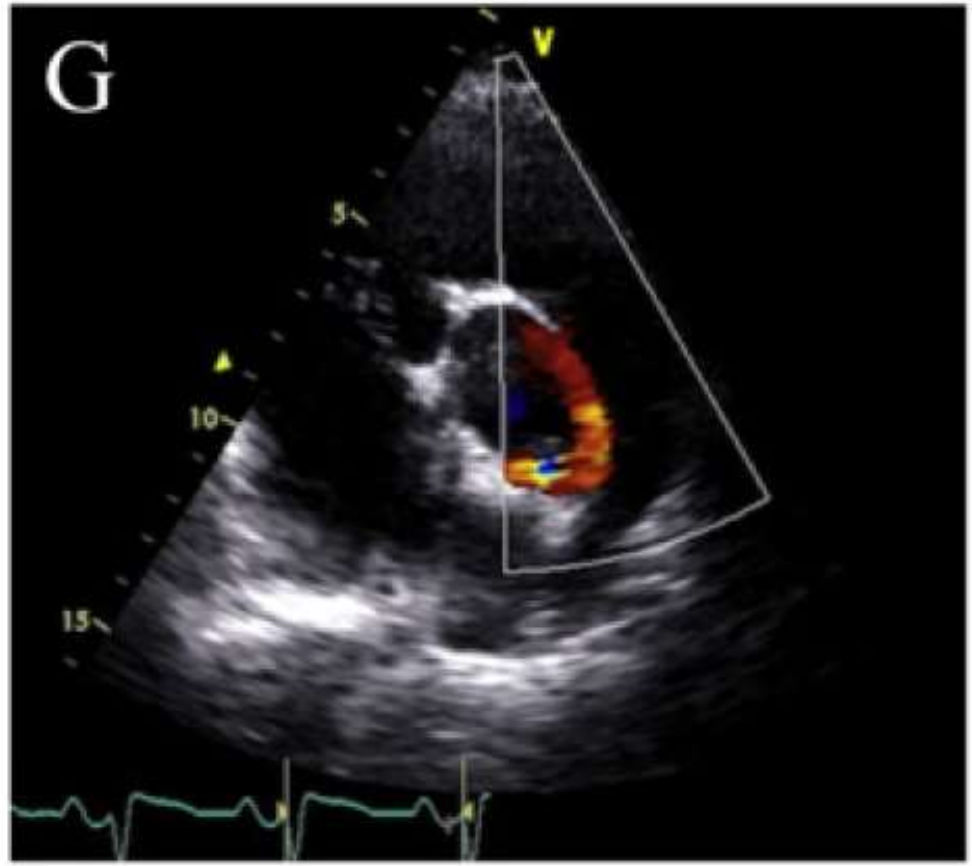
Effect of Imaging Windows on Doppler Recordings of the Apical Inflow Cannula

- (A) Standard 4-chamber apical view with nonaliasing color Doppler apical inflow (red arrow) and low peak velocity (1.5 m/s) with flow directed toward the apical transducer.
- (B) Off-axis 2-chamber apical view illustration of normal apical inflow characteristics (white arrow). Note the Doppler signal directed away from the transducer with normal flow relative to the device.
- (C) Parasternal long-axis view illustration of normal apical inflow (yellow arrow), similar to B

- A **slight clockwise rotation from the parasternal long-axis view** shows the outflow graft flow for patients with a descending thoracic aortic anastamosis.
- Tilt the imaging plane to the **basal parasternal short-axis view** (blue arrow) to evaluate flow from the outflow graft into the aortic root (G).

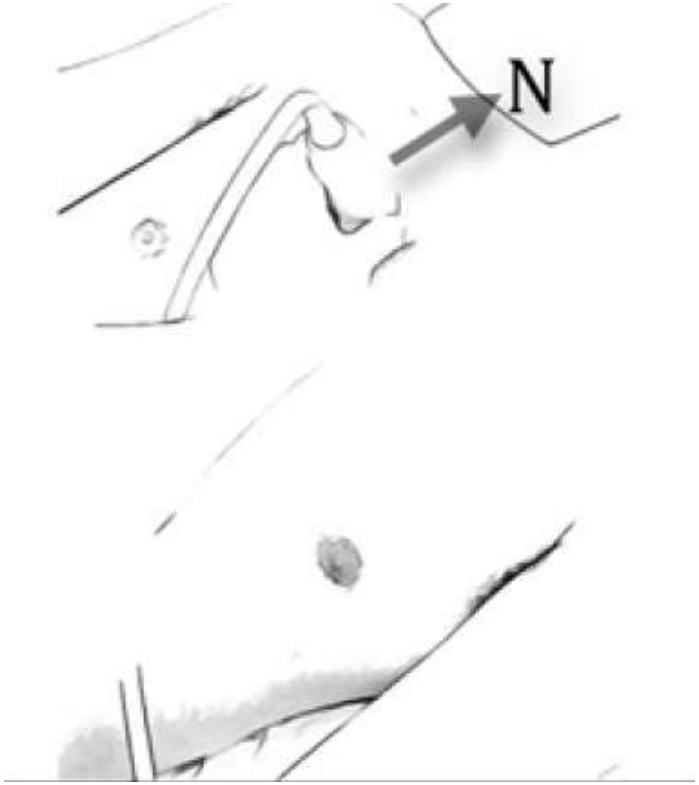
Outflow Cannula

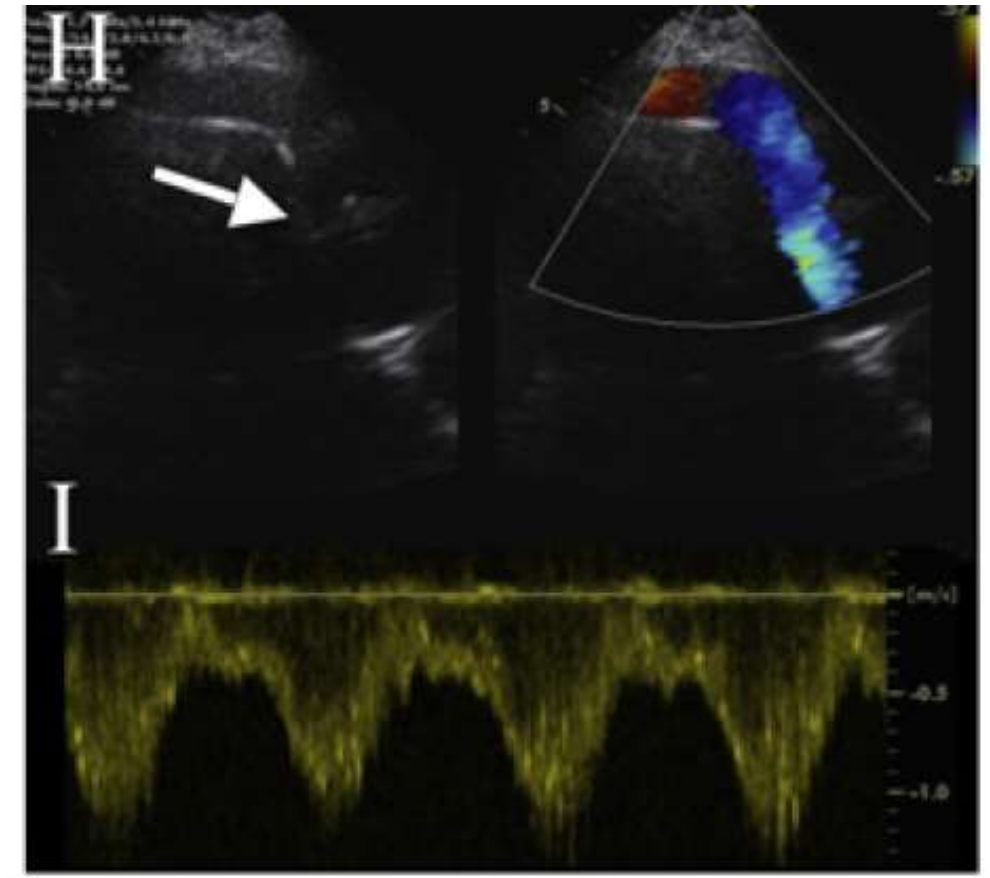




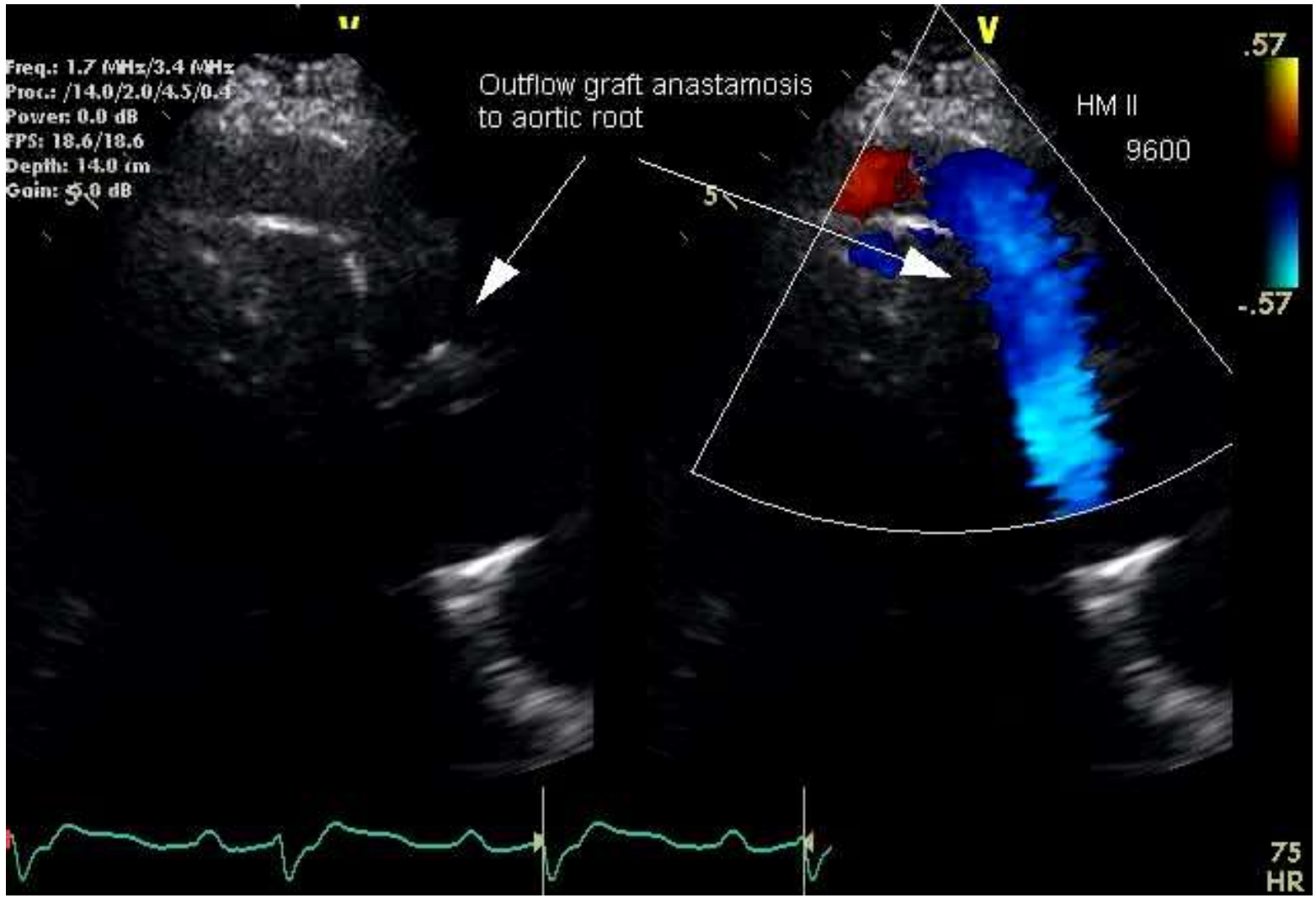
- With an aortic root outflow graft anastamosis, a **high right or left parasternal window** (transducer notch facing "12 o'clock") often provides the best determination of outflow graft velocities as flow is most parallel to the ultrasound beam.
- High right parasternal image of the outflow graft anastamosis to the aortic root (arrow), with color Doppler (H) and pulsed-wave Doppler (I).

Outflow Cannula



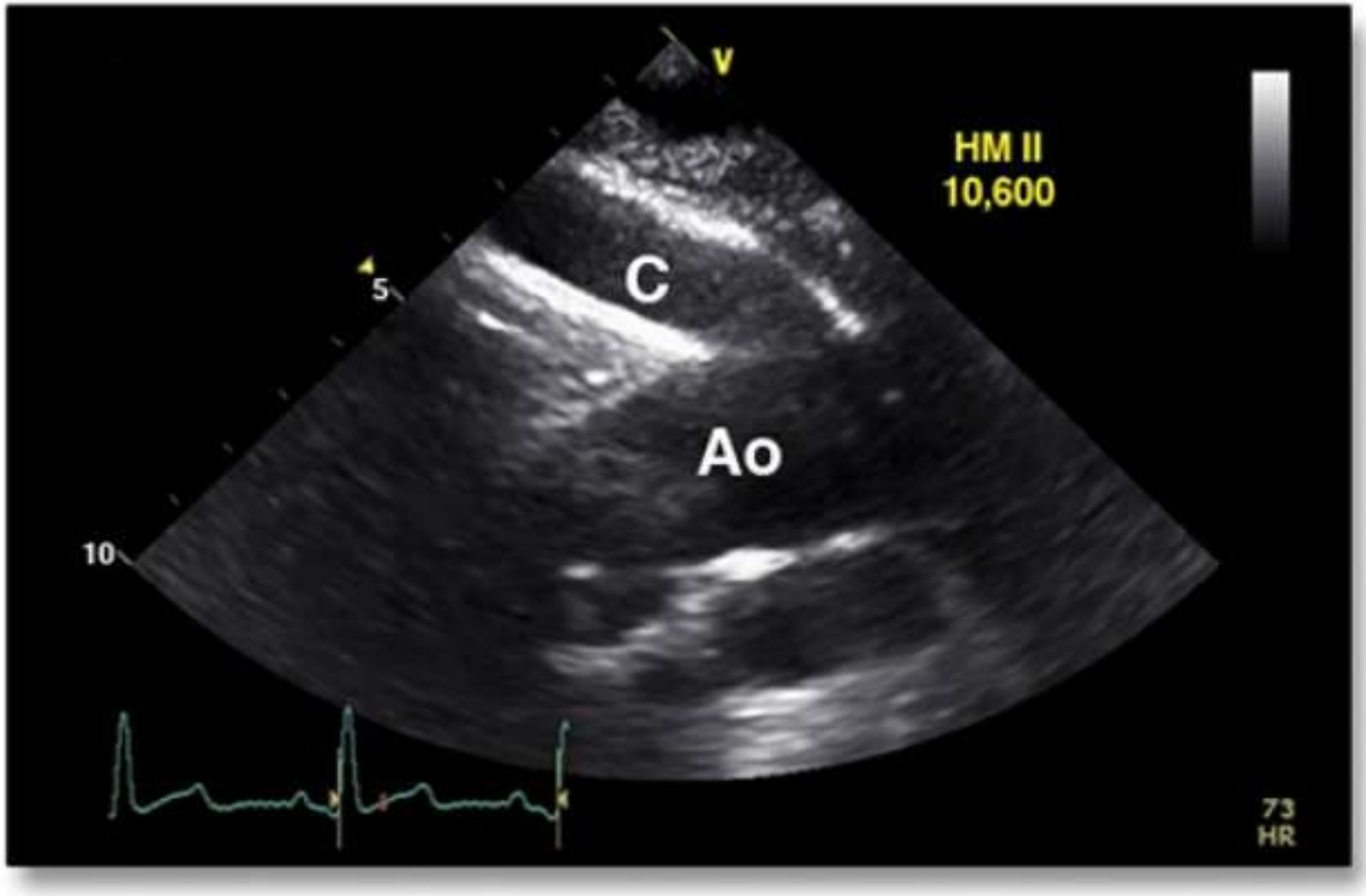


High right parasternal window

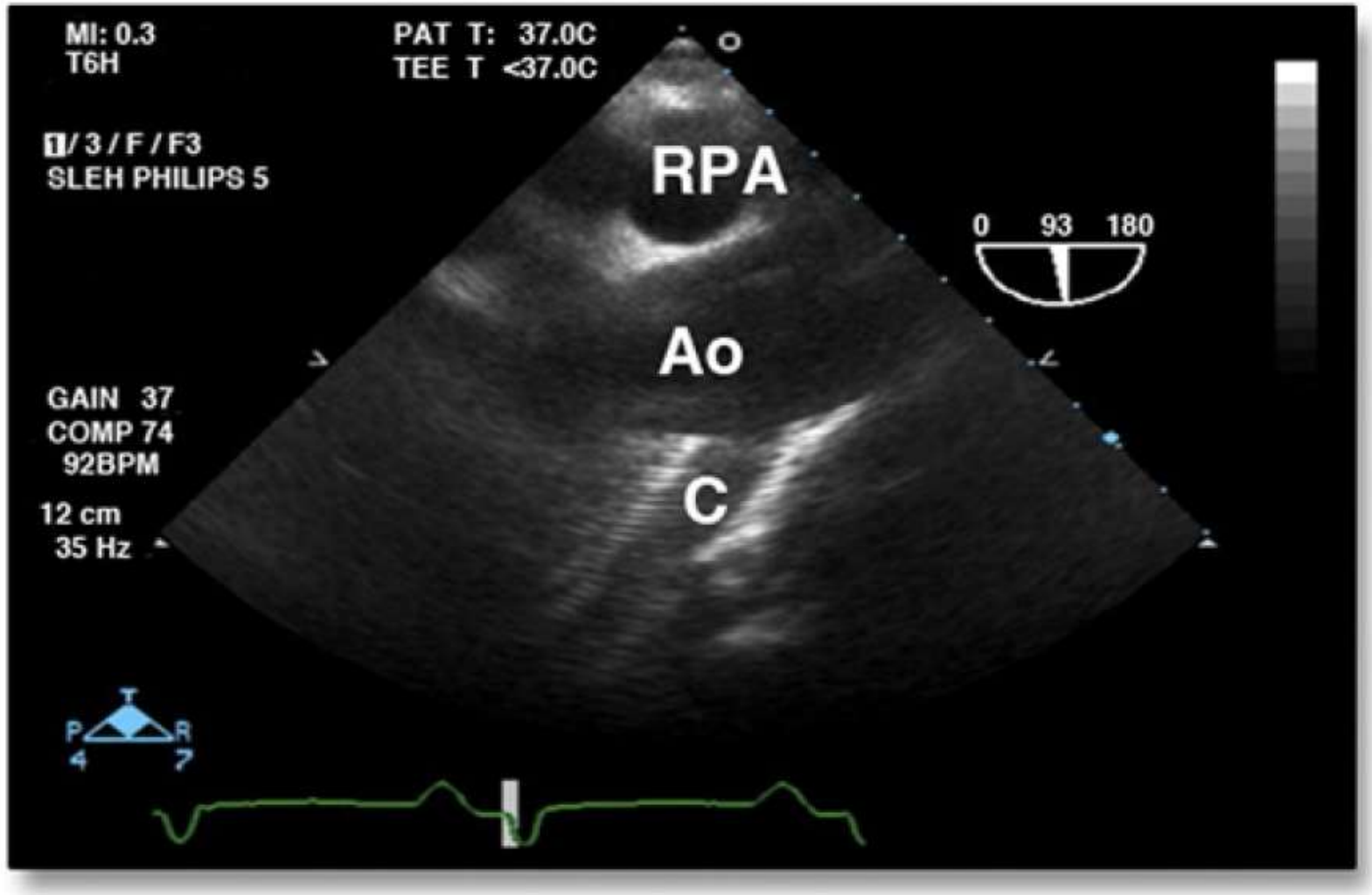


High right parasternal window

Transthoracic echo using the low right parasternal view

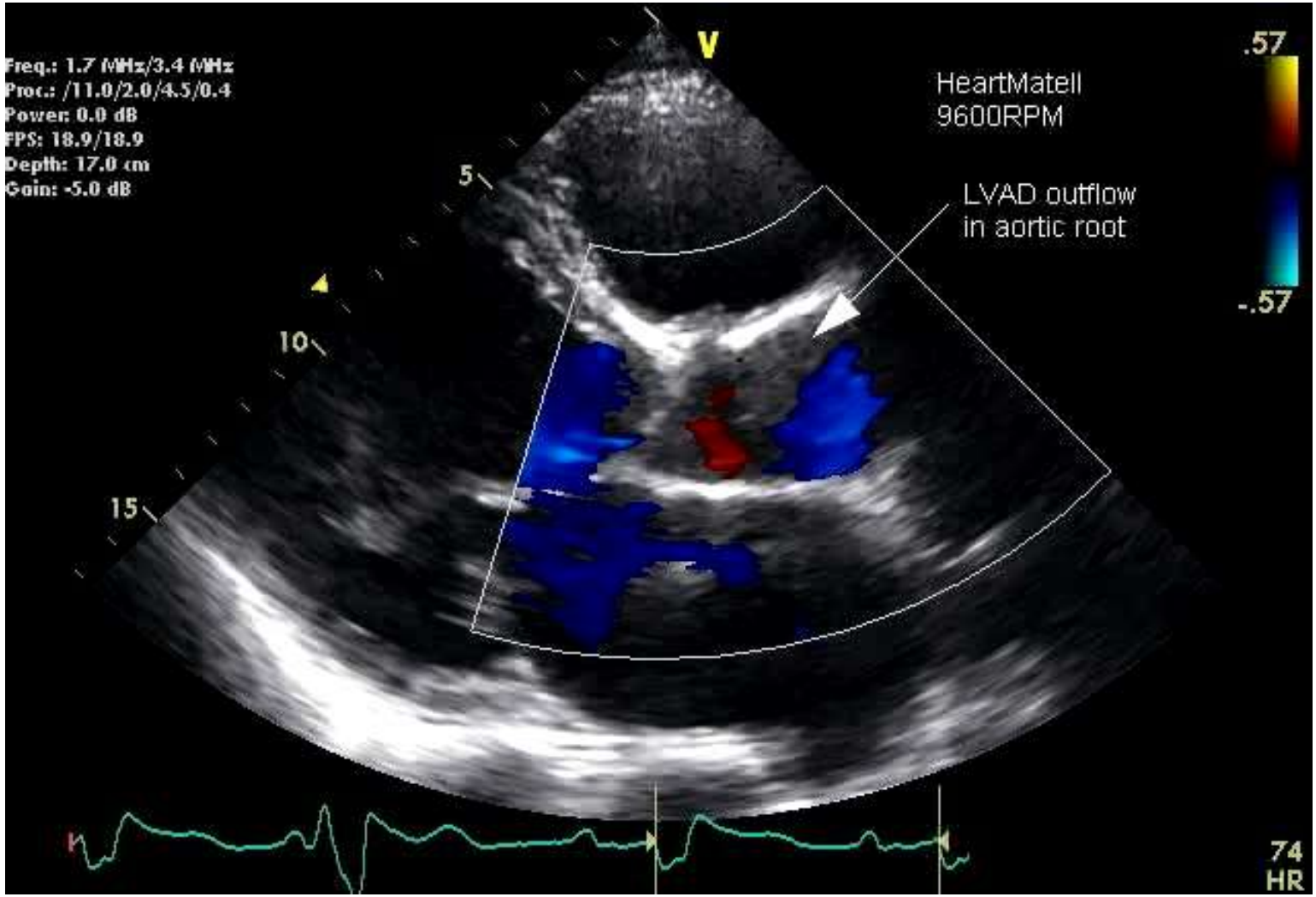


Transesophageal echo at the level of the right pulmonary artery to visualize the outflow cannula



Valvular Assessment With LVAD Support

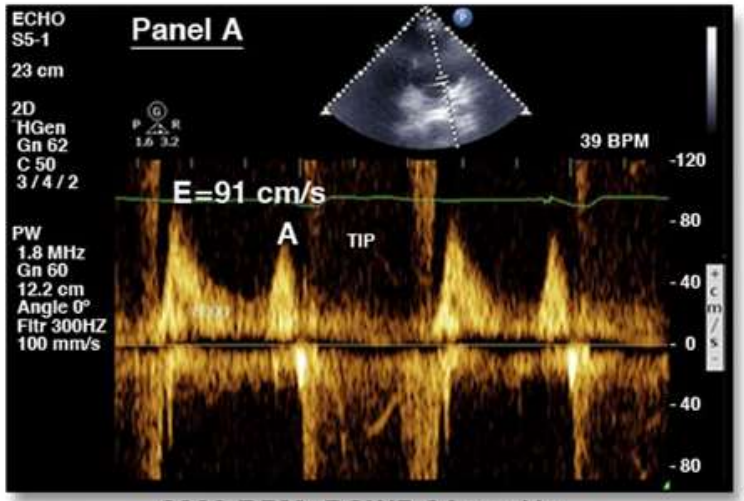
Mitral Regurgitation



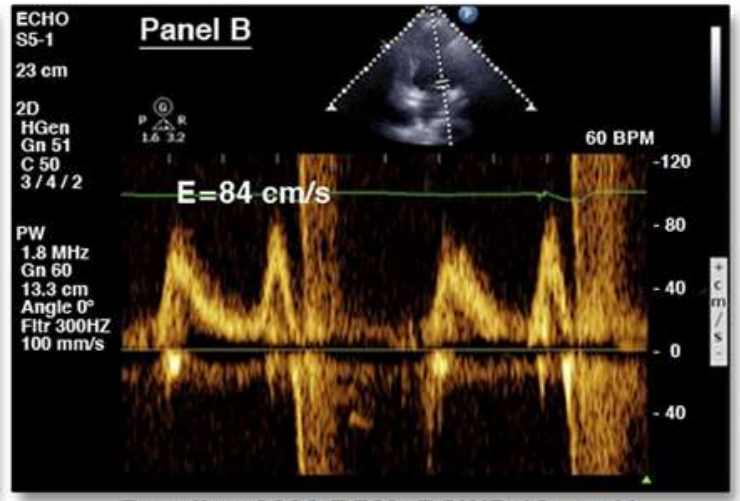
Mitral Valve

- Mitral regurgitation often significantly reduced after LVAD placement
- Secondary to
  - Reduction in LV size
  - Reduction in Filling pressures
  - and improved coaptation of the MV leaflets
- Persistence of significant MR after continuous LVAD placement may indicate inadequate LV decompression:
  - Changing the pump speed setting with real-time echo imaging can be used to evaluate the effect of various pump speeds on LV dimensions, MV inflow parameters, and severity of MR

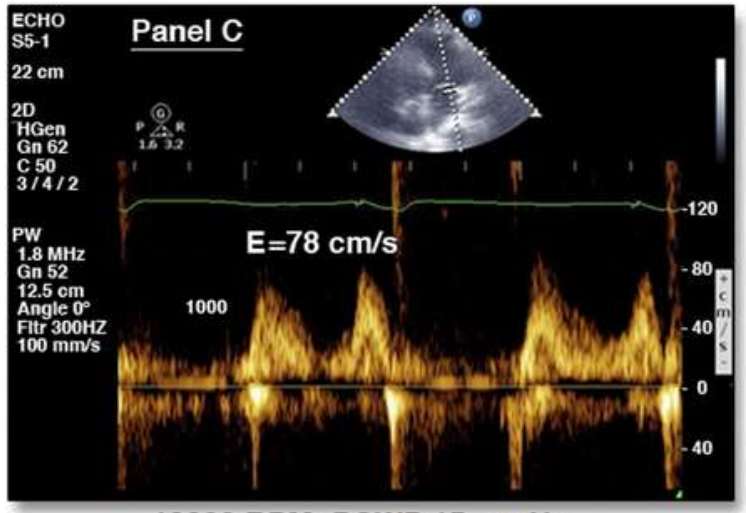
Mitral Valve Inflow Doppler Pattern at Various Continuous-Flow LVAD Pump Speeds



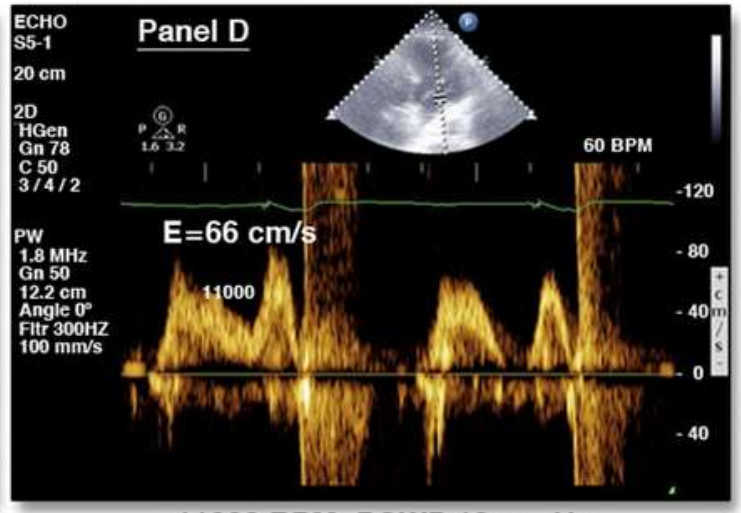
8000 RPM; PCWP 24 mmHg



Baseline 9000 RPM; PCWP 18 mmHg



10000 RPM; PCWP 15 mmHg



11000 RPM; PCWP 13 mmHg

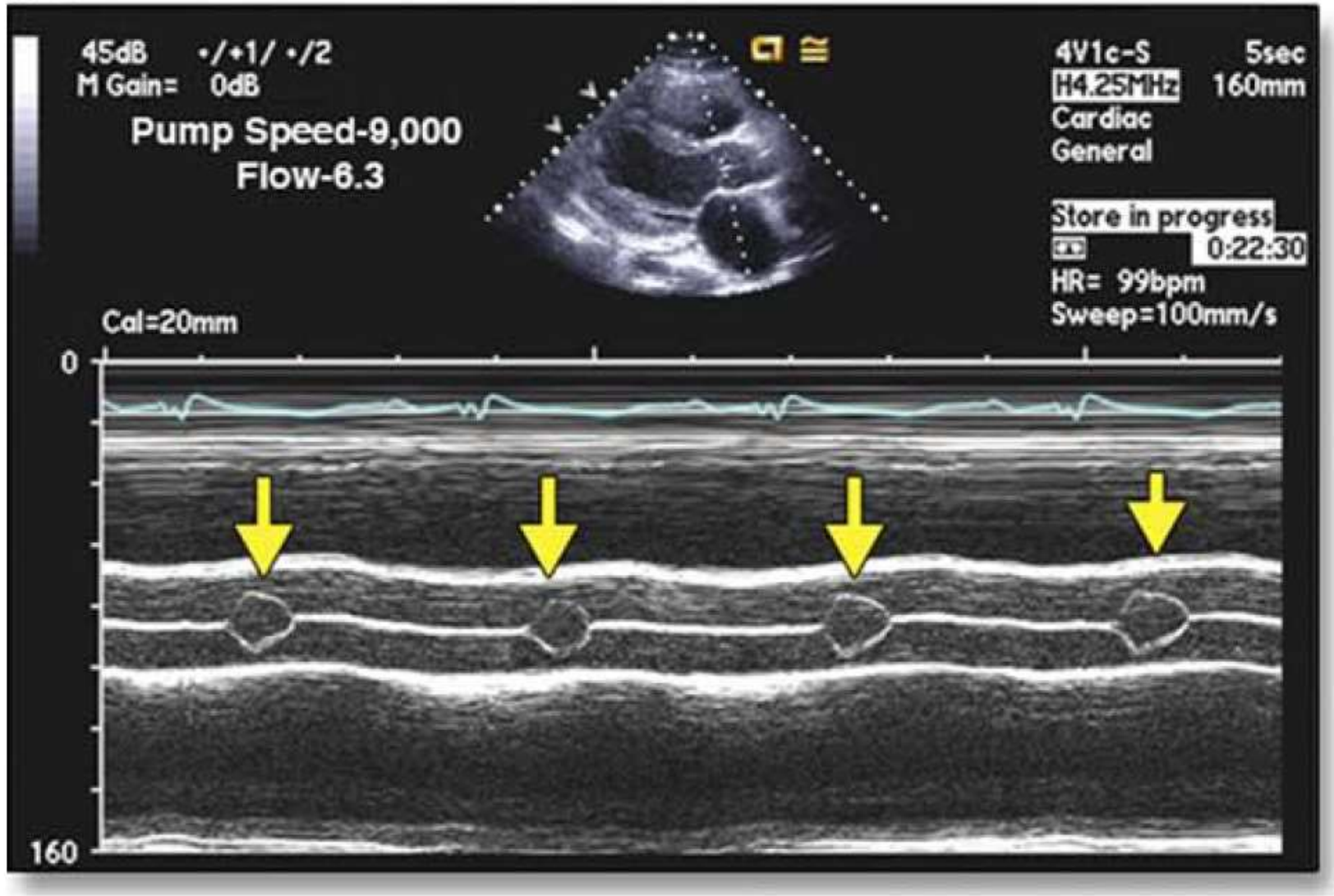
Tricupsid Valve

- With continuous-flow pumps, higher pump speed settings can potentially increase the severity of TR because of
  - Increased RV preload and
  - Distortion of the tricuspid valve annulus (shifting of the IV septum and subsequent papillary muscle distortion).
- Realtime echo can be used to adjust the pump speed setting (i.e., decrease the RPMs)
  - To produce a more rightward shift of the interventricular septum and a decrease in the severity of TR

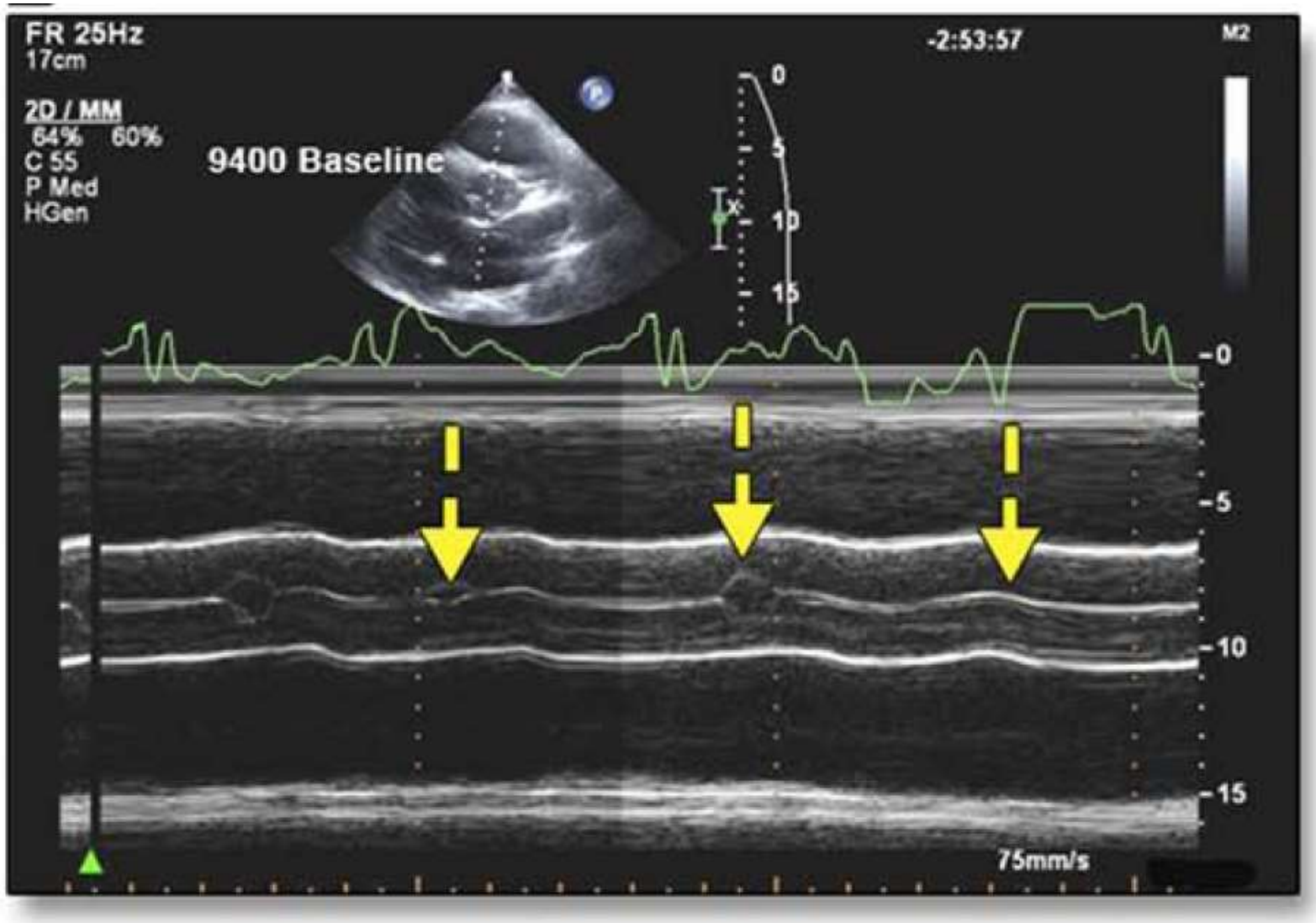
Aortic Valve opening

- Aortic valve opening during continuous-flow LVAD support depends on the balance between
  - Native LV systolic function,
  - the LVAD pump speed, the degree of LV unloading and preload and afterload pressures
- Clinical implications of reduced AV pulsatility/persistent AV closure:
  - Aortic regurgitation worsens and seen throughout the cardiac cycle;
  - Complete AV closure associated with thrombus in the aortic root;
  - Complete AV closure at low pump settings may indicate a high level of LVAD dependency

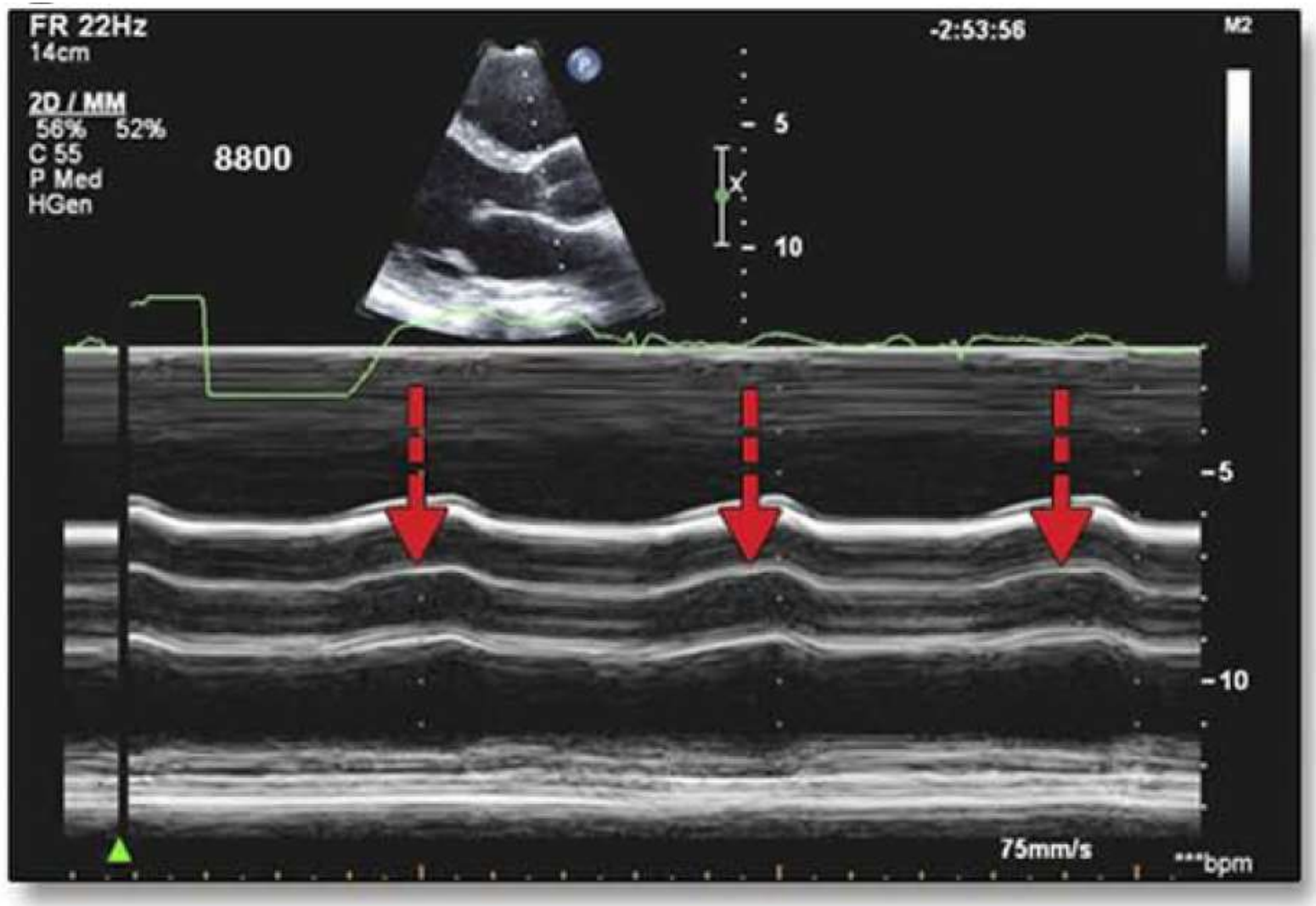
HeartMate II, Various AV op



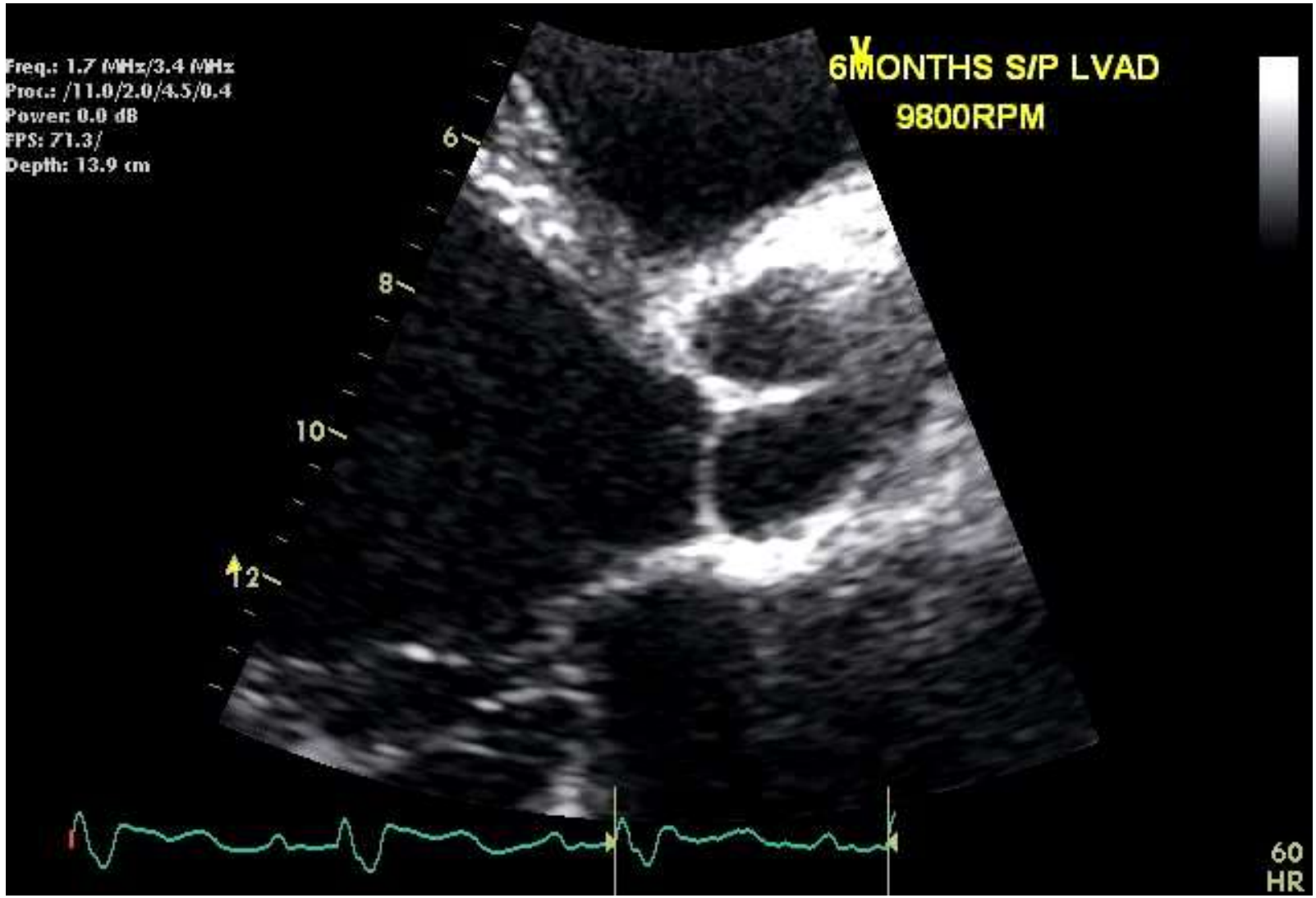
HeartMate II, Various AV op



HeartMate II, Various AV op



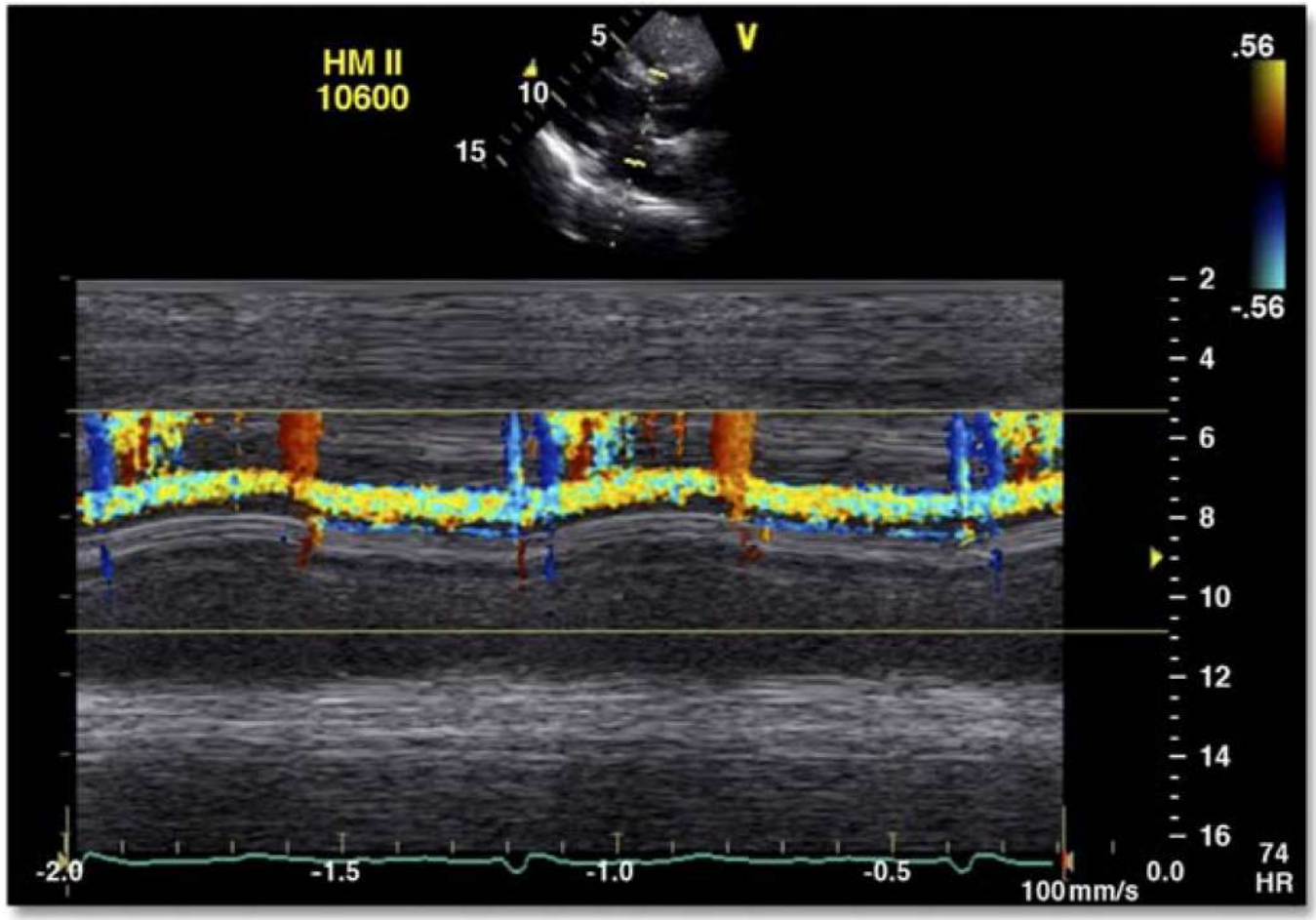
HeartMate II, Various AV op



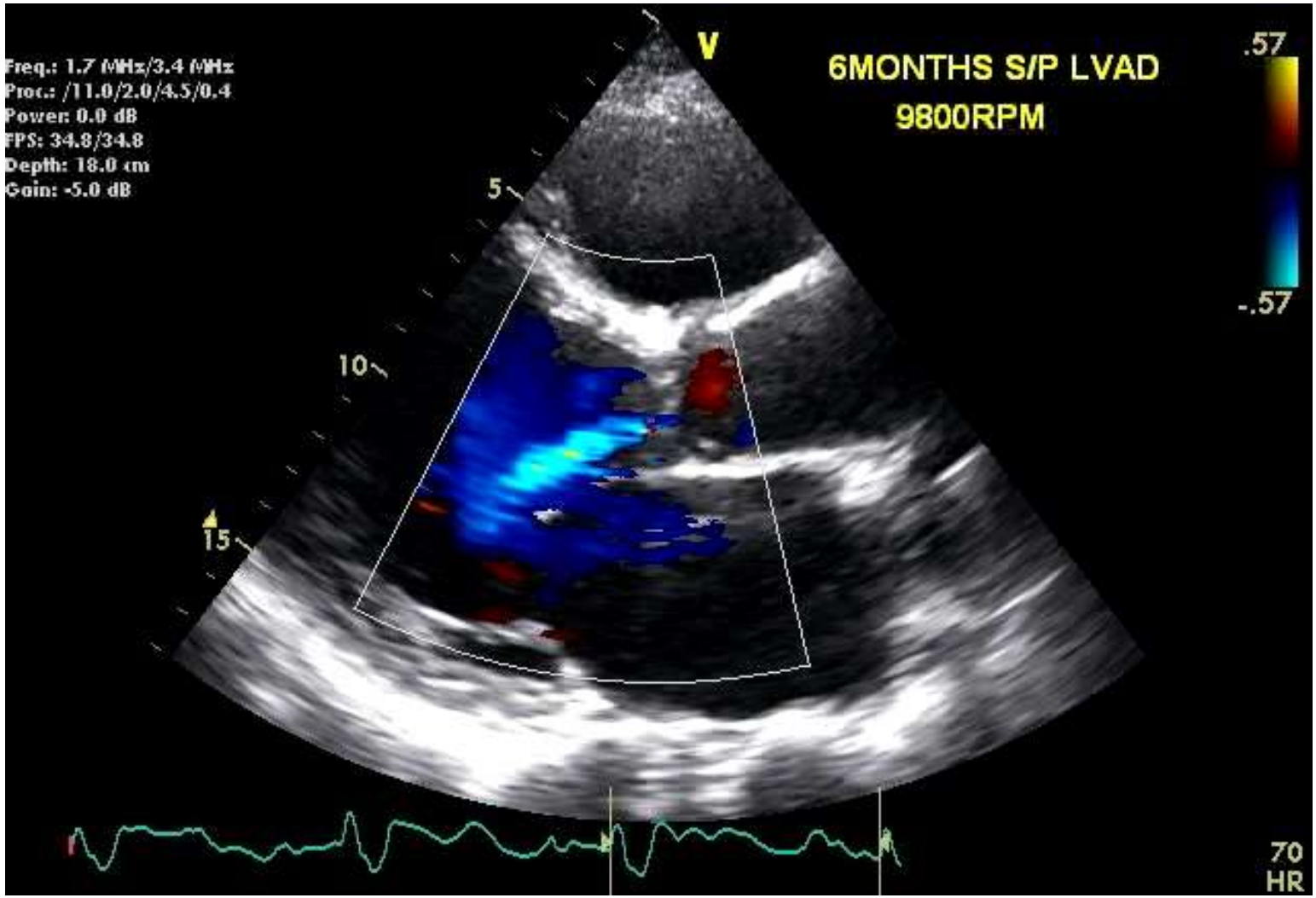
Aortic Valve regurgitation

- The risk of developing AR is increased during LVAD support because the continuously closed AV is exposed to a higher pressure gradient
- The incidence of AR after LVAD placement in patients without previous aortic insufficiency is low however
- Clinically significant AR suspicion can be confirmed by
  - Reduced flows across the RV outflow tract
  - Despite normal inflow/outflow cannula Doppler profiles
  - Significant regurgitation parameters by echo color Doppler

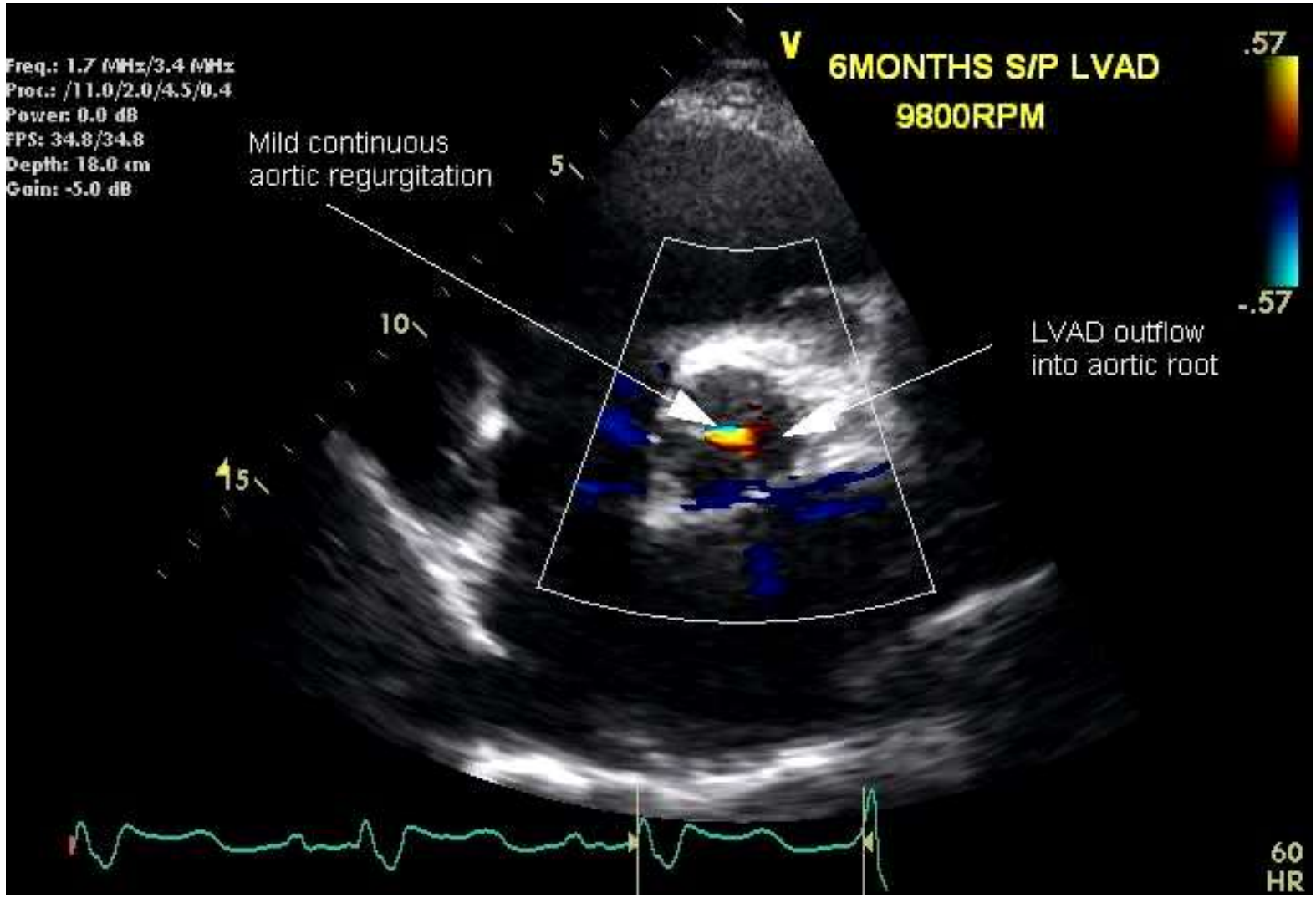
LVAD-Associated Continuous Aortic Regurgitation



LVAD-Associated Continuous Aortic Regurgitation



LVAD-Associated Continuous Aortic Regurgitation



Abnormal LVAD cannula Doppler findings

Abnormal LVAD cannula Doppler findings

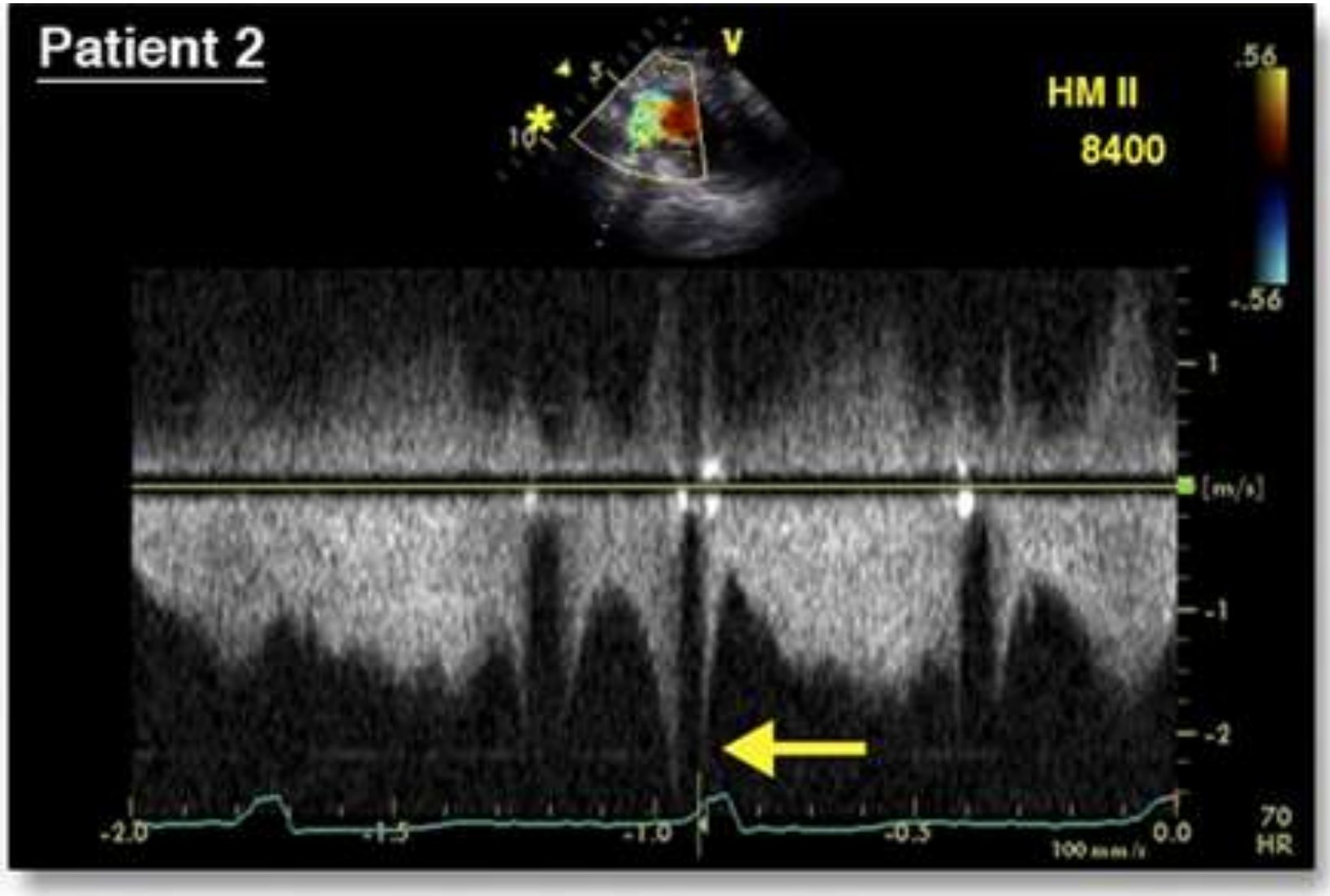
- LVAD dysfunction may be indicated by built-in alarm systems
- Sense low pump rates caused by various mechanisms of cannula obstruction
  - Cannula thrombus
  - Partial inlet occlusion by adjacent myocardial trabeculations
  - Cannula angulation into the myocardium or
  - Other cannula malposition caused by LV underfilling, and inlet or outlet kinking

Abnormal LVAD cannula Doppler findings

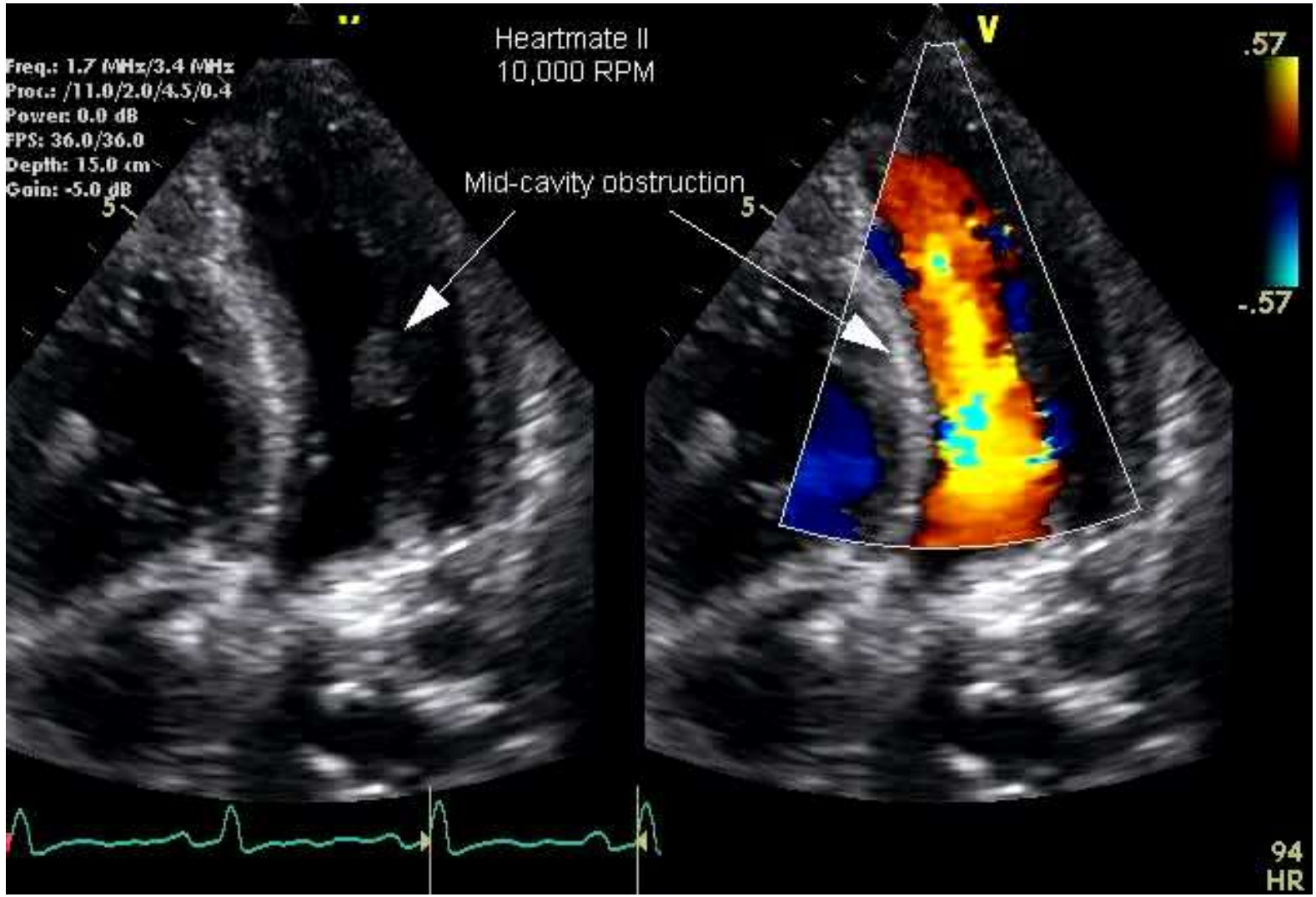
- For continuous-flow pumps, a peak inflow velocity >2 m/s with associated turbulent flow may represent
  - Inflow cannula obstruction, malposition, OR
  - Improved LV systolic function
- Because continuous flow LVADs are valveless, diastolic regurgitation through the outflow graft from the aorta into the LV secondary to pump failure is associated with an abnormal retrograde apical flow pattern

HeartMate II dynamic inflow cannula obstruction due to overly decompressed left ventricle with septum abutting device inflow

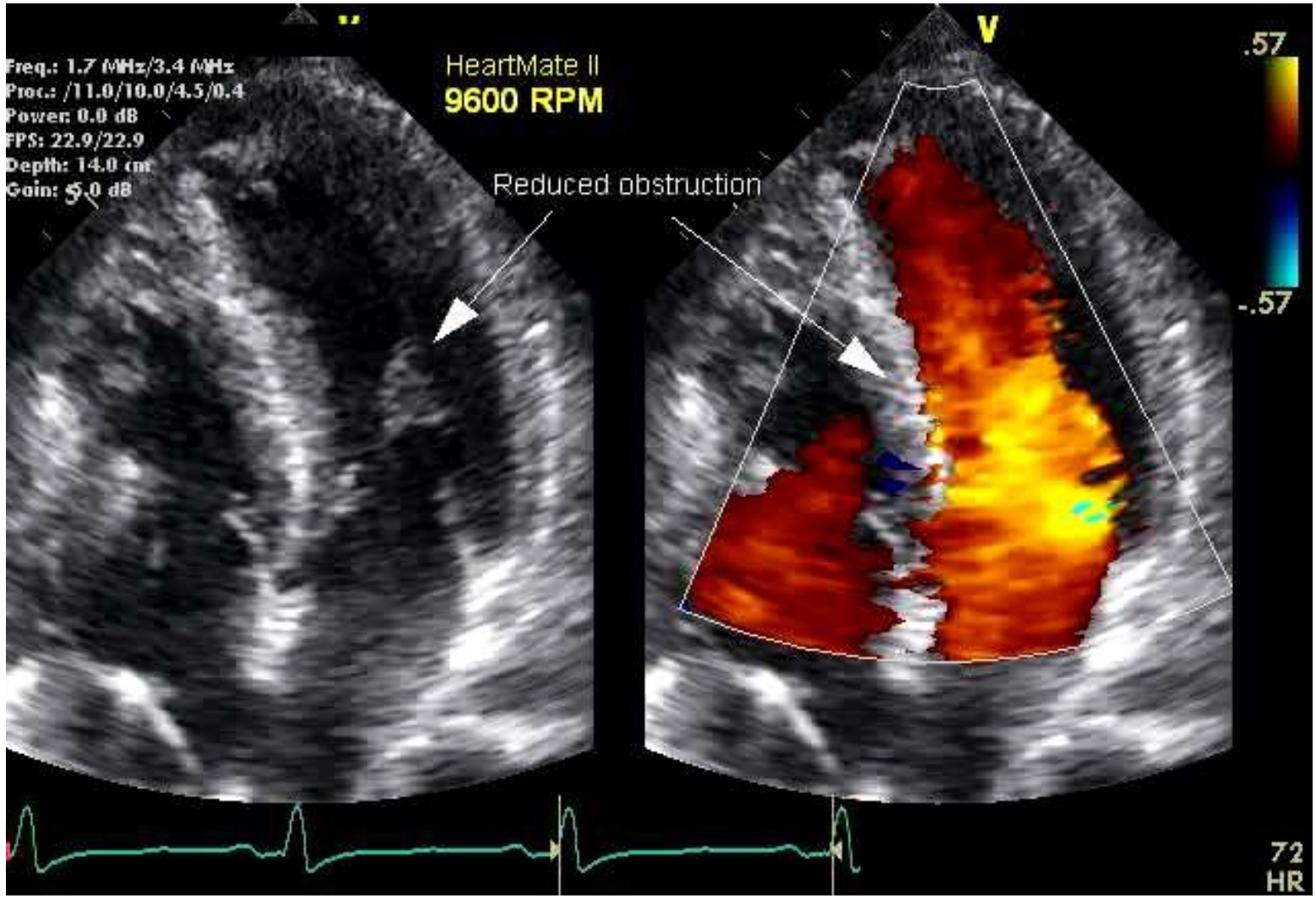
Modified apical parasternal long-axis view with turbulent flow (yellow *) and continuous wave Doppler peak inflow velocity intermittently approaching 2 m/s



HeartMate II dynamic inflow cannula obstruction due to inlet cannula obtruction from trabeculation or papillary muscle

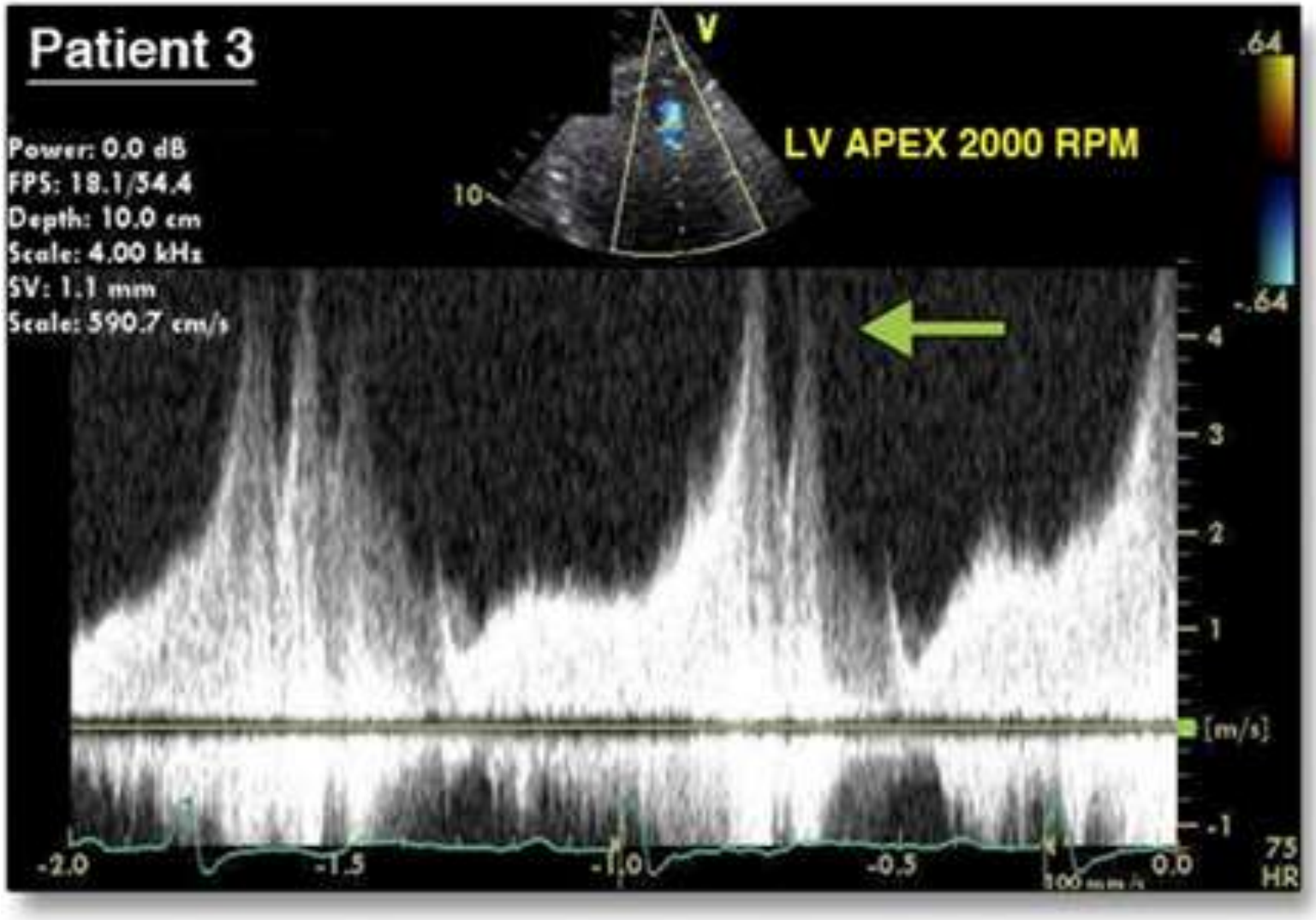


HeartMate II dynamic inflow cannula obstruction due to inlet cannula obtruction
Reduction of HM II RPM



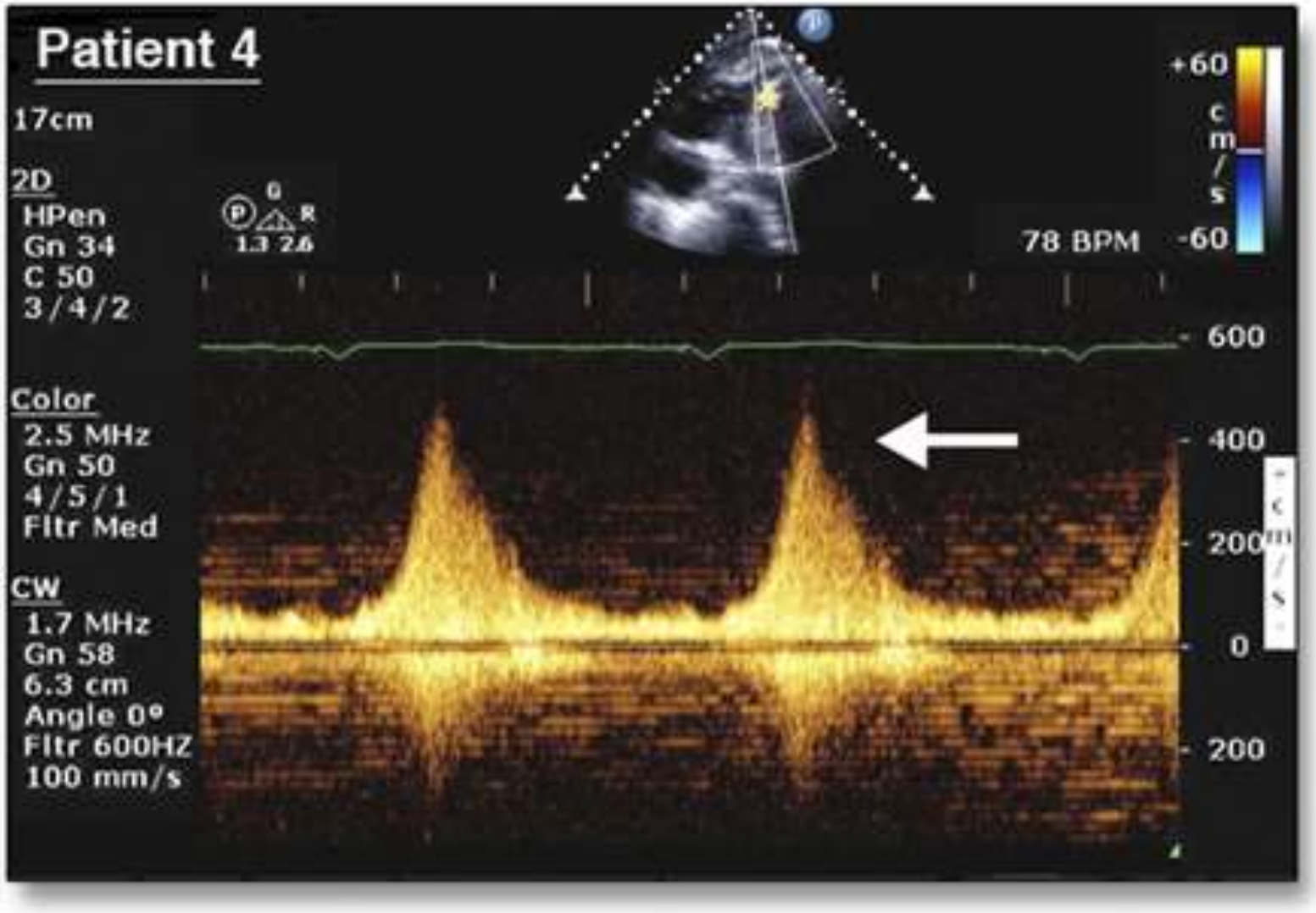
VentrAssist (Ventracor) inflow cannula obstruction from malposition

Apical view with increased continuous wave Doppler peak inflow velocities 4 m/s (green arrow)



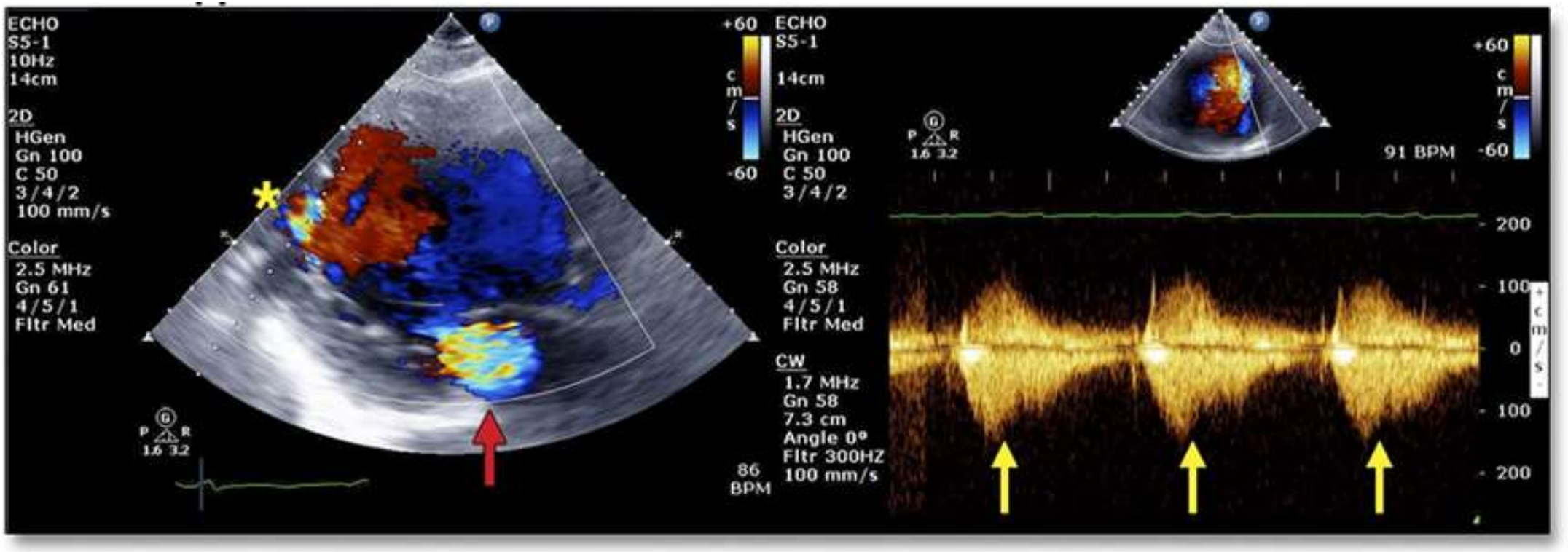
HeartMate II hyperdynamic left ventricular ejection into the device after myocardial recovery

Off-axis apical view with continuous wave Doppler peak inflow velocity >4 m/s



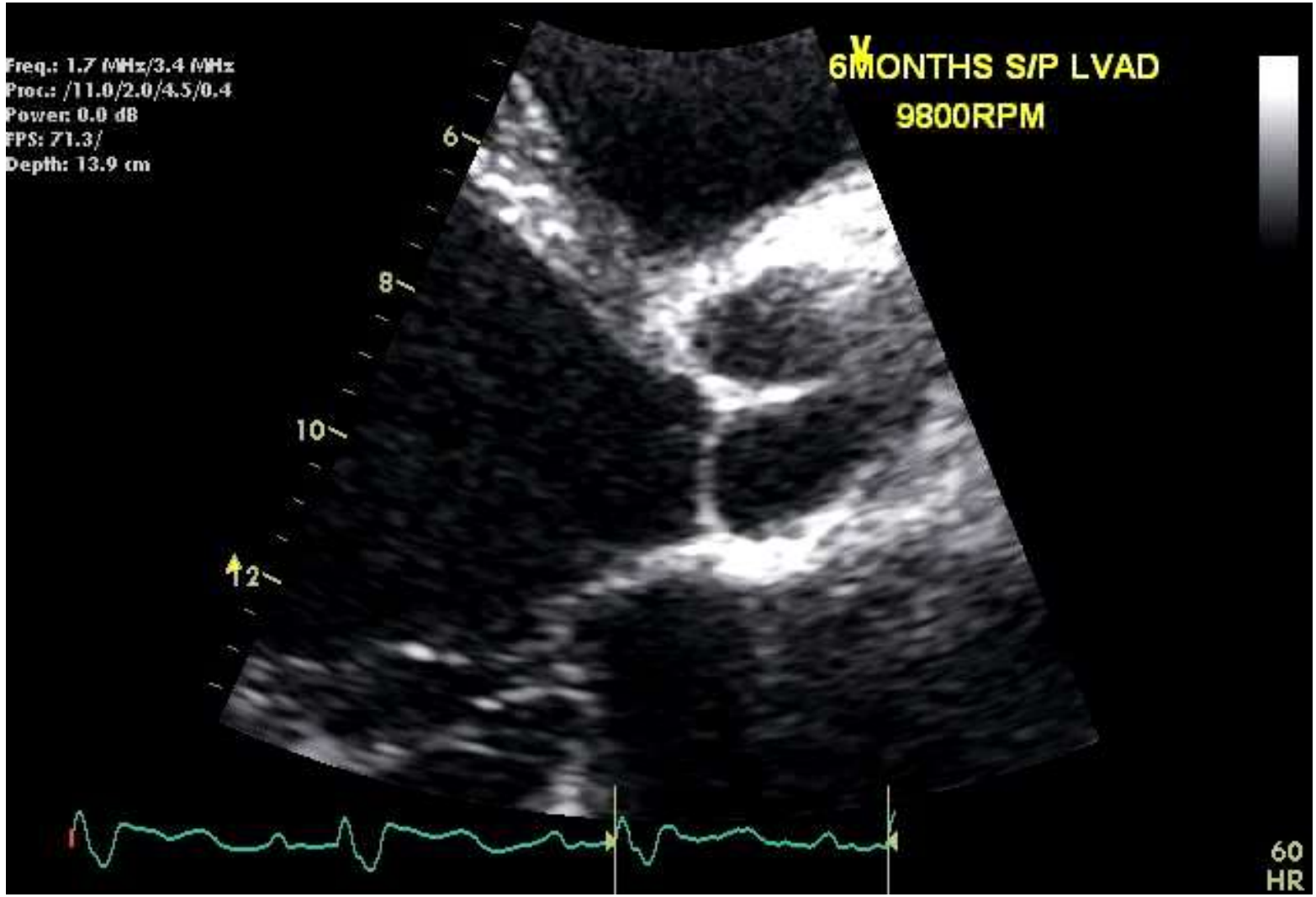
Continous LVAD mechanical failure:

VentrAssist (Ventracor) pump failure with regurgitant inflow (yellow *), increased mitral regurgitation (red arrow), and reversal of apical inflow (yellow arrows) using spectral Doppler standard apical view

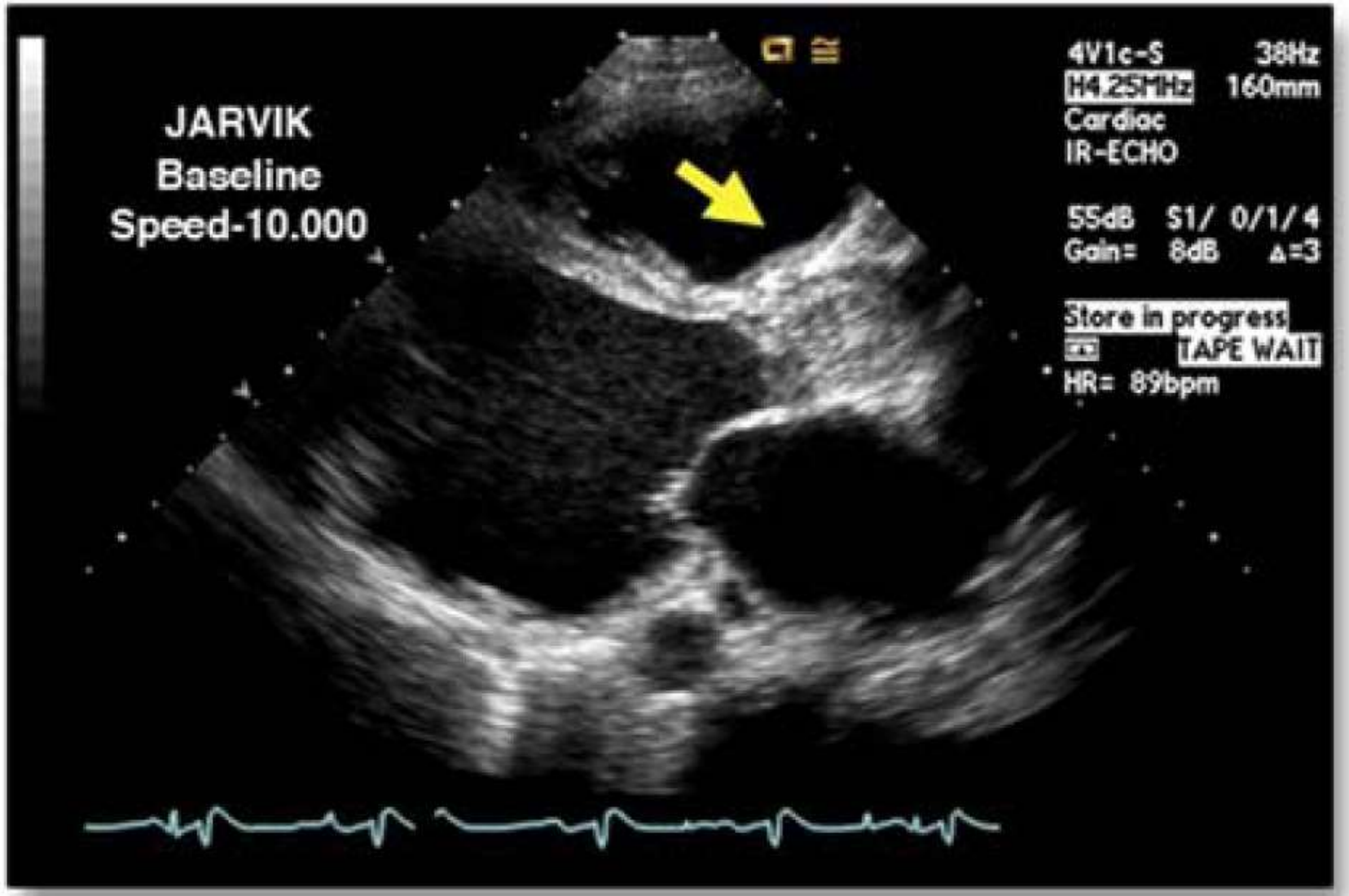


Other LVAD dysfunction/related complications

AV commissural fusion



Aortic root thrombus



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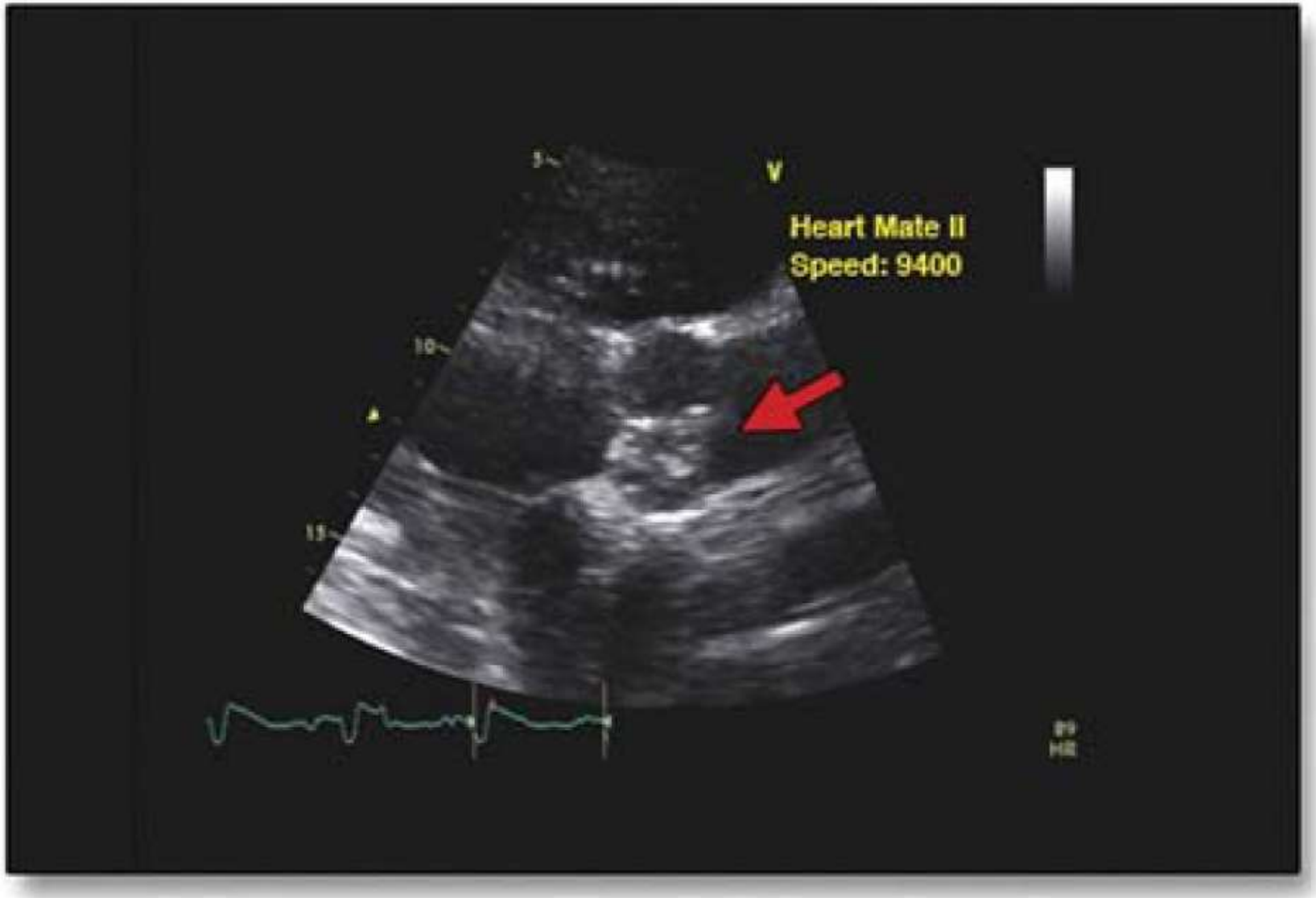
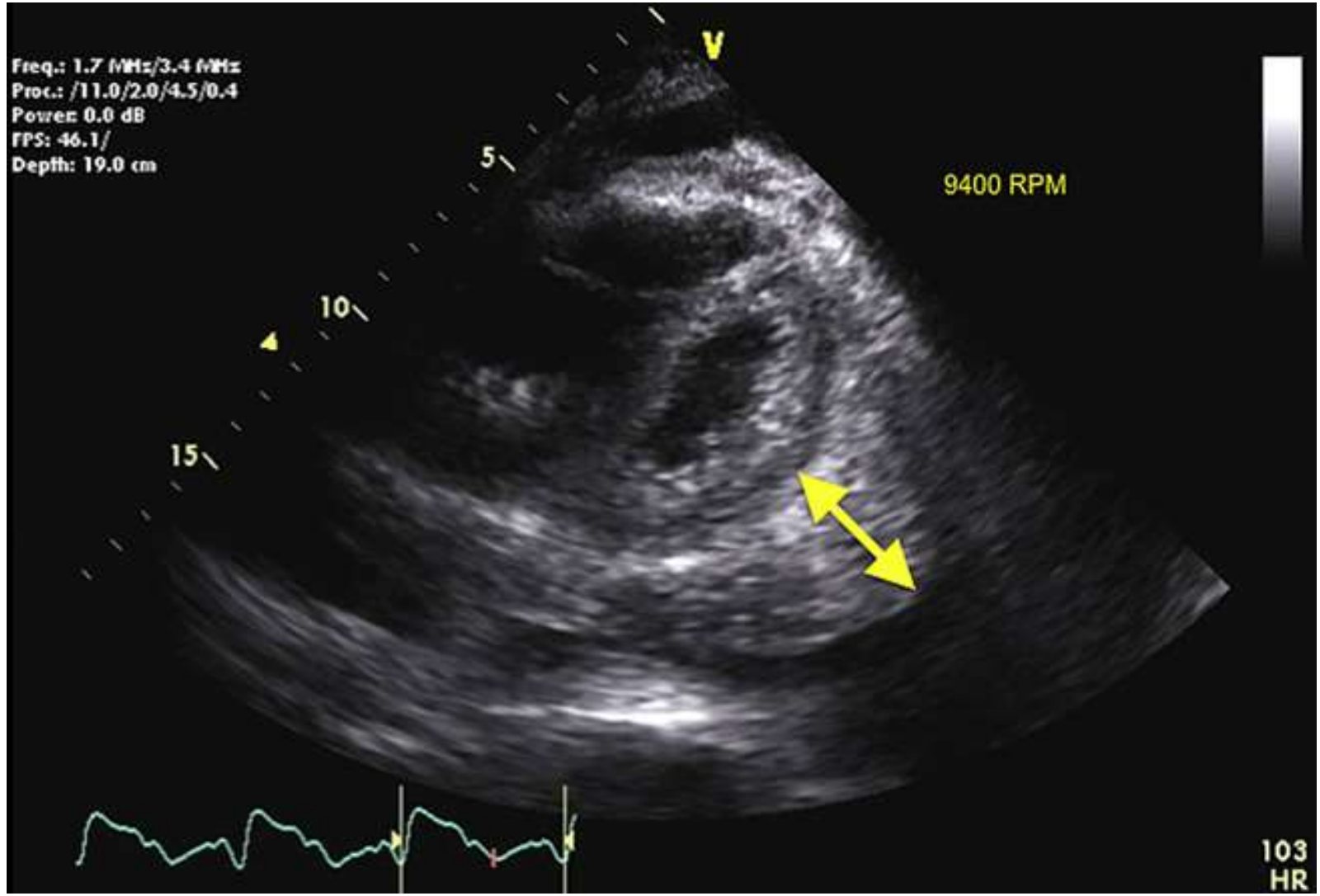
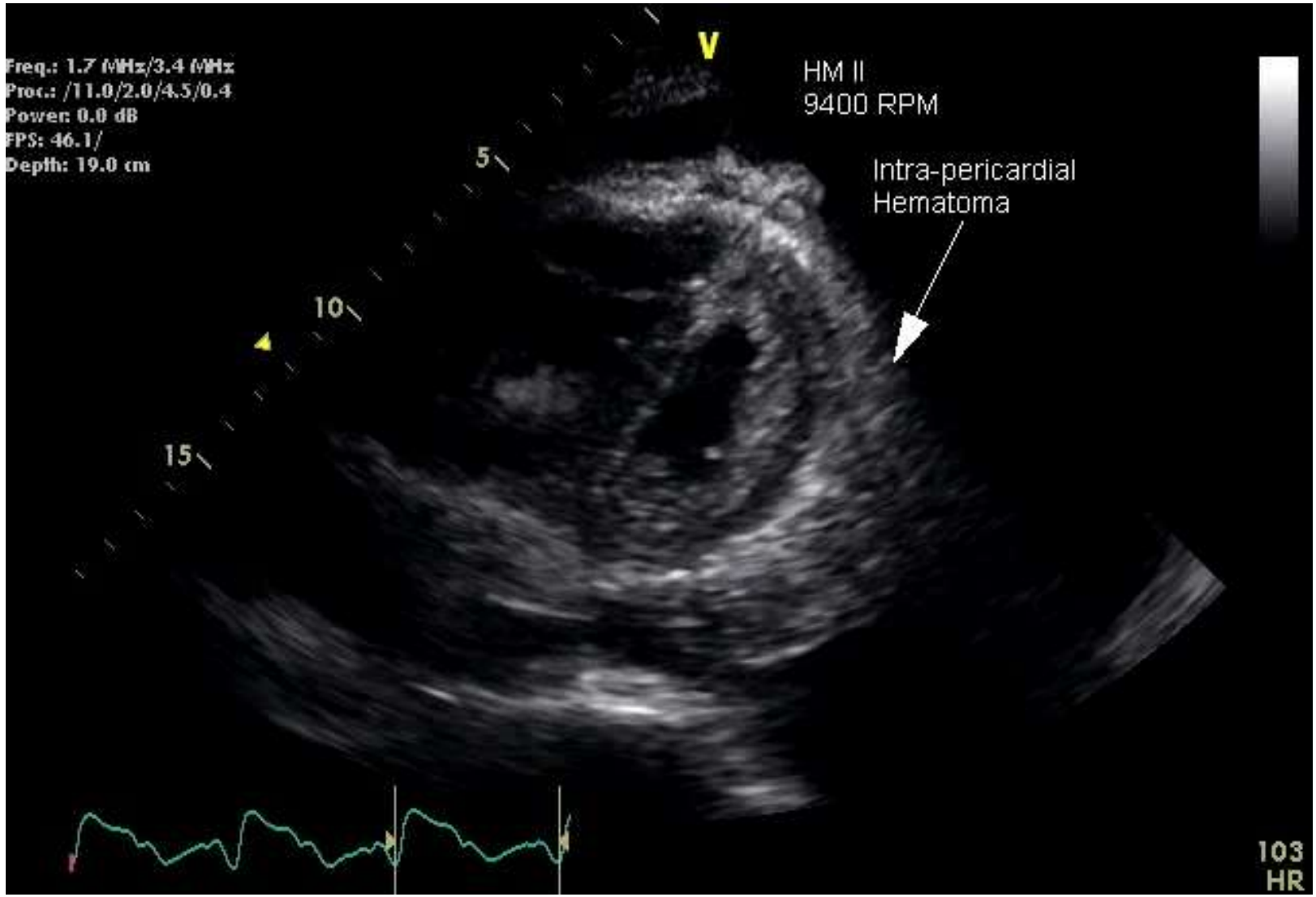
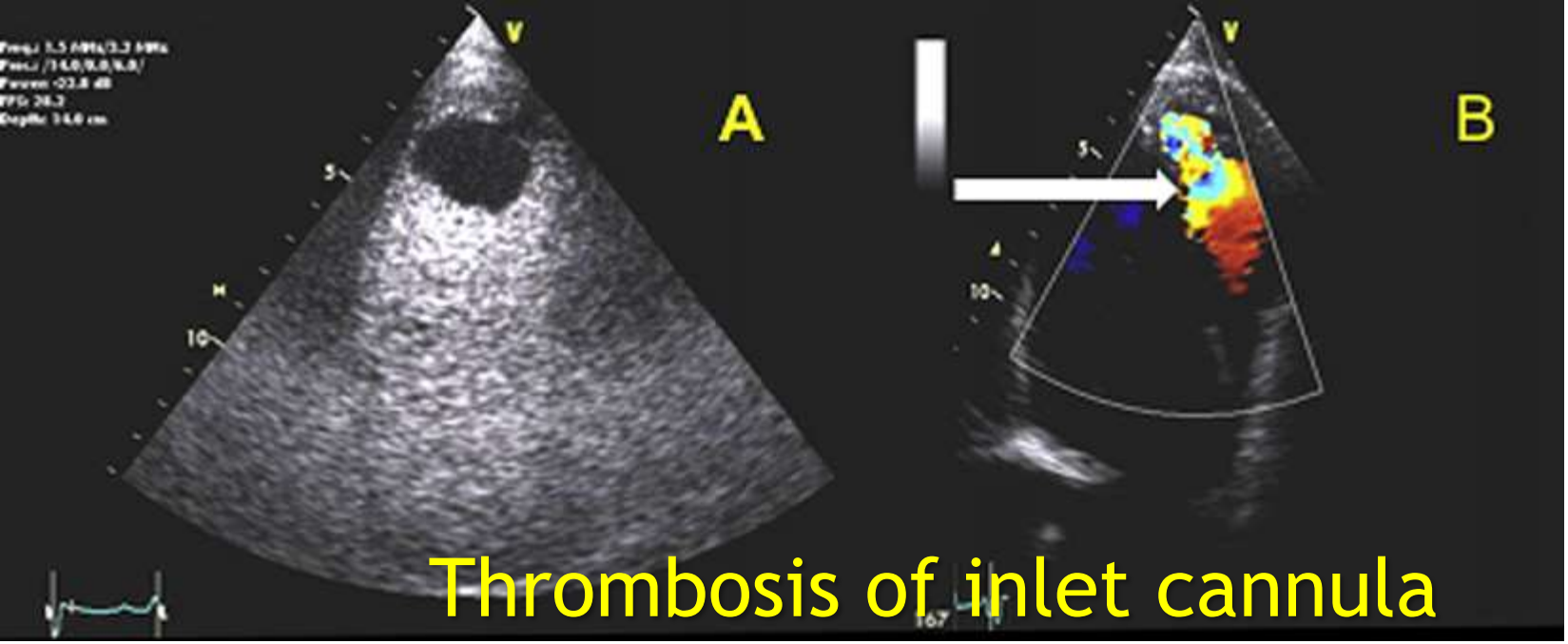


Pericardial hematoma



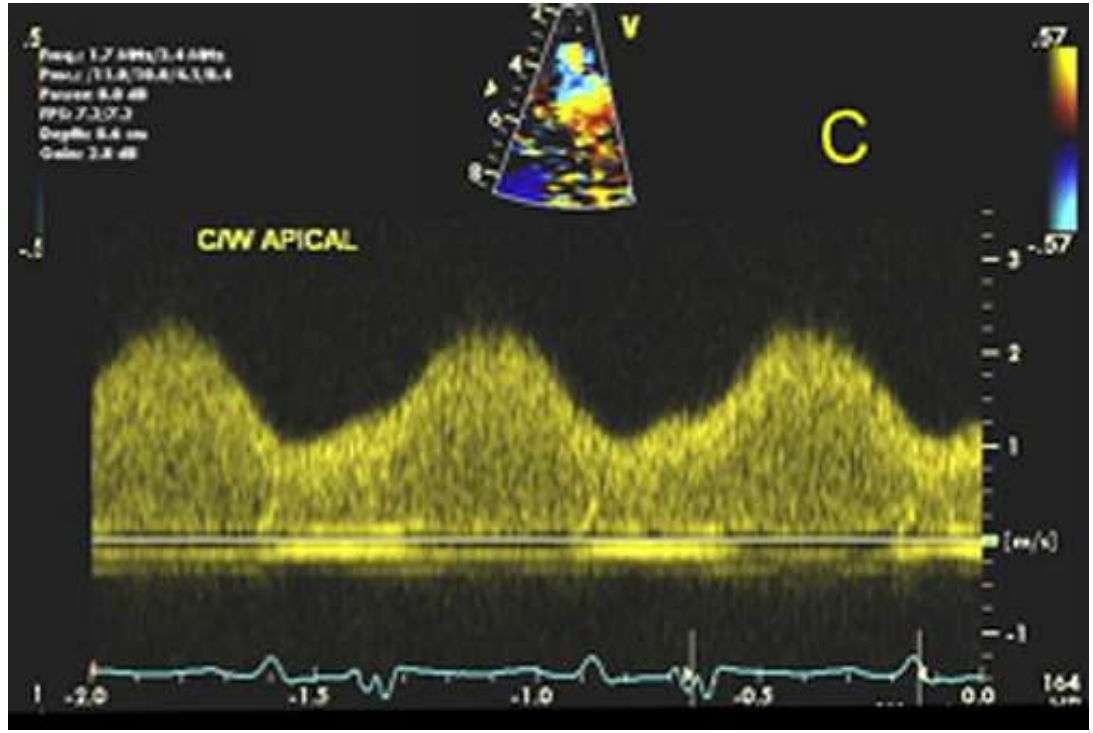
Pericardial hematoma



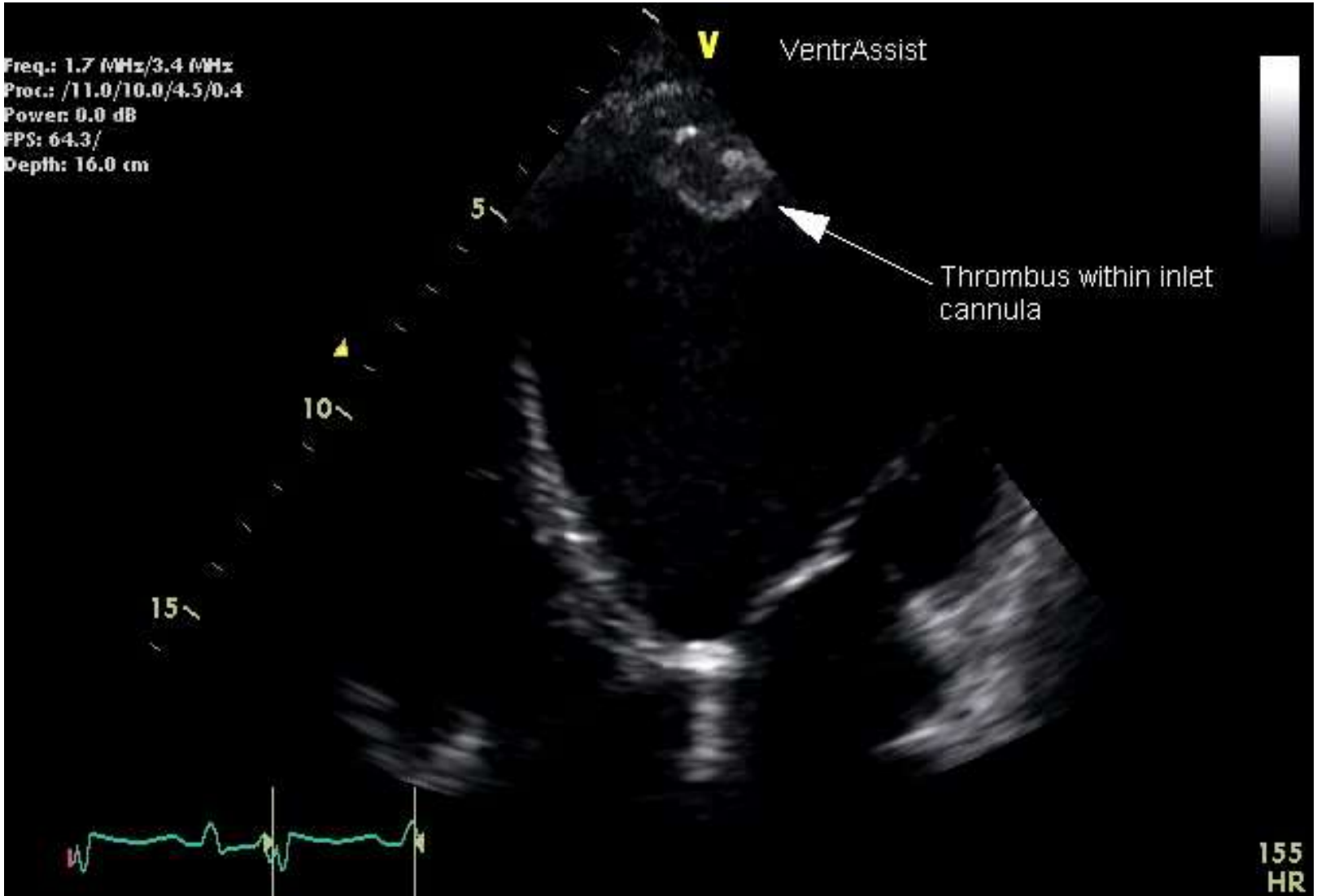


Thrombosis of inlet cannula

Obstruction of LVAD inflow cannula with thrombus seen in apical four-chamber view with contrast enhancement (A) causing turbulence and flow convergence (arrow) at the site of obstruction (B), with resultant markedly elevated peak velocity (C)



Thrombosis of inlet cannula



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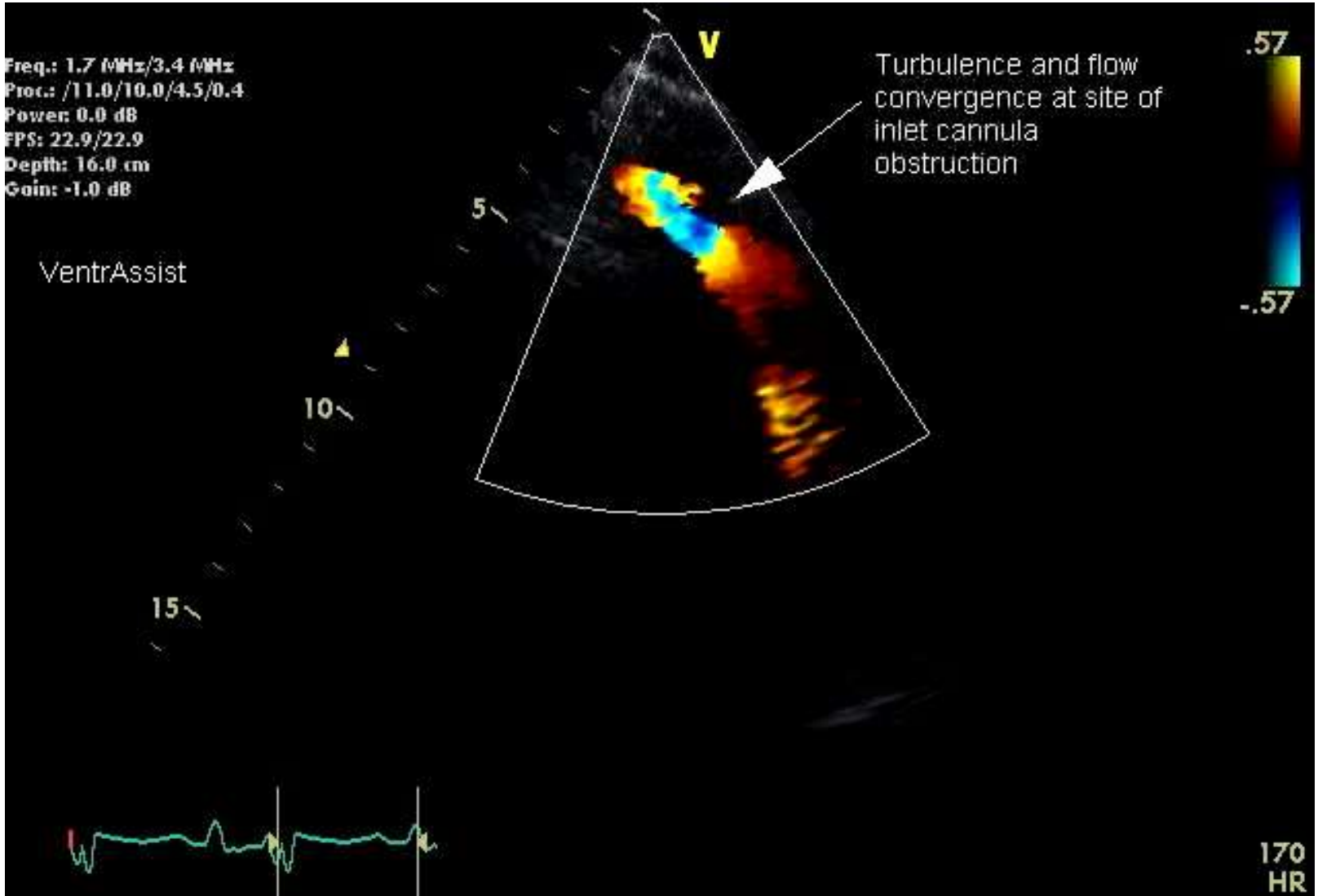
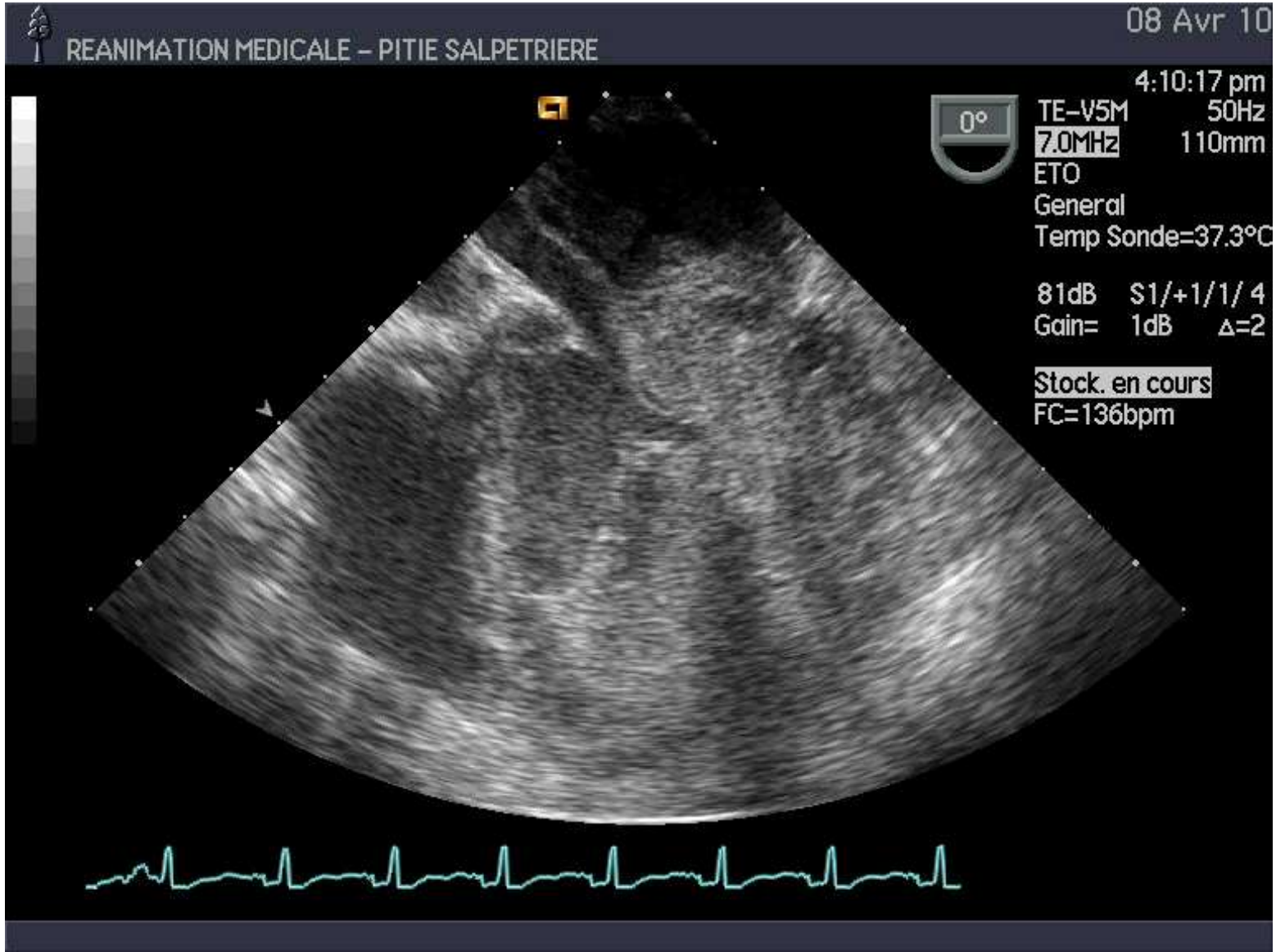


HM II, LV Thrombosis



Conclusion

- ECHO is fundamental…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