

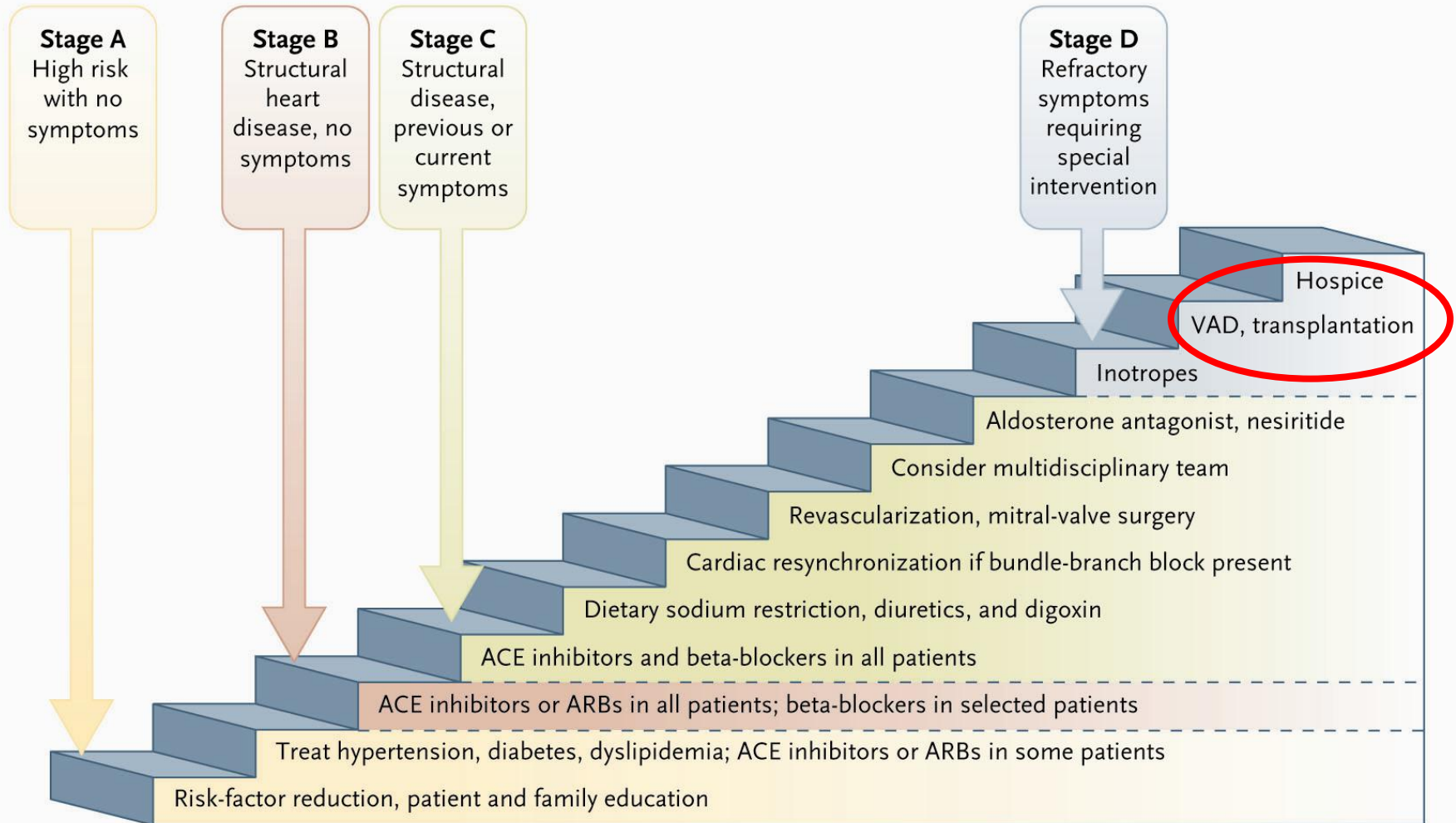


Ο ΡΟΛΟΣ ΤΗΣ ΗΧΩΚΑΡΔΙΟΓΡΑΦΙΑΣ ΣΤΗΝ ΜΕΤΑΜΟΣΧΕΥΣΗ ΚΑΙ ΤΙΣ ΣΥΣΚΕΥΕΣ ΥΠΟΒΟΗΘΗΣΗΣ ΤΗΣ ΚΥΚΛΟΦΟΡΙΑΣ

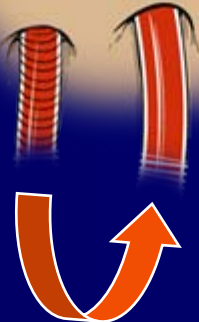
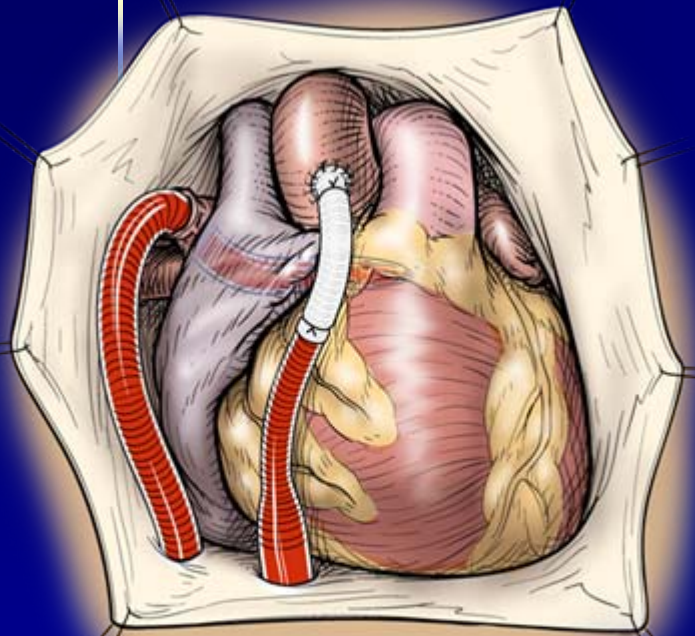
Ε. Δ. Λεοντιάδης
Καρδιολόγος

Α' Καρδιολογική Κλινική και
Μονάδα Μεταμοσχεύσεων-Μηχανικής Υποστήριξης της Κυκλοφορίας
Ωνάσειο Καρδιοχειρουργικό Κέντρο

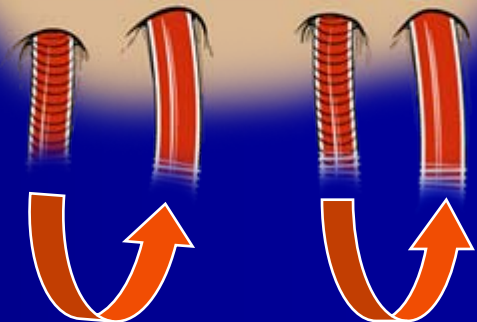
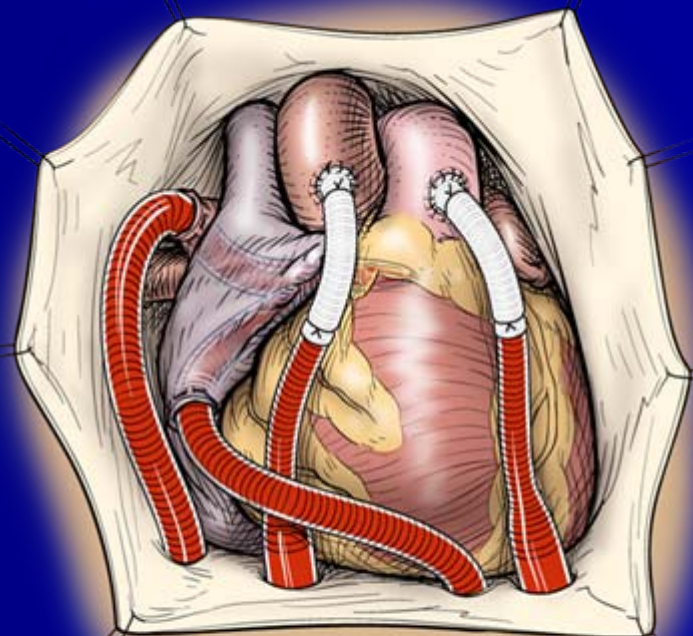
Treatment Overview of HEART FAILURE



Left Ventricular Support



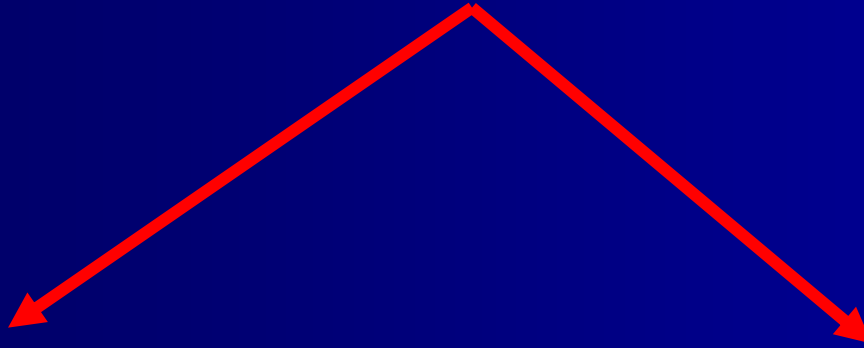
Biventricular support



Weaning → **RECOVERY**



Bridge To Bridge



BTR



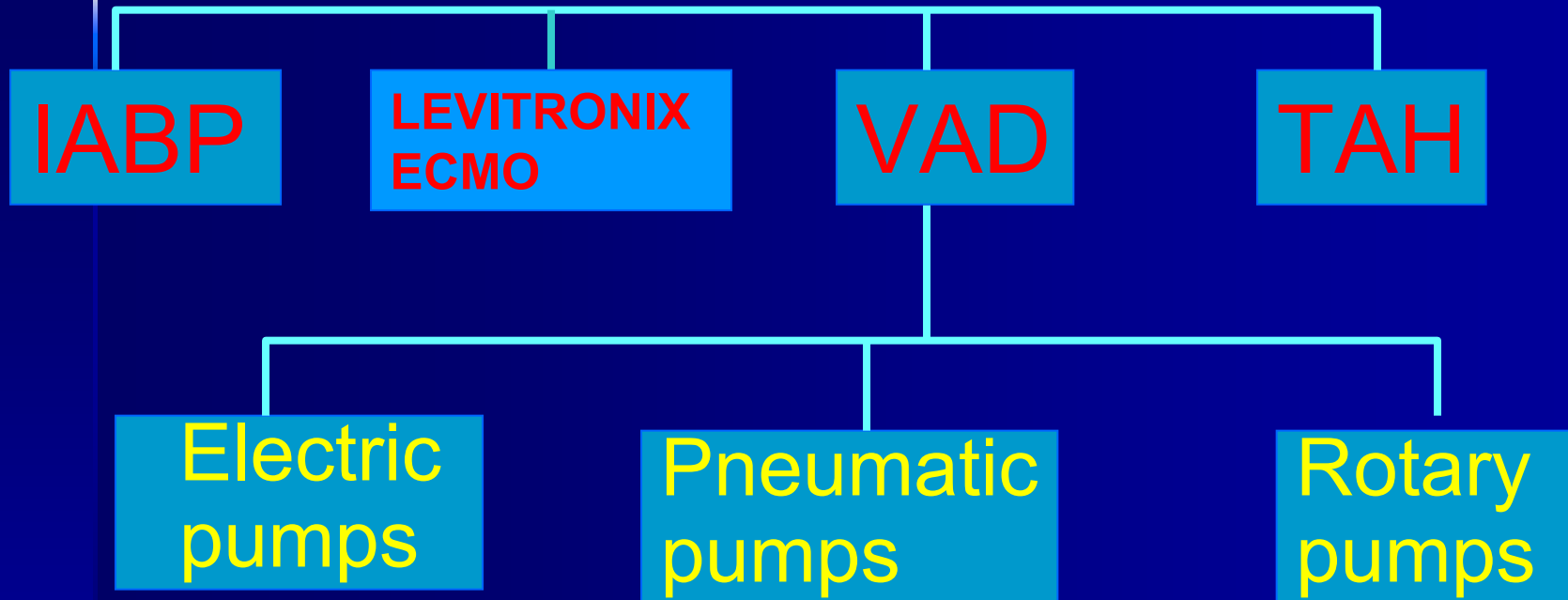
BTT

Recovery of myocardial function expected
(myocarditis, RV failure after LVAD implantation...)

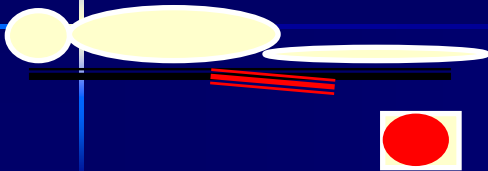
- Listed patients for HTx
- Low-Output Syndrome, inotropic dependent
(failure to wean within 5-7days) ± IABP,
- Pending (cardiac output related) multiorgane failure

Mechanical Circulatory Support

Systems

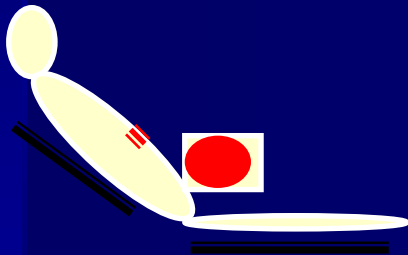


MCS Classification by Position



Extra-corporeal

Centrifugal pumps,
Abiomed



Para-corporeal

Thoratec, MEDOS, Berlin Heart



Partially Implantable

Heartmate, Novacor,
CardioWest TAH,
Rotary VADs

Totally Implantable

LionHeart, AbioCor

Levitronix

- **CHEAP!!!**
- Extracorporeal, single use, centrifugal pump
- Continuous flow
- Can be attached easily to CPB cannulas already in place
- **Fem-Fem implantation possible**



PRICE	Levitronix	Berlin EXCOR	Berlin INCOR	Heartware
Euro	8000	130.000	174.000	206.000

Vascular Access for Extracorporeal Life Support

177

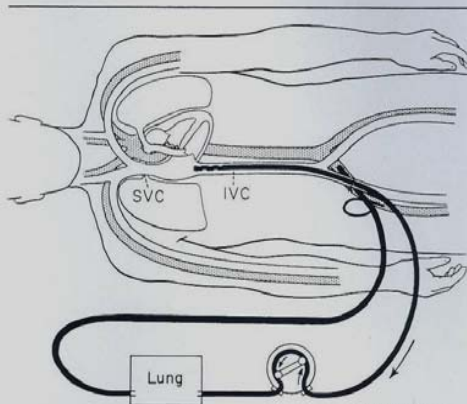


FIGURE 12.2 Venoarterial bypass via the femoral vessels. (Modified with permission from Bartlett RH. Extracorporeal life support for cardiopulmonary failure. Curr Probl Surg 1990; 27:635.)

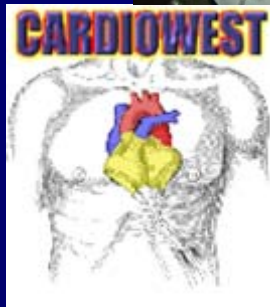
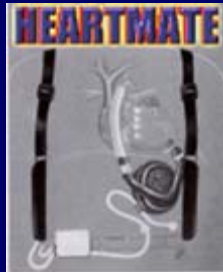
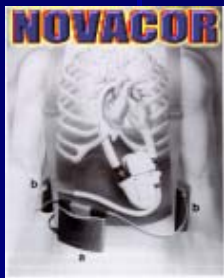
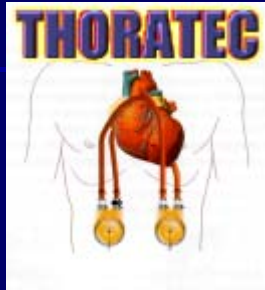
© 1991, University of Michigan



Diverse systems



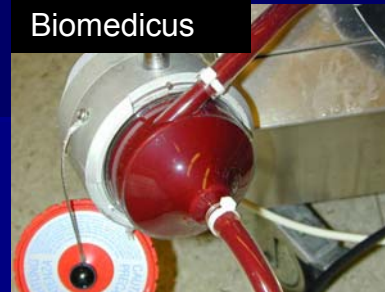
AB5000 Ventricle



Abiomed BVS



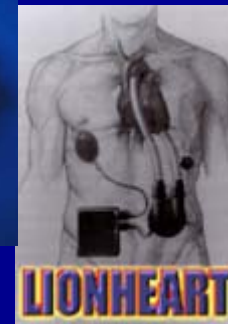
Biomedicus



BerlinHeart Excor



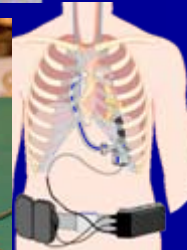
Medos



DuraHeart



CorAide



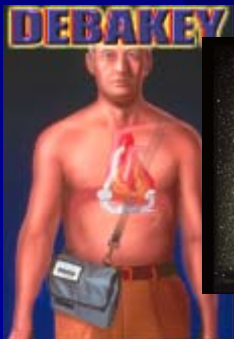
HeartQuest



HeartMate II



INCOR

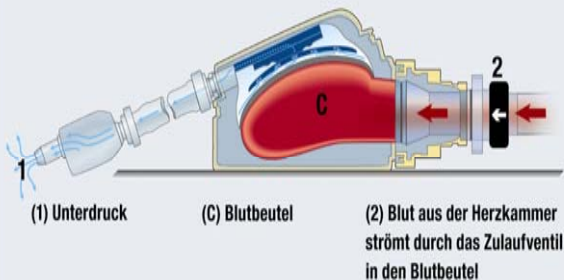


BerlinHeart Excor

- Uni-, Biventricular VAD
- Paracorporeal, pneumatically driven
- Advantage: Variety of sizes (even SV 10 ml possible for pediatric patients)
- 2x/weekly inspection of the pumps for thrombus formation

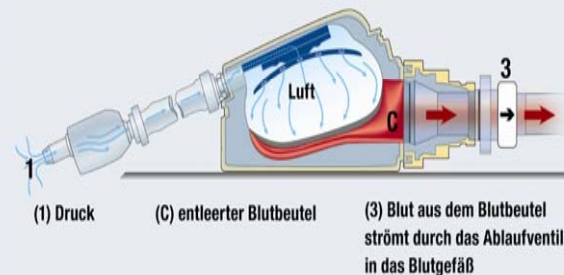


Detailansicht der Pulsationspumpe:



Füllung:

In dem starren Pumpengehäuse (Seitenansicht) befindet sich ein Blutbeutel (C), der über ein Schlauchsystem Verbindung zur Herzkammer und zum korrespondierenden Gefäß hat. Über einen weiteren Schlauch ist das Pumpengehäuse mit einem Druckluftsystem verbunden. Bei Sog (Unterdruck, 1) entfalt sich der Beutel und füllt sich mit dem Blut der Herzkammer über das Zulaufventil (2).

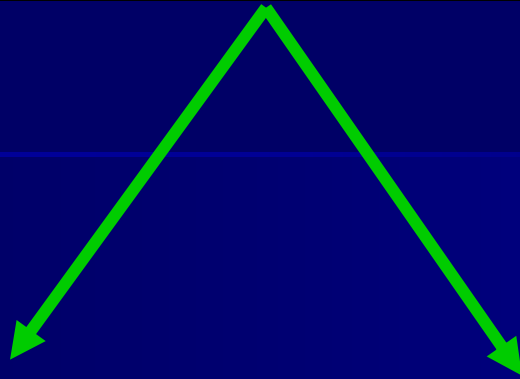


Entleerung:

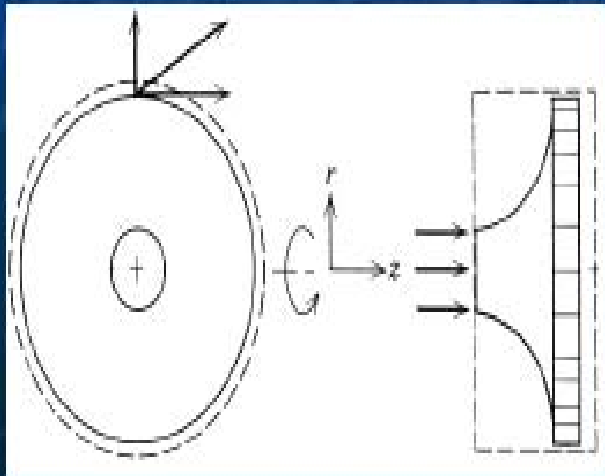
Wird über das Druckluftsystem Druck (1) im Pumpengehäuse (Seitenansicht) aufgebaut, schließt sich das Zulaufventil. Das Ablaufventil (3) zum Gefäß öffnet sich und das Blut strömt aus dem Blutbeutel (C) in Richtung Gefäß.

ROTARY PUMPS

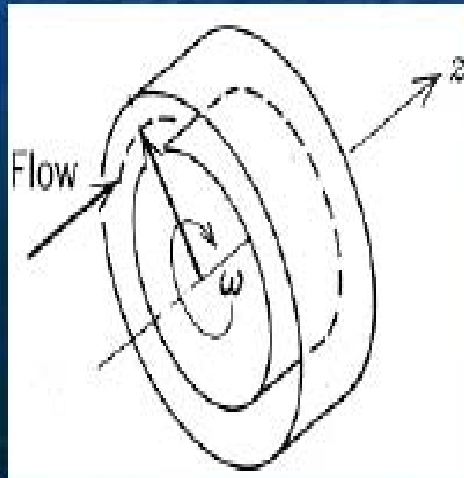
(nonpulsatile- continuous flow)



- **Continuous** flow: Flow amplitude (output) is independent of time
- **Pulsatile** flow : Flow amplitude (output) is dependent of time (e.g. normal circulation from the heart is pulsatile)



Centrifugal

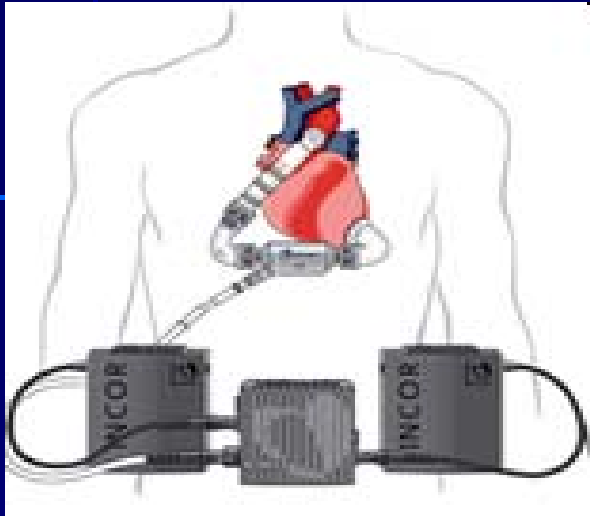


Axial flow

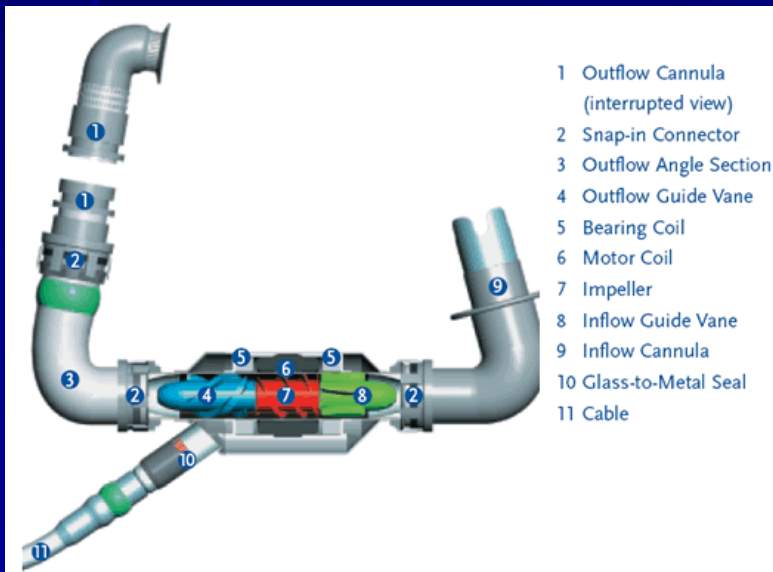
Advantages:

- Miniaturized
- Easy to implant
- Shorter CPB time
- Small pocket
- Less bleeding
- Less infection
- Suitable for children
- No noise
- Durable

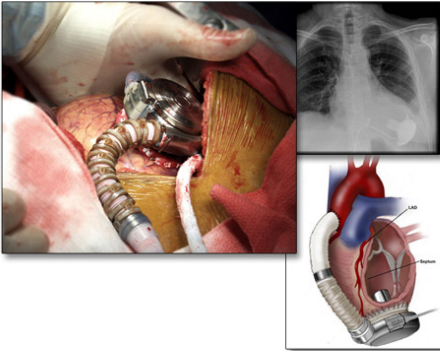
BERLIN INCOR



- Active magnetic bearing (non-friction and non-wearing)
- Pulsatility control → prevention of SUCTION
- 5000-10000 rpm
- Volume= 82ml,
Diameter= 30mm,
Length 12 cm,
Weight = 200gr



HeartWare HVAD
Implanted in Pericardial Space



Potential Benefits

No pump pocket or
abd surgery

Shorter implant time

Reduced procedural
invasiveness
and complexity

Reduced recovery time

Heartware

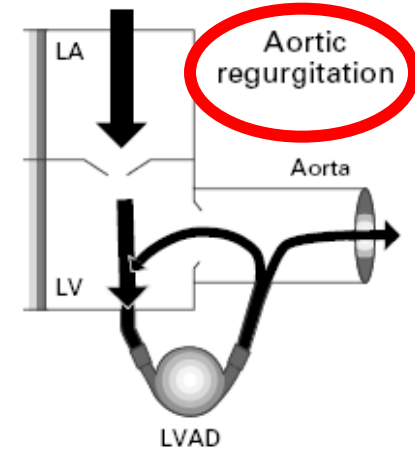
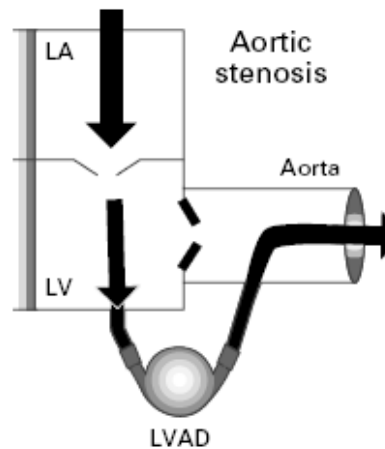
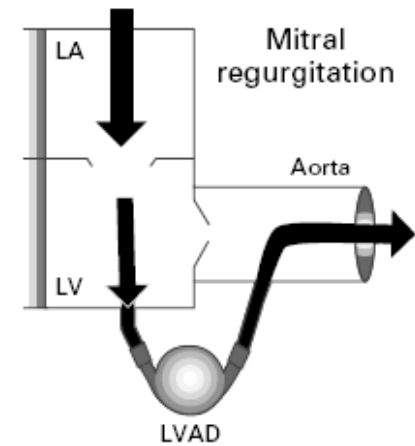
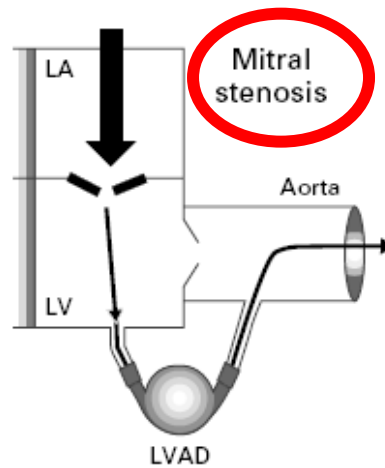
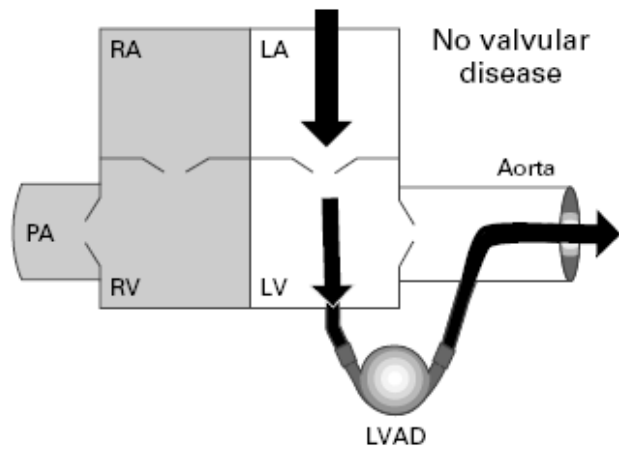
- Centrifugal pump
- The impeller is suspended through a combination of passive magnets and a hydrodynamic thrust bearing
- Implanted in the pericardial space
- 2000-3000 rpm





PRE-operative assessment

1. **PFO/ASD** (esp. LVAD: LA pressure $\downarrow \rightarrow$ R-L-shunting $\rightarrow$ arterial hypoxemia!)
2. **VSD**
3. **RV function** (LVAD? BVAD?TAH?)
4. **LA/LV apex thrombi**
5. **Aorta ascendens** (atheromatous plaques at anastomosis site...)
6. **Valve disease** (AVR for AR $\geq$ 1+, MVR for severe MS, BIOPROSTHETIC !)



INTRA-OPERATIVE assessment



1. RV failure

1. CVP > 20 mmHg
2. LAP < 10 mmHg
3. SAP < 90 mmHg
4. CI < 2 l/min/²

→ epicardial pacing, dobutamine, NO, levosimendan, prostaglandin E1, milrinone...ECMO/R-VAD

2. De-airing and initiation of pumping (Air embolism!)

3. LV apex /LA Inflow cannula (position/ obstruction/thrombus...)

4. LV unloading (IVS position ↔ Inflow cannula ↔ MV position)

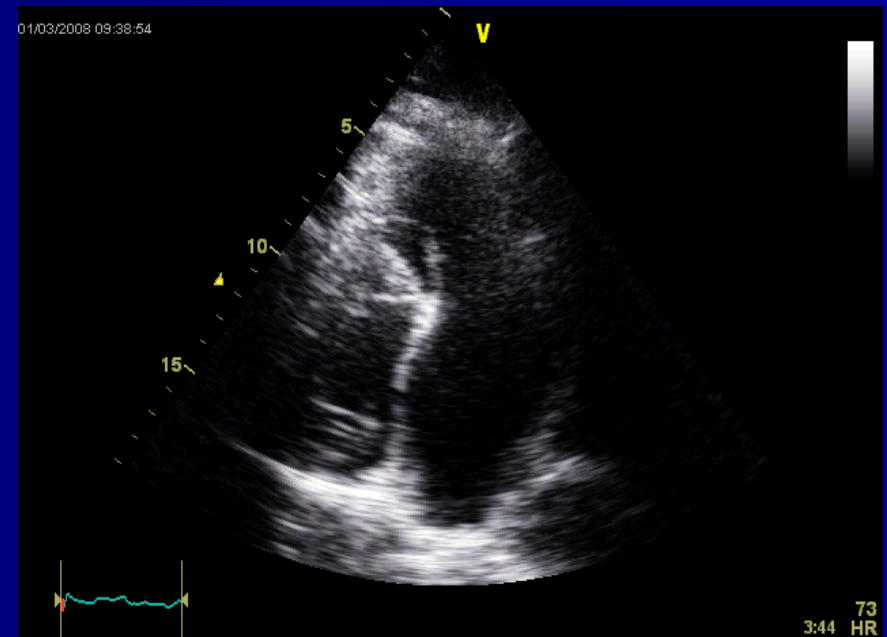
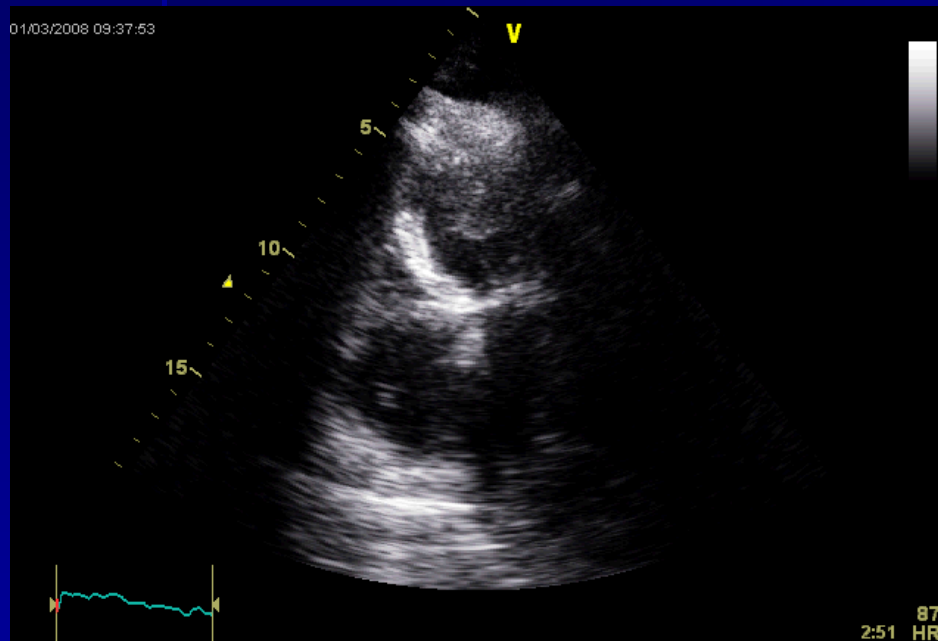


POST-OPERATIVE assessment

1. **Tamponade** (inadequate BP and low VAD flow)
2. **Weaning evaluation/ Myocardial recovery**
3. **LVAD dysfunction**
 - **TTE**: Inflow valve regurgitation, Inflow conduit obstruction, Outflow graft kinking, new regurgitation of the native valves

(Horton SC, JACC 2005;35:1435)

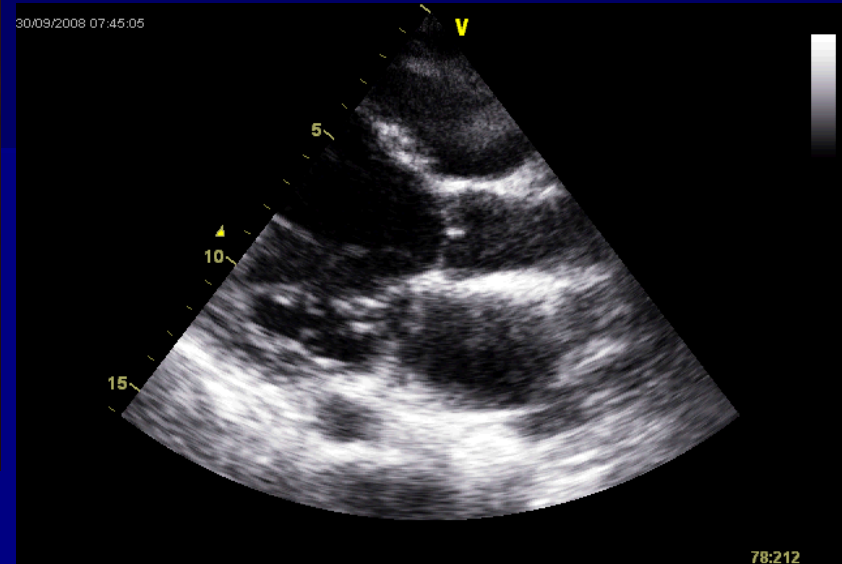
43 yo, F, RCM→DCM,
→BiVAD
→Inflow cannula reposition



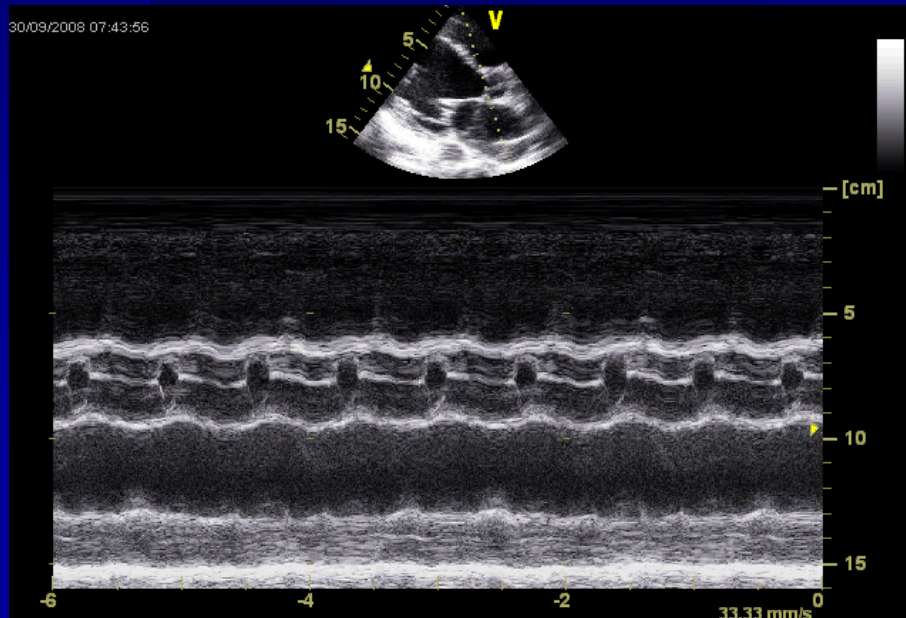
31 yo, M, DCM
→ Controller malfunction



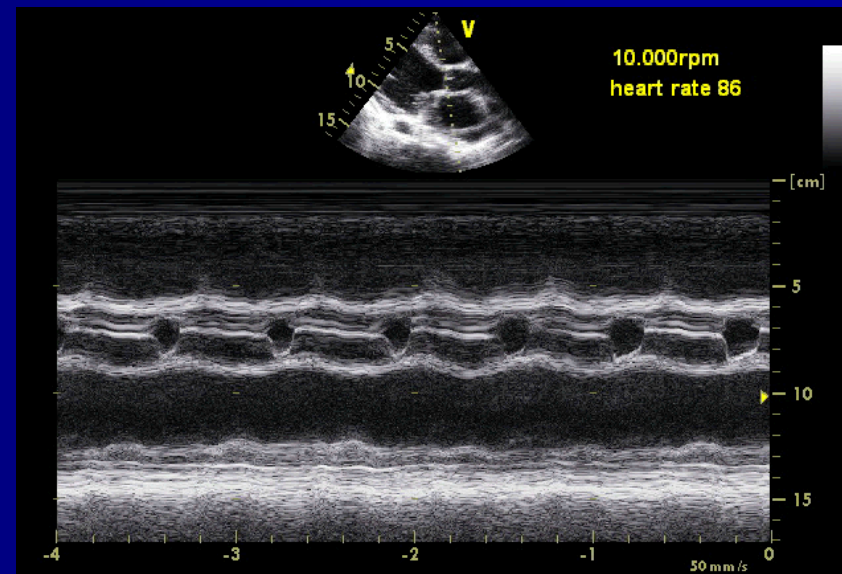
9000rpm
Heart rate 80



8000rpm
Heart rate 80

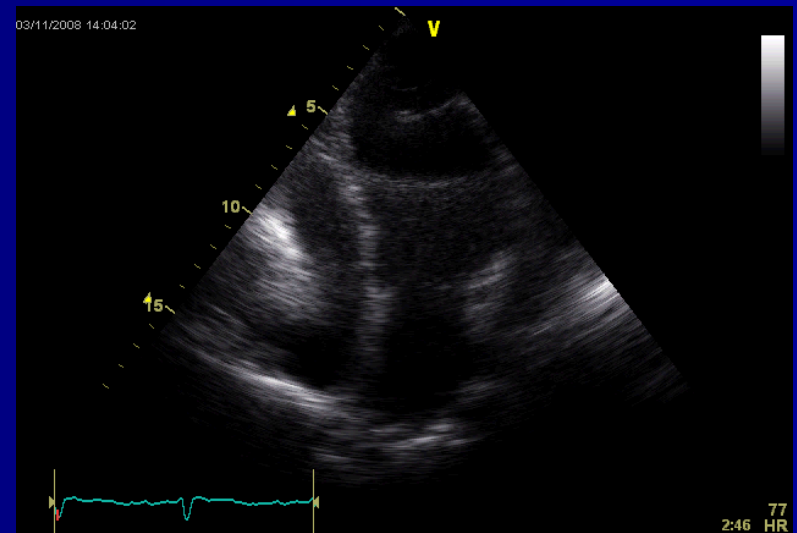
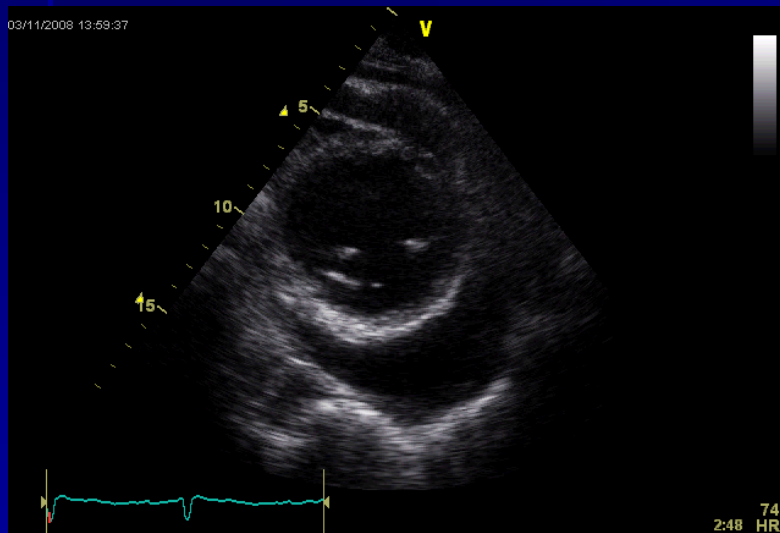


10.000rpm
heart rate 86





28 yo, F, ΥΠΕΡΗΩΣΗΝΟΦΙΛΙΚΟ ΣΥΝΔΡΟΜΟ → DCM
→ LVAD
→ Tamponade

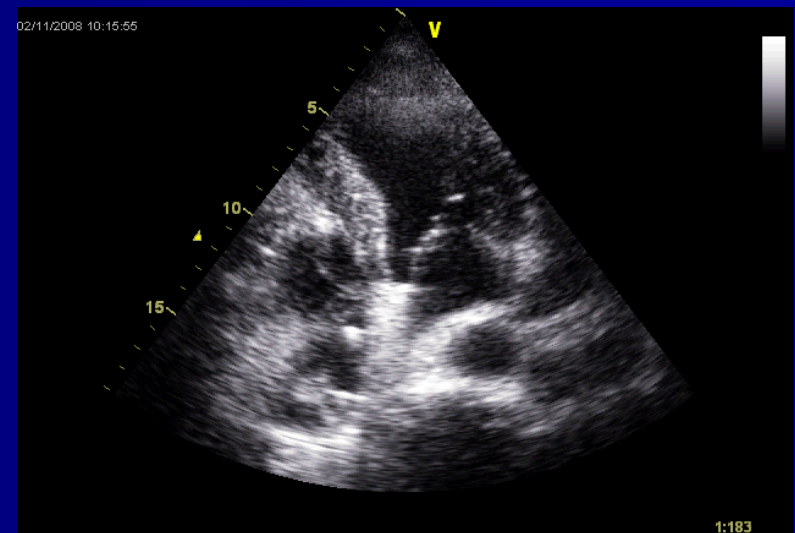
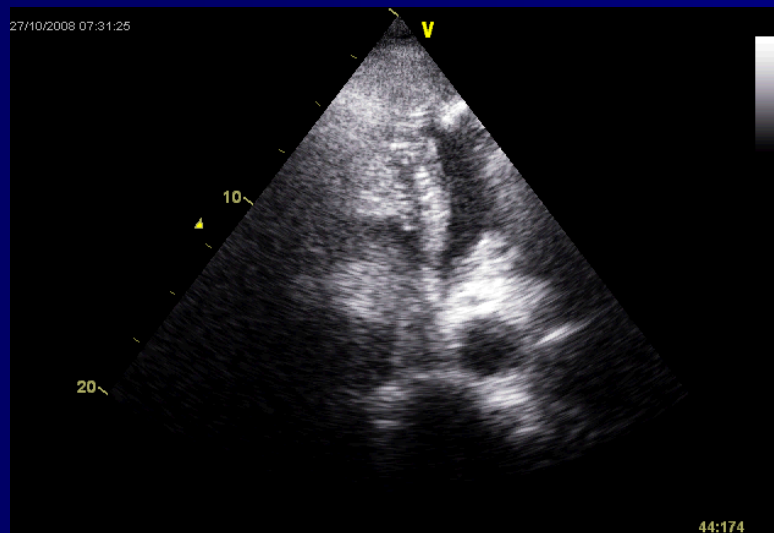




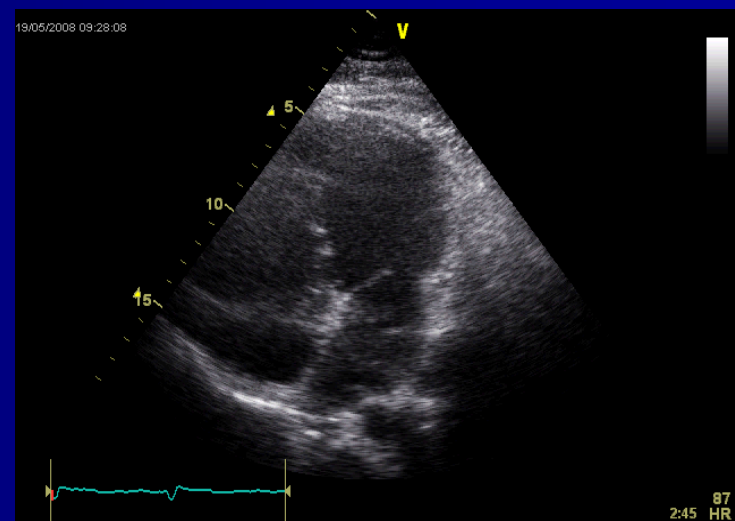
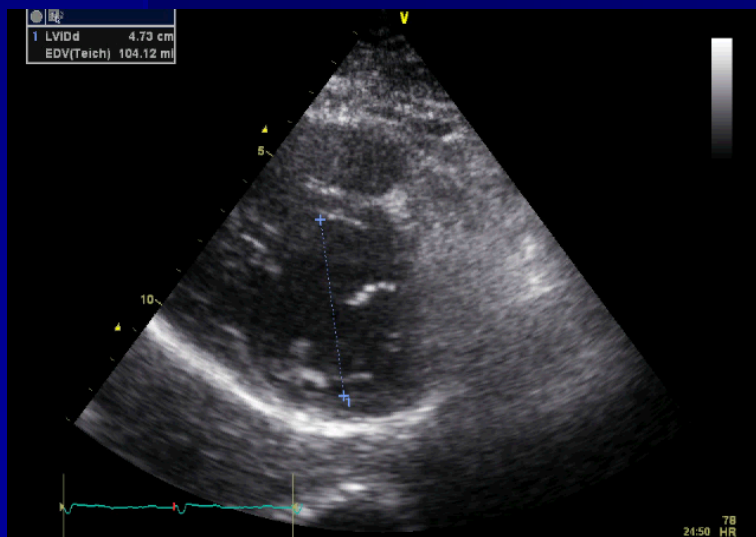
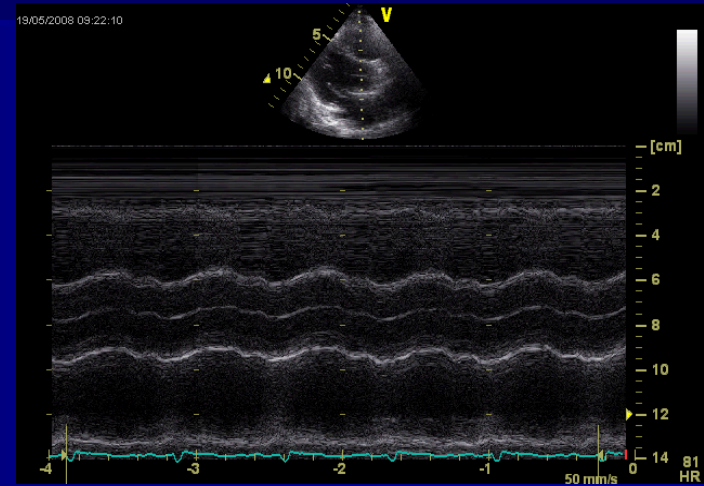
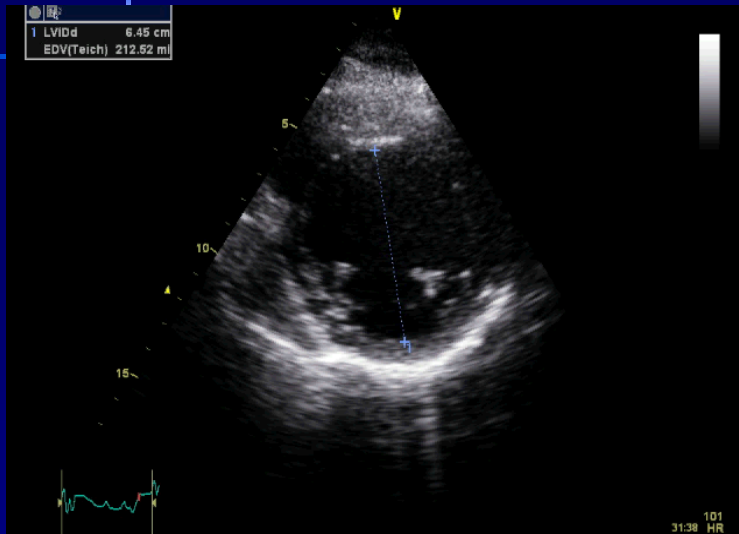
51, M, DCM

→BiVAD + AVR (Bio)

→Volume depletion



20 yo, M, chemotherapy→DCM
→LVAD
→LV unloading

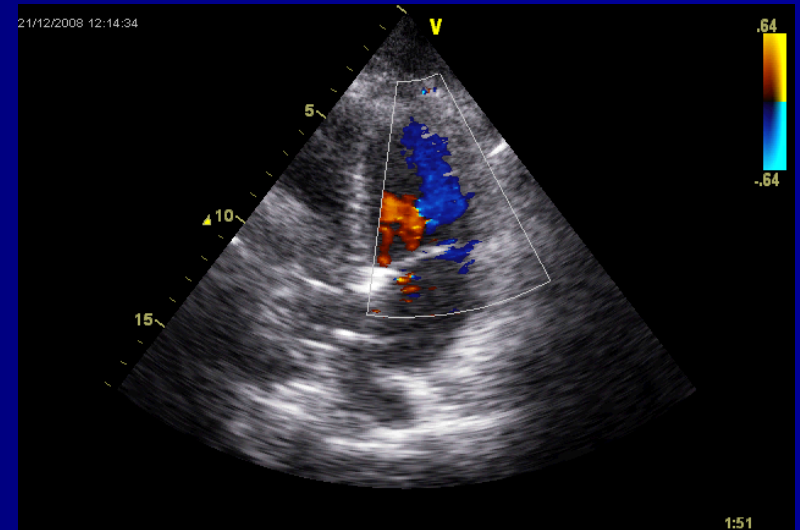
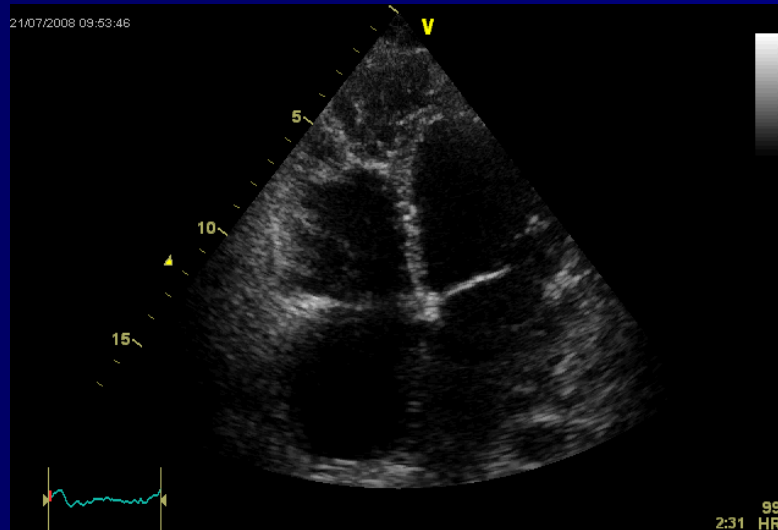




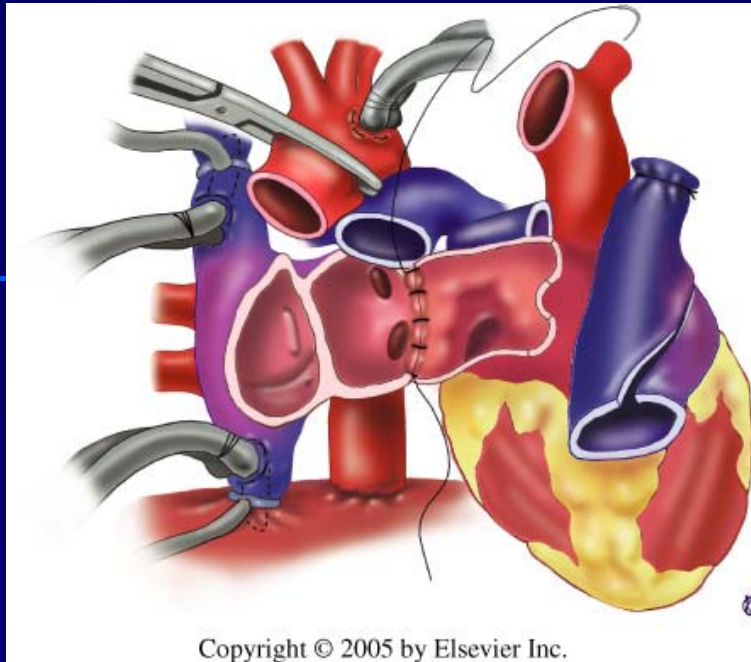
51, F, Arrhythmogenic Right Ventricular Dysplasia

→ BiVAD

→ Inflow cannula malapposition

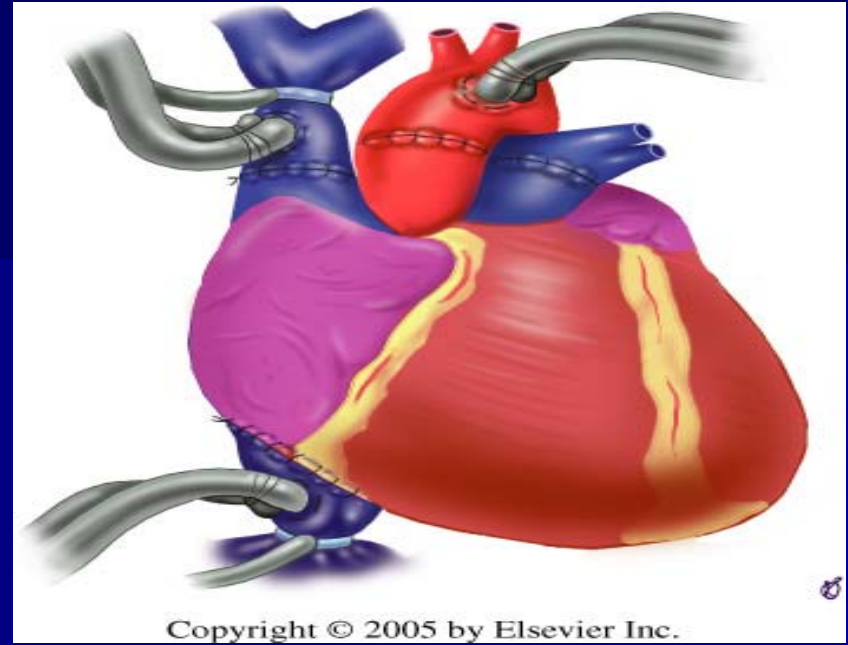


Standard technique



- Most common because the ischemic time is shorter.
- Complications include **atrial dysfunction** due to size mismatch of atrial remnants and **arrhythmia** (sinus node dysfunction, bradyarrhythmias, and AV conduction disturbances) that necessitate PPM implantation in 10-20% of patients.

Bicaval technique



- Decreases incidence of arrhythmias, the need for a pacemaker, and risk for mitral or tricuspid regurgitation.
- However **narrowing of the SVC and IVC** make biopsy surveillance difficult and ischemic times can be prolonged

HTx

Indications-Contraindications

Table 1 Cardiac transplantation indication criteria

1. <i>Accepted</i>	Heart Failure Survival Score (HFSS, Aaronson 1997 ⁴) high risk Peak $\text{VO}_2 < 10$ ml/kg/min after reaching anaerobic threshold NYHA class III/IV heart failure refractory to maximal medical treatment Severely limiting ischaemia not amenable to interventional or surgical revascularisation Recurrent symptomatic ventricular arrhythmias refractory to medical, ICD, and surgical treatment
2. <i>Probable</i>	HFSS medium risk Peak $\text{VO}_2 < 14$ ml/kg/min and severe functional limitations Instability of fluid status and renal function despite good compliance, daily weights, salt and fluid restriction and flexible diuretics Recurrent unstable ischaemia not amenable to revascularisation
3. <i>Inadequate</i>	HFSS low risk alone Peak $\text{VO}_2 > 15$ –18 ml/kg/min without other indications Left ventricular ejection fraction $< 20\%$ alone History of NYHA class III/IV symptoms alone History of ventricular arrhythmias alone

ICD, implantable cardioverter-defibrillator; NYHA, New York Heart Association; VO_2 , oxygen consumption.

Table 2 Cardiac transplantation contraindication criteria

<i>Cardiac disease</i>	Irreversible pulmonary hypertension (PVR > 6 WU despite standardised reversibility testing protocol)
<i>Other diseases</i>	Active infection Pulmonary infarction within the last 6–8 weeks Significant chronic renal impairment with persistent creatinine > 2.5 or clearance < 25 ml/min Significant chronic hepatic impairment with persistent bilirubin > 2.5 or ALT/AST $> \times 2$ Active or recent malignancy Systemic diseases such as amyloidosis Significant chronic lung disease Significant symptomatic carotid or peripheral vascular disease Significant coagulopathies Recent peptic ulcer disease Major chronic disabling disease Diabetes with end organ damage and/or brittle diabetes Excessive obesity (e.g. $> 30\%$ over normal)
<i>Psychosocial</i>	Active mental illness Evidence of drug, tobacco, or alcohol abuse within the last six months refractory to expert intervention Psychosocial instability refractory to expert intervention
<i>Age</i>	> 65 years

ALT/AST, ratio of serum alanine aminotransferase to aspartate aminotransferase; PVR, pulmonary vascular resistance; WU woods units.

Postoperative Complications (1)

■ Surgical

- Aortic pseudoaneurysm or rupture at cannulation site

■ Rhythm disturbances

- Asystole, Complete heart block.
- Sinus node dysfunction with bradyarrhythmias
(25% permanent but most resolve within 1-2 weeks).
- Atrial fibrillation

■ Coagulopathy induced by cardiopulmonary bypass

■ Respiratory failure

■ Renal or hepatic insufficiency

Postoperative Complications (2)

■ Medical

- Hemorrhagic pericardial effusion due to bleeding or coagulopathy
- LV failure
 - Ischemia time
 - Operative Injury
 - Acute (humoral !) rejection
- RV failure
 - $\uparrow$ TPG/ PVR $\rightarrow$ Pulmonary hypertension
- Severe tricuspid regurgitation

Common echocardiographic findings

- **Intra-atrial ridge** (esp. in biatrial technique)
 - Mass? Thrombus? **Obstruction???**
- **Abnormal IVS motion** → No effect on global LVEF
- **↑ in LV thickness/mass** (rejection → edema, periTx injury, hypertension, chronic tachycardia, CCIs/Prednisone)
- **Pericardial effusions** (usually resolve after the first month, low sensitivity/specificity for rejection Dx)
- **Diastolic filling pattern** (early-late)
- **Valvular regurgitation** (esp. **TR** : 55% of pts >2+ early after Tx → 11% 3 months later, **MR**: 30% → 3%)

Causes of TR after HTx

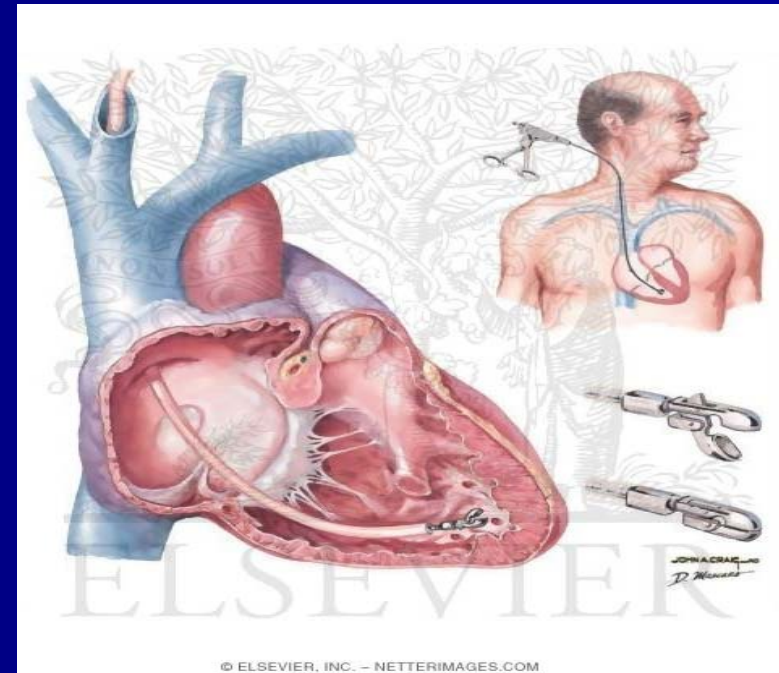
■ FUNCTIONAL

- Central jet
- Geometric distortion/dilatation of the TV annular ring → malcoaptation of leaflets

- Biatrial technique
- Rejection >2+ w/ RV dysfx
- D/R mismatch
- Preoperative abnormal PVR and/or TPG

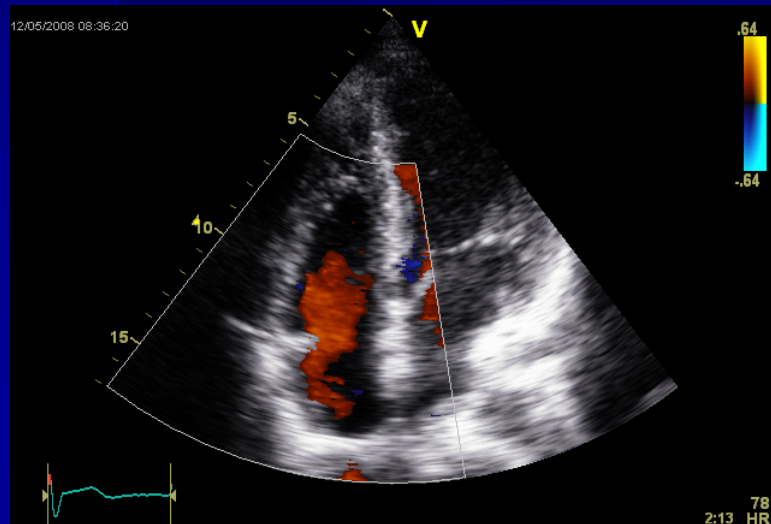
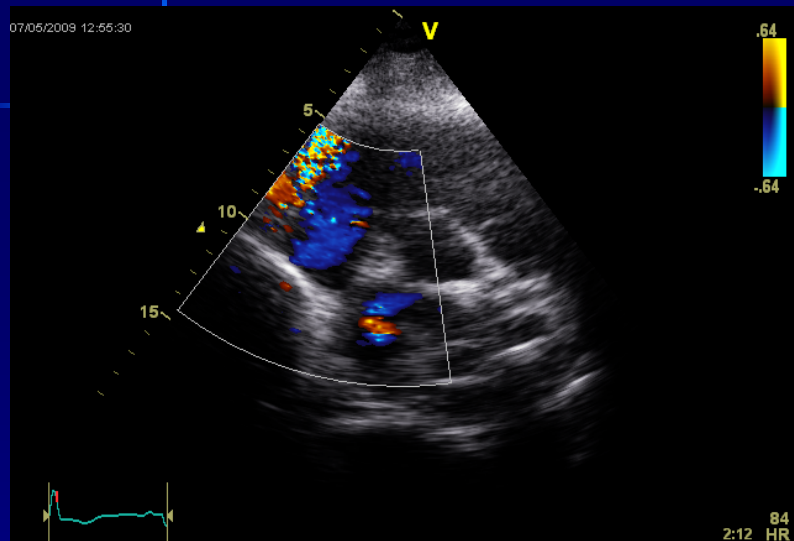
■ ANATOMIC

- Anatomic disruption of the valve apparatus (torn leaflet, ruptured chordae tendinae)
 - prolapse/flail valve

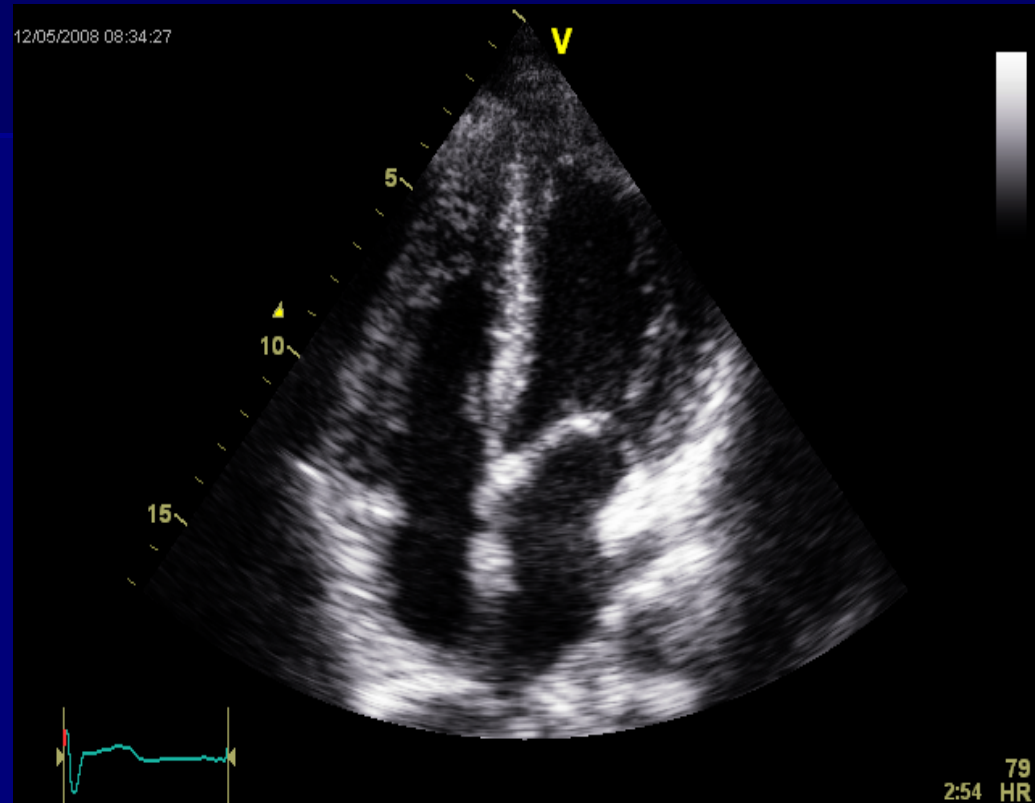


Tricuspid regurgitation

■ FUNCTIONAL

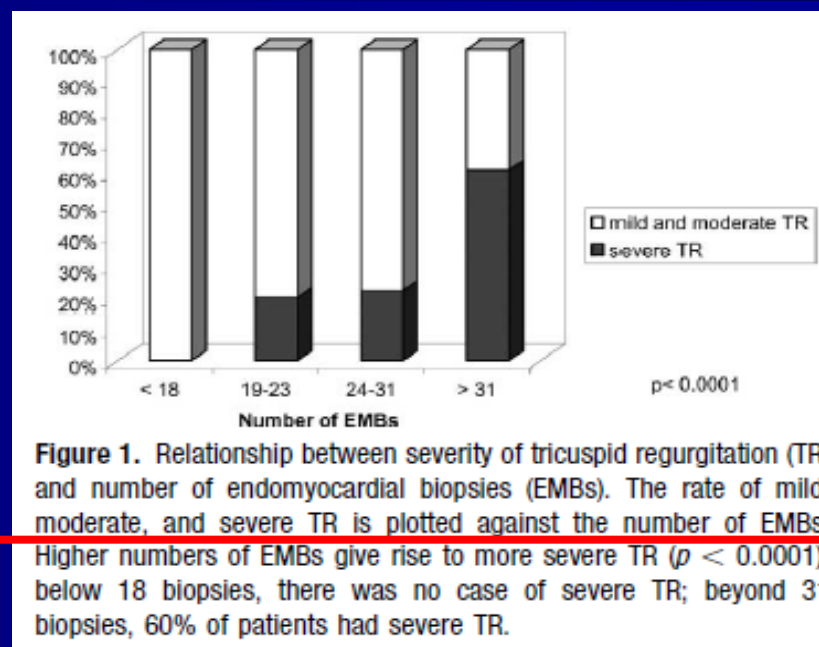


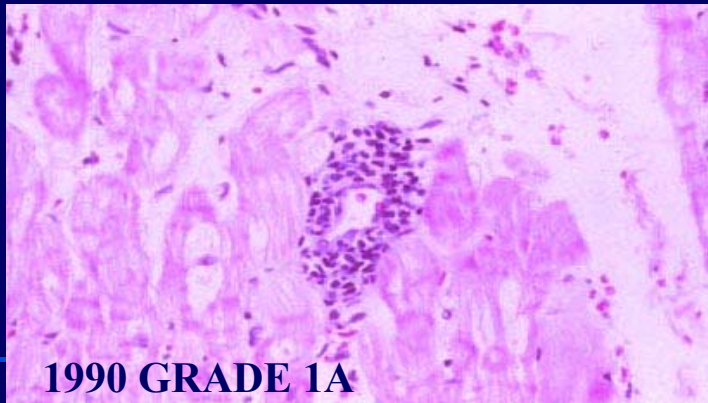
■ ANATOMIC



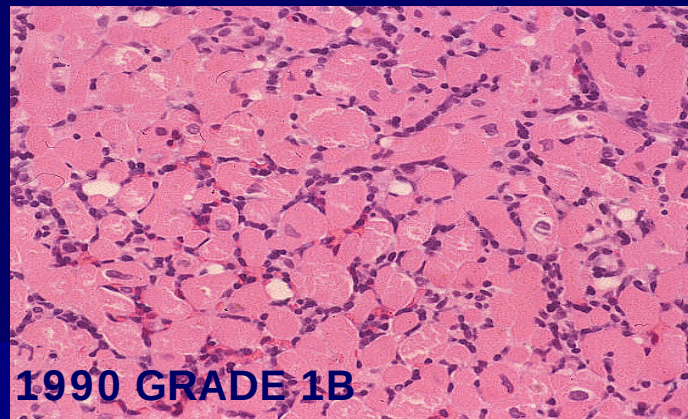
How many biopsies are too many?

- 101 pts w/ HTx
- **RESULTS**
 - Beyond 31 EMBs 60 % had severe TR, thus suggesting a **cutoff of less than 31 EMBs**

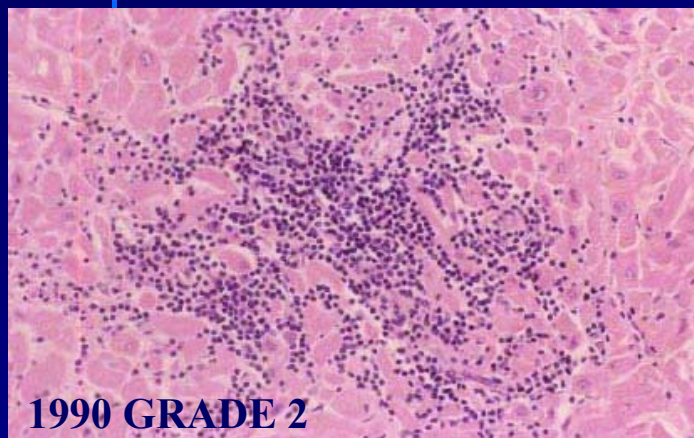




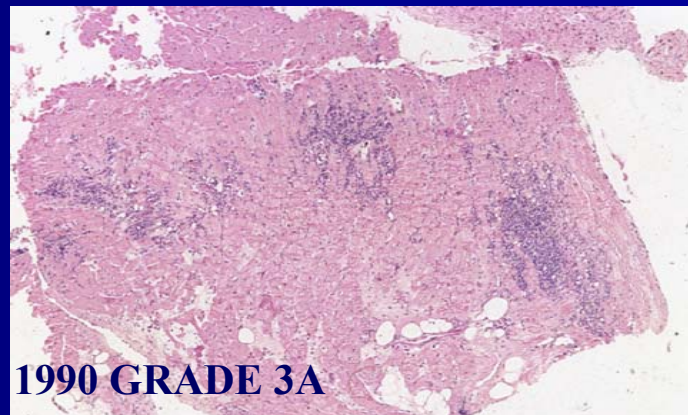
1990 GRADE 1A



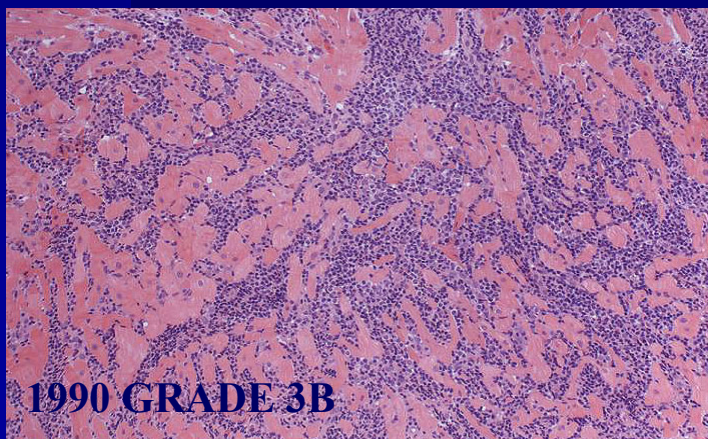
1990 GRADE 1B



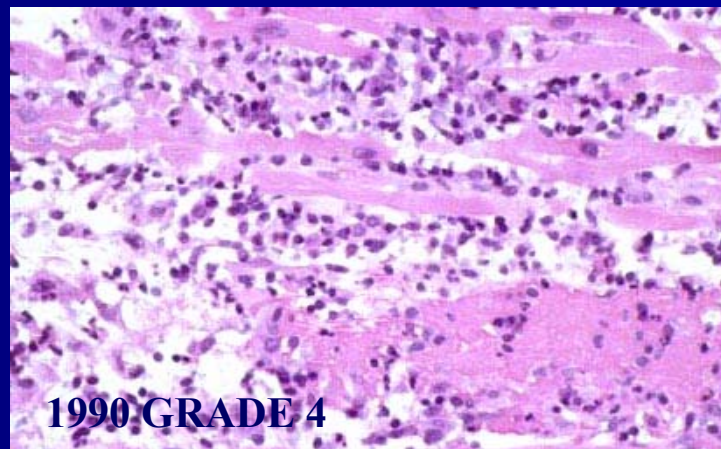
1990 GRADE 2



1990 GRADE 3A



1990 GRADE 3B



1990 GRADE 4

Echocardiographic evaluation of HTx rejection

Parameters associated with rejection episodes

- Increased pericardial effusion and PW thickness
- Shortened IVRT
- $E/A \text{ (MV)} > 1.7$
- Duration of PV atrial reversal
- $\uparrow$ of Myocardial performance index (MPI)
- $\downarrow$ Ejection fraction-stroke volume
- Decreased tissue Doppler velocity (radial strain from basal post wall)
- E/Ea ratio (inconsistent results!)

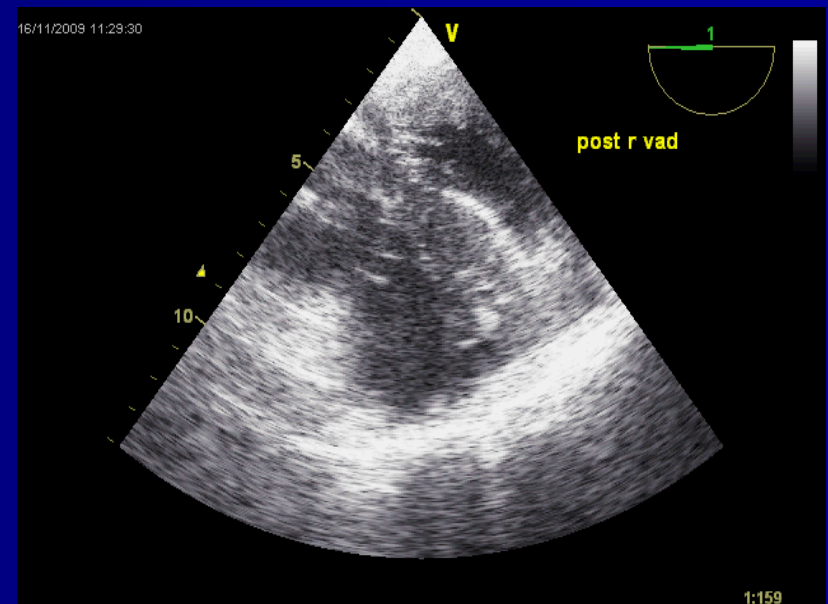
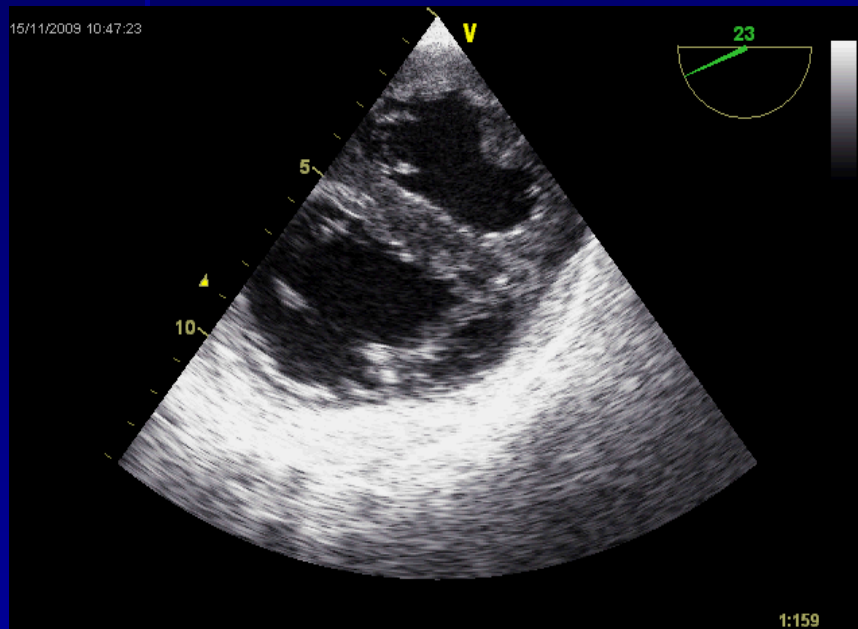
Detection of chronic rejection (1) (CAV, Cardiac allograft vasculopathy)

- Approx. 54% of pts 10 yrs after HTx
- Early recognition (coronary angiography-
IVUS: IMT 0.5 mm) is important because of rapid CAV progression
- **RESTING 2D Echo** has
 - limited diagnostic accuracy for CAV detection (Resting WMAbn sensitivity 47%),
 - BUT **Resting WMAbn is specific for the presence of CAV.**

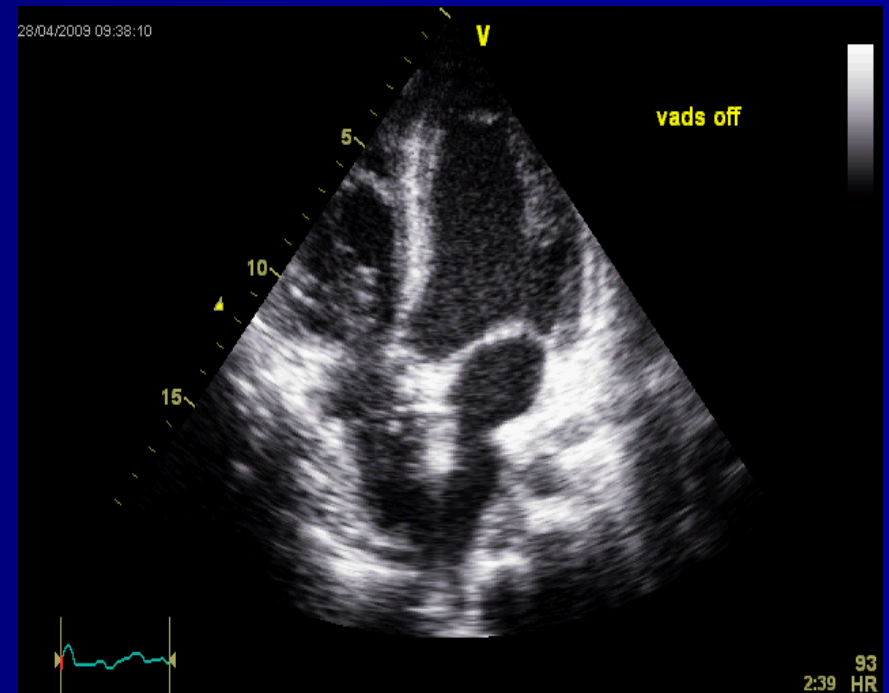
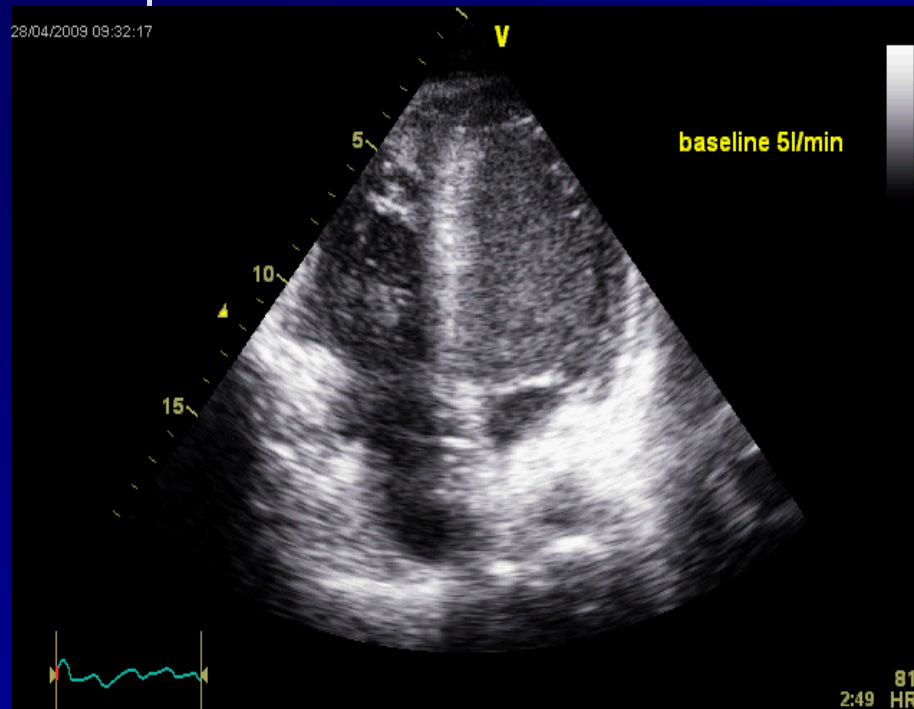
Detection of chronic rejection (2) (CAV, Cardiac allograft vasculopathy)

- **DSE** (heart rate of the denervated heart not blunted, dob increases oxygen demand in all viable segments)
 - **Sensitive for CAV detection** (sensitivity 85%, sensitivity increases when angiographic lesions > 50%)
 - DSE is very sensitive for identifying pts **at risk for MACE** (annual testing necessary!)
 - The use of TDI, Coronary Flow Reserve of LAD and contrast-enhanced echo remains to be established

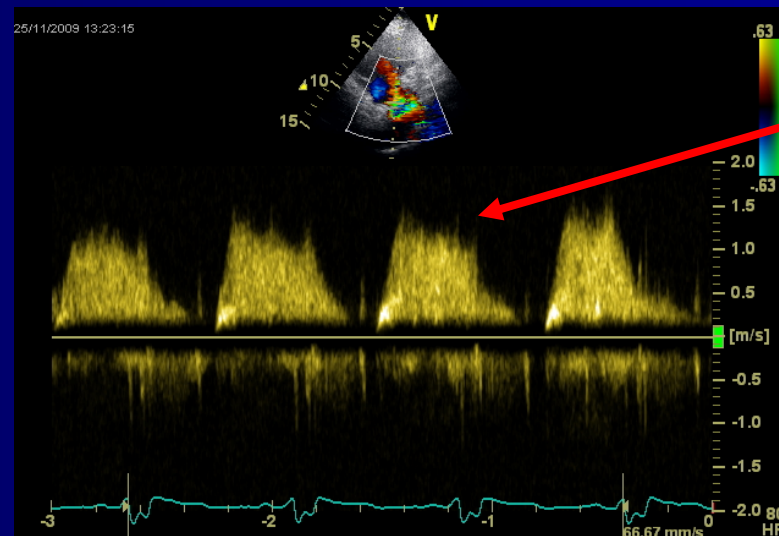
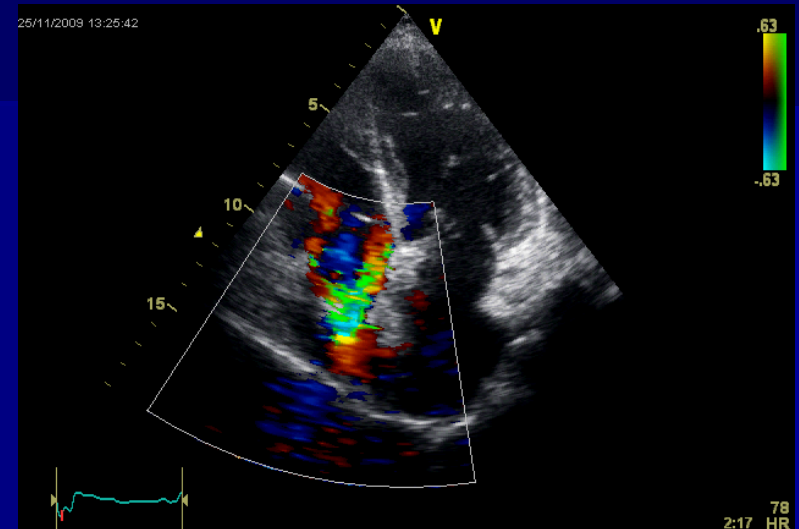
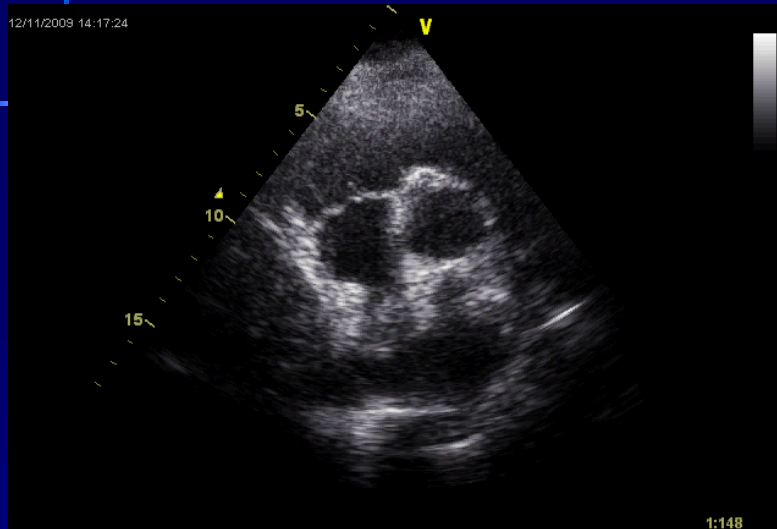
Acute RV dysfunction after VAD/HTx→ Levitronix BiVAD



Graft failure 5 yrs after HTx→ Levitronix as Bridge -To-Bridge



SVC/IVC narrowing



Mean gradient
5 mmHg

The Onassis CSC experience



BiVAD
LVAD



TOTAL

Results	HEARTMATE	NOVACOR	BiVAD LVAD	Heartware	Heartware	<u>TOTAL</u>
Implants	5	5	37 9	5	7	68
Transplants	4	1	19 2	4	0	30
On Support	0	0	11 5	0	6	22
Died	1	3	7 2	0	1	14
Exchanged	0	1	0 0	1	0	2

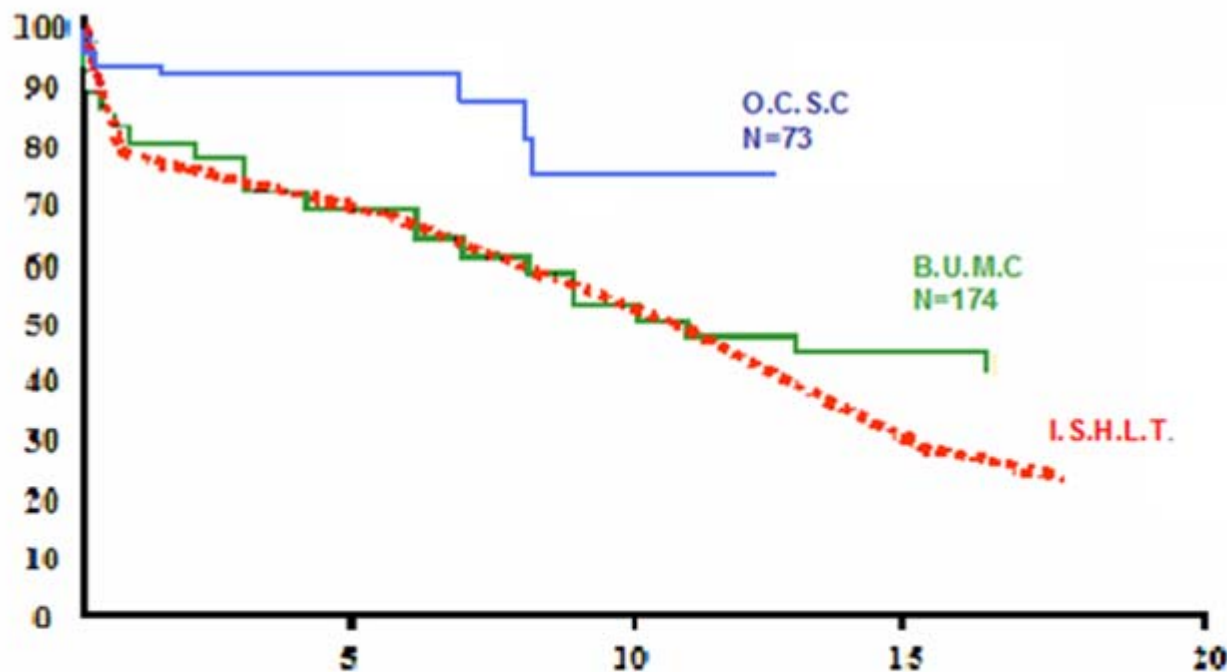


ONASSIS CARDIAC SURGERY CENTER TRANSPLANTATION SERVICES (1996-2010)

Heart transplantations (Retransplant)	80 (1)
Lung transplantations	10
VAD implantations (65 pts.)	68



ONASSIS CARDIAC SURGERY CENTER TRANSPLANTATION SERVICES (1996-2008)



O.C.S.C. : Ωνάσιο Καρδιοχειρουργικό Κέντρο (n=73) 1995-2008

B.U.M.C.: Baylor University Medical Center (n=174) 1986-1996

I.S.H.L.T.: International Society of Heart and Lung Transplantation

Conclusions

- MCS and HTx are a well established treatment option for patients with end-stage heart failure
- Echocardiography (TTE/TEE) is the primary noninvasive modality for monitoring cardiac function in HTx patients and for assessing patients before and after VAD implantation.
- The use of new echocardiographic techniques, incl. Tissue Doppler Imaging, strain-strain rate, contrast-enhanced echocardiography could be of great importance once validated in large clinical trials.