



Abteilung für Anästhesiologie und Intensivmedizin

TOE/TEE for patients undergoing LVAD implantation

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- Anaesthesia induction and management
- Haemodynamic management
- Pharmacological management
- Echocardiographic control

Knowing your patient

Table 13.2 INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support) stages for classifying patients with advanced heart failure

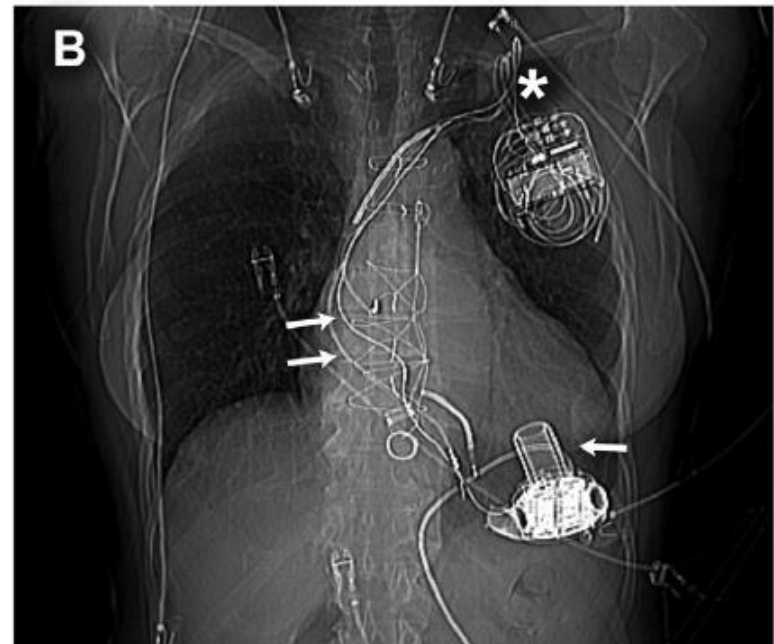
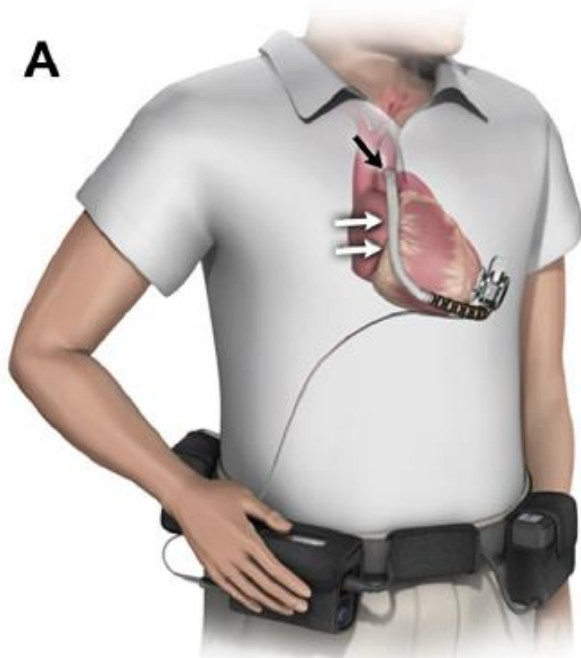
INTERMACS level	NYHA Class	Description	Device	1y survival with LVAD therapy
1. Cardiogenic shock "Crash and burn"	IV	Haemodynamic instability in spite of increasing doses of catecholamines and/or mechanical circulatory support with critical hypoperfusion of target organs (severe cardiogenic shock).	ECLS, ECMO, percutaneous support devices	52.6±5.6%
2. Progressive decline despite inotropic support "Sliding on inotropes"	IV	Intravenous inotropic support with acceptable blood pressure but rapid deterioration of renal function, nutritional state, or signs of congestion.	ECLS, ECMO, LVAD	63.1±3.1%
3. Stable but inotrope dependent "Dependent stability"	IV	Haemodynamic stability with low or intermediate doses of inotropics, but necessary due to hypotension, worsening of symptoms, or progressive renal failure.	LVAD	78.4±2.5%
4. Resting symptoms "Frequent flyer"	IV ambulatory	Temporary cessation of inotropic treatment is possible, but patient presents with frequent symptom recurrences and typically with fluid overload.	LVAD	78.7±3.0%
5. Exertion intolerant "Housebound"	IV ambulatory	Complete cessation of physical activity, stable at rest, but frequently with moderate fluid retention and some level of renal dysfunction.	LVAD	93.0±3.9% ^a
6. Exertion limited "Walking wounded"	III	Minor limitation on physical activity and absence of congestion while at rest. Easily fatigued by light activity.	LVAD / Discuss LVAD as option	-
7. "Placeholder"	III	Patient in NYHA Class III with no current or recent unstable fluid balance.	Discuss LVAD as option	-

Knowing your patient

- **Specific Considerations**

- Aortic valve regurgitation
- Right ventricle function
- Ventricular arrhythmias
- Congenital cardiac defects
- Age
- BMI
- Renal dysfunction
- Infection
- Bleeding disorders
- Psychosocial factors

Knowing the device



Journal of the American Society of Echocardiography
August 2015

Knowing the device

Device Type	HeartWare HVAD System	HeartMate II	HeartMate III
Speed range, rotations per minute	2400–3200	6000–15,000	3000–9000
Rotor design	Centrifugal	Axial	Centrifugal
Pump position	Intrapericardial	Pump pocket	Intrapericardial
Blood flow gaps, mm	≈0.05	≈0.08	≈0.12
Food and Drug Administration–approved indication	Bridge to transplant (2012) Destination therapy (2017)	Bridge to transplant (2008) Destination therapy (2010)	Bridge to transplant (2017) Destination therapy (2017)
Magnetic levitation	*		*
Artificial pulsatility			*
High inlet suction		*	

Circulation. 2018;138:2841–2851.

Knowing the operation technique and the device



European Journal of Heart Failure (2017) 19, 595–602
doi:10.1002/ehf.779

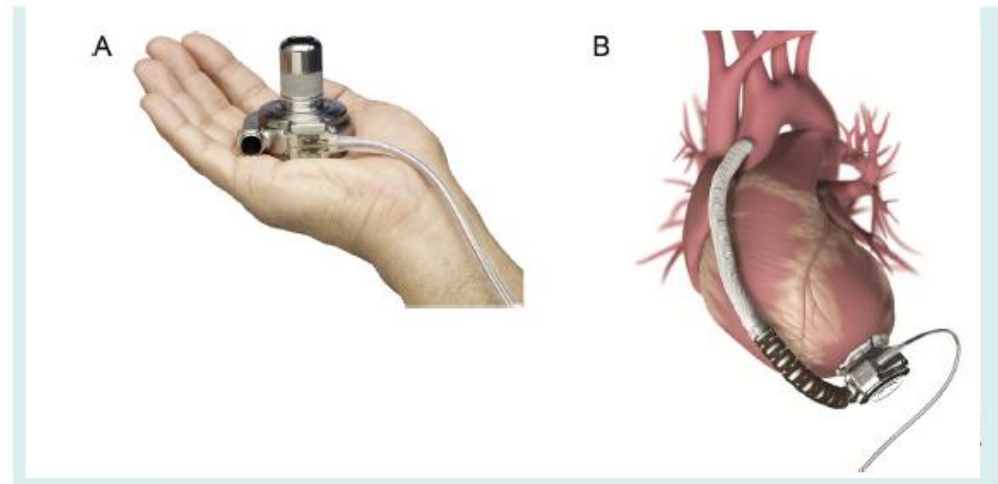
REVIEW

Left ventricular assist device therapy in advanced heart failure: patient selection and outcomes

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Premedication

- Preoperative anxiolytics must be used with caution
- Avoidance of oversedation and hypoventilation



Hypoxaemia
Hypercarbia



↑ PVR

Induction of Anaesthesia

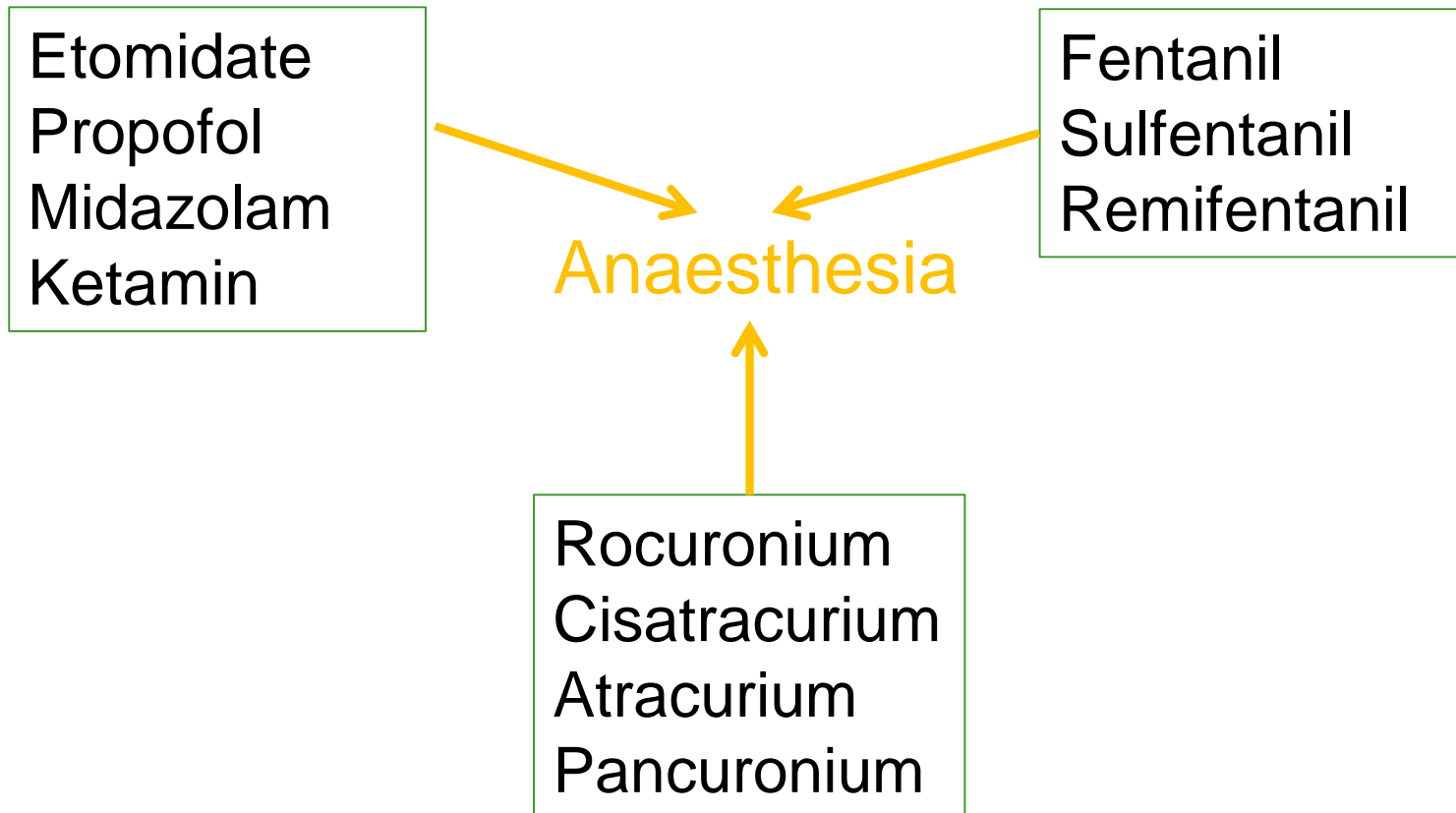


- Induction of anaesthesia takes place once the patient is fully monitored
 - Standard monitoring:
 - 5-lead ECG
 - Pulse oximetry
 - Invasive arterial blood pressure
 - Multi-lumen central venous catheter
 - Capnography
 - Urinary catheter
 - Core temperature
 - Central venous introducer access
 - Pulmonary artery catheter
 - Large-bore peripheral venous access
 - External defibrillator pads
- } re-do
minimally invasive incision

Induction and Maintenance of Anaesthesia



OP room should be readily equipped
The presence of a surgeon is indicated



Anaesthetic management

- MV -> normoxia, normocarbica
 - Tidal Volume 6-8 ml/Kg (ideal body weight)
 - PEEP 6-10 mmHg
- Monitoring depth of anaesthesia
- Monitoring cerebral oxygenation
- Fluid management
- Blood transfusion

Haemodynamic management

- Inotropes used before anaesthesia induction should be continued
- The aim is to optimize haemodynamics:
 - Preserving coronary perfusion pressure
 - Preserving RV performance

- **PRE-Implantation:**

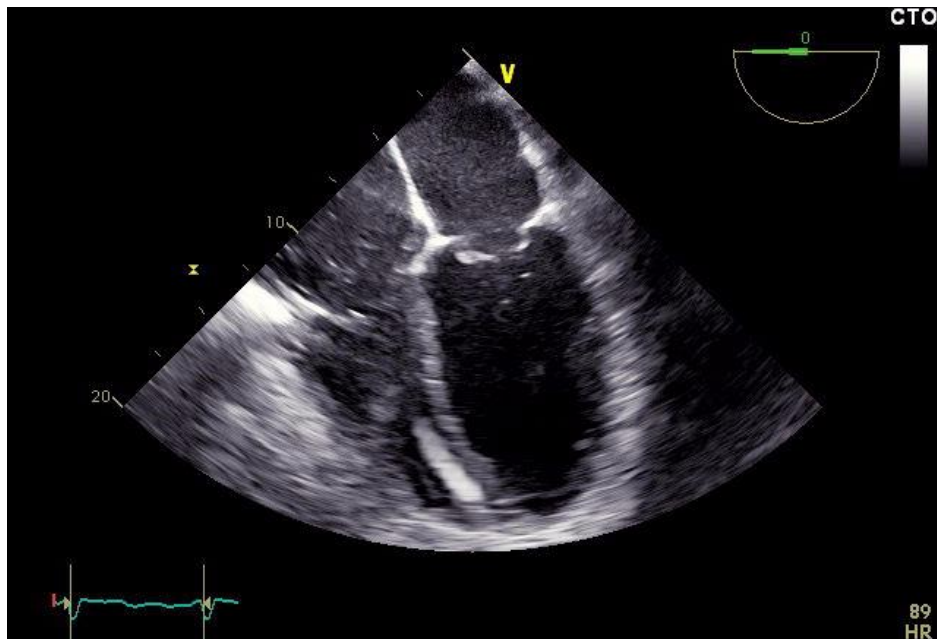
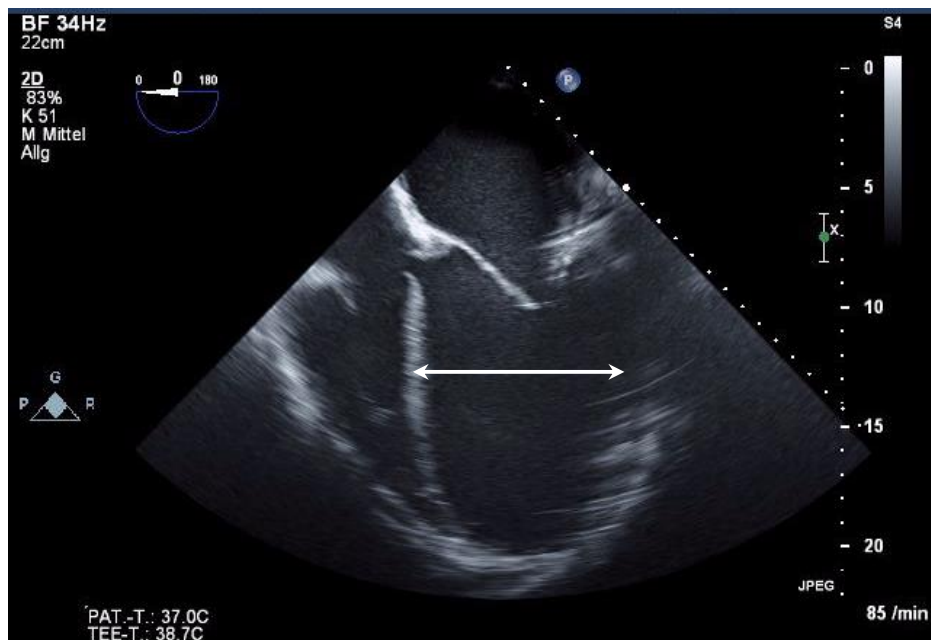
- LV structure and function
- RV structure and function
- Rule out intracardiac abnormalities
 - Intracardiac clots: ventricular or/and atrial
 - Intracardiac shunts: PFO, ASD, VSD
 - Valve regurgitation: AR, TR
 - Valve stenosis: MS, AS
 - Aortic diseases

STAR

- **S**hunts
- **T**hrombi
- **A**I
- **R**V

– LV structure and function

- » LVED Volume and end-diastolic internal diameter
 - Primary clinical measure of LVAD-mediated LV unloading
 - LVIDd < 63 mm – associated with increased morbidity and mortality rates



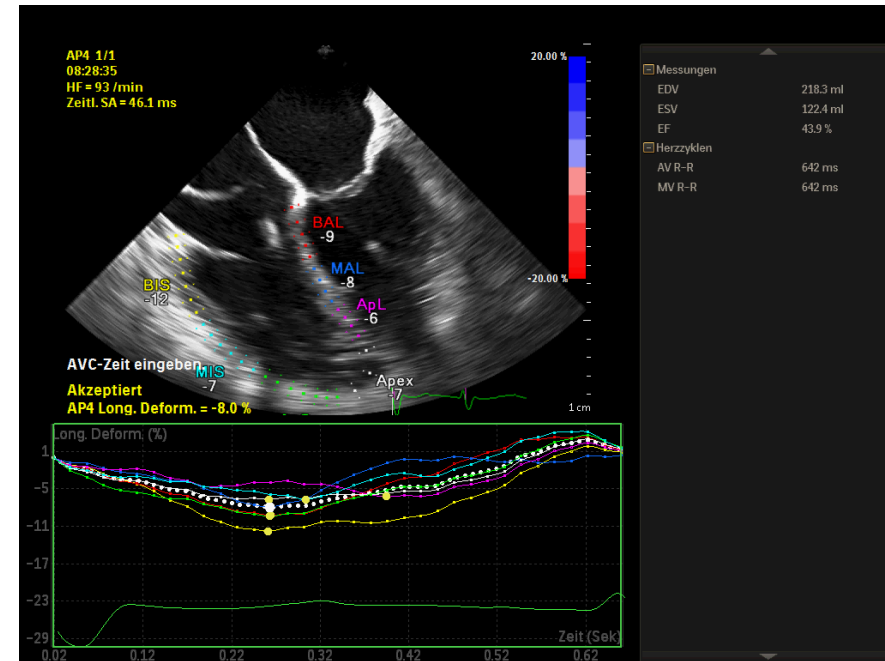
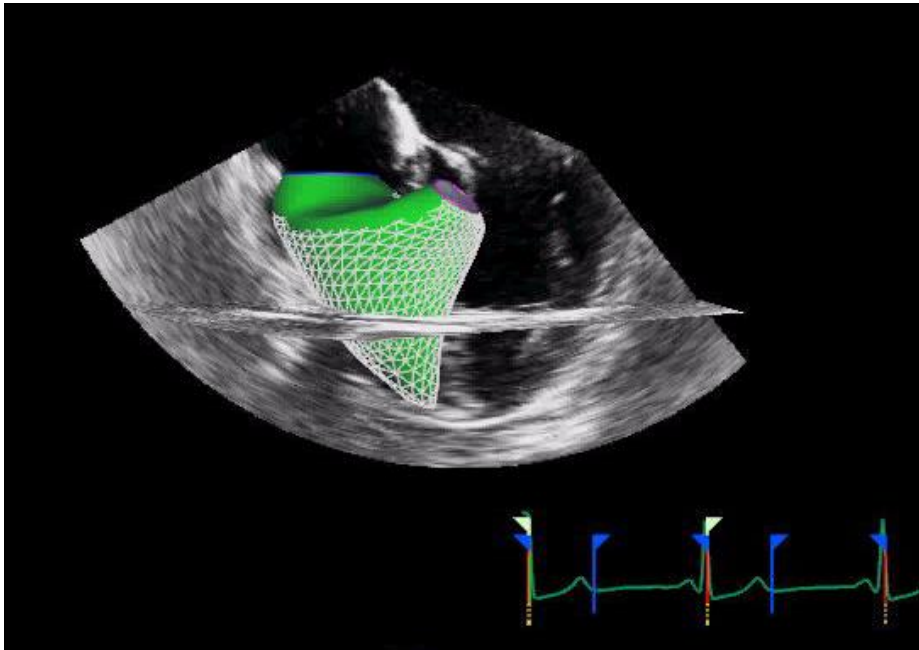
Pre-Implantation ECHO

- RV structure and function
 - RV size
 - RV systolic function
 - 3D
 - Strain Rate
 - FAC: fractional area change
 - TAPSE: tricuspid annular plane systolic excursion
 - S'
 - RA pressure
 - Tricuspid valve regurgitation

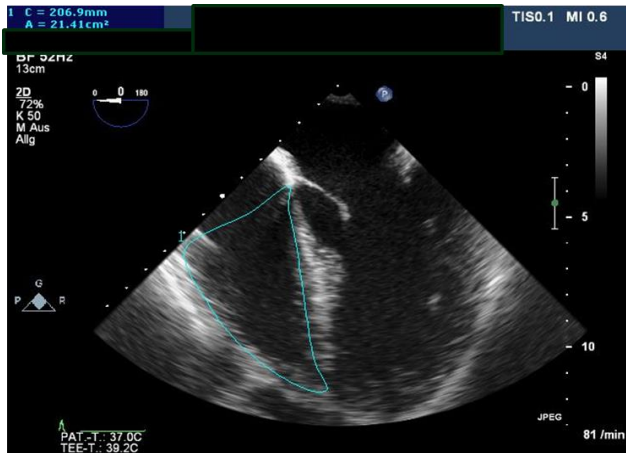
Pre-Implantation ECHO



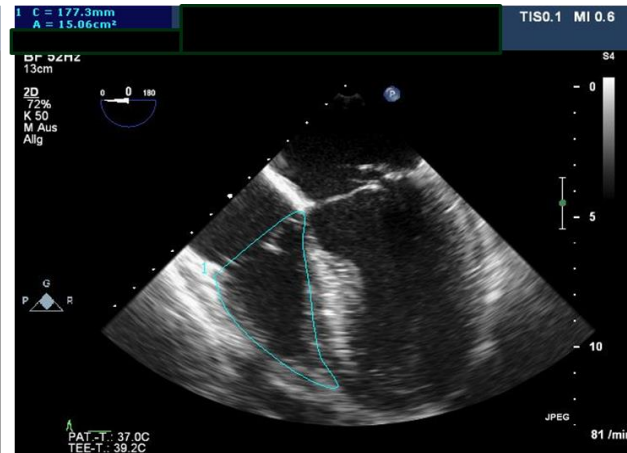
- RV systolic function: 3D and strain rate



Pre-Implantation ECHO



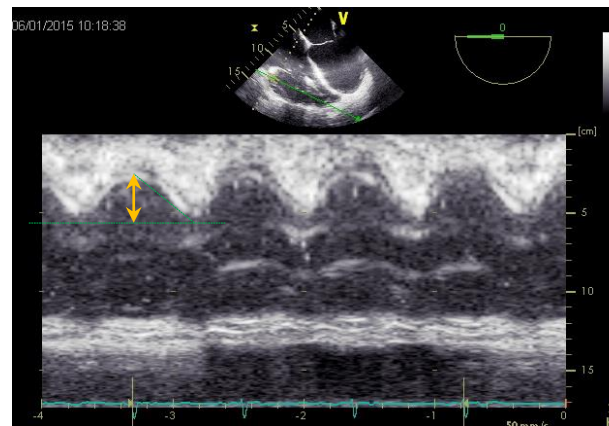
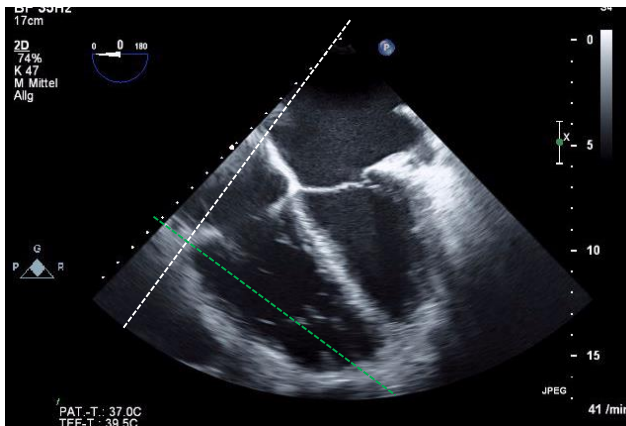
end-diastolic area



end-systolic area

$$\text{FAC: } \frac{\text{EDA} - \text{ESA}}{\text{EDA}}$$

RV-dysfunction:
FAC < 35%



$$\text{TAPSE} = \text{Systole} - \text{Diastole}$$

RV-dysfunction:
TAPSE < 17 mm

RV-Evaluation for LVAD

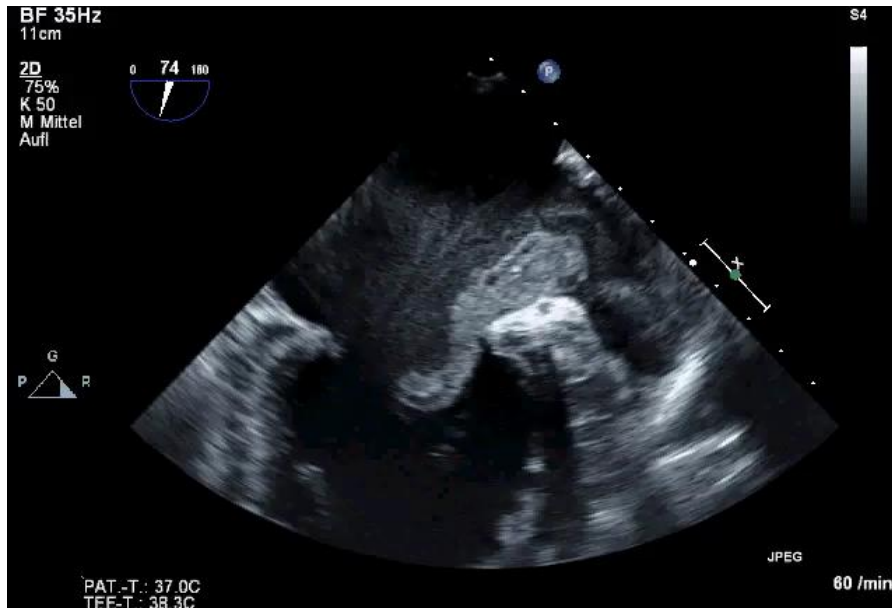
- **TAPSE < 7.5 mm**
- TR > II
- RV- FAC < 20%
- **RV : LV end diastolic ratio < 0.75**
- RV short axis : long axis ratio > 0.62
- Tissue Doppler
 - $S' < 4,4 \text{ cm/sec}$, $RV E/E' > 10$, $RV \text{ Strain} < - 14$

ECHOCARDIOGRAPHY

pre-implantation



- Rule out:
 - Intracardiac clots: ventricular or atrial



LA Thrombus



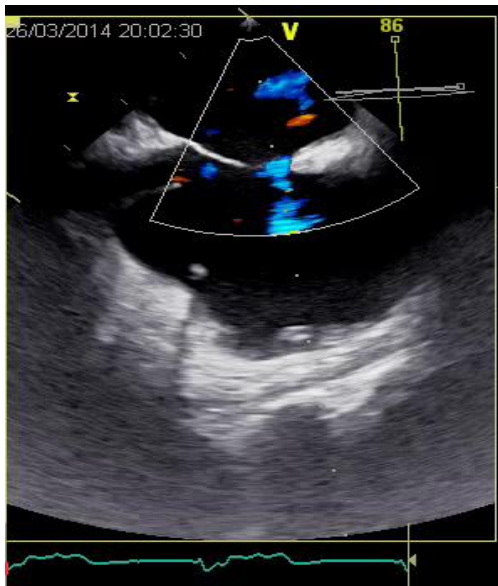
LV Thrombus

ECHOCARDIOGRAPHY

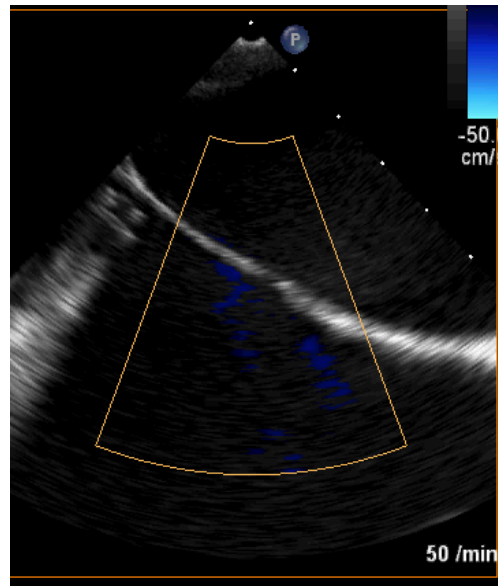
pre-implantation



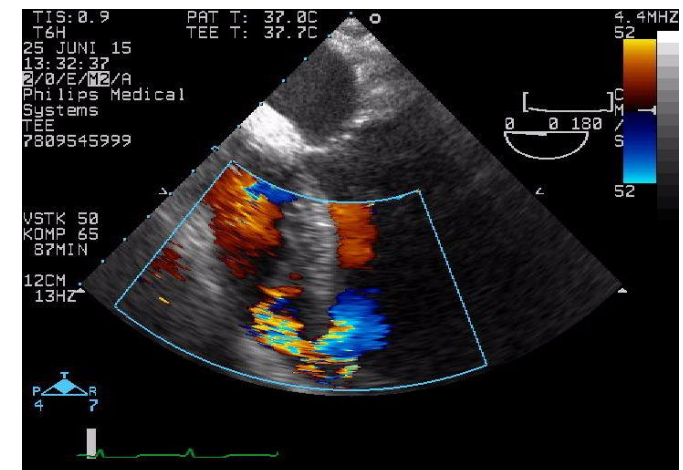
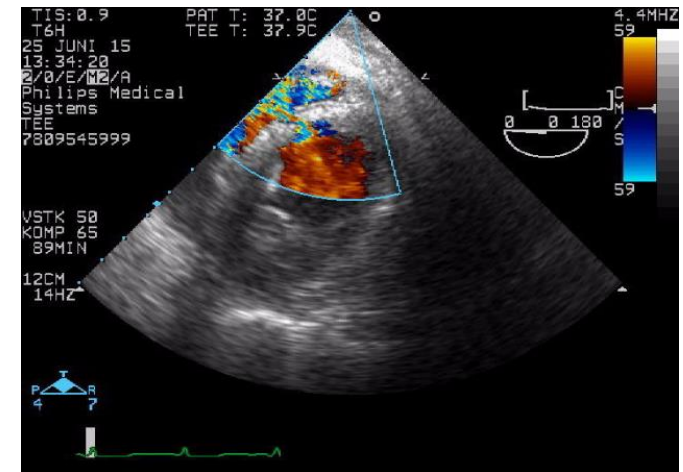
- Rule out:
 - Intracardiac shunts:



PFO



Iatrogenic ASD
post-Mitraclip
implantation



VSD

ECHOCARDIOGRAPHY

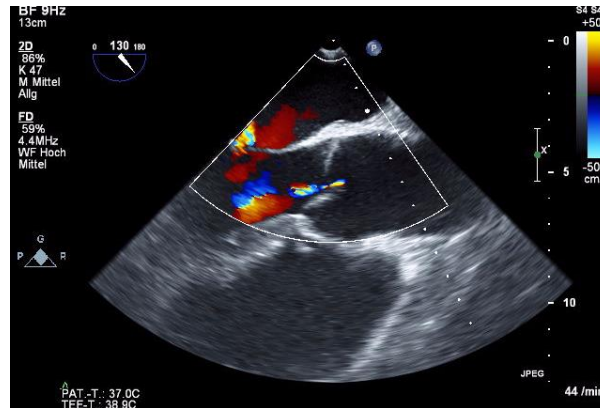
pre-implantation



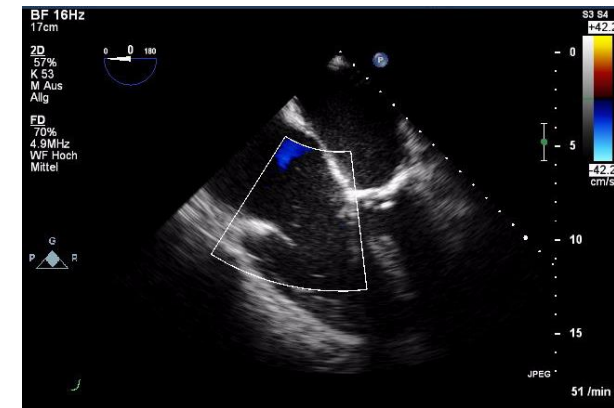
- Rule out valve dysfunctions that will interfere with correct LVAD performance:
 - Valve regurgitation: MR, AR, TR



Mitral regurgitation



Aortic regurgitation
< mild
“blind” loop



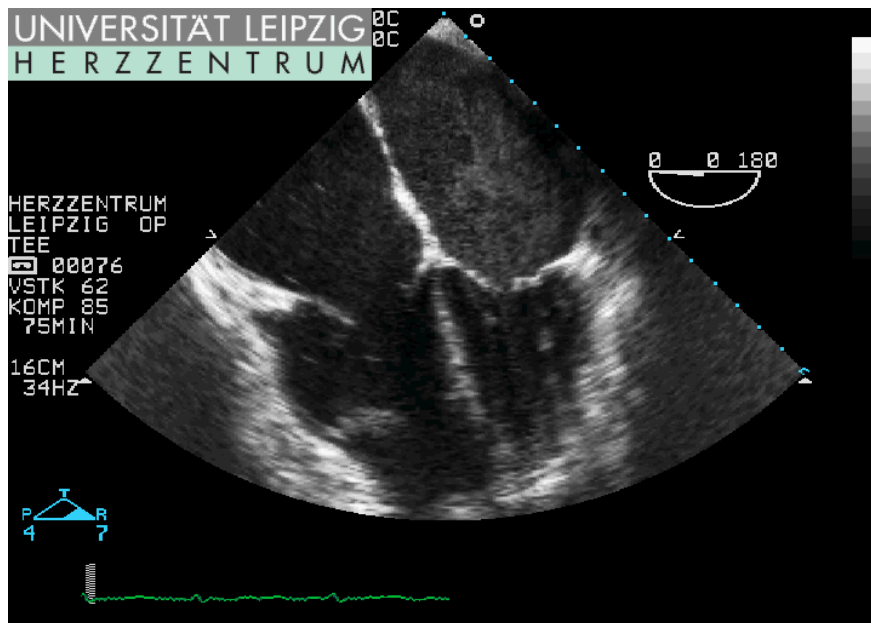
Tricuspid regurgitation
- < moderate

ECHOCARDIOGRAPHY

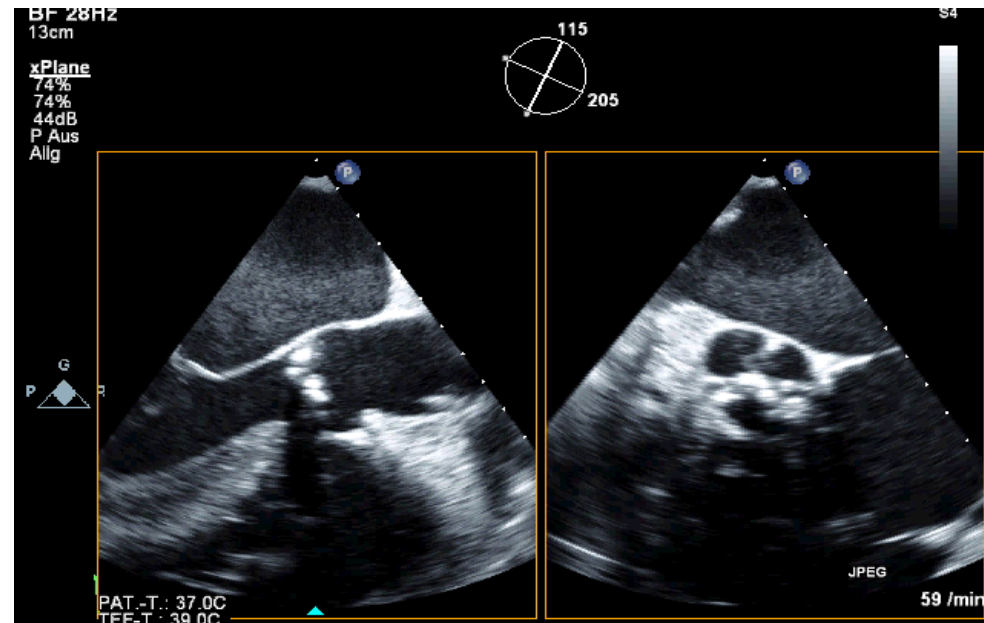
pre-implantation



- Valve stenosis: MS, AS



Mitral stenosis



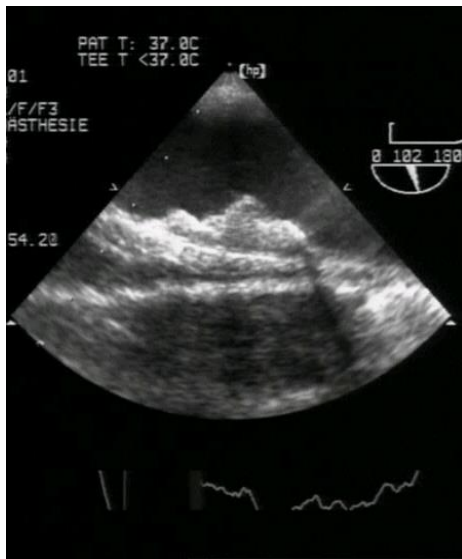
Aorta stenosis

ECHOCARDIOGRAPHY

pre-implantation



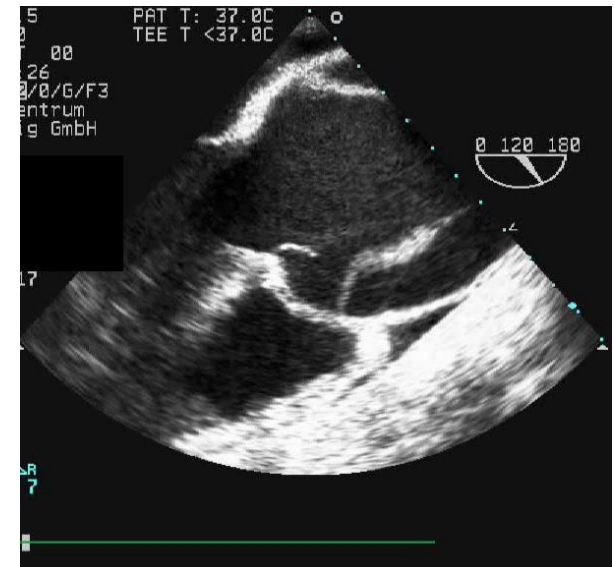
- Rule out:
 - Aortic diseases



Atheroma Plaque



Aortic aneurysm



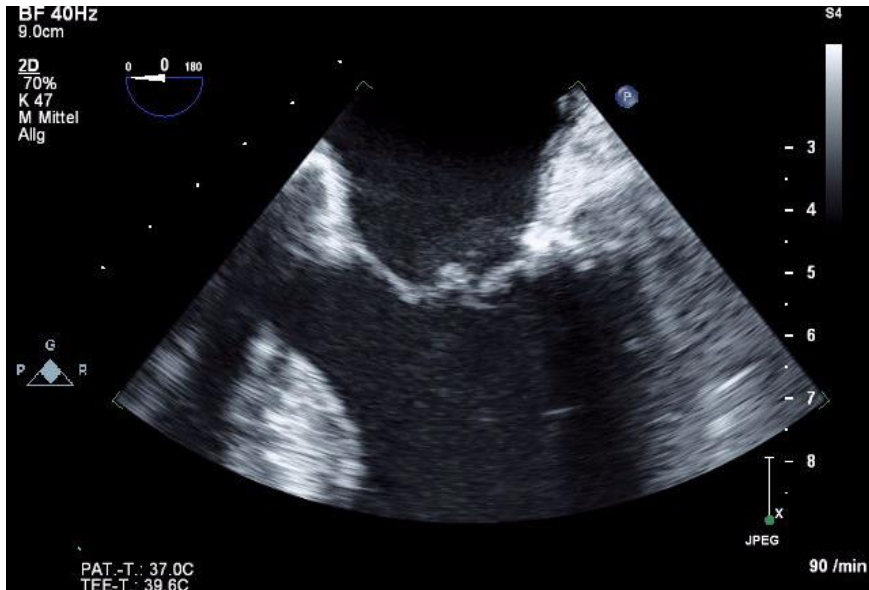
Aortic dissection

ECHOCARDIOGRAPHY

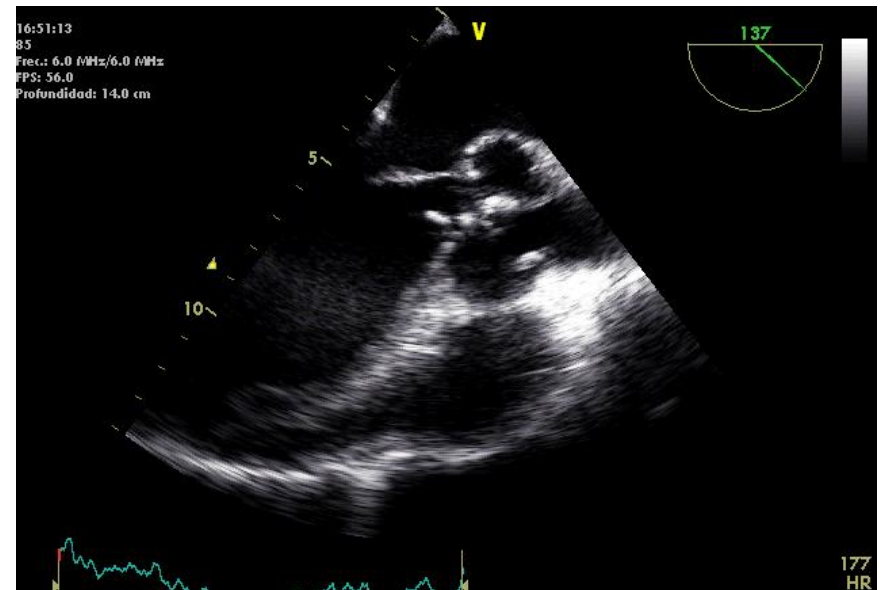
pre-implantation



- Rule out:
 - Valve endocarditis

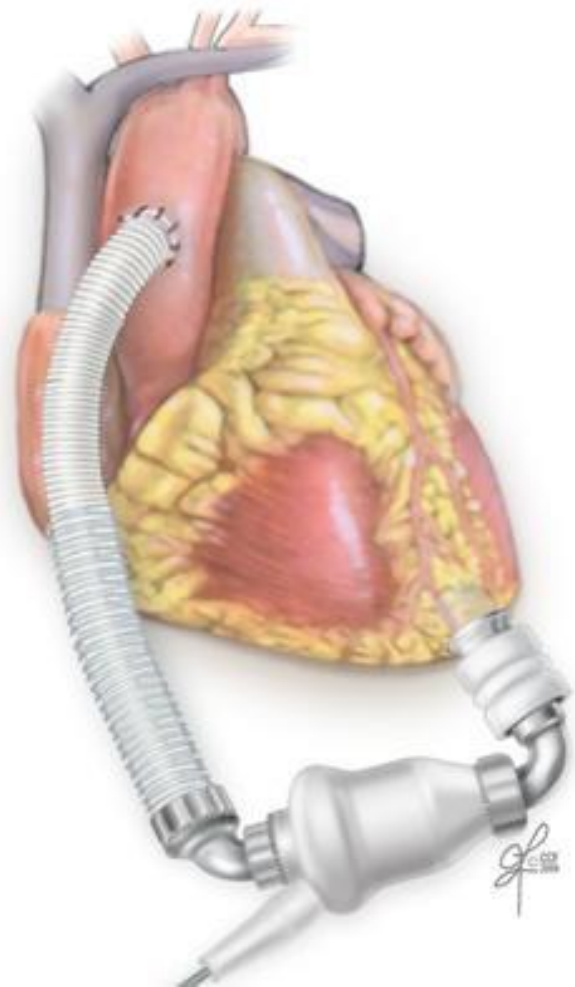
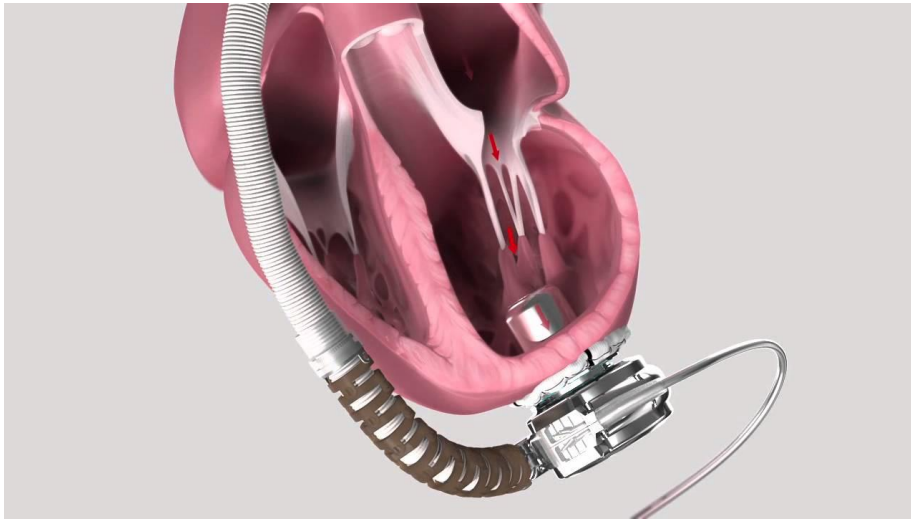


Mitral valve endocarditis



Aortic valve endocarditis

ECHO during LVAD - Implantation

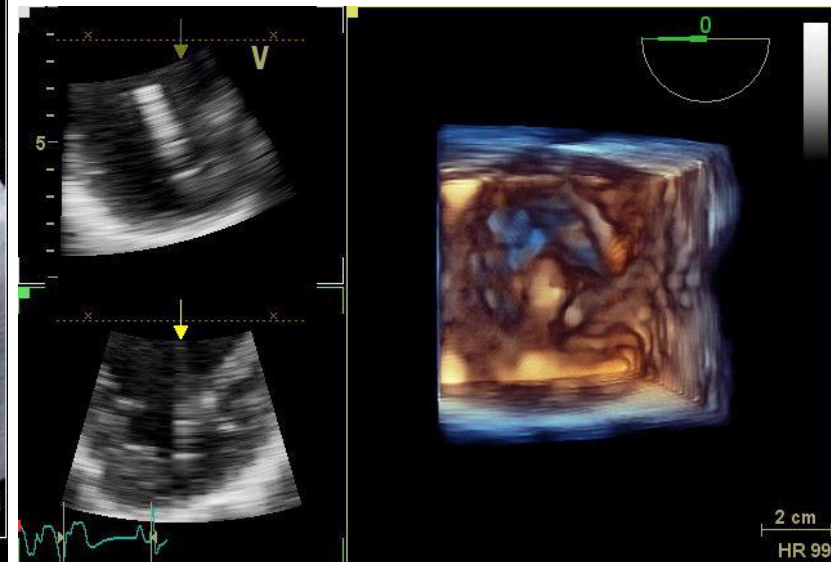
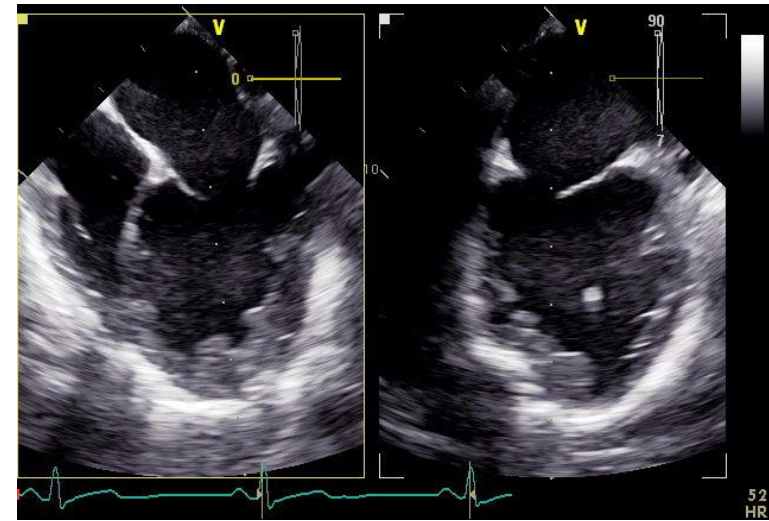
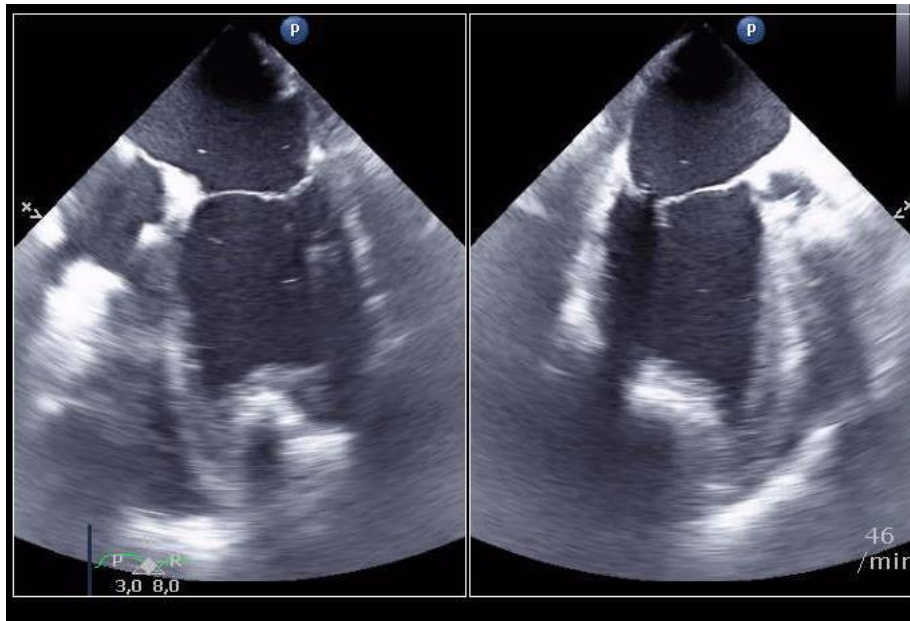


ECHO during LVAD - Implantation



- Inflow cannula positioning:

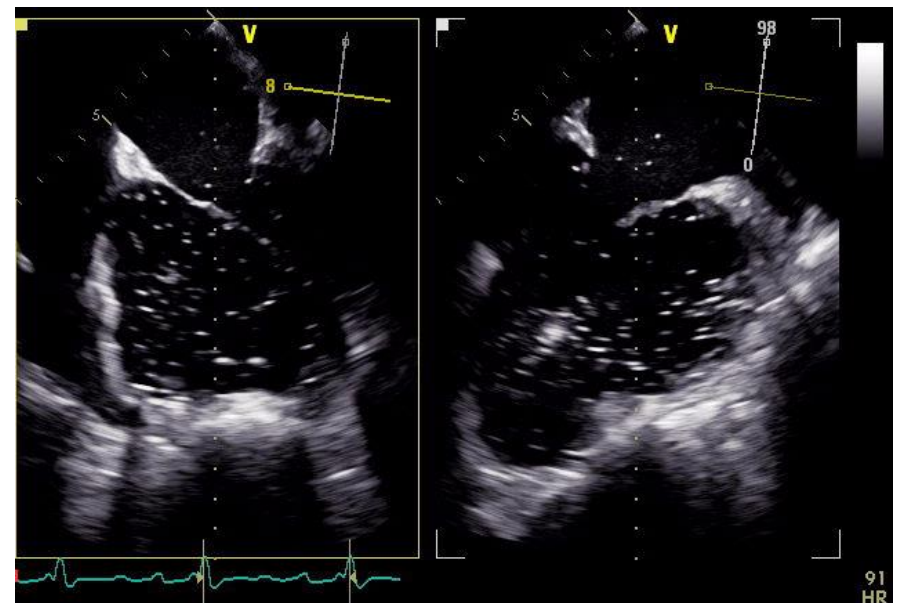
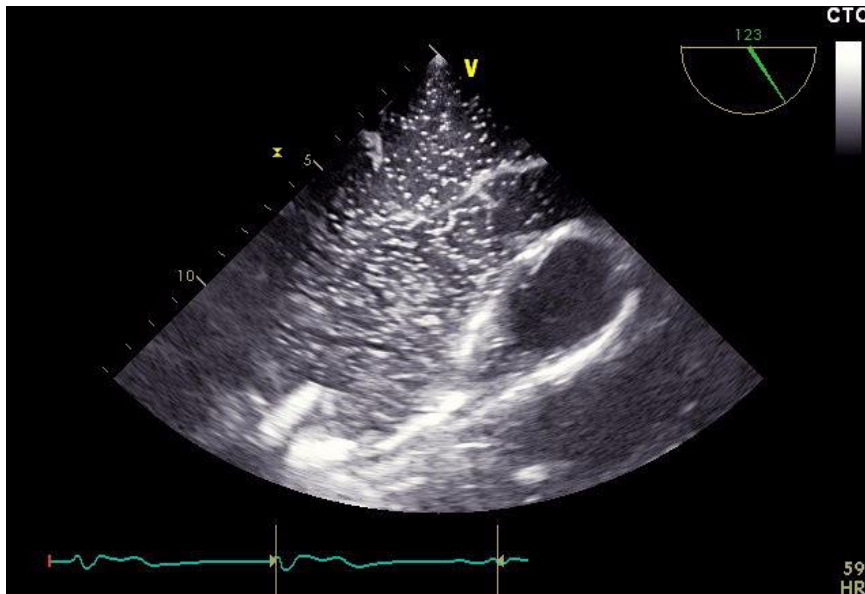
- LV apex palpation
- LV apex needle placement



ECHO during LVAD - Implantation



- Rule out the presence of air in LV, inflow cannula and ascending aorta



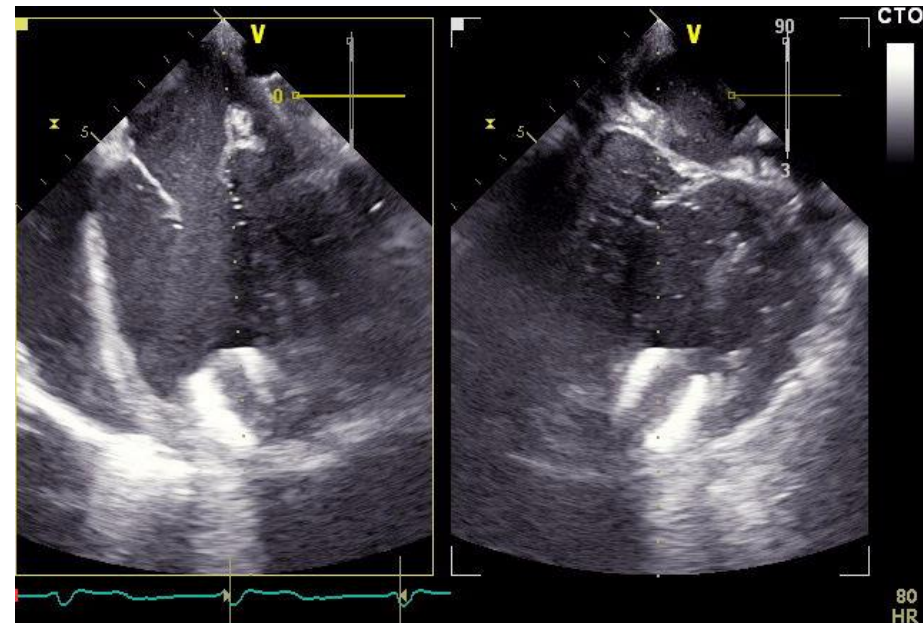
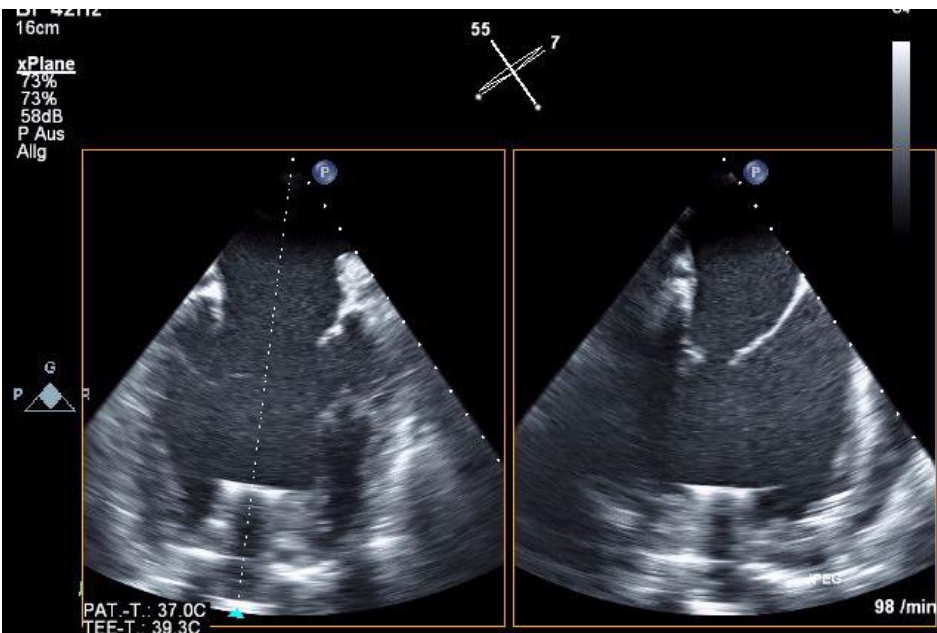
ECHO during LVAD - Activation

- Appropriated positioning of the Inflow-Cannula
- Absence of air in LV/ Aorta
- INFLOW - Cannula flow – Color / PW / CW Doppler
- OUTFLOW – Cannula flow – Color / PW / CW Doppler
- LV unloading
- RV-Function control
- Severity of TR
- Absence of intracardiac shunts
- Absence of AR

ECHO during LVAD - Activation



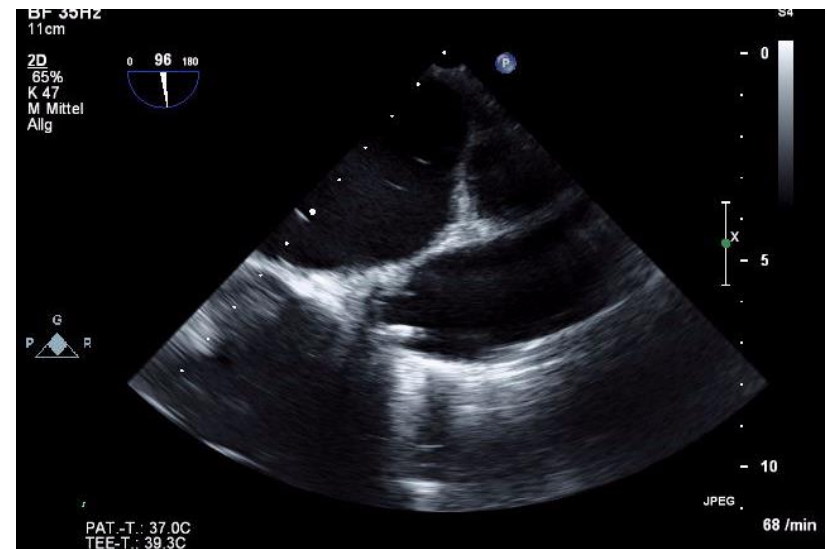
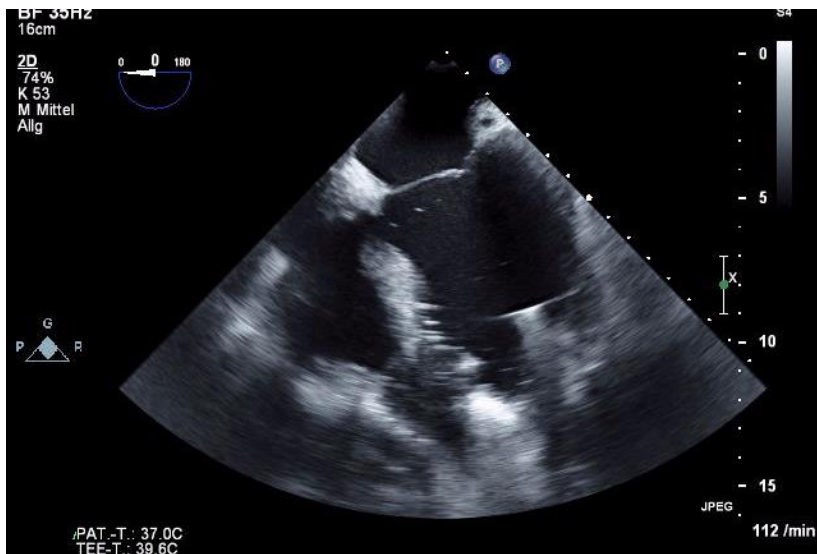
- INFLOW – Cannula Position
 - Appropriate position
 - Direct contact of the cannula with the interventricular septum or left ventricular wall should be avoided



ECHO during LVAD



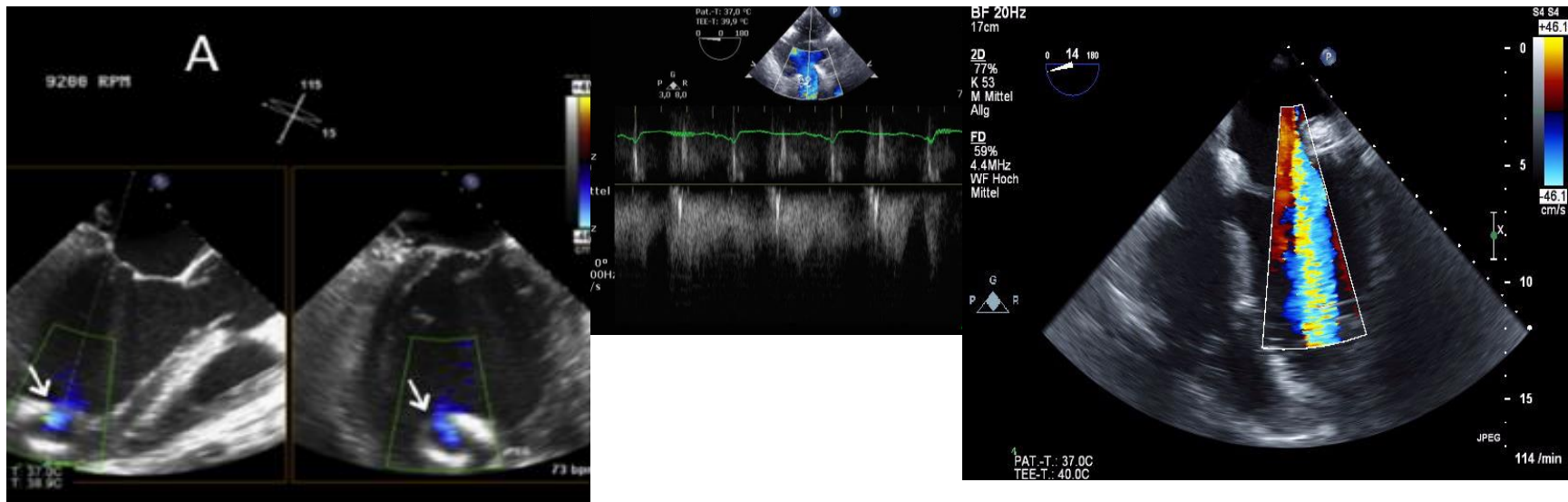
Check for air



ECHO during LVAD - Activation



- **INFLOW – Cannula**
 - unidirectional laminar flow from ventricle to the inflow cannula
 - Low velocity, slightly pulsatile pattern of flow
 - PW Doppler: ($V_{max} \leq 1,5 \text{ m/s}$)

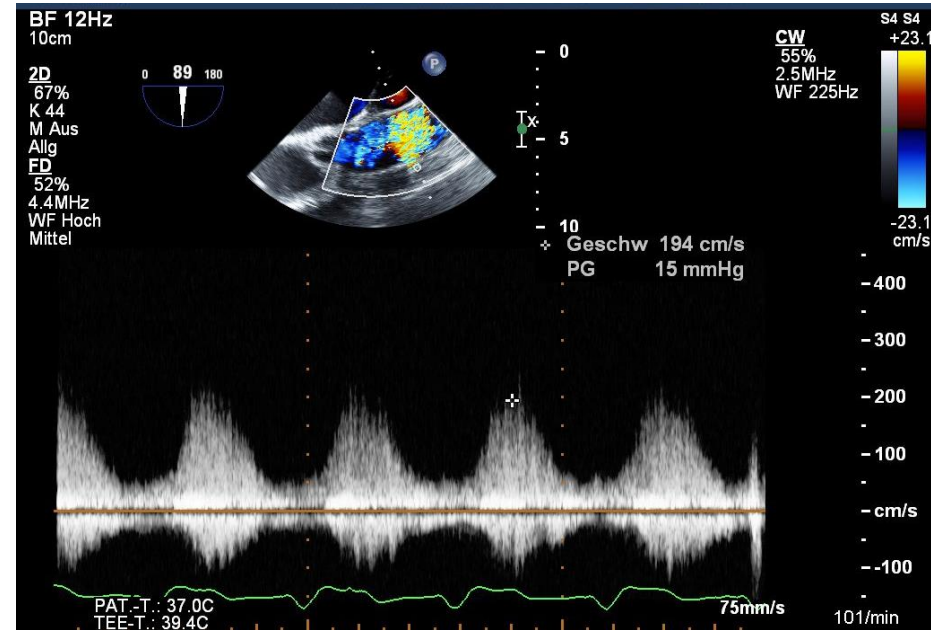
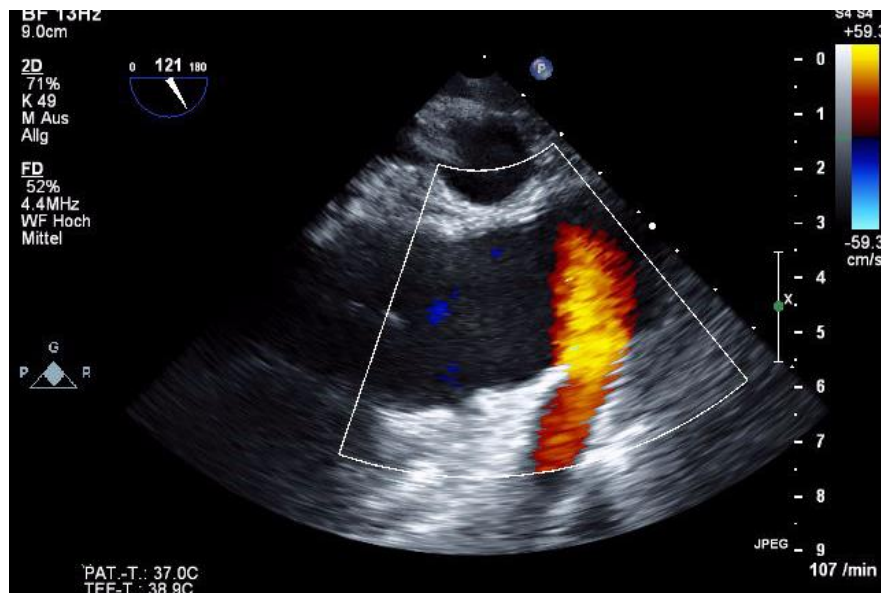


ECHO during LVAD - Activation



– OUTFLOW- Cannula

- It is normally anastomosed to the ascending aorta
- Flow pattern is similar to the inflow cannula (unidirectional laminar flow)
- PW Doppler: ($V_{max} \leq 2$ m/s)

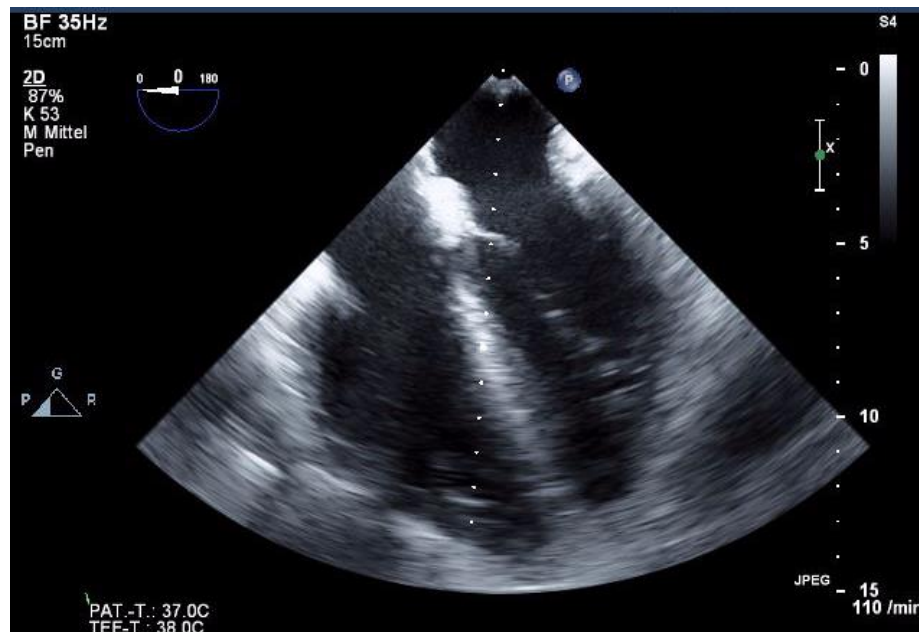


ECHO during LVAD - Activation



- LVAD and left Ventricle

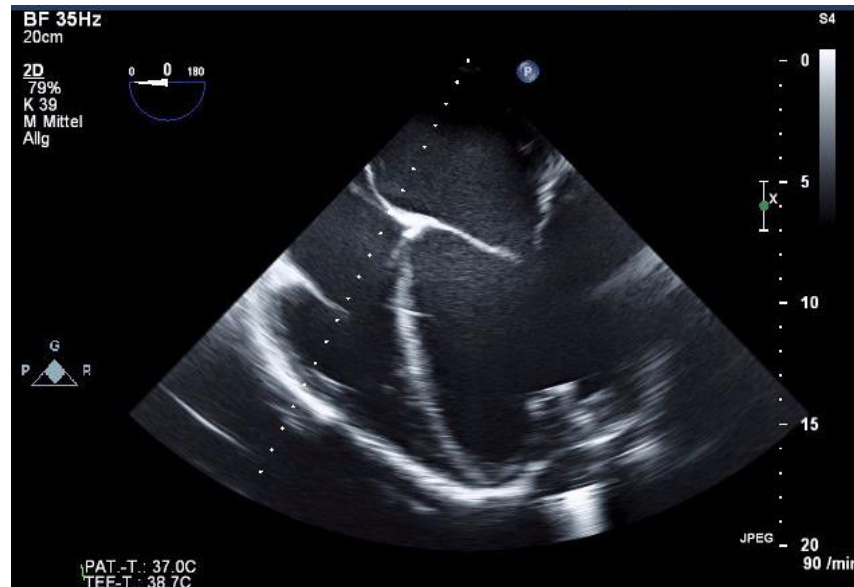
- LV should be unloaded
- LA should be unloaded
- IV-Septum is expected to remain neutral



ECHO during LVAD - Activation



- LVAD and left ventricle
 - IV Septum shifts rightwards
 - » Inadequate LV unloading (inadequate LVAD speed, suboptimal LVAD Function, Inflow-cannula obstruction)

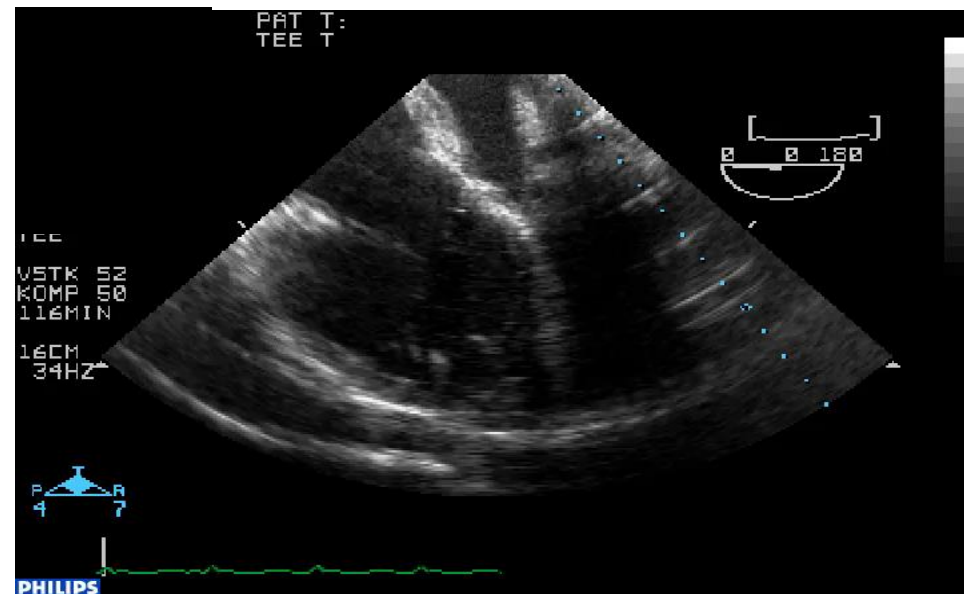
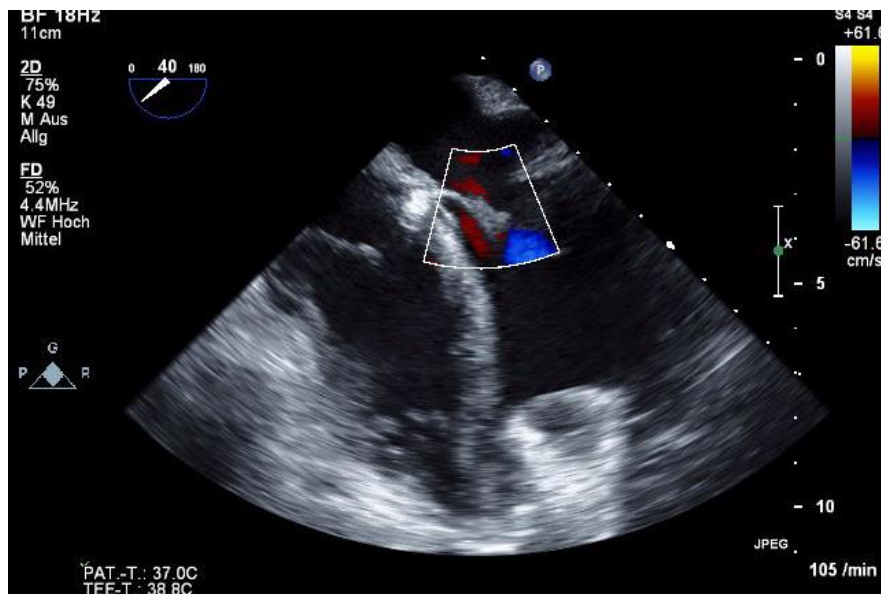


ECHO during LVAD - Activation



- LVAD and left ventricle

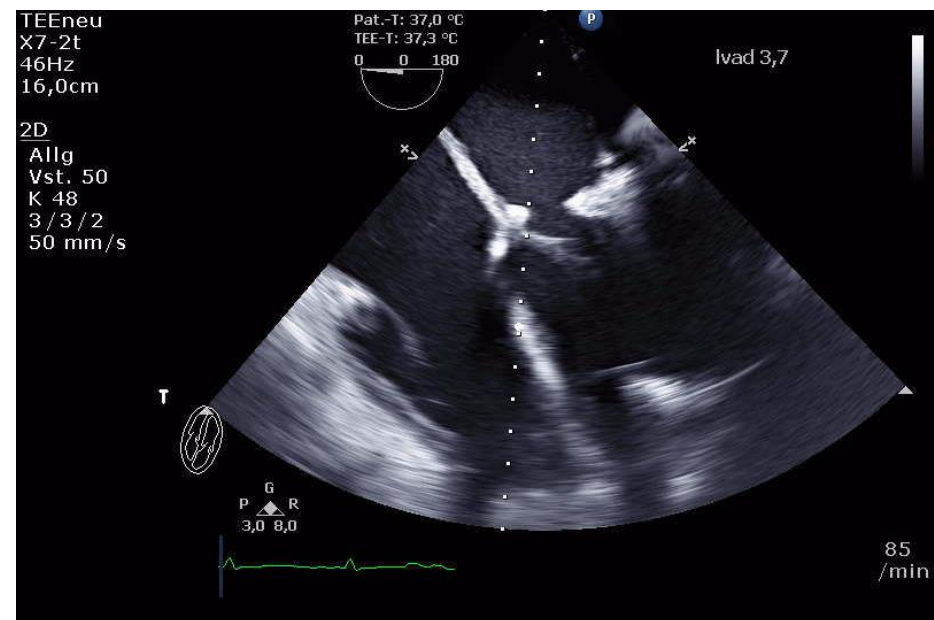
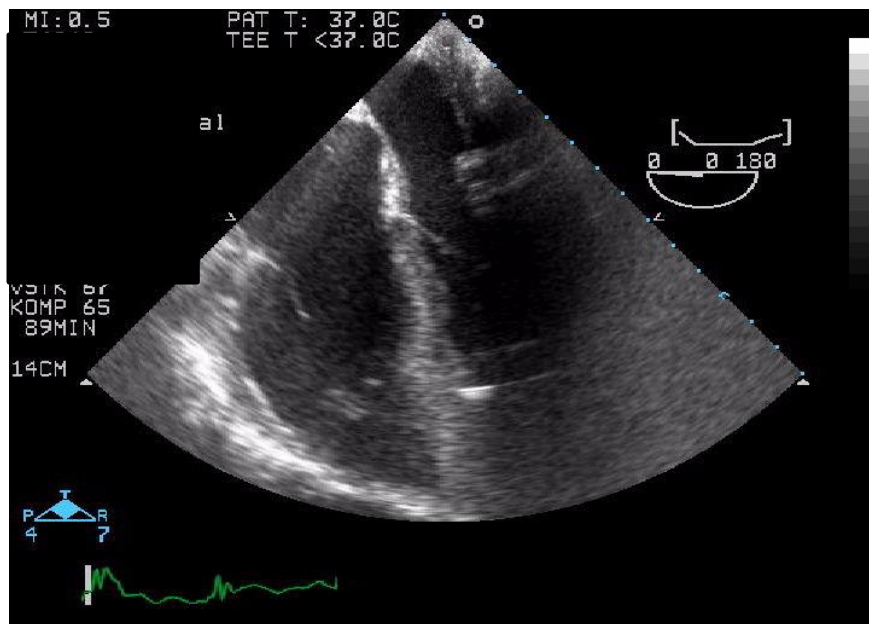
- IV Septum shifts leftwards
 - » Excessive LV-unloading –
 - Hypovolemie
 - High pump speed
 - RV Failure
 - » Result in RV dysfunction, worsening of TR and onset of RV failure



ECHO during LVAD - Activation



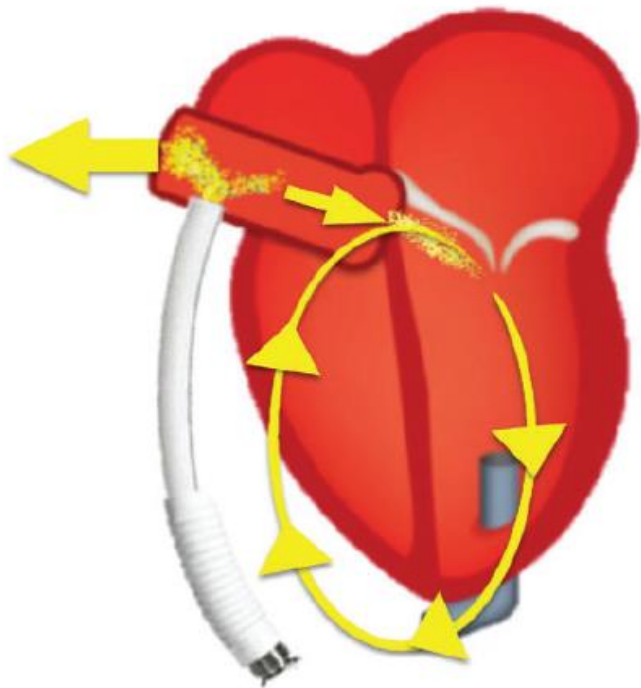
- **LVAD and right ventricle**
 - LV mechanical decompression -> \downarrow RV after-load
 - \uparrow Left-side output -> \uparrow RV pre-load
 - Excessive unloading LV -> leftward shift of septum
 - Air in the RCA -> RV dysfunction



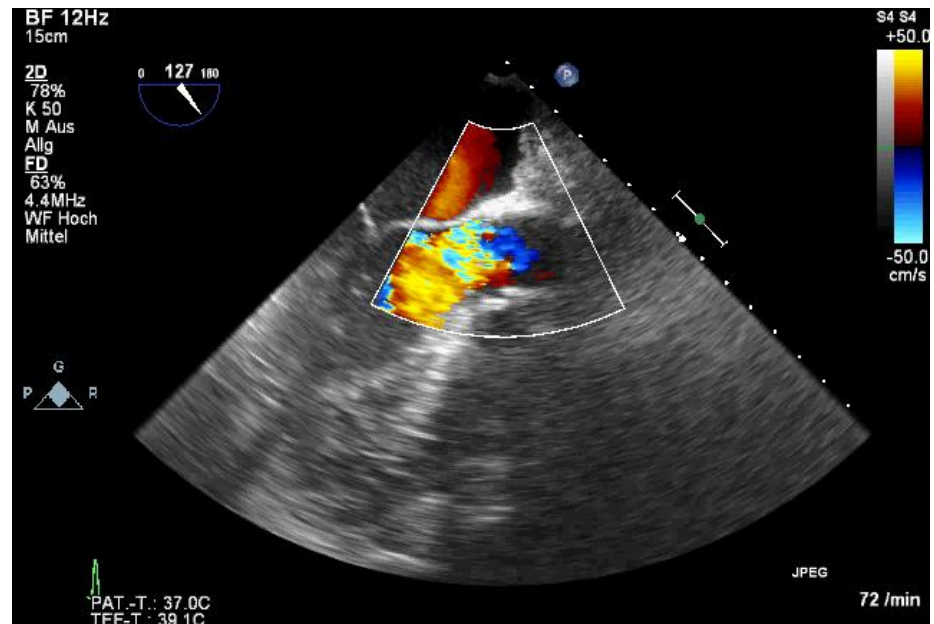
ECHO during LVAD - Activation



- Re-evaluation of AR



closed loop

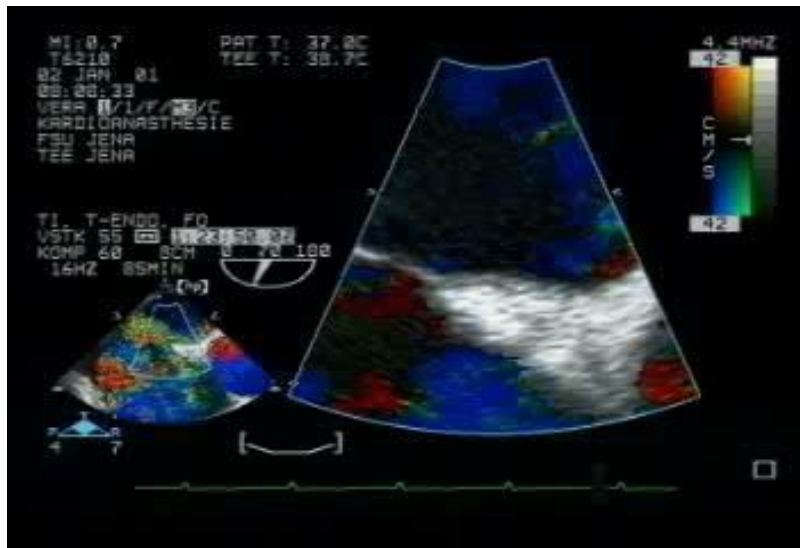


S. Bouchez et.al EHJ 2019 20 373-382

ECHO during LVAD - Activation



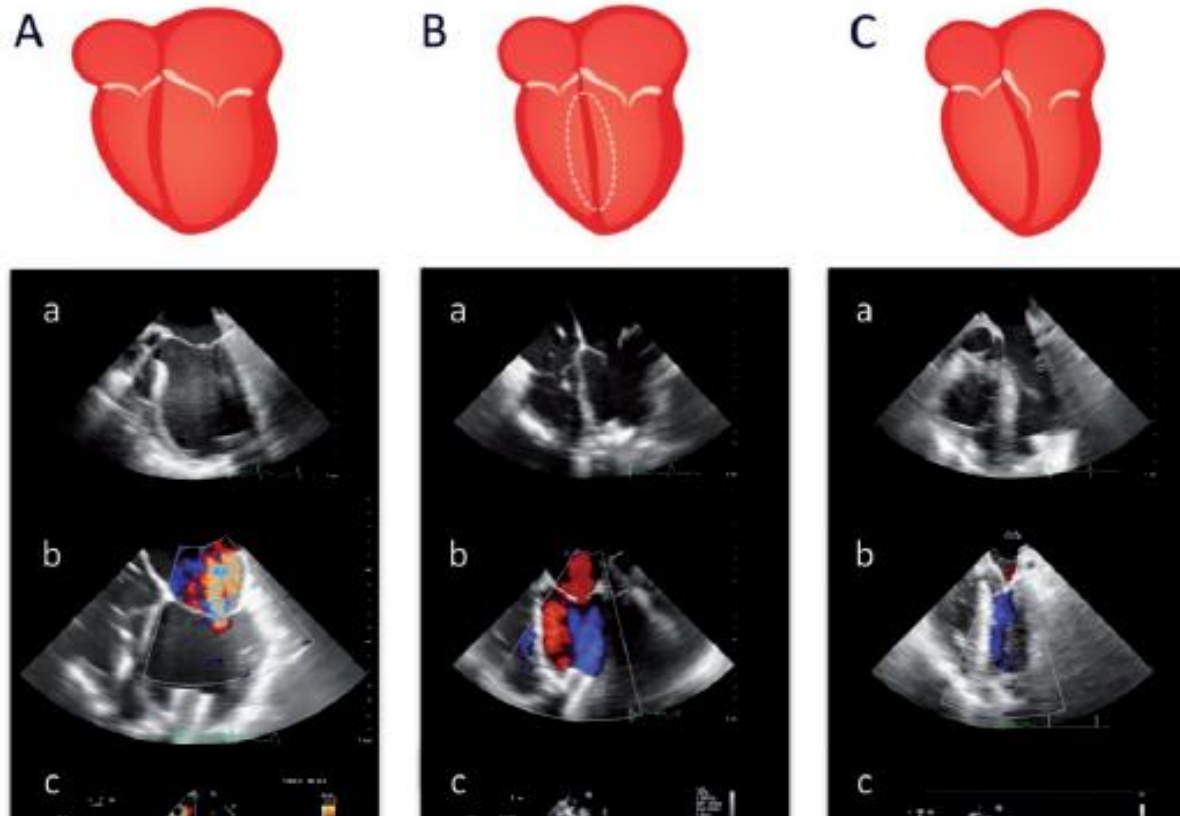
- Intracardiac shunts
 - LA-pressure reduces
 - RA-pressure remains
 - PFO / ASD: R-L Shunt
 - 20% of PFO may be unmasked after LVAD activation



RV dysfunction after LVAD

- Pre-existing increased transpulmonary gradient
- Increase CO by LVAD leading to increased RV-preload
- RV- ischaemic injury
- Altered RV geometry – septum position
- Chest closure
- RV cardiac tamponade

LV- RV ECHO



$$\text{LV unloading} = \frac{\text{Rotor speed} \times \text{PVR} \times \text{TR}}{\text{Preload} \times \text{SVR} \times \text{RVC}}$$

Haemodynamic management after LVAD activation

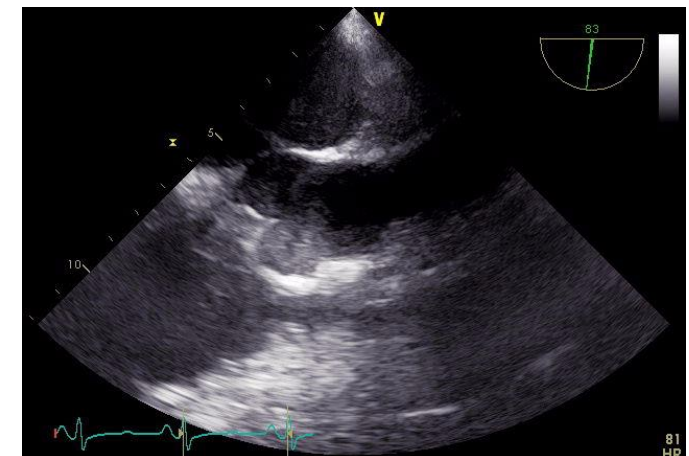
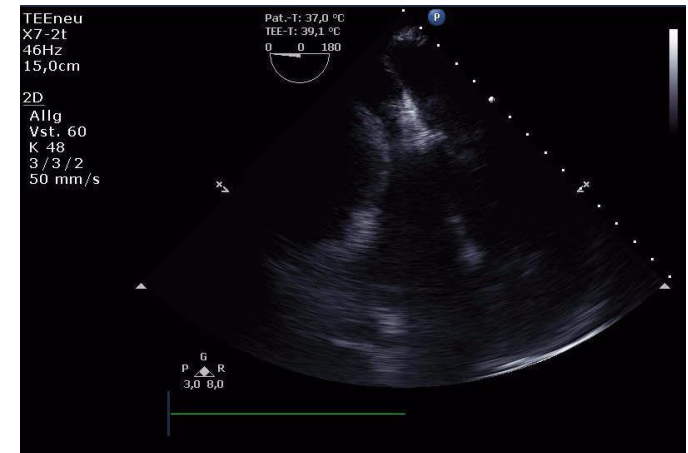


- Optimize the RV function by:
 - Reducing PVR - iNO, PG
 - Increasing the RV contractility:
 - PDE inhibitors
 - Adrenaline
 - SVO2, CI, PAP-diastolic, CVP
- Administer enough fluid volume to allow sufficient LVAD performance, avoiding the overloading of the RV
- Individualize blood transfusion for anaemia (TRALI)
- Treat vasoplegia with norepinephrine or vasopressin to preserve perfusion pressure

End of surgery



- Maintain MAP < 90 mmHg
- Maintain CVP 10-15 mmHg
- Maintain Hct around 30%
- Normoxia, normocarbida
- Reverse Heparin with Protamin
- **TOE till the end of surgery:**
 - RV
 - Inflow Cannula
 - Outflow Cannula



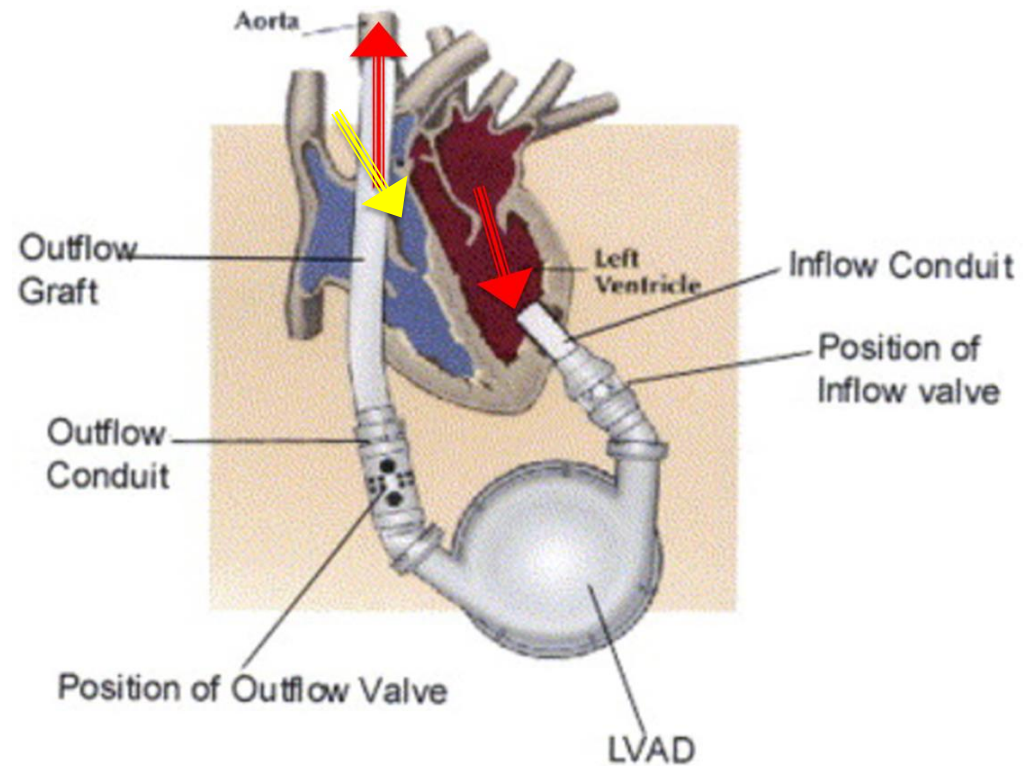
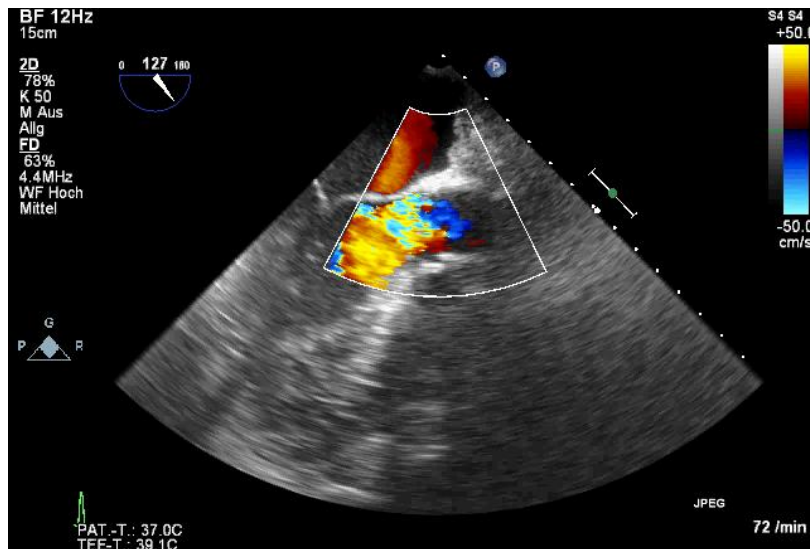
Thank you for your attention



ECHO during LVAD - Activation

- Re-evaluation of AR

closed loop



ECHO during LVAD - Activation



- Rule out the presence of air in the LV, the inflow cannula and the ascending aorta

