Echo Assessment of Left Ventricular Assist Devices

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ASE American Society of Echocardiography

- I have No conflict of interests to disclose

Acknowledgement: Dr Rachel Marcus

Outline

- Indications for implant
- Available devices
- Role of Echo during implant and Follow-up

Heart Failure

- HF affect over 5M patients in the US
- Around 250,000 suffer advanced HF with suboptimal response despite optimal Medical Therapies
- Heart Transplant is only available to 2,500 patients/year.

LVADs

- Long Term Assist Devices:
  - Heartmate II,III
  - Heartware
- Short term support:
  - Impella,
  - Tandem heart,
  - Centrimag,
  - A-V ECMO (Circulatory and Resp support)

Indications for LVAD

- Bridge to transplant
- Bridge to recovery: Acute myocarditis, Tako Tsubo, Post MI Shock.
- Destination Therapy: Refractory HF, not transplant candidate

Anatomy of an LVAD

Inflow Cannula (LV)

Pump:

- Axial magnetic Rotor (HMII)
- Centrifugal propeller (HVAD)

Outflow Cannula (Aorta)

External Battery connected to pump by a cable (drive line).

Heartmate II

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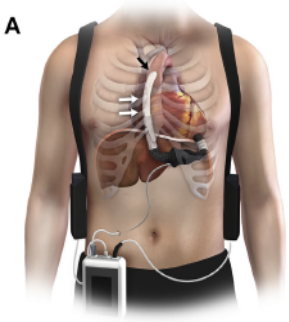


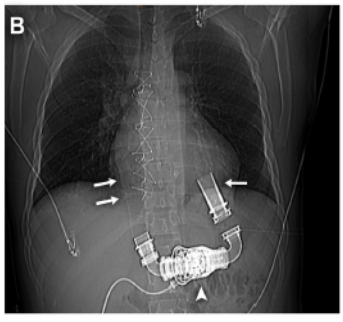
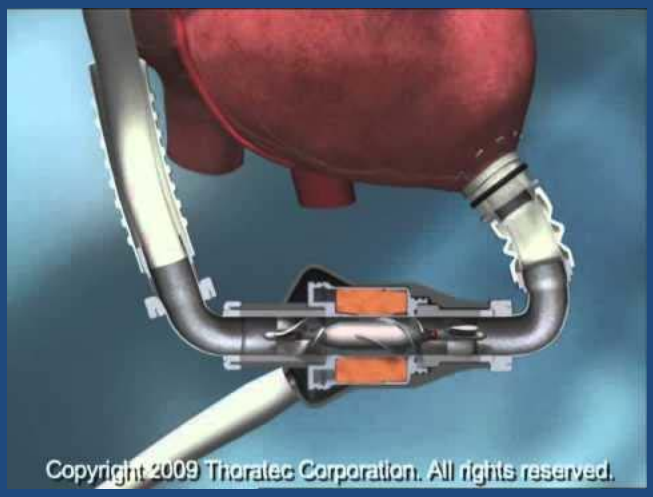


Figure 1 **(A)** Drawing of the HM-II LVAD, showing the subdiaphragmatic pump location, right parasternal outflow-graft position (*double white arrows*), and outflow graft-to-ascending aorta anastomosis (*black arrow*). **(B)** X-ray CT scout image showing the anatomic relationship between the left ventricle and the device inflow cannula (*single arrow*), impeller housing (*arrowhead*), and outflow graft (*double arrows*), controller (*white box*), battery packs (*black boxes*).



Heartware

smaller, longer battery life, less thrombosis

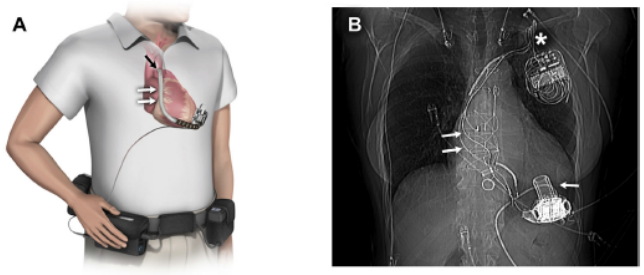
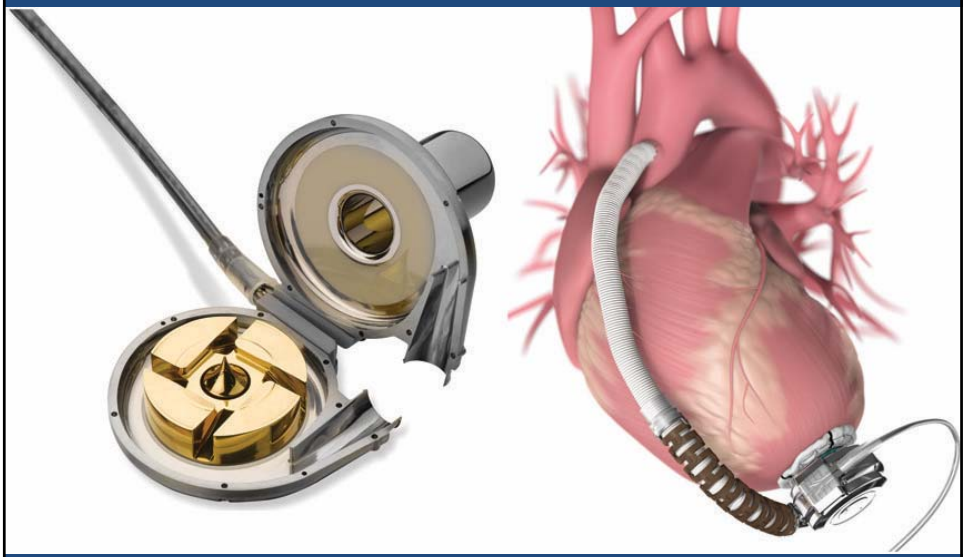


Figure 2 **(A)** Drawing of the HVAD, showing the intrapericardial pump location, right parasternal outflow graft position (*double white arrows*), and outflow graft-to-ascending aorta anastomosis (*black arrow*). (Courtesy of Heartware, Inc.). **(B)** X-ray CT scout image showing the anatomic relationship between the left ventricle and the device inlet cannula with its attached intrapericardial pump (*single arrow*). Although not visible here, the outflow graft would typically be imaged in the right parasternal area (*double arrows*). The asterisk denotes a cardiac implantable electronic device.



The role of Echo

ASE GUIDELINES & STANDARDS

Echocardiography in the Management of Patients with Left Ventricular Assist Devices: Recommendations from the American Society of Echocardiography

Raymond F. Stainback, MD, FASE, Chair, Jerry D. Estep, MD, FASE, Co-Chair, Deborah A. Agler, RCT, RDCS, FASE, Emma J. Birks, MD, PhD, Merri Bremer, RN, RDCS, EdD, FASE, Judy Hung, MD, FASE, James N. Kirkpatrick, MD, FASE, Joseph G. Rogers, MD, and Nishant R. Shah, MD, MSc, *Houston, Texas; Cleveland, Ohio; Louisville, Kentucky; Rochester, Minnesota; Boston, Massachusetts; Philadelphia, Pennsylvania; and Durham, North Carolina*

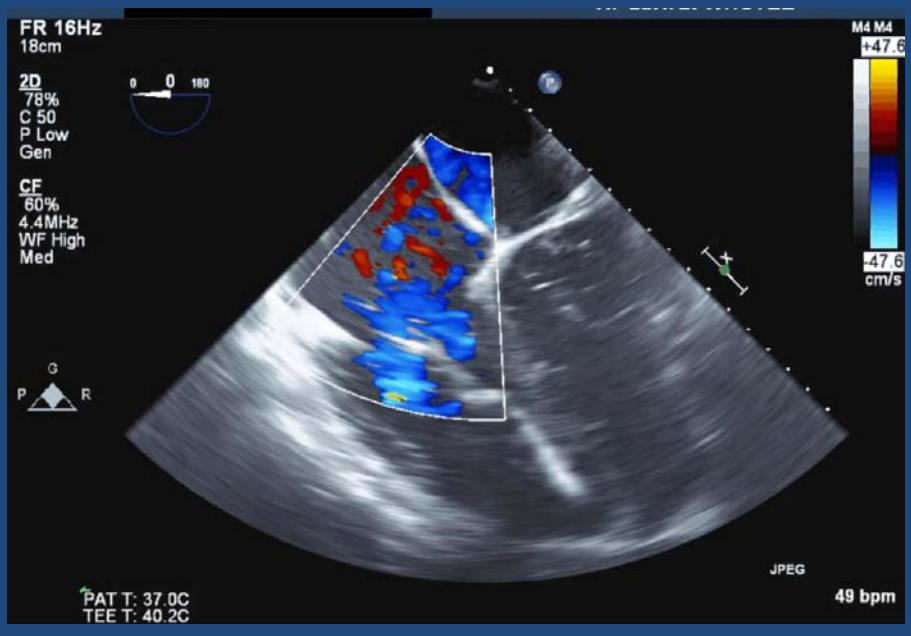
(J Am Soc Echocardiogr 2015;28:853-909.)

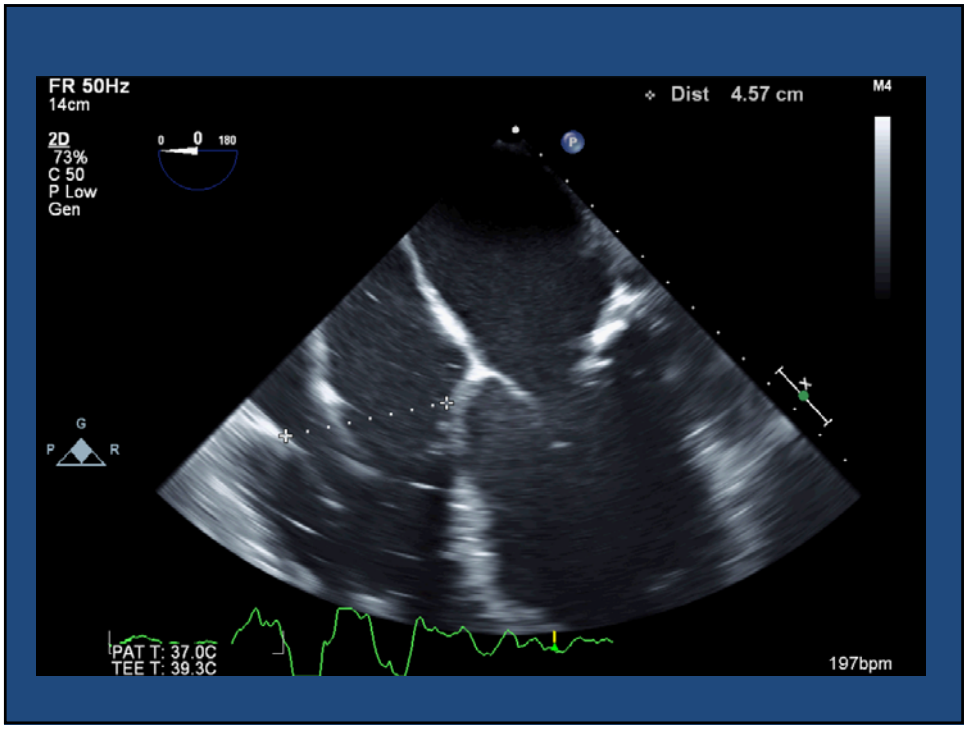
Selecting the right candidate –Red Flags

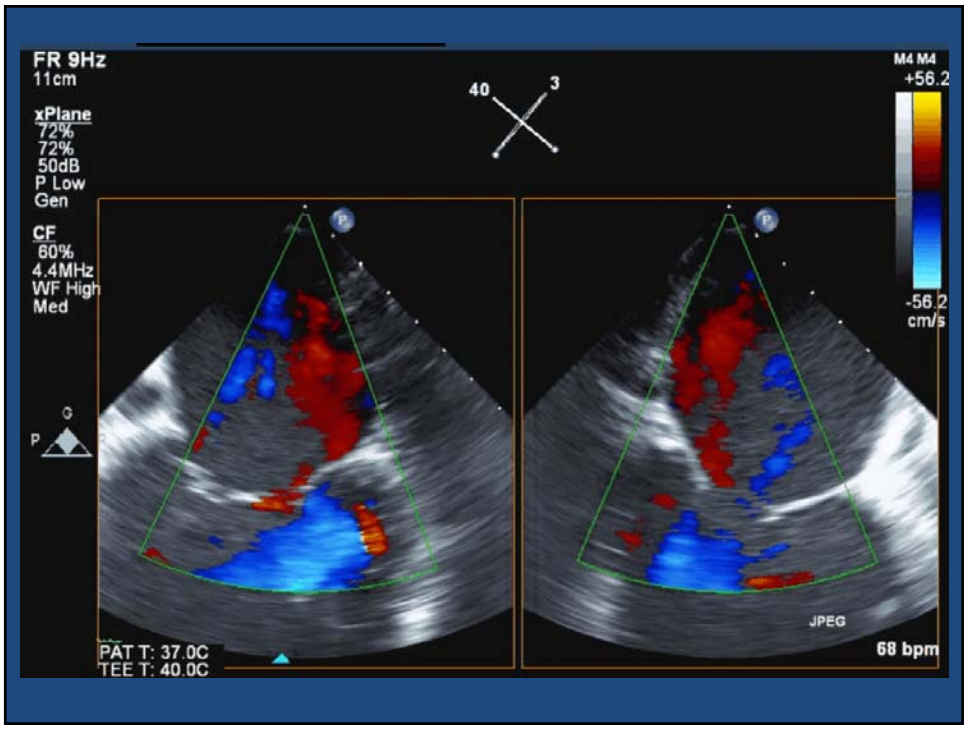
Table 1 Preimplantation TTE/TEE "*red-flag*" findings

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

ASE Guidelines - J Am Soc Echocardiogr 2015;28:853-909.




FR 50Hz
14cm
2D
73%
C 50
P Low
Gen
Dist 4.57 cm
M4
PAT T: 37.0C
TEE T: 39.3C
197bpm


FR 9Hz
11cm
xPlane
72%
72%
50dB
P Low
Gen
CF
60%
4.4MHz
WF High
Med
M4 M4
+56.2
-56.2
cm/s
JPEG
PAT T: 37.0C
TEE T: 40.0C
68 bpm

LVAD Troubleshoting: Problems and LVAD optimization

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Table 2 Continuous-flow LVAD postimplant complications and device dysfunction detected by echocardiography

Pericardial effusion
With or without cardiac tamponade including RV compression. Tamponade: respirophasic flow changes; poor RVOT SV.

LV failure secondary to partial LV unloading
(by serial exam comparison)
a. 2D/3D: increasing LV size by linear or volume measurements; increased AV opening duration, increased left atrial volume.
b. Doppler: increased mitral inflow peak E-wave diastolic velocity, increased E/A and E/e' ratio, decreased deceleration time of mitral E velocity, worsening functional MR, and elevated pulmonary artery systolic pressure.

RV failure
a. 2D: increased RV size, decreased RV systolic function, high RAP (dilated IVC/leftward atrial septal shift), leftward deviation of ventricular septum.
b. Doppler: increased TR severity, reduced RVOT SV, reduced LVAD inflow cannula and/or outflow-graft velocities (ie, <0.5 m/sec with severe failure); inflow-cannula high velocities if associated with a suction event. Note: a "too-high" LVAD pump speed may contribute to RV failure by increasing TR (septal shift) and/or by increasing RV preload.

Inadequate LV filling or excessive LV unloading
Small LV dimensions (typically <3 cm and/or marked deviation of interventricular septum towards LV). Note: May be due to RV failure and/or pump speed too high for loading conditions.

LVAD suction with induced ventricular ectopy
Underfilled LV and mechanical impact of inflow cannula with LV endocardium, typically septum, resolves with speed turndown.

LVAD-related continuous aortic insufficiency
Clinically significant—at least moderate and possibly severe—characterized by an AR proximal jet-to-LVOT height ratio >46%, or AR vena contracta ≥3 mm; increased LV size and relatively decreased RVOT SV despite normal/increased inflow cannula and/or outflow graft flows.

LVAD-related mitral regurgitation
a. Primary: inflow cannula interference with mitral apparatus.
b. Secondary: MR-functional, related to partial LV unloading/persistent heart failure.
Note: Elements of both a and b may be present.

Intracardiac thrombus
Including right and left atrial, LV apical, and aortic root thrombus

Inflow-cannula abnormality
a. 2D/3D: small or crowded inflow zone with or without evidence of localized obstructive muscle trabeculation, adjacent MV apparatus or thrombus; malpositioned inflow cannula.
b. High-velocity color or spectral Doppler at inflow orifice. Results from malposition, suction event/other inflow obstruction: aliased color-flow Doppler, CW Doppler velocity >1.9 m/s.
c. *Low-velocity* inflow (markedly reduced peak systolic and nadir diastolic velocities) may indicate internal inflow-cannula thrombosis or more distal obstruction within the system. Doppler flow velocity profile may appear relatively "continuous" (decreased phasic / pulsatile pattern).

Outflow-graft abnormality
Typically due to obstruction/pump cessation.
a. 2D/3D imaging: visible kink or thrombus (infrequently seen).
b. Doppler: peak outflow-graft velocity >2 m/s* if near obstruction site; however, diminished or absent spectral Doppler signal if sample volume is remote from obstruction location, combined with lack of RVOT SV change and/or expected LV-dimension change with pump-speed changes.

Hypertensive emergency
New reduced/minimal AV opening relative to baseline exam at normal BP, especially if associated with new/worsened LV dilatation and worsening MR. Note: hypertension may follow an increase in pump speed.

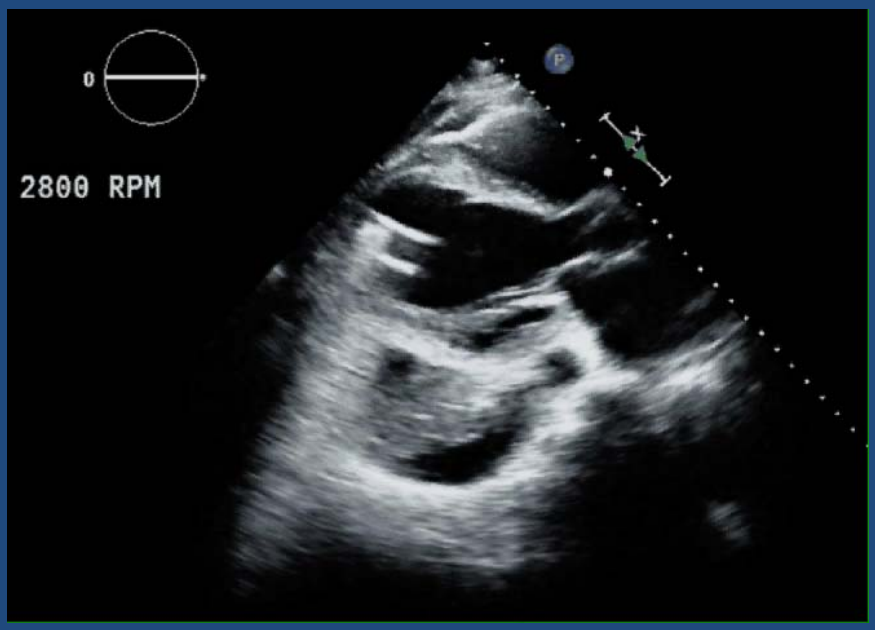
Pump malfunction/pump arrest
a. Reduced inflow-cannula or outflow-graft flow velocities on color and spectral Doppler or, with pump arrest, shows diastolic flow reversal.
b. Signs of worsening HF: including dilated LV, worsening MR, worsened TR, and/or increased TR velocity; attenuated speed-change responses: decrease or absence of expected changes in LV linear dimension, AV opening duration, and RVOT SV with increased or decreased pump speeds; for HVAD, loss of inflow-cannula Doppler artifact.

Eco and LVAD: Key items to evaluate and report

- LV size and function
- Position of the IV septum and cannulas
- Ao Valve opening and AI severity.
- RV size and function
- Always report the RPM at time of exam. (HM II 8500-10000, HVAD 2400-3200)
- Evidence of thrombus
- Compare with prior echoes side-to-side

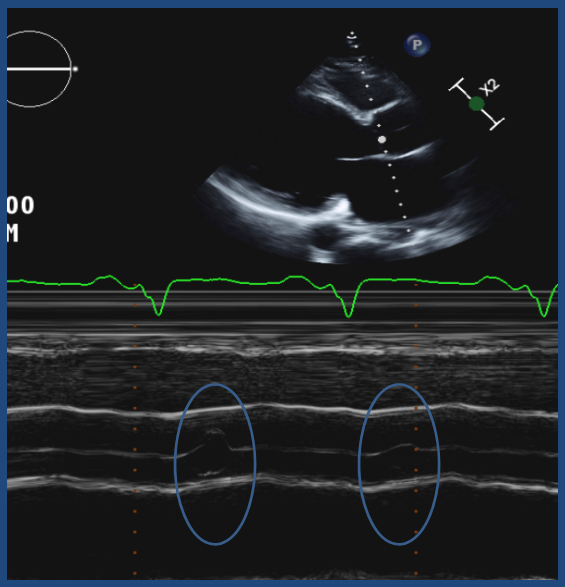
Parasternal views

- LV and RV size
- Aortic Valve
- Cannulas: Orientation and flow.



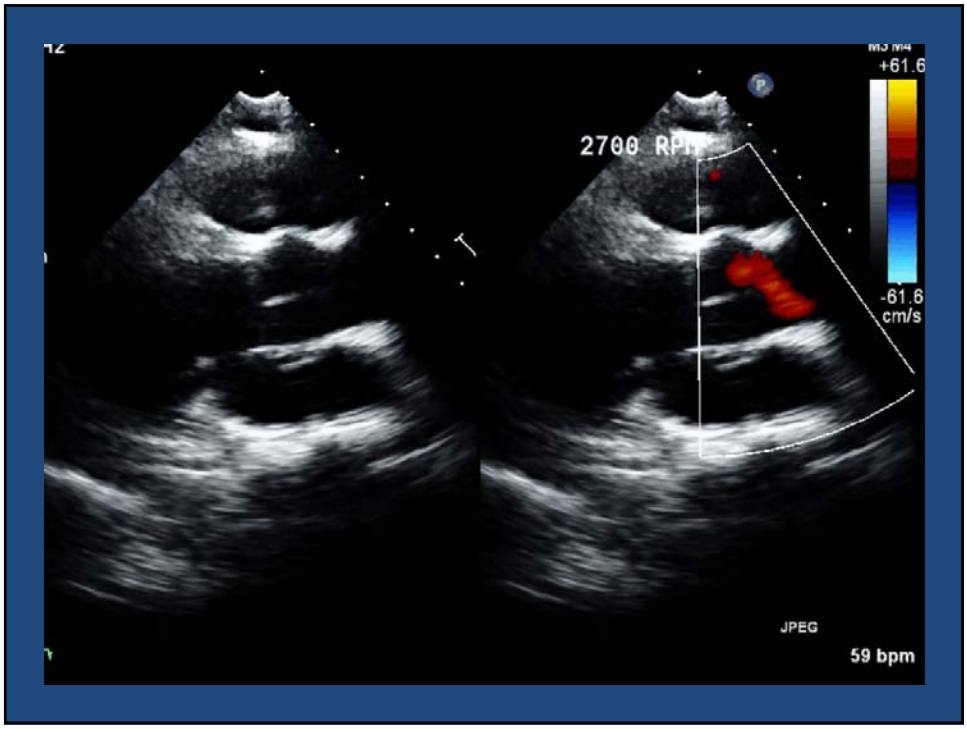
Importance of Ao Valve Opening

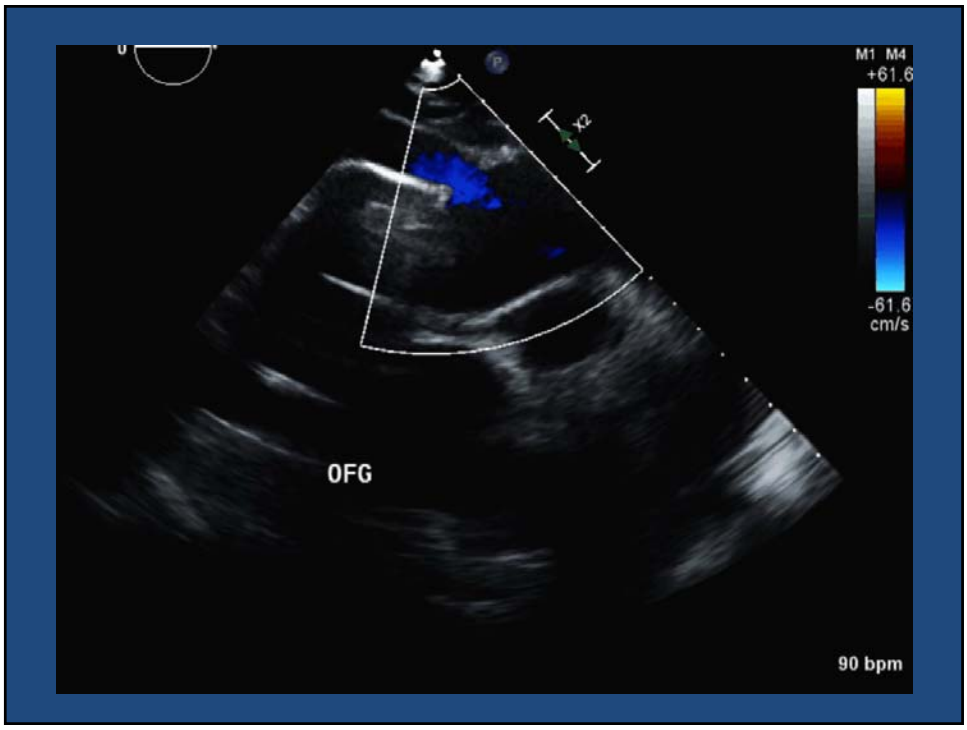
- Prevents healing and chronic closure
- Prevents thrombosis
- In the event of LVAD dysfunction, allows LV ejection.

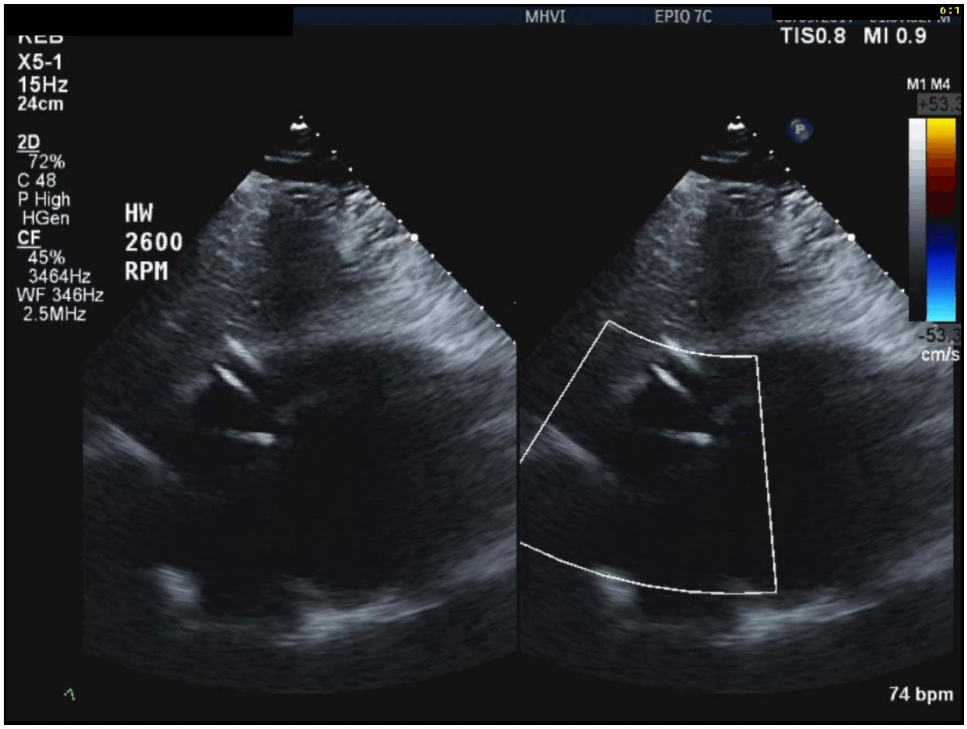


Cannulas

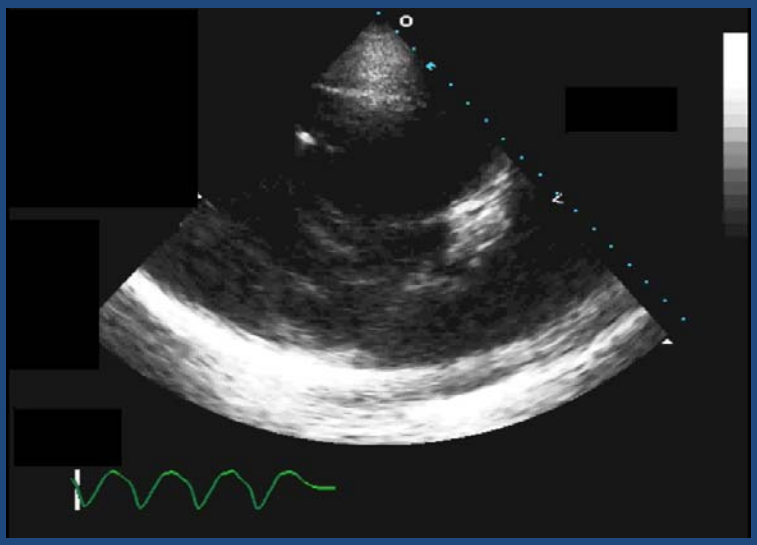
- Inflow: in off-axis PLAX and Apical views
- Outflow: Long axis of the ascending aorta frequently at the level of the right PA.

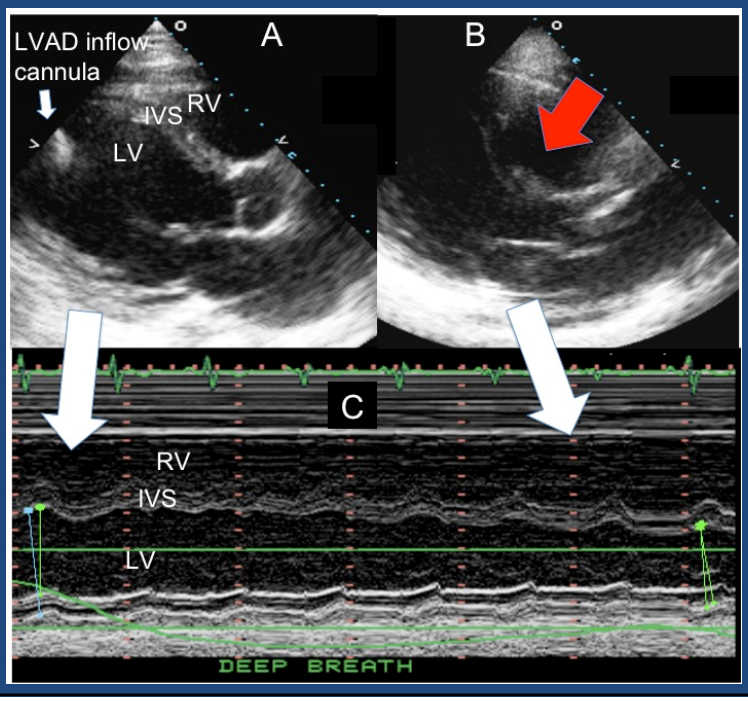

+61.6
2700 RPM
-61.6
cm/s
JPEG
59 bpm


M1 M4
+61.6
-61.6
cm/s
OFG
90 bpm

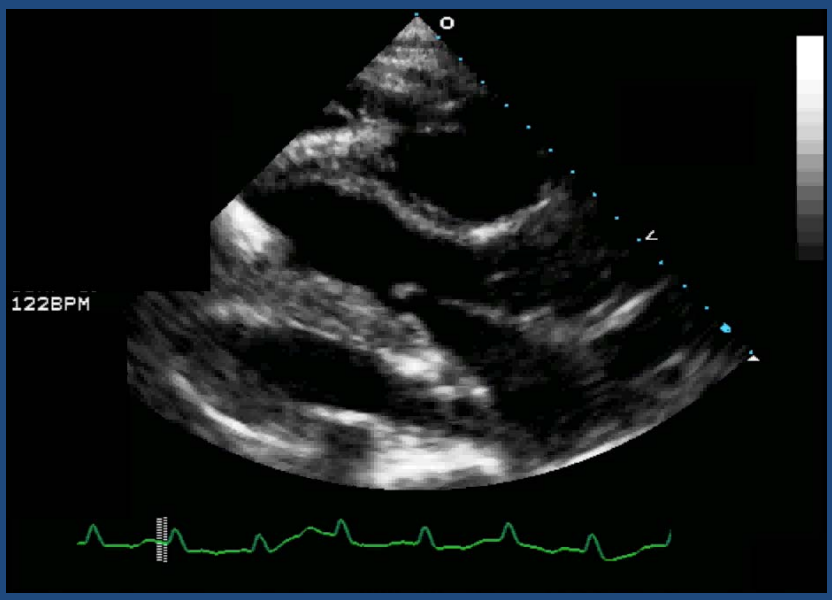


LVAD-induced VT



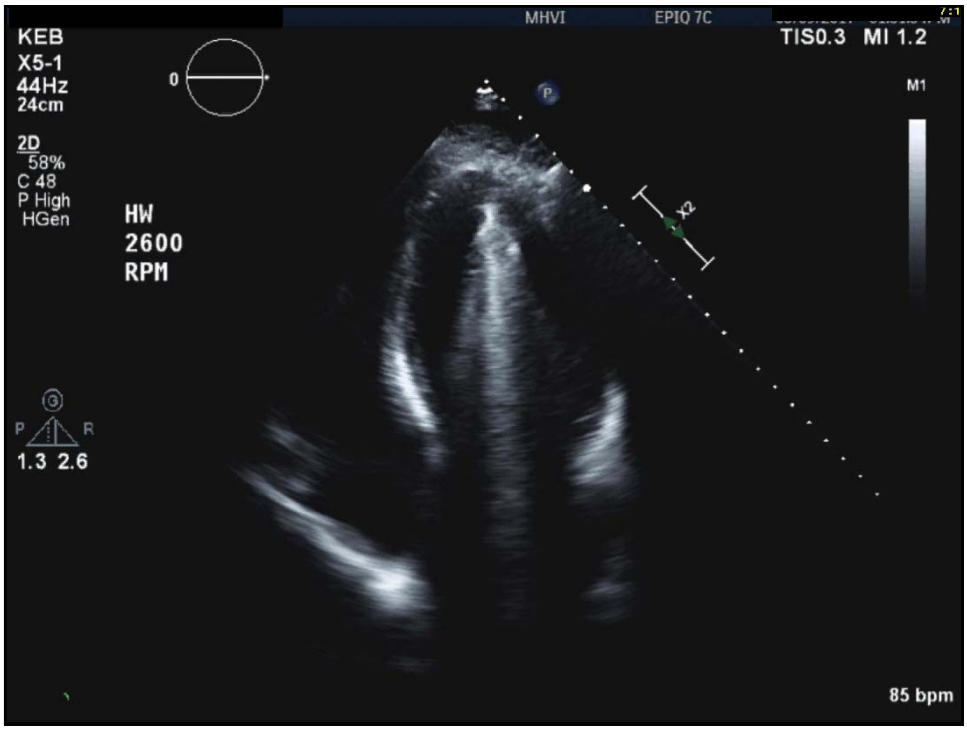


LVAD Tamponade

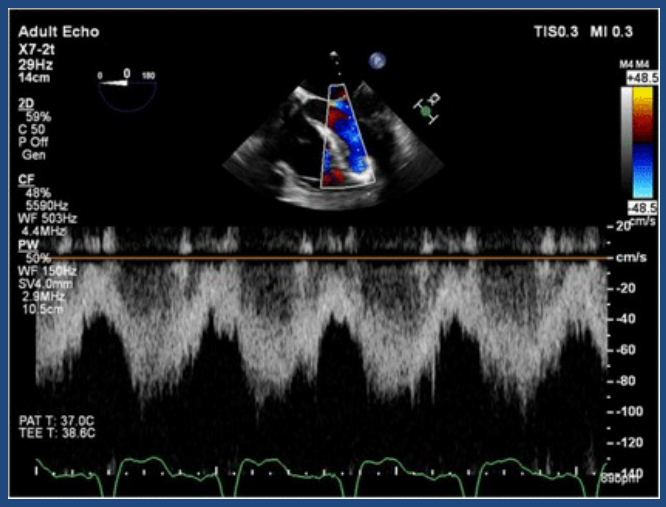


Apical Views

- IV septum position
- Cannula orientation and relationship with LV walls.
- Main limitation is artifact from device.



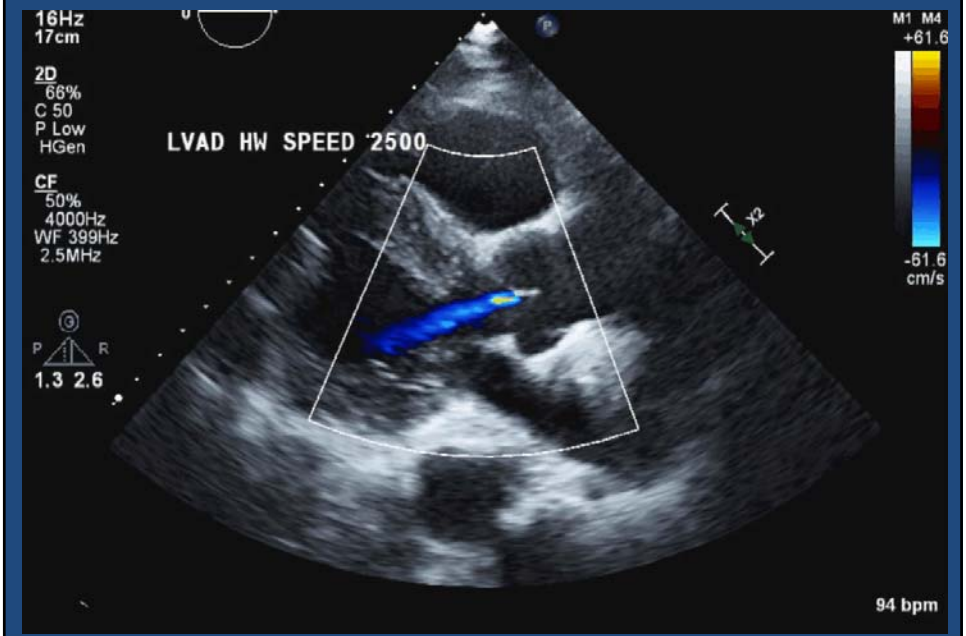
PW to evaluate Doppler velocities



HVAD – Color Doppler artifact

Aortic Regurgitation

- Continuous (D + S)
- Grading severity is challenging
- If ≧Moderate, affects LVAD performance



Echo Red Flags: When to suspect LVAD thrombosis

Signs of LVAD Dysfunction:

- Right-shift of the IVS and LV enlargement
- Ao Valve opening with every beat (9-10/10 beats)
- Blunted flow through both cannulas (PW/CW Doppler)
- RAMP studies (lack of LV dimensions change with increase in pump support/RPM)

A standard Echo report in LVAD pts

- LV and RV function and dimensions (LVIdD)
- Septal position (right, midline, left)
- Inflow cannula position/orientation and relationship to walls
- Aortic valve opening (x/10 beats)
- AI severity
- Direct comparison to prior echoes.
- Device and RPM settings

Non Durable Mechanical Circulatory Support (ND MCS)

- Impella
- Tandem Heart
- ECMO

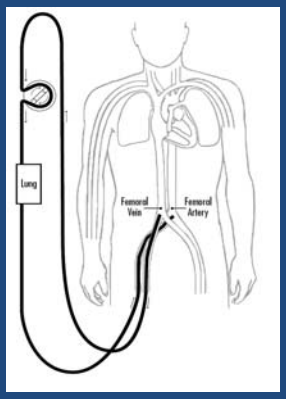
ND-MCS: Characteristics

Decision making: nondurable MCS device-specific characteristics

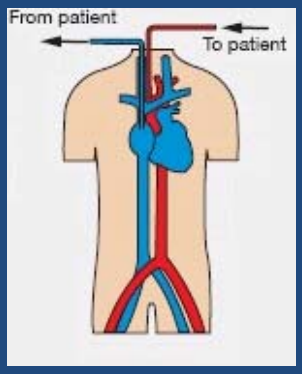
	Deployment <l h	Percutaneous	Surgical Access	Ambulatory Support (wk)	Bedside Deployment	Oxygenation
IABP	Yes	Yes	No	No/yes	Yes	No
Impella CP	Yes	Yes	No	No	No	No
Impella 5.0 (axillary)	No	No	Yes	Yes	No	No
Impella RP (investigational)	Yes	Yes	No	No	No	No
TandemHeart LVAD	Yes	Yes	No	No	No	Yes
TandemHeart RVAD	Yes	Yes	No	No	No	Yes
Centrimag LVAD (surgical)	No	No	Yes	Yes	Yes	Yes
VA-ECMO	Yes	Yes	No	No	Yes	Yes

V-A ECMO

Standard Approach

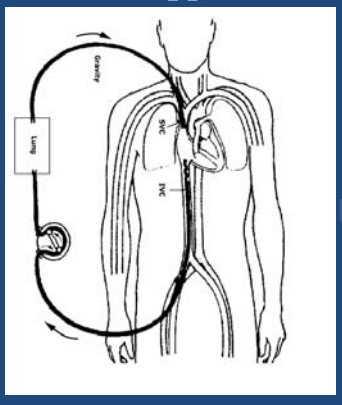


Alternate approach

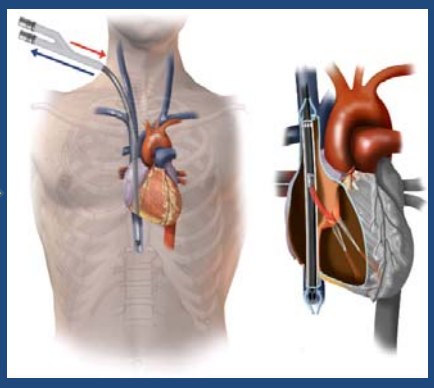


V-V ECMO

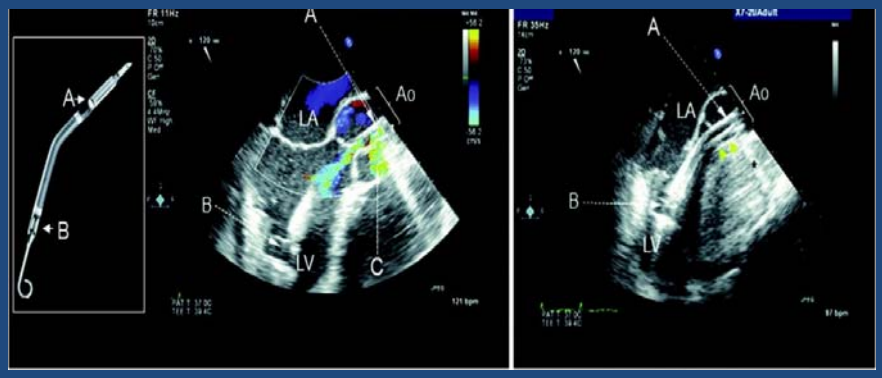
Standard approach



Alternate approach

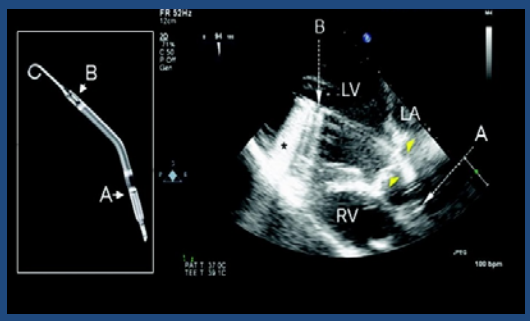


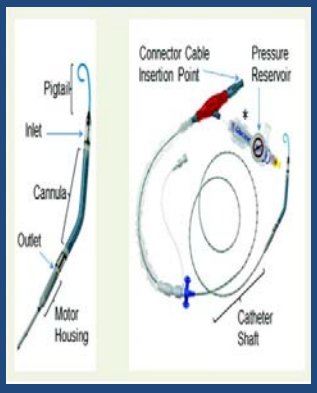
Impella



Heart Failure Clinics, Volume 11, Issue 2, 2015, 215 - 230

Impella





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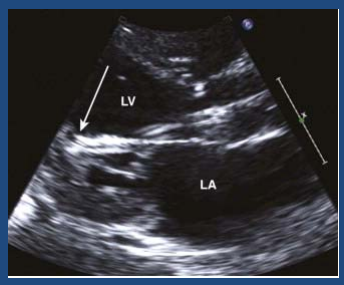
Impella

- Inlet: 3 - 4 cm below Ao Valve
- Should not touch septum or ant MV leaflet
- Outlet: 1.5 - 2 cm above sinuses of Valsalva.



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Summary

- Echo is critical in LVAD evaluation
- Determine candidacy and co-morbidities that should be addressd in the OR
- Determine LVAD function and Dysfunction
- Device optimization
- LV recovery?

LVAD and Echo QUIZ

Which of the following findings is critical to report to the surgeon at the time of LVAD implant?

- A- Aortic Regurgitation Severity
- B- LV Dysfunction
- C- TR severity
- D- A and C are correct
- E- All are correct

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Which of the following findings Suggest LVAD Dysfunction?

- A- Severe AR
- B- Significant LVIdD changes in RAMP study
- C- Flat LVIdD changes in RAMP study
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Thank You