ANESTHESIA FOR PATIENTS ON LVAD FOR NON-CARDIAC SURGERY

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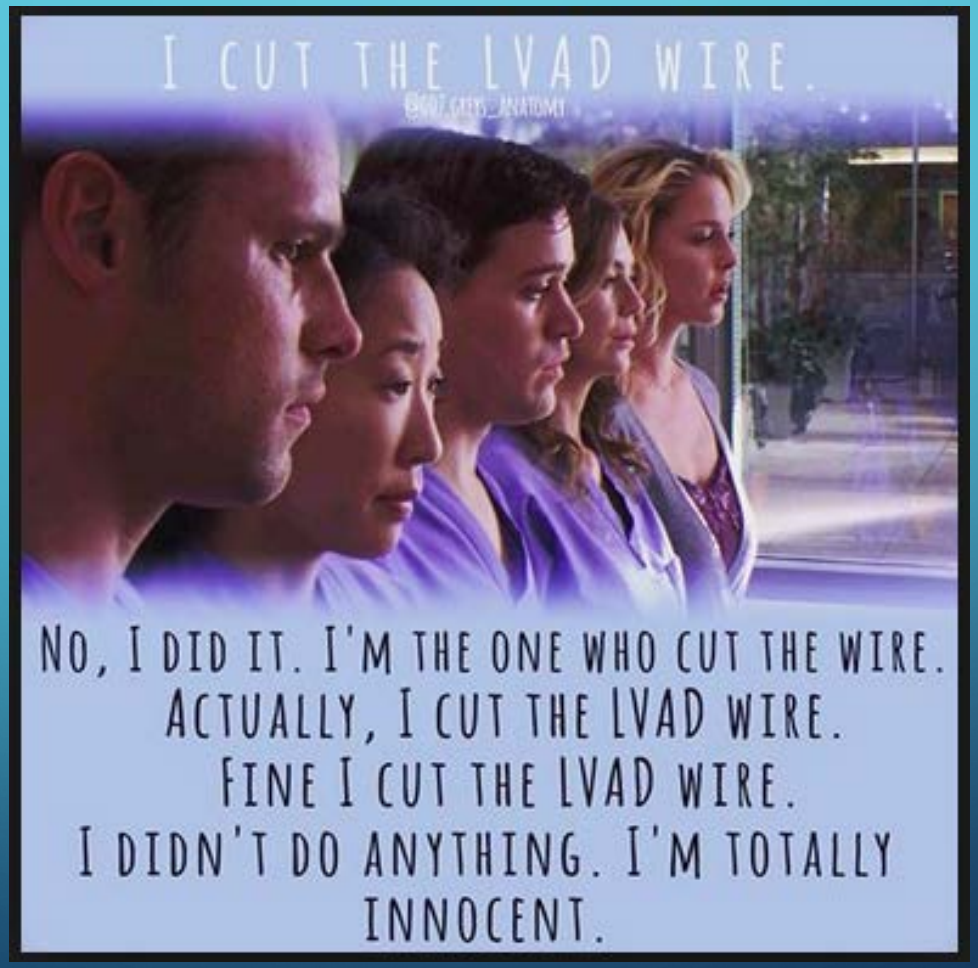
DISCLOSURES

- none

OBJECTIVES

- Describe the current indications for LVAD implantation
- Describe the major characteristics of commonly used LVADs
- Describe the most common surgical procedures done in this group of patients and the specific anesthetic considerations for their perioperative care
- Describe the most common perioperative device complications and their management

LEFT VENTRICULAR ASSIST DEVICES (LVAD)



CASE - ELECTIVE

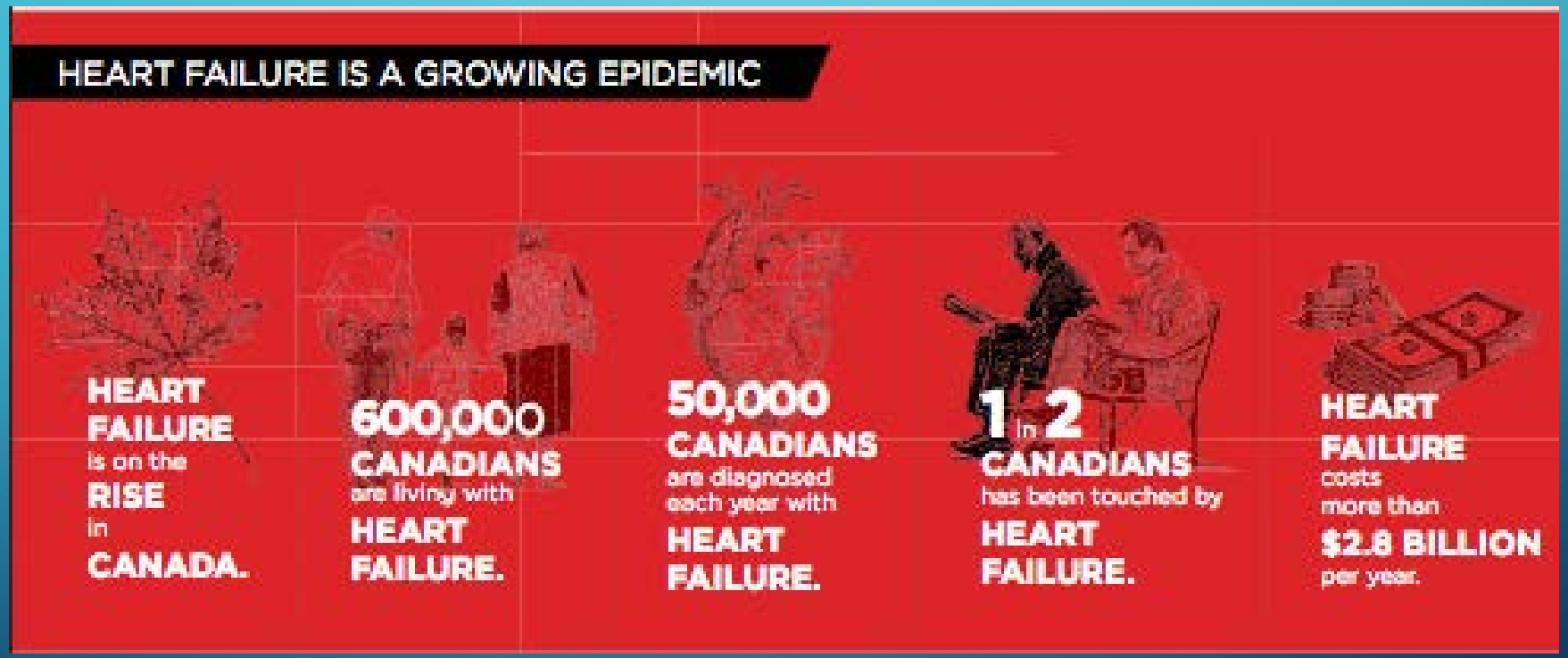
- Mr Jones, 53y, LVAD implanted for non-ischemic cardiomyopathy 1 year ago
- Trying to get on the transplant list for a new heart
- Scheduled for elective total knee arthroplasty in 1 month for osteoarthritis
- What to do?

CASE - EMERGENT

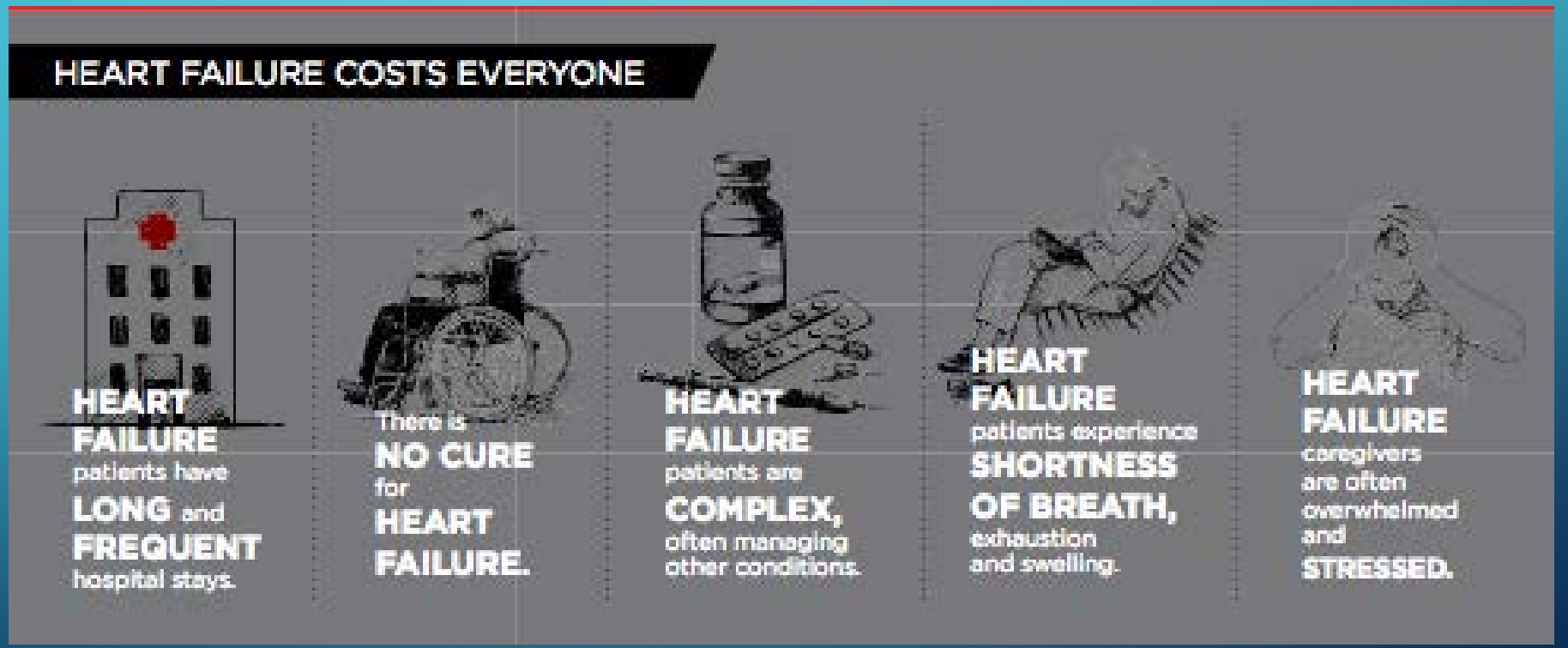
- On call
- 72 year old male, DM2, HTN, has LVAD for ischemic cardiomyopathy
- E1 Burr holes for subdural hematoma
- What to do?

HEART FAILURE

HEART FAILURE



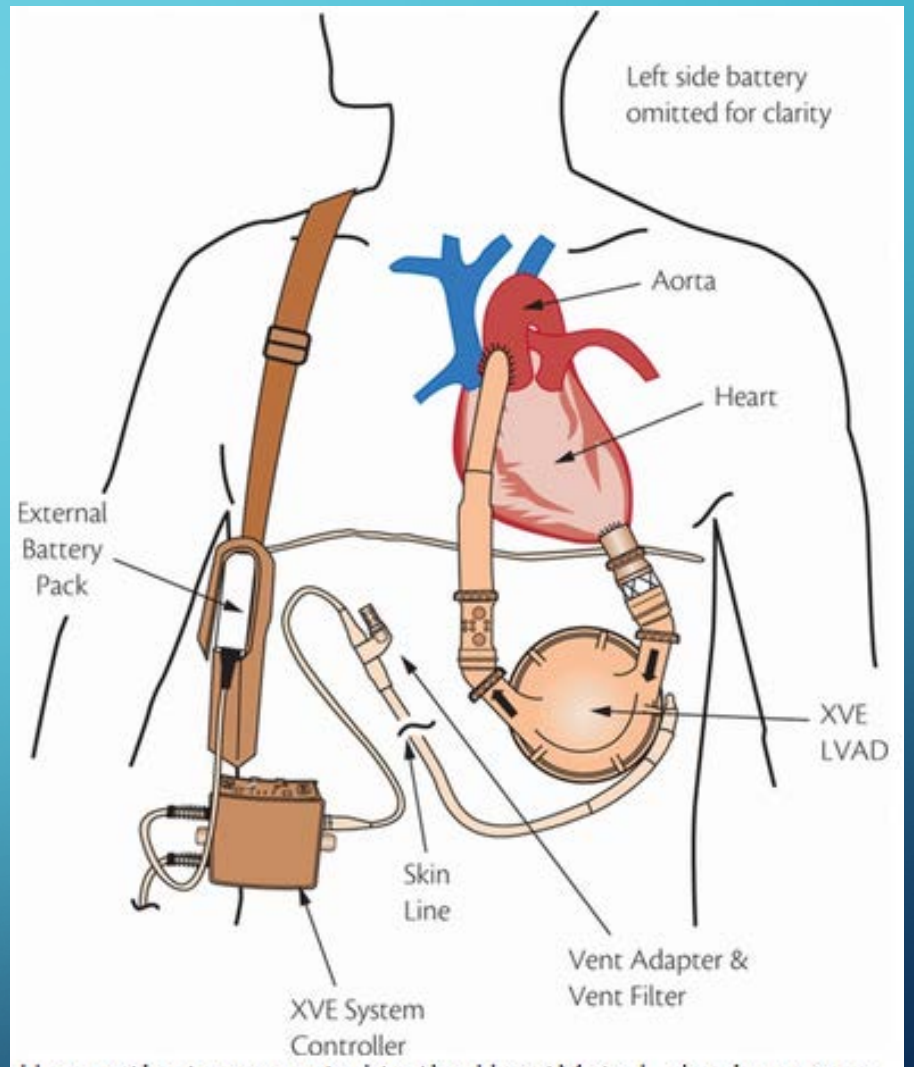
HEART FAILURE



LVAD PHYSIOLOGY

- CHF > neurohormonal activation > inc catecholamines > LV remodeling

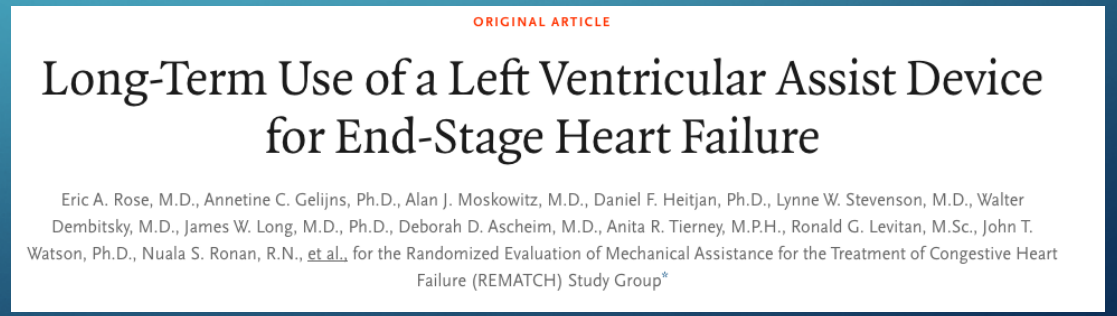
- LVAD > offloaded LV > decrease neurohormones > improved perfusion



How patients connected to the HeartMate I, also known as the XVE. Image courtesy of St. Jude Medical, Inc.

REMATCH TRIAL: LVAD VS MEDICAL THERAPY

- 2001 NEJM, Rose et al
- 129 patients randomized to either LVAD or medical therapy
- 48% reduction in death at 1 year
- Increased frequency of adverse effects in the device group
  - Infection
  - Bleeding
  - Device malfunction



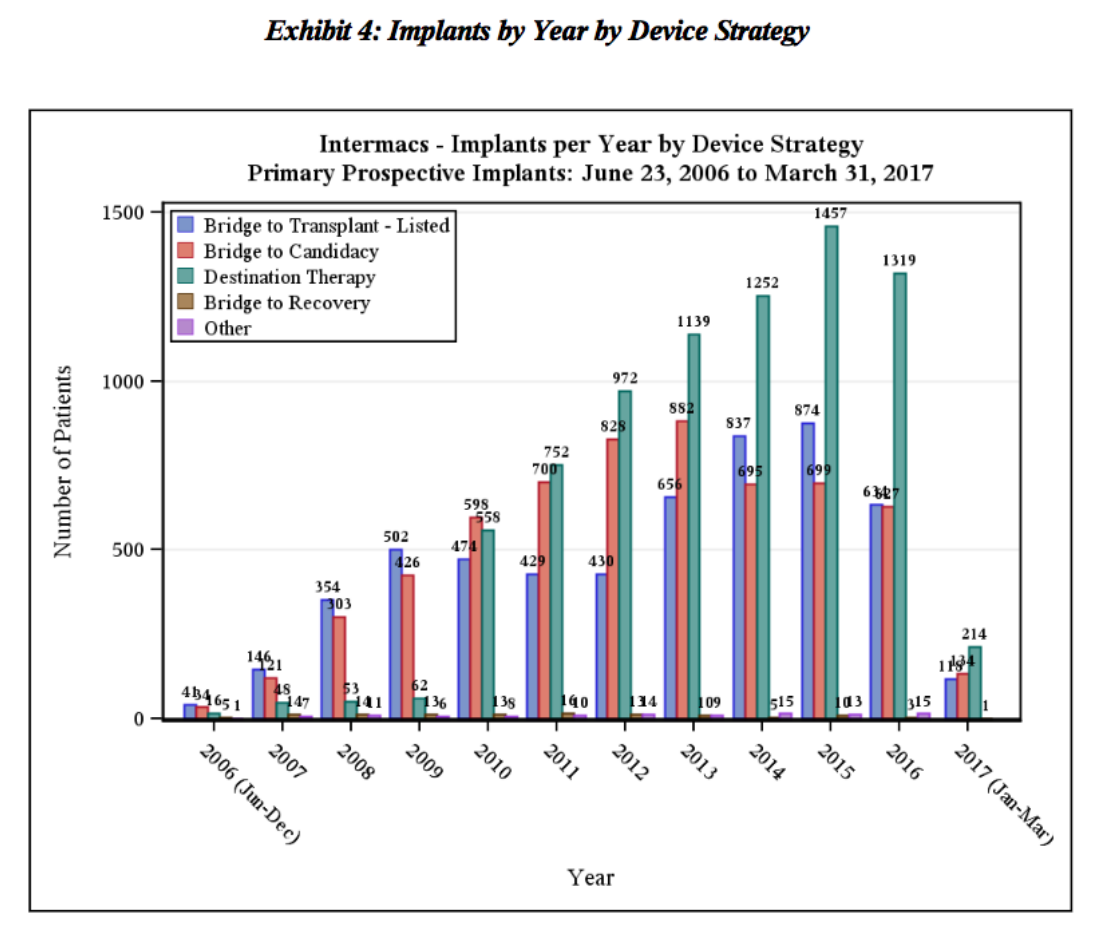
ORIGINAL ARTICLE

Long-Term Use of a Left Ventricular Assist Device for End-Stage Heart Failure

Eric A. Rose, M.D., Annetine C. Gelijns, Ph.D., Alan J. Moskowitz, M.D., Daniel F. Heitjan, Ph.D., Lynne W. Stevenson, M.D., Walter Dembitsky, M.D., James W. Long, M.D., Ph.D., Deborah D. Ascheim, M.D., Anita R. Tierney, M.P.H., Ronald G. Levitan, M.Sc., John T. Watson, Ph.D., Nuala S. Ronan, R.N., et al., for the Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) Study Group*

INDICATIONS FOR LVAD IMPLANTATION

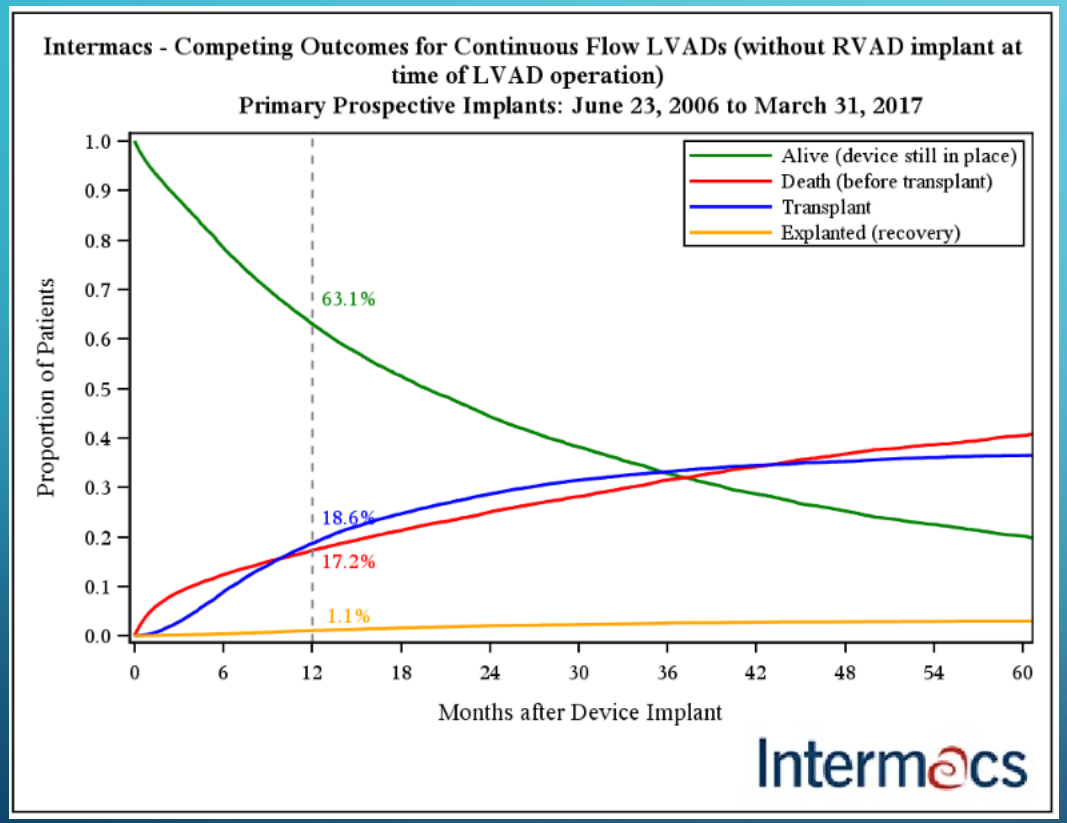
- Bridge to recovery
- Bridge to transplantation
  - Bridge to candidacy
- Destination therapy



PATIENTS RECEIVING VADS

PATIENT PROFILE AT TIME OF IMPLANT	IMPLANT DATE PERIOD						TOTAL	
	< 2010		2010 - 2013		2014 - 2017 (Jan-Mar)			
	n	%	n	%	n	%	n	%
1 Critical Cardiogenic Shock	637	29.2 %	1256	14.7 %	1469	16.4 %	3362	17.1 %
2 Progressive Decline	925	42.4 %	3204	37.6 %	3042	34.0 %	7171	36.5 %
3 Stable but Inotrope Dependent	334	15.3 %	2419	28.4 %	3195	35.8 %	5948	30.3 %
4 Resting Symptoms	197	9.0 %	1217	14.2 %	1022	11.4 %	2436	12.4 %
5 Exertion Intolerant	42	1.9 %	246	2.8 %	137	1.5 %	425	2.1 %
6 Exertion Limited	23	1.0 %	110	1.2 %	34	0.3 %	167	0.8 %
7 Advanced NYHA Class 3	19	0.8 %	55	0.6 %	16	0.1 %	90	0.4 %
Unspecified	.	.	4	0.0 %	7	0.0 %	11	0.0 %
TOTAL	2177	100.0 %	8511	100.0 %	8922	100.0 %	19610	100.0 %

LVAD OUTCOMES



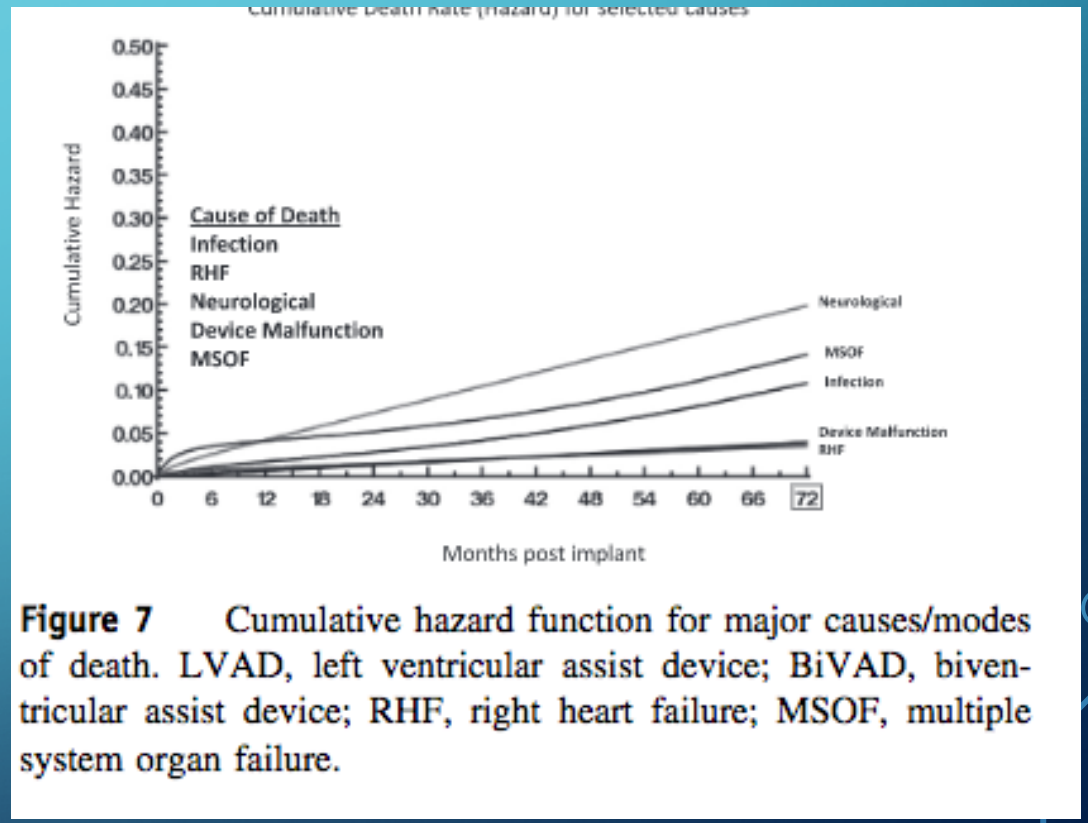
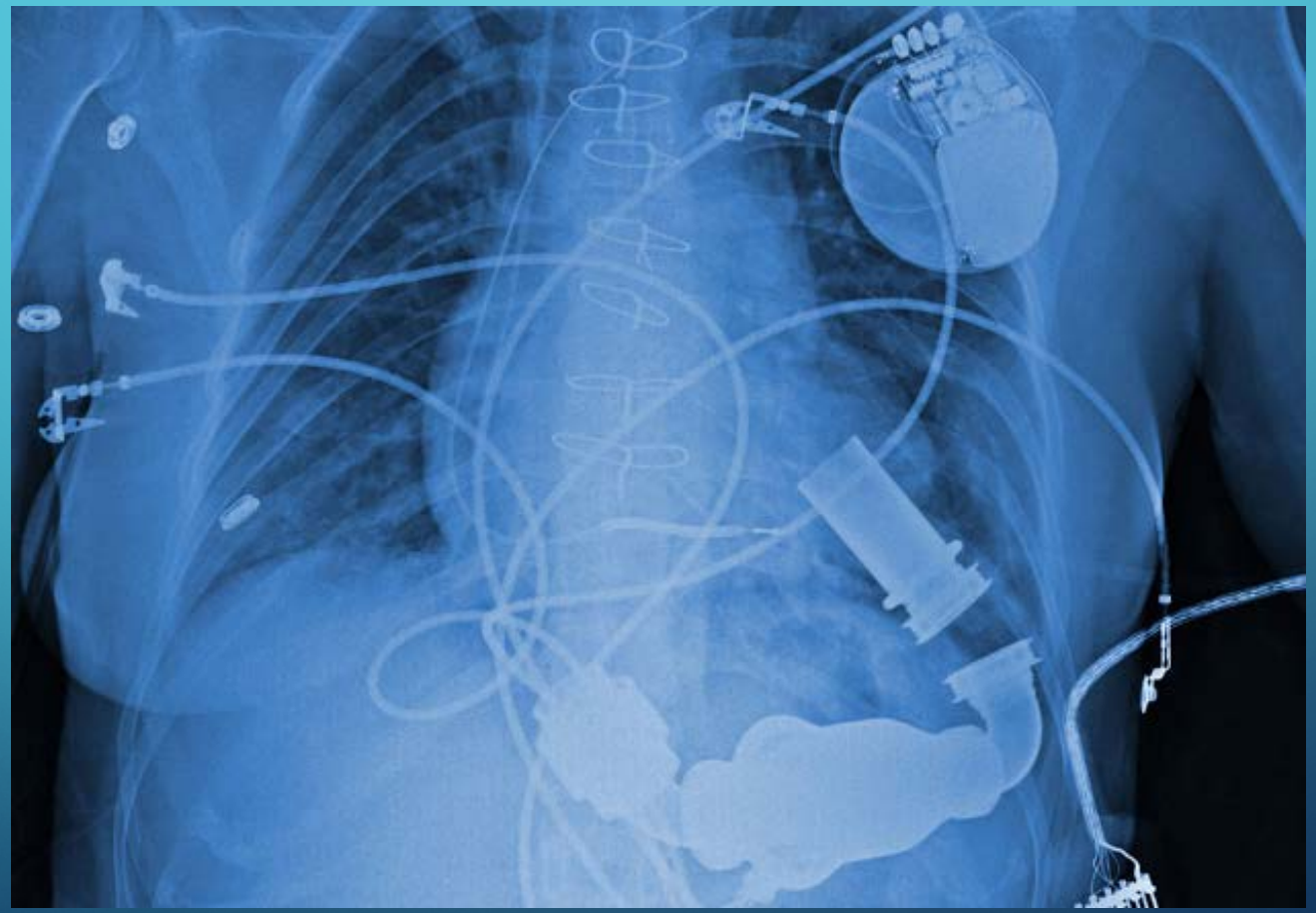


Figure 7 Cumulative hazard function for major causes/modes of death. LVAD, left ventricular assist device; BiVAD, biventricular assist device; RHF, right heart failure; MSOF, multiple system organ failure.

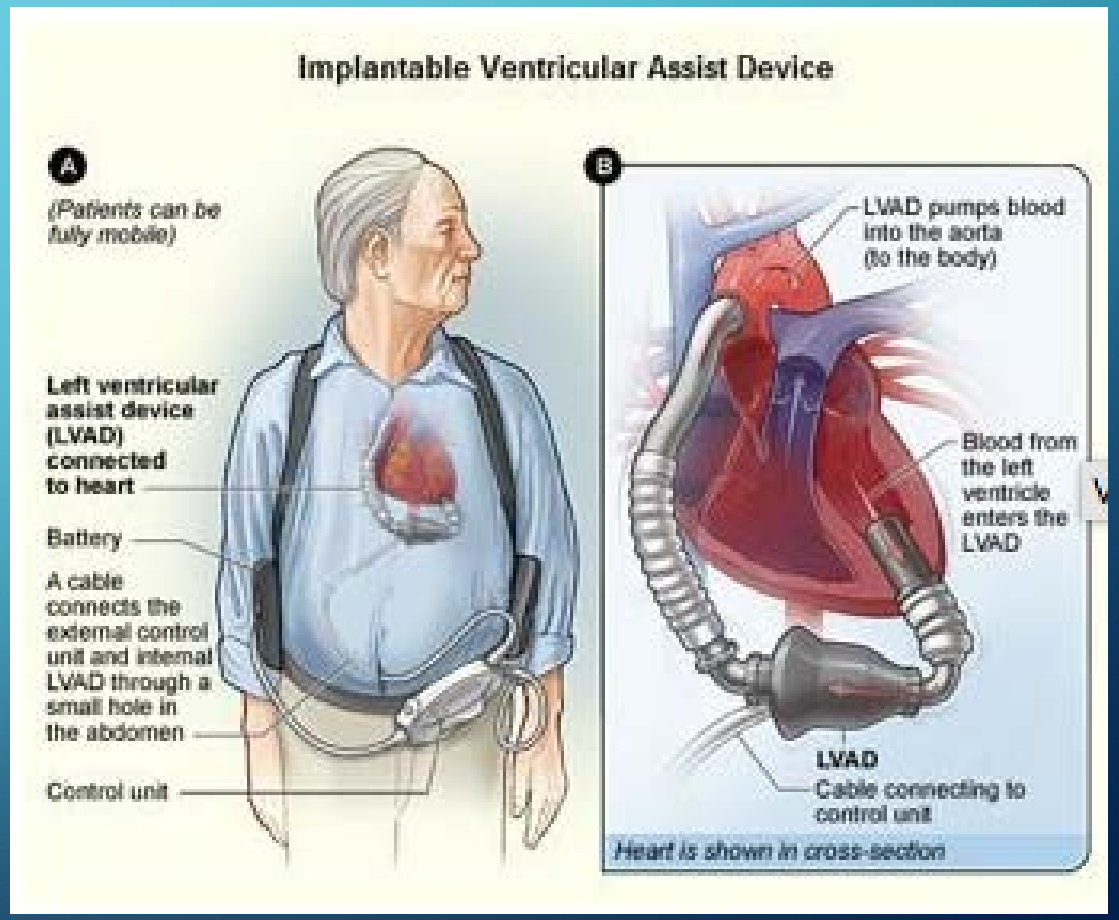
LVADS

- First generation: pulsatile, bulkier with intra-abdominal insertion
- **Second/third generation:** continuous flow via either centrifugal or axial pump with inflow from LV apex and outflow to ascending aorta
- INTERMACS
- International Society for Heart and Lung Transplantation – Guidelines 2013

LVAD DEVICES

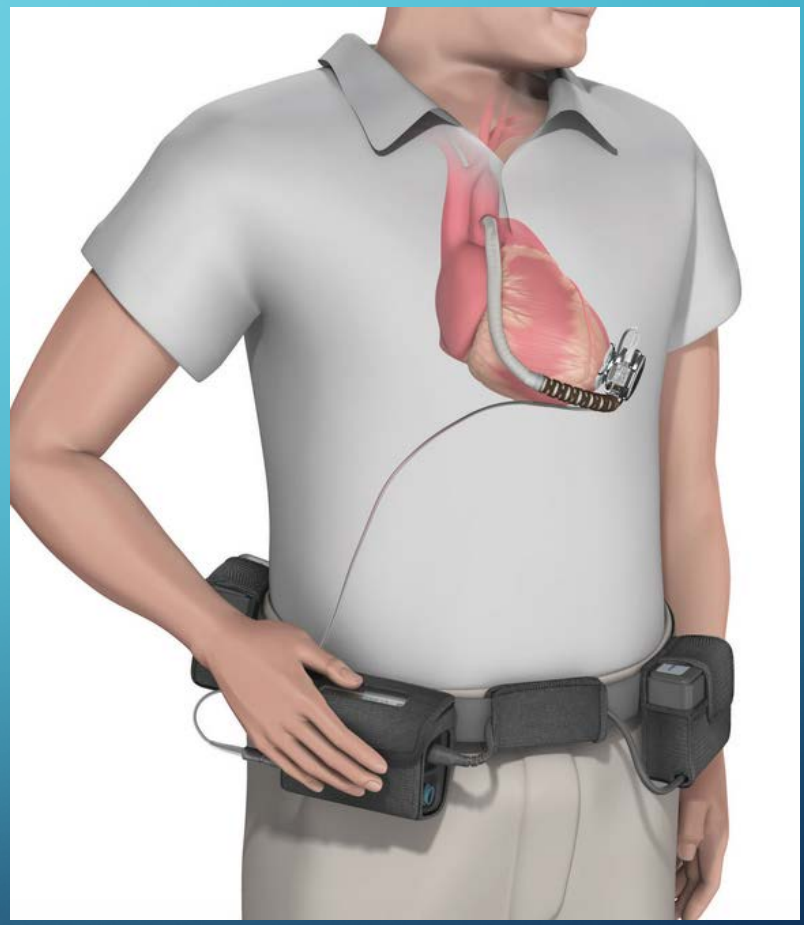


HEARTMATE II



HEARTWARE (HVAD)

- 3rd generation centrifugal pump



HEARTMATE III

HVAD (RIGHT) AND HEARTMATE III (LEFT)

The Journal of Thoracic and Cardiovascular Surgery 2017 154, 850-852DOI: (10.1016/j.jtcvs.2017.04.033)

CHARACTERISTICS OF LVADS

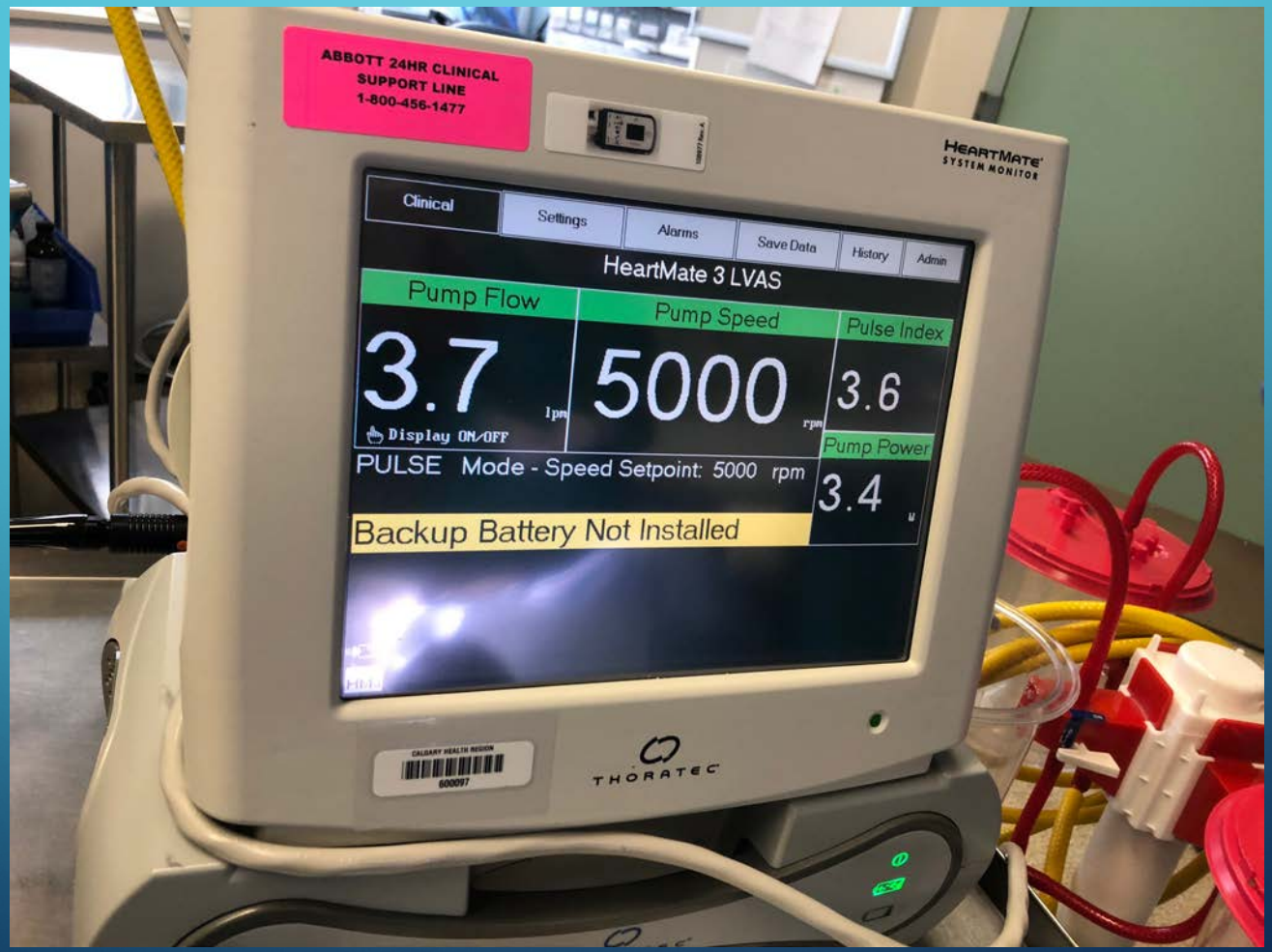
- Pump Flow 3.5-7L/min depending on the device
- Pump Power: HMII 5-8W, HMIII 3-4W, HW 3-7W
- Pump Speed: HMII 8000-10000, HMII 5000-6000, HW 2400-3200
- Pulsatility index (PI): average of the flow pulses seen with ventricular contraction. 5.0 +/- 0.9
  - Improved PI with inotropes, exercise, myocardial recovery
  - Low PI with hypovolemia or minimal native cardiac function

VAD PARAMETERS

https://lifeinthefastlane.com/ccc/ventricular-assist-device/

Device	Flow Estimate (L/min)	Speed (RPM)	Power (W)	Pulsatility
HeartWare	4 – 7	2500 – 2900	3 – 7	flow/time waveformpulsatility of 2-4 L/min from peak to trough
HeartMate II	4 – 8	8600 – 9800	6 – 7	4 – 6
HeartMate III	3 – 6	5000 – 6000	3 – 7	1 – 4

VAD PARAMETERS



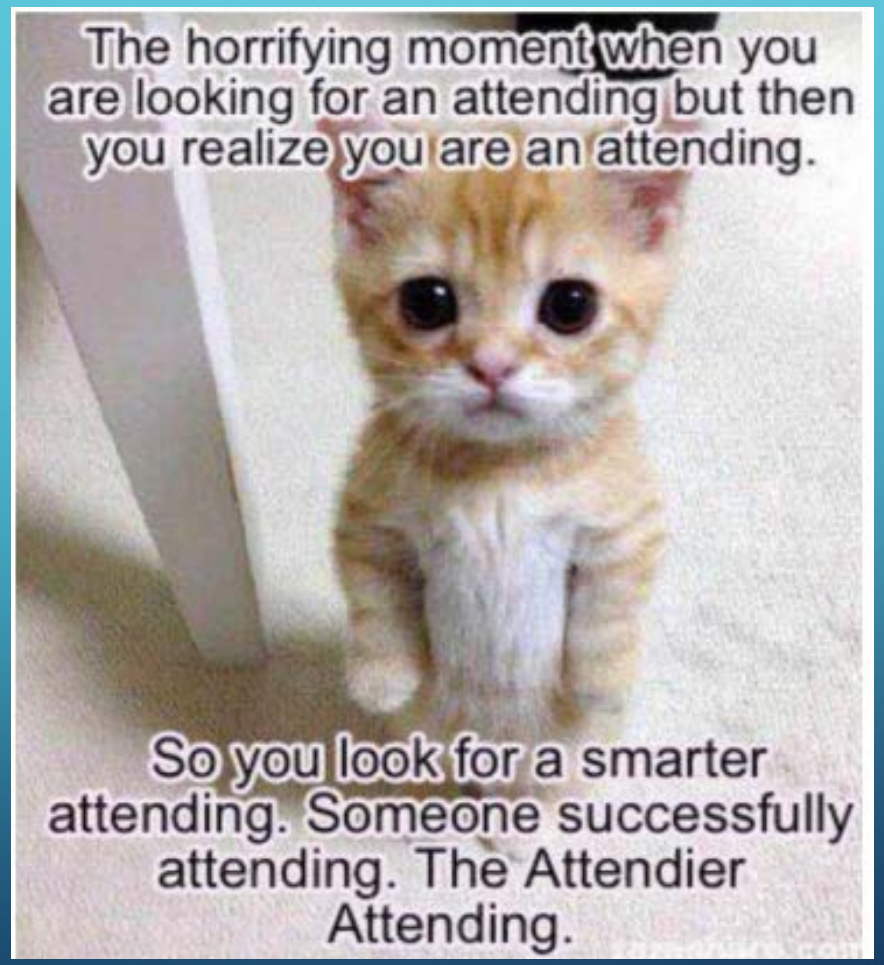
CHARACTERISTICS OF LVADS - COAGULOPATHY

- **Anticoagulation:** warfarin and ASA 325mg
  - For HMII goal INR 2.0-3.0
- Can develop acquired **vonWillebrand's** disease (as with severe AS)
- **Factor XIII deficiency** – detected by thromboelastography
  - Clot firmness <85% suggests hyperfibrinolysis
- Can have **platelet dysfunction**
- Increased incidence in GI bleeds

COMMON NON-CARDIAC SURGICAL PROCEDURES

- **23-27% LVAD patients undergo non-cardiac surgery**
- Study 2006-2015 U of Michigan (Mathis et al)
- 246 patients, 702 procedures
  - 38% ”major surgical procedures”
  - 62% minor
- 37% upper or lower GI endoscopies
- 35% implantable cardioverter-defibrillator
- 2.5-10% intracranial hemorrhage (Drews et al 2003)

SO YOUR NEXT PATIENT HAS AN LVAD



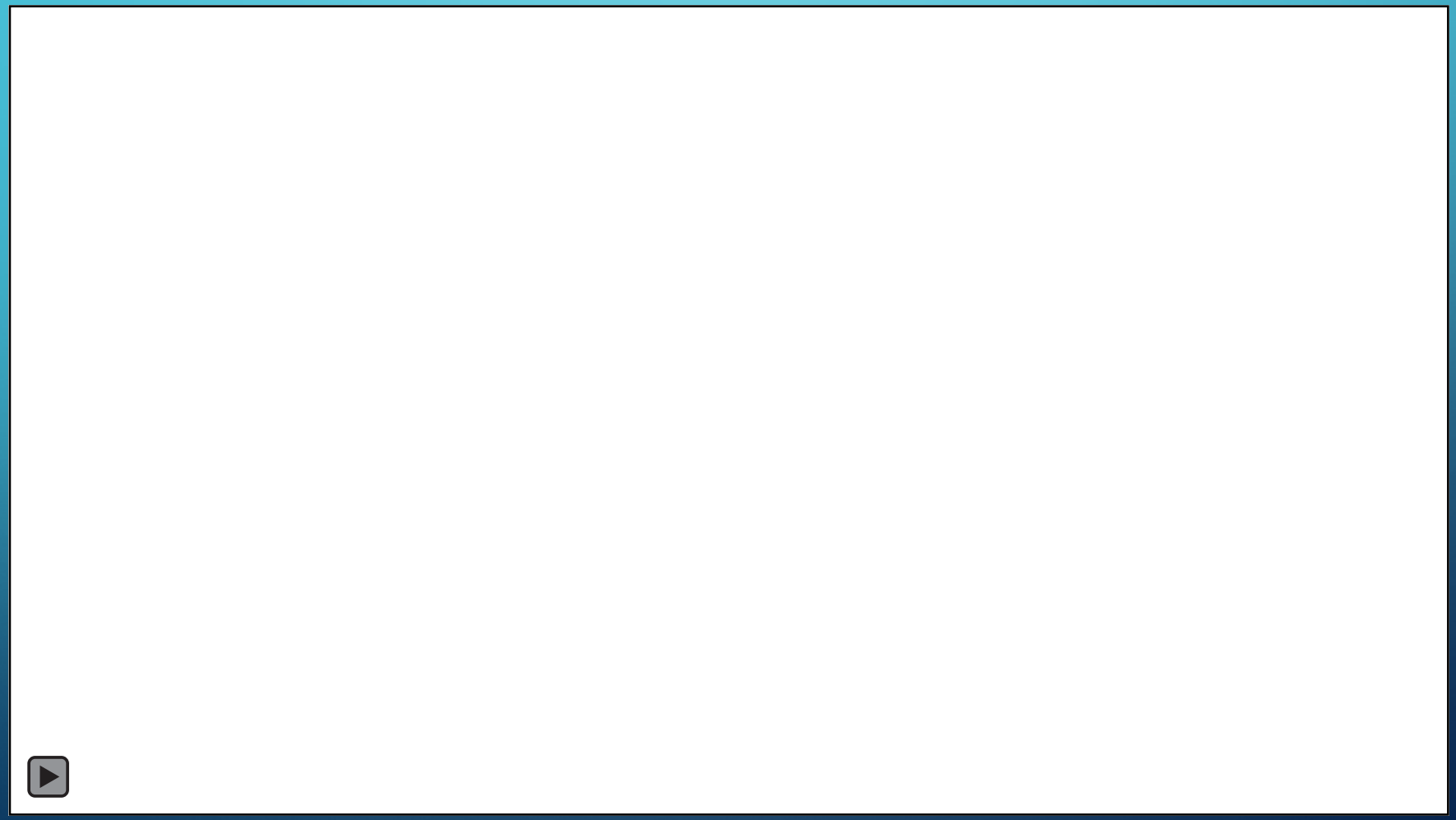
PATIENT ASSESSMENT

- If elective, multidisciplinary approach, esp heart failure cardiologist
- Assess for end-organ damage (renal, hepatic, pulmonary)
- Screen for history of thromboembolic neurologic event
- Often have pacemaker or ICD
- Review coagulation panel and current anticoagulation

PATIENT ASSESSMENT

- Usually no palpable pulse
- Assess the percutaneous driveline for infection or damage
- Chest auscultation: continuous hum
- ECG
- Review most recent echo
- Look at controller for info re: flow, speed, power and PI

LVAD ON ECHOCARDIOGRAPHY



ANTICOAGULATION

- D/C warfarin 2-5 days pre-procedure and bridge with IV heparin infusion
- Stop heparin the morning of surgery
- Transplant candidates should have leukoreduced and irradiated blood products

ANESTHETIC CONSIDERATIONS

- Automated BP unreliable, may need invasive arterial monitoring
  - General anesthesia or major procedure
- Pulse oximetry may be unreliable
  - consider cerebral saturation as surrogate/adjunct
- TEE if significant fluid shifts expected, PA cath for severe pulmHTN
- Consider processed EEG for depth of anesthesia

ANESTHETIC GOALS

- LVAD output: directly related to speed, inversely to gradient across the pump
- Goals: optimize preload (and RV function), avoid increases in afterload and pulmonary vascular resistance
- Be prepared to treat arrhythmias
- Routine antibiotic prophylaxis is indicated
- **Hypotension generally treated with fluid and inotropes *prior* to vasopressors**

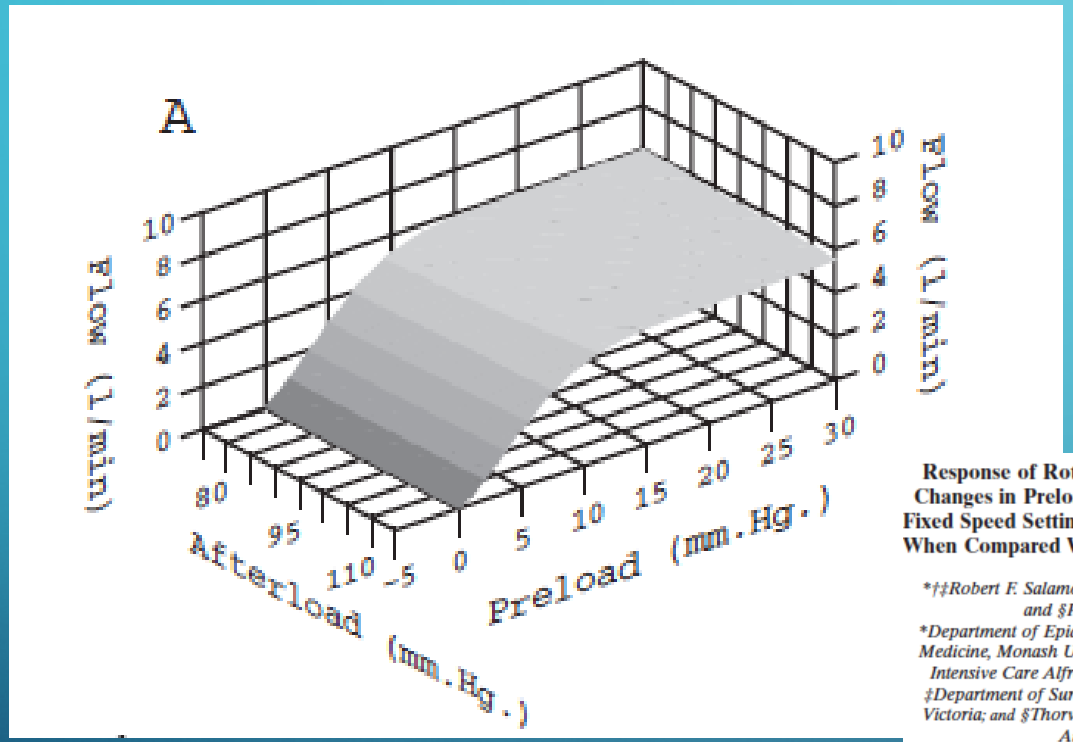
SUMMARY: PRE-OPERATIVE (ROBERTS 2015)

- Preoperative
  - Multidisciplinary team identified (primary surgical and anesthesia teams, cardiac surgery, heart failure cardiologist, VAD personnel)
  - Preoperative medical optimization when possible or necessary
  - Physical examination focused on the sequelae of heart failure
  - Baseline EKG, echocardiogram, and laboratory values
  - Manage pacemaker/AICD settings when indicated
  - Hold, bridge, or reverse anticoagulation when indicated

SUMMARY: INTRA-OPERATIVE (ROBERTS 2015)

• Intraoperative
○ Standard ASA monitors
○ Cerebral tissue oxygenation, processed EEG, arterial line with ultrasound guidance, central venous catheter if fluid shifts are expected, PA catheter only if severe pulmonary hypertension, TEE available
○ Monitor VAD control console
○ External defibrillator pads in place
○ Optimize preload, support RV function, avoid increased in afterload
○ Gradual peritoneal insufflations and position changes

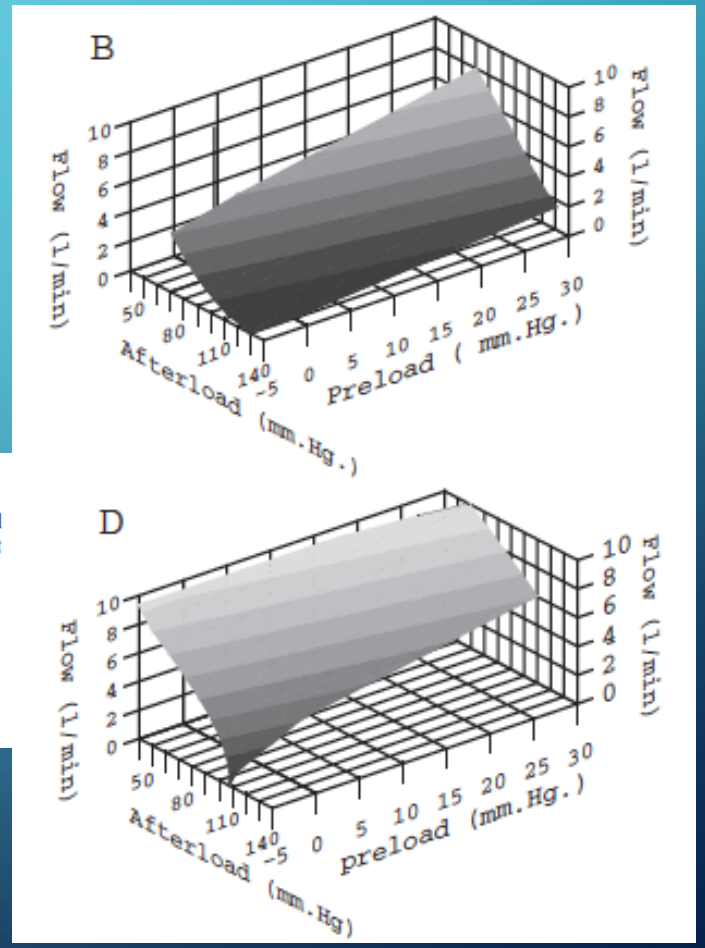
ANESTHETIC GOALS - HEMODYNAMICS



Response of Rotary Blood Pumps to Changes in Preload and Afterload at a Fixed Speed Setting Are Unphysiological When Compared With the Natural Heart

*†‡Robert F. Salamonsen, ‡David G. Mason, and §Peter J. Ayre
*Department of Epidemiology and Preventive Medicine, Monash University; †Department of Intensive Care Alfred Hospital, Melbourne; ‡Department of Surgery, Monash University, Victoria; and §Thorvascular Pty Ltd., Sydney, Australia

Artificial Organs
35(3):E47–E53, Wiley Periodicals, Inc.



TROUBLESHOOTING

Abnormality	Cause	Intervention
High Power	Pump thrombus	Anticoagulation
Low Power	Device Issue	Check batteries, power source

TROUBLESHOOTING

Abnormality	Cause	Intervention
High PI	Recovered LV function	Wean VAD support or inotrope
Low PI	Worsening function	Increase speed, add inotropes
	Hypovolemia	Fluid trial
	Excess pump speed	Lower pump speed

TROUBLESHOOTING

Abnormality	Cause	Intervention
High Flow	Vasodilation (ie sepsis)	Administer vasopressors, tx sepsis
Low Flow*	Hypovolemia, RV failure, HTN, arrhythmias	Fluid trial, RV support, wean vasopressor, tx HTN

SPECIAL CONSIDERATIONS:

- Lithotomy
- Reverse Trendelenburg
- Laparoscopic procedures: standard insufflation pressures have been used
- Prone
- Neuraxial?

POST-OPERATIVE

- Most patients managed without need for ICU (in procedures where ICU not normally indicated) (Mathis et al 2017)
- Resume anticoagulation once adequate surgical hemostasis
- Contact PM/ICD personnel to assess devices PRN
- Coordinate with VAD team for follow-up

COMPLICATIONS – IMMEDIATE POST-INSERTION

- Bleeding
- Thrombosis
- Hemolysis
- Right heart failure
- Infection
- Failure to wean/need for tracheostomy

COMPLICATIONS POST NON-CARDIAC SURGERY

- Arrhythmias are common post-operatively
- U of Michigan, Mathis et al 2017
  - 18% developed AKI
  - 6.4% bleeding complications
  - Elevated LDH 2.6% (surrogate marker of potential pump thrombosis)
- Most common complication is hypotension (MAP < 55mmHg)
- No independent associations between cardiac and non-cardiac anesthesiologists for low risk cases (Brown et al 2018)

CARDIAC VS NON-CARDIAC ANESTHESIOLOGIST?

Table 1. Anesthesiologist Recommendations for VAD-Supported Patients.

Noncardiac Anesthesiologist Appropriate	Cardiac Anesthesiologist Recommended
The VAD-supported patient: • Is not on pharmacological support • Is without "major" comorbidities • Is undergoing a routine "minor" procedure (eg, endoscopies, tracheostomy, CT scan) • There is availability of a knowledgeable consultant as needed	The VAD-supported patient: • Is on pharmacological support • Has "major" comorbidities or membrane oxygenator • Is undergoing "major" procedures (predicted large fluid shifts, predictable significant hemodynamic changes)

CASE

- Mr Jones, 53y, LVAD implanted for non-ischemic cardiomyopathy 1 year ago
- Currently on the transplant list awaiting cardiac graft
- Scheduled for elective total knee arthroplasty in 1 month for osteoarthritis – pain is decreasing his exercise levels
- What to do?

CASE

- On call
- 72 year old, DM2, HTN, has LVAD for ischemic cardiomyopathy
- E1 Burr holes for subdural hematoma
- What to do?

QUESTIONS?

REFERENCES

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COST EFFECTIVENESS – DESTINATION THERAPY

- Compared with med mgmt. LVAD has higher cost and QALY over a lifetime
- Mostly related to initial cost of LVAD implantation
- Survival trends suggests that initial cost would need to be less than $123,000 to be considered cost effective