MAYO CLINIC

LVADs & noncardiac surgery: What to do when they come to your OR

David W. Barbara, M.D.
Department of Anesthesiology
Division of Cardiovascular Anesthesiology
Division of Critical Care Medicine

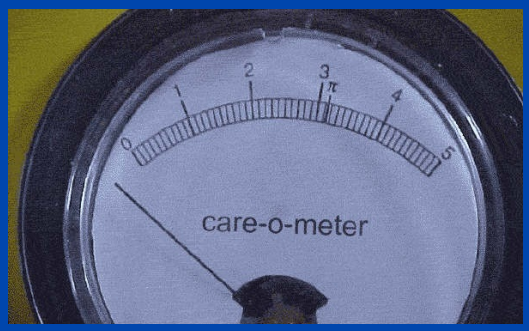
Minnesota Society of Anesthesiologists Fall Conference
November 12, 2016

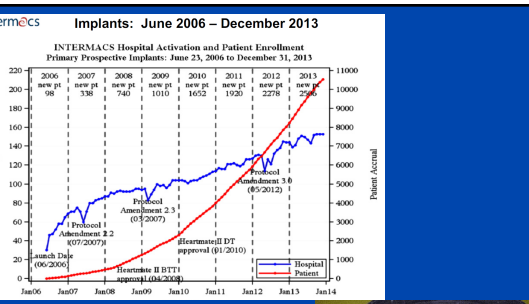
Disclosures or Off-Label Use

- None

Learning Objectives

- Explain the overall indications, physiologic effect, and types of LVADs.
- Identify the various LVAD console parameters and diagnose common abnormalities.
- Explain generalized anticoagulation/antiplatelet goals in patients with LVADs and evaluate the merits of continuation or reversal in the non-cardiac surgical perioperative period.
- Assess perioperative management strategies and indications for non-cardiac surgeries in patients with LVADs.

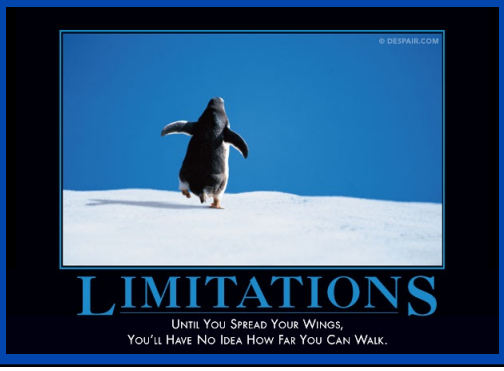




Outline

- Recent Case
- LVAD basics
- LVAD anticoagulation, physiology, and acute management
- NCS & LVADs
- LVAD perioperative considerations

What this talk is not…



Outline

- Recent Case

Recent Case

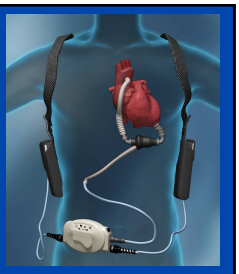
- 78 y/o male
- HM-II placed 6 y prior for ischemic CM (DT)
- Fall → R subtrochanteric femur fracture → OSH
- INR 1.8, Hb 8.3, Plt 180, Cr 1.8, lactate 1

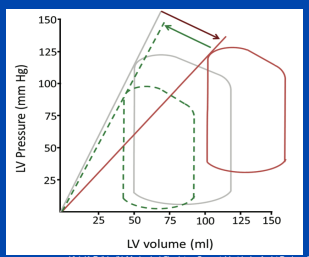
Questions

- Where should this pt be cared for?
- How does LVAD change anesthetic?
- How should anticoagulation be managed?
- How to manage transfusions?
- How to monitor and manage hemodynamics?
- Who should anesthetize this patient?
- Where should this pt go after surgery?
- Who should care for this pt post-op?
- When to restart anticoagulation?

Outline

- Recent Case
- LVAD basics





High K, Pulido JN. Mechanical Circulatory Support. Ventricular Assist Devices (VADs) and Extracorporeal Membrane Oxygenation (ECMO). A Society of Cardiovascular Anesthesiologists Monograph. 2014.

REMATCH

The New England
Journal of Medicine

Copyright © 2001 by the Massachusetts Medical Society

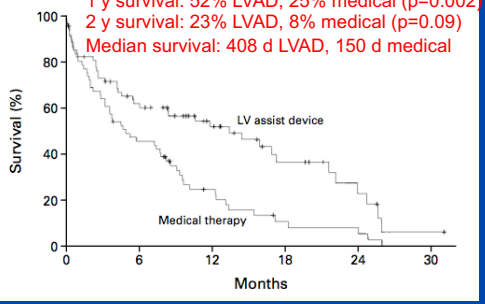
VOLUME 345 NOVEMBER 15, 2001 NUMBER 20

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., AND PAUL MEIER, PH.D., FOR THE RANDOMIZED EVALUATION OF MECHANICAL ASSISTANCE FOR THE TREATMENT OF CONGESTIVE HEART FAILURE (REMATCH) STUDY GROUP*

REMATCH - Survival

1 y survival: 52% LVAD, 25% medical (p=0.002)
2 y survival: 23% LVAD, 8% medical (p=0.09)
Median survival: 408 d LVAD, 150 d medical



REMATCH – Quality of Life

Scale†	One Year		P Value
	No. assessed/ total no. (%)	Score	
SF-36			
Physical function			0.01
LVAD group	23/24 (96)	46±19	
Medical-therapy group	6/11 (55)	21±21	
Emotional role			0.03
LVAD group	23/24 (96)	64±45	
Medical-therapy group	6/11 (55)	17±28	
Minnesota Living with Heart Failure			0.11
LVAD group	23/24 (96)	41±22	
Medical-therapy group	6/11 (55)	58±21	
Beck Depression Inventory			0.04
LVAD group	22/24 (92)	8±7	
Medical-therapy group	5/11 (45)	13±7	
Median NYHA class			<0.001
LVAD group	24/24 (100)	II	
Medical-therapy group	7/11 (64)	IV	

LVAD Goals of Therapy

Goals of Therapy	Definition
Bridge to a decision	Temporary circulatory support to maintain organ perfusion until neurologic status can be ascertained
Bridge to recovery	Temporary circulatory support until myocardial recovery is achieved
Bridge to a bridge	Temporary circulatory support to maintain organ perfusion until a more durable device can be implanted
Bridge to transplant	Temporary circulatory support until a donor heart becomes available
Destination therapy	Permanent implantation of a VAD

High K, Pulido JN. Mechanical Circulatory Support: Ventricular Assist Devices (VADs) and Extracorporeal Membrane Oxygenation (ECMO), A Society of Cardiovascular Anesthesiologists Monograph, 2014.

LVAD Types

Class			Example
Percutaneous			Impella 2.5® (L) TandemHeart® (R)
Extracorporeal			CentriMag®
Paracorporeal			Thoratec PVAD®
Intracorporeal 1st Generation: Pulsatile			HeartMate XVE®
Intracorporeal 2nd Generation: Axial Continuous			HeartMate II®
Intracorporeal 3rd Generation: Centrifugal Continuous			HeartWare® HVAD

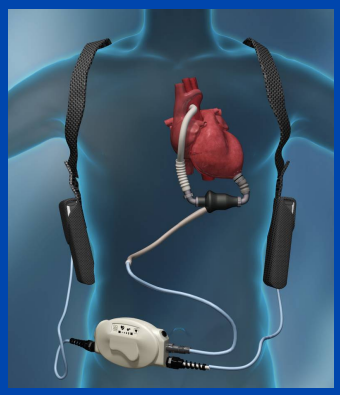
High K, Pulido JN. Mechanical Circulatory Support: Ventricular Assist Devices (VADs) and Extracorporeal Membrane Oxygenation (ECMO), A Society of Cardiovascular Anesthesiologists Monograph, 2014.

1st generation device problems

- Large size
- Durability (2-4 y lifespan)
- Infection
- Thrombotic complications

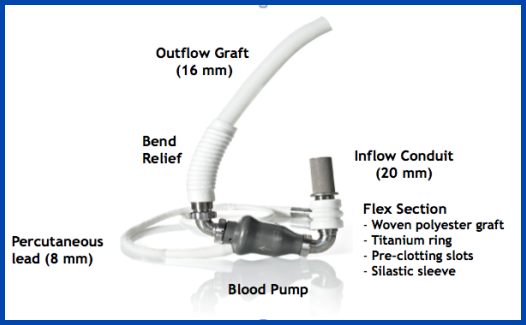
HM-II

- FDA approved for BTT and DT



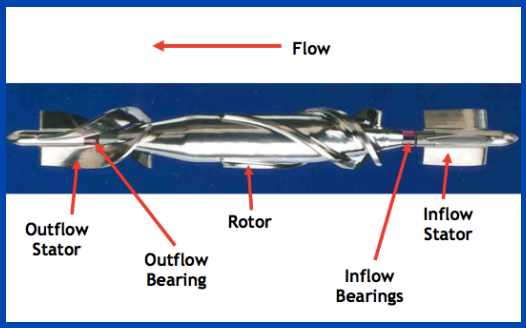
Courtesy of Thoratec

HM-II



Courtesy of Thoratec

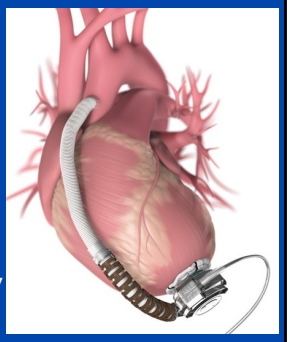
HM-II



Courtesy of Thoratec

HeartWare

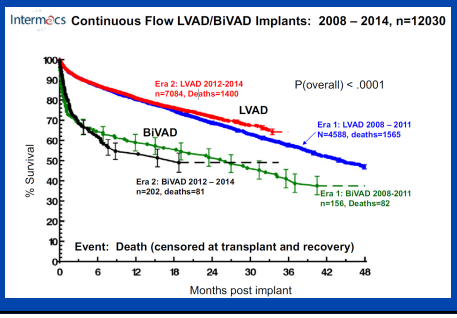
- 3rd generation
- Continuous centrifugal flow
- FDA approved BTT 2012
- 1 y survival similar to HM-II (84% vs 85%)
- No pump pocket
  - Pump integrated in LV apex



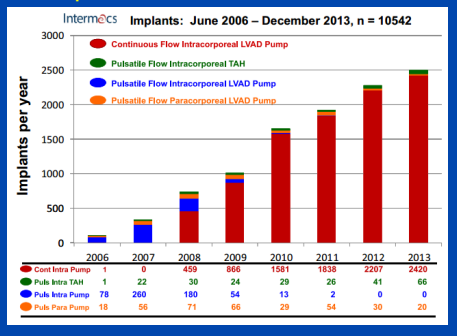
Courtesy of HeartWare Inc.

Survival

81% 1 y, 70% 2 y, 47% 4 y for continuous flow devices



LVAD implantation trends



6th INTERMACS Annual Report, 2014

Outline

- Recent Case
- LVAD basics
- LVAD anticoagulation, physiology, and acute management

Anticoagulation

	Antiplatelet agent(s)	Anticoagulation
Heartware®	Aspirin and/or clopidogrel	Warfarin for INR 2 to 3
Jarvik 2000	Aspirin and/or dipyridamole	Warfarin for INR 2.5 to 3.5
SynCardia Total Artificial Heart	Aspirin	Warfarin for INR 2.5 to 3.5
Thoratec® CentriMag®	Aspirin	Heparin for PTT 1.5 to 1.8x normal or ACT 190 to 210 s
Thoratec® Heartmate II®	Aspirin and/or dipyridamole	Warfarin for INR 2 to 3
Thoratec® Heartmate® XVE	Aspirin	Not required
Thoratec® IVAD™	Aspirin and/or dipyridamole	Warfarin for INR 2.5 to 3.5

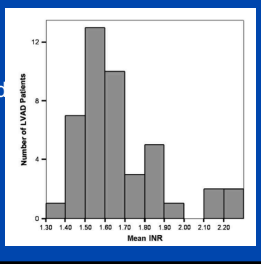
Anticoagulation – Can we get by with less?

Low thromboembolic risk for patients with the Heartmate II left ventricular assist device

Ranjit John, MD,[a] Forum Kamdar, BS,[a] Kenneth Liao, MD,[a] Monica Colvin-Adams, MD,[b] Leslie Miller, MD,[b] Lyle Joyce, MD,[a] and Andrew Boyle, MD[b]

JTCVS 2008

- 45 HM-II pts
  - 7.2 ± 5.2 months
- All recorded INRs averaged
- 21 had mean INR < 1.6
- 1 thrombotic event (INR 2.4)
- Less stringent AC requirements

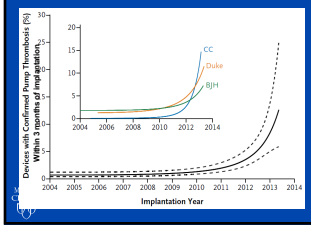


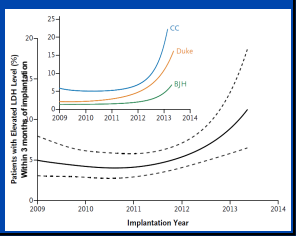
The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

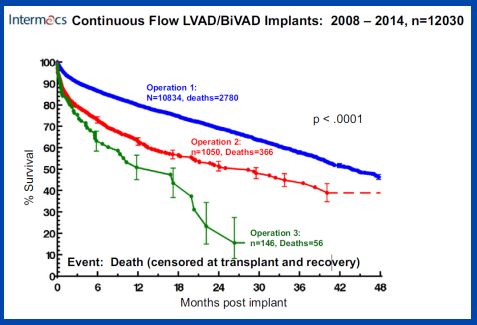
2014

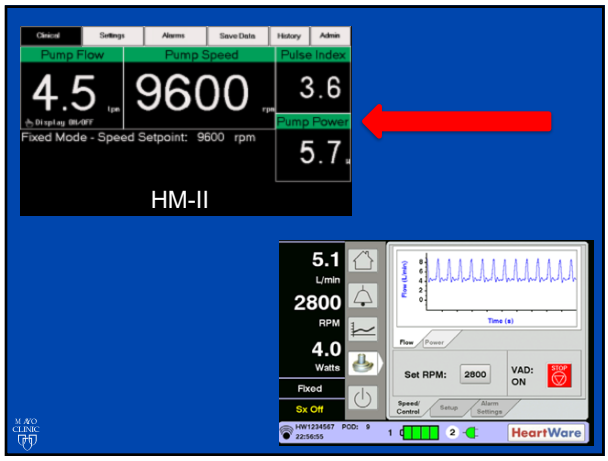
Unexpected Abrupt Increase in Left Ventricular Assist Device Thrombosis





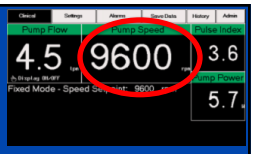
Survival after LVAD Exchange

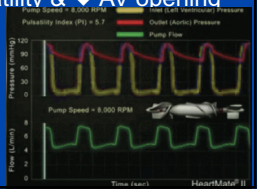


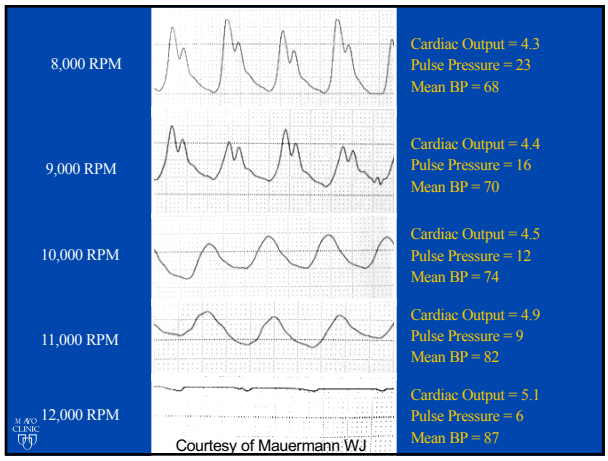


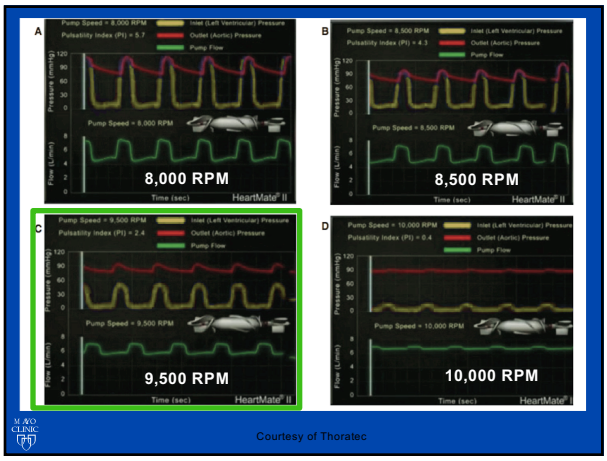
HM-II Pump Speed

- Pump speed is rpm
- Range 6,000-15,000 rpm
- Flow range 3-10 L/min
- ↑ pump speed → ↑ pump flow → ↑ LV unloading → ↓ pulsatility & ↓ AV opening

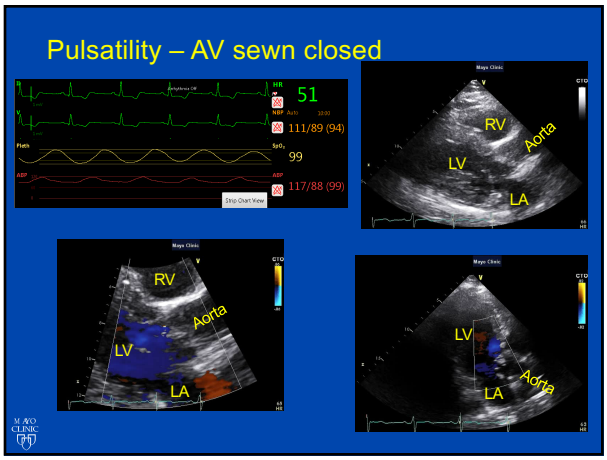




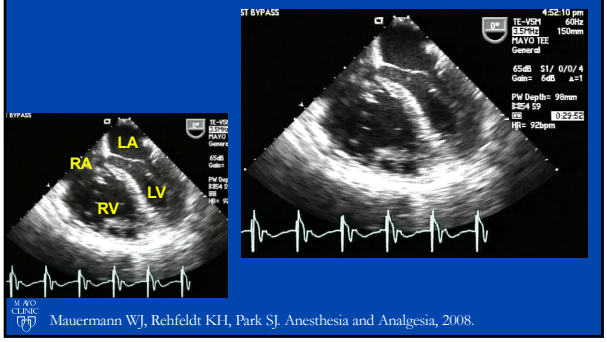




Pulsatility – AV sewn closed

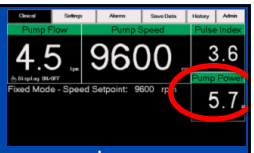


Suck-down effect



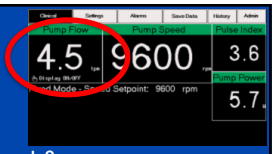
Mauermann WJ, Rehfeldt KH, Park SJ. Anesthesia and Analgesia, 2008.

HM-II Pump Power



- Directly measured
- Normally 6-8 W, depending on speed
- ↑ may indicate pump thrombus

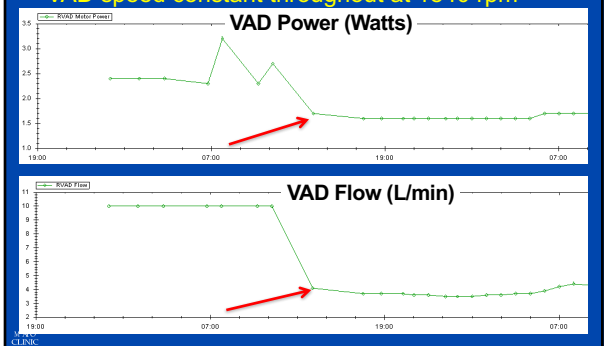
HM-II Pump Flow



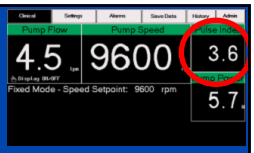
- Not measured!
- Calculated from pump speed & power
- 20% variability from actual flow through LVAD at normal flow rates (4-6 L/min)
  - Even less accurate at <3 L/m
- LVAD functions in parallel with heart
  - Systemic flow may exceed displayed pump flow with LV ejection through AV
- Falsely high ↑ in flow occur with pump thrombus

VAD Thrombus

VAD speed constant throughout at 1840 rpm

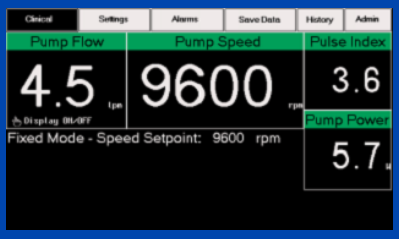


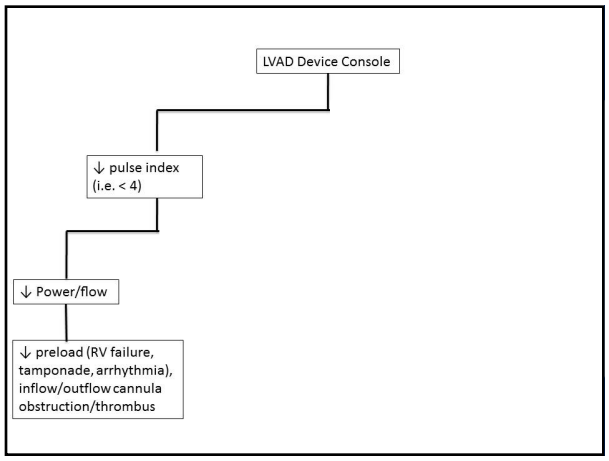
HM-II Pulsatility Index

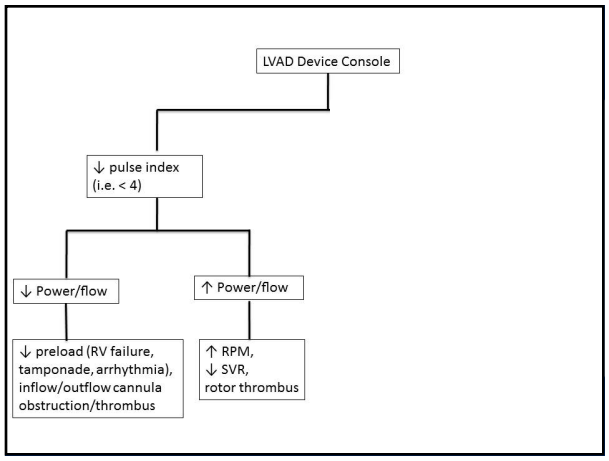


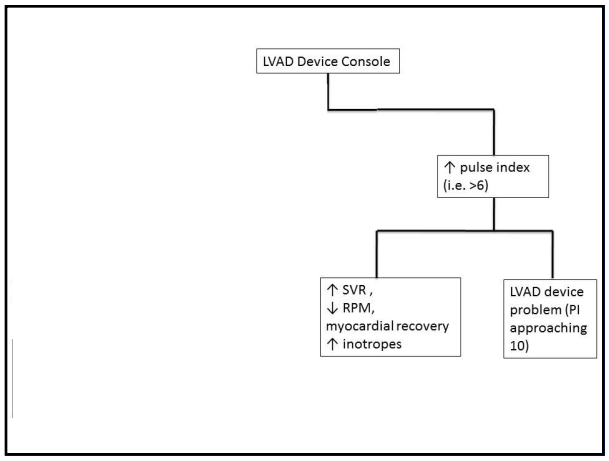
- Variability in LVAD flow in cardiac cycle
- PI = $(Q_{max}-Q_{min})/Q_{avg}$
- Averaged over 15 s
- Normally 4-6
- Since Q (flow) is calculated from power, PI is actually calculated from power variations
- LV contractility increases flow through LVAD

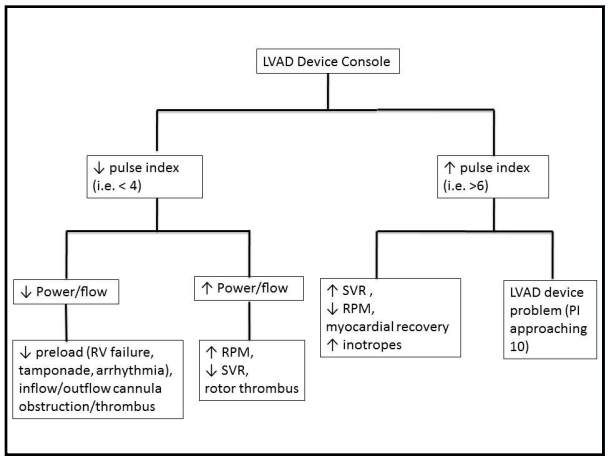
What's going on with the LVAD?




LVAD Device Console
↓ pulse index (i.e. < 4)
↓ Power/flow
↓ preload (RV failure, tamponade, arrhythmia), inflow/outflow cannula obstruction/thrombus


LVAD Device Console
↓ pulse index (i.e. < 4)
↓ Power/flow
↑ Power/flow
↓ preload (RV failure, tamponade, arrhythmia), inflow/outflow cannula obstruction/thrombus
↑ RPM, ↓ SVR, rotor thrombus


LVAD Device Console
↑ pulse index (i.e. >6)
↑ SVR , ↓ RPM, myocardial recovery ↑ inotropes
LVAD device problem (PI approaching 10)



Outline

- Recent Case
- LVAD basics
- LVAD anticoagulation, physiology, and acute management
- NCS & LVADs

INTERMACS

ELSEVIER

The Journal of Heart and Lung Transplantation

http://www.jhltonline.org

ORIGINAL CLINICAL SCIENCE

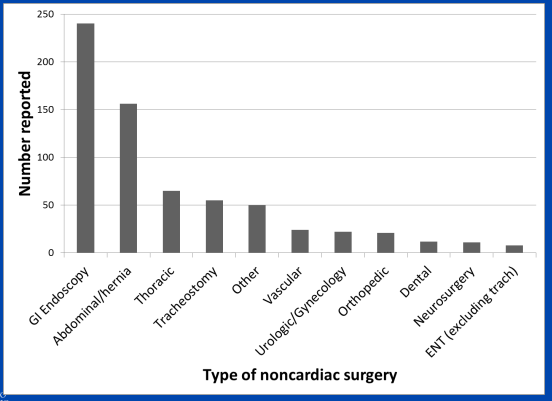
Seventh INTERMACS annual report: 15,000 patients and counting

James K. Kirklin, MD,[a] David C. Naftel, PhD,[a] Francis D. Pagani, MD, PhD,[b] Robert L. Kormos, MD,[c] Lynne W. Stevenson, MD,[d] Elizabeth D. Blume, MD,[e] Susan L. Myers, BBA, QMIS,[a] Marissa A. Miller, DVM, MPH,[f] J. Timothy Baldwin, PhD,[f] and James B. Young, MD[g]

2015

NCS Literature

Study, year	# NCSs reported	# of reported device implants	VAD type at time of NCS	Median duration of support at NCS (days)	Emergent NCS (%)	Surgeries performed during index hospitalization (%)	30-day mortality (%)
Votapka 1994	7	NR	57% pulsatile LVAD, 29% BiVAD, 14% TAH	NR	NR	NR	29%
Goldstein 1995	12	NR	100% pulsatile	NR (range 21-138)	NR	NR	0%
Schmid 2001	20	1	100% pulsatile	32 (range 5-267)	NR	NR	0%
Stone 2002	8	NR	100% pulsatile	24 (range 9-114)	NR	NR	13%
Eckhauser 2006	5	NR	100% pulsatile	120 (range 14-630)	NR	40%	0%
Stehlik 2009	59	84	3% CF, 78% pulsatile, 14% BiVAD, 2% TAH	98 (range 7-1460)	20%	NR	12%
Garratti 2009	12	7	73% CF, 27% pulsatile	79 (range 9-160)	NR	NR	0%
Ficke 2010	2	NR	100% CF	11 (range 9-12)	50%	100%	50%
Morgan 2012	25	6	100% CF	285	12%	NR	0%
Ahmed 2012	6	41	83% CF, 17% pulsatile	513 (range 83-1084)	0%	0%	0%
McKellar 2012	28	9	NR	28 (range NR)	NR	NR	NR
Gilbert 2012	43	60	27 unspecified LVAD, 16 BiVad	NR (range 1-103)	NR	NR	0%
Bhat 2012	63	10	100% CF for DT	137 (10-1016)	16%	NR	16%
Barbara 2013	67	88	99% CF LVAD, 1% pulsatile LVAD	119 (16-1819)	NR	0	9%
Goudra 2013	68	05	100% CF LVAD	NR (11-1108)	76%	NR	0%
Arnaoutakis	67	73	75% CF, 25% pulsatile	38	31%	NR	10%
Barbara 2015	172	218	99% CF LVAD	353 (31-1899)	NR	0%	11%



Mayo papers

Evolution of general surgical problems in patients with left ventricular assist devices

Surgery 2012

Stephen H. McKellar, MD, MSc,[a] David S. Morris, MD,[b] William J. Mauermann, MD,[c] Soon J. Park, MD, MSc,[a] *and* Scott P. Zietlow, MD,[b] *Rochester, MN*

The Perioperative Management of Patients With Left Ventricular Assist Devices Undergoing Noncardiac Surgery

David W. Barbara, MD; David R. Wetzel, MD; Juan N. Pulido, MD; Bryan S. Pershing, MD; Soon J. Park, MD; John M. Stulak, MD; Scott P. Zietlow, MD; David S. Morris, MD; Barry A. Boilson, MD; and William J. Mauermann, MD

Mayo Clin Proc. ■ July 2013;88(7):674-682

ASAIO Journal 2015 Clinical Cardiovascular

Periprocedural Management of 172 Gastrointestinal Endoscopies in Patients with Left Ventricular Assist Devices

David W. Barbara,* David A. Olsen,* Juan N. Pulido,* Barry A. Boilson,† David H. Bruining,‡ John M. Stulak,§ and William J. Mauermann*

"Larger" recent series of LVADs and NCS

Experience With Noncardiac Surgery in Destination Therapy Left Ventricular Assist Devices Patients

Non-cardiac surgery in patients on long-term left ventricular assist device support

Trends in the Management of Patients With Left Ventricular Assist Devices Presenting for Noncardiac Surgery: A 10-Year Institutional Experience

Anesthesia for gastrointestinal endoscopy in patients with left ventricular assist devices: Initial experience with 68 procedures

Goudra BG, Singh PM

Annals Cardiac Anaesthesia. 2013; 16: 250-6

General and Acute Care Surgical Procedures in Patients with Left Ventricular Assist Devices

	Noncardiac Surgery				GI Endoscopy	
	Bhat 2012	Morgan 2012	Barbara 2013	Stone 2016	Goudra 2013	Barbara 2015
Pts	36	20	33	138	39	53
Procedures	63	25	67	291	68	172
CF-LVAD	100%	100%	99%	83%	100%	99%

	Noncardiac Surgery				GI Endoscopy	
	Bhat 2012	Morgan 2012	Barbara 2013	Stone 2016	Goudra 2013	Barbara 2015
On AC/AP pre-op	?100%	96%	73%	NR	100%	70%
Passively reversed (% of pts on AC/AP)	Majority	?	47%	NR	76%	52%
Actively reversed (% of pts on AC/AP)	?	8%	18%	NR	"Rarely"	24%

Outline

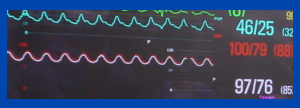
- Recent Case
- LVAD basics
- LVAD anticoagulation, physiology, and acute management
- NCS & LVADs
- LVAD perioperative considerations

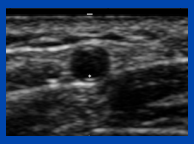
Considerations

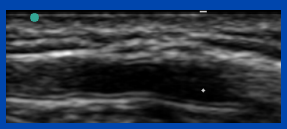
Team approach

- Clinically optimized preoperatively by heart failure cardiologists familiar with device management
- Careful coordination among the cardiology, cardiac and noncardiac surgical, and anesthesia teams is important
- NCS at the cardiac hospital with cardiac surgical resources readily available
- Accompanied in OR by LVAD technician
- LVAD console continuously displays LVAD parameters
- Postoperatively recovered in a single ICU or monitored unit with nursing staff who are familiar with these devices

Monitoring blood pressure

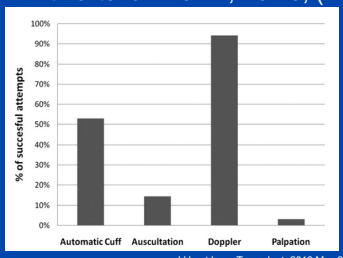


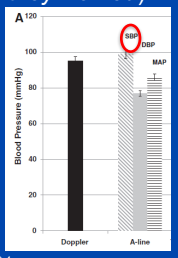




NIBP & LVADs

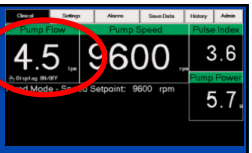
- 17 pts w HM-II
- Both cuff and Doppler correlated reasonably well with arterial line BP, r 0.75, (*when they worked*)

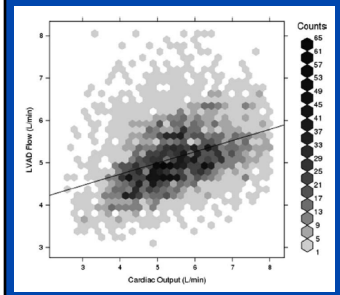




J Heart Lung Transplant. 2010 May;29(5):593-4
Circ Heart Fail. 2013 Sep 1;6(5):1005-12

C.O. on HM-II vs. CCO

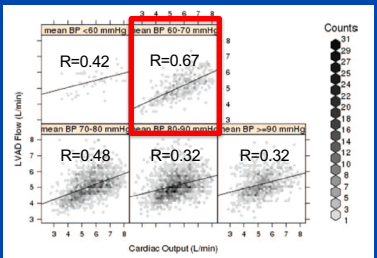




- N = 4898 C.O. (81 pts)
- R = 0.42
- C.O. LVAD < PAC
- Mean difference = 0.36 L/min

Hasin T, et al. ASAIO J. 2014 Sep-Oct;60(5):513-8.

C.O. on HM-II vs. PAC



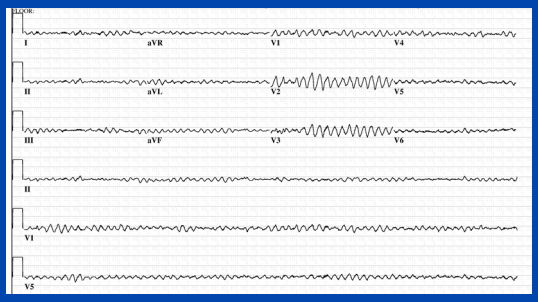
- Sensitive to SVR changes, and calculated flow inaccurate
- Portion of total C.O. may occur via AV

BP Monitoring Recommendations

- General anesthesia: Arterial line
- MAC / Moderate sedation: Likely ok without arterial line, but have back-up plan

Defibrillation & Cardioversion

Rhythm



CPR

ELSEVIER
European Journal of Cardio-thoracic Surgery 36 (2009) 3–28
EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY
www.elsevier.com/locate/ejcts

Guideline

Guideline for resuscitation in cardiac arrest after cardiac surgery

Joel Dunning[a], Alessandro Fabbri[b], Philippe H. Kolh[c], Adrian Levine[d], Ulf Lockowandt[e], Jonathan Mackay[f], Alain J. Pavie[g], Tim Strang[h], Michael I.M. Versteegh[i], Samer A.M. Nashef[j,*], on behalf of the EACTS Clinical Guidelines Committee

7.4. Patients with a cardiac assist device

All clinicians caring for these patients should have full training in the procedures for equipment failure and the 'cardiac arrest' situation. The guidelines presented in this document do not apply to these patients. They are highly complicated due to the fact that an 'arrest' may be due to mechanical failure and in this situation ECM is not appropriate. A protocol for resuscitation and back-up support must be established and rehearsed.

MECHANICAL ASSIST DEVICES

The presence of mechanical assist devices in the cardiac surgery ICU further complicates the management of cardiac arrest in cardiac surgery patients, because cardiac arrest in these patients could be a consequence of mechanical device failure. In such cases, ECM might not be appropriate. Furthermore, the lack of a peripheral pulse in patients with a left ventricular assist device (LVAD) in place makes determination of the occurrence of a cardiac arrest and implementation of the standard ACLS protocol challenging. Although device manufacturers and practitioners have raised concerns regarding potential damage to the inflow or outflow cannula position during standard ECM in LVAD patients, a study of 8 LVAD patients who received standard CPR suggested that standard chest compressions can be safely delivered to LVAD patients.[13–15] However, the shortest interval from LVAD implantation to the cardiac arrest in that small, retrospective study was 50 days. Thus, the concern that patients with more recent LVAD implantation who receive ECM are at risk of LVAD dislodgement remains.

J Thorac Cardiovasc Surg 2014;148:1152-6

HM-II Manual

External Chest Compressions

There may be risks associated with performing external chest compressions in the event of cardiac arrest, due to the location of the outflow graft and the presence of ventricular apical anastomosis. External chest compressions may damage the outflow graft conduit or dislodge the Left Ventricular Assist Device inflow tract.

Cardiac massage under direct vision, performed by a skilled surgeon, may be effective in patients who have had recent pump implantation (prior to mediastinal healing).

HeartWare Manual

18.2 Emergency Management

In the event of an emergency, such as a cardiac arrest, patients with the HeartWare® System may be defibrillated with either an internal or external defibrillator. The HeartWare® System can be left on, nothing needs to be turned off or disconnected. If chest compressions are performed, confirm function and positioning of HVAD® Pump once the patient is stable.

CAUTION: Chest compressions may pose a risk due to pump location and position of the outflow graft on the aorta - use clinical judgment. If chest compressions have been administered, confirm function and positioning of HVAD® Pump.

Rottenberg *et al. Journal of Cardiothoracic Surgery* 2011, **6**:91
http://www.cardiothoracicsurgery.org/content/6/1/91

JCTS JOURNAL OF CARDIOTHORACIC SURGERY

CASE REPORT Open Access

Abdominal only CPR during cardiac arrest for a patient with an LVAD during resternotomy: A case report

Eric M Rottenberg[1], Jarrett Heard[2], Robert Hamlin[3], Benjamin C Sun[4] and Hamdy Awad[2*]

Figure 1 Abdominal only cardiopulmonary resuscitation during cardiac arrest in patient with HeartMate. Abdominal only cardiopulmonary resuscitation using a left paramedian technique 1 to 2 inches left of the midline while the surgeon performs cannulation of the femoral artery and vein for placement of extra-corporeal membrane oxygenation for long-term mechanical support.

Figure 2 Monitor after 15 minutes of abdominal only cardiopulmonary resuscitation. Monitor showing the hemodynamic waveforms and their means during abdominal only cardiopulmonary resuscitation during cardiac arrest while the surgeon performed cannulation of the femoral artery and vein as shown in Figure 1. Coronary perfusion pressure: Mean arterial pressure (MAP) - central venous pressure (CVP) = 15 mmHg.

Resuscitation 85 (2014) 702–704

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Short communication

Chest compressions may be safe in arresting patients with left ventricular assist devices (LVADs)☆

Zachary Shinar[a,*], Joseph Bellezzo[a], Marcia Stahovich[a], Sheldon Cheskes[b], Suzanne Chillcott[a], Walter Dembitsky[a]

Table 1
Demographics of LVAD patients receiving chest compressions.

Patient	Type of LVAD	Gender	Age	Time from insertion to arrest	Duration of chest compressions	OHCA
1	Heartmate II	M	57	254 days	>20 min	Yes
2	Heartmate II	M	64	556 days	15–20 min	Yes
3	Heartmate II	M	69	234 days	10–15 min	Yes
4	Heartmate II	M	80	50 days	<1 min	No
5	Heartmate II	M	50	1324 days	Unclear	Yes
6	Heartmate II	M	79	431 days	2.5 h	Yes
7	Heartmate II	F	56	753 days	Unclear	Yes
8	Heartmate II	M	76	85 days	6 min/3 min	No

Table 2
Results of LVAD patients post-chest compressions.

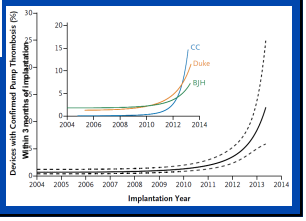
Patient	ROEC	RONF	Reason for arrest	Defibrillation	VAD flow	Autopsy
1	No	No	Accidental disconnect	No	5 l min^{-1}	No
2	Yes	No	Accidental disconnect	No	5.7 l min^{-1}	Yes, confirmed intact cannulas
3	Yes	No	Accidental disconnect	Yes, AICD	5.4 l min^{-1}	No
4	Yes	Yes	LV thrombus	No	6.6 l min^{-1}	Yes, confirmed intact cannulas
5	Yes	Yes	Accidental disconnect	No	5.2 l min^{-1}	No
6	No	No	Vfib	Yes, AICD	No flow documented	Yes, confirmed intact cannulas
7	Yes	Yes	Driveline malfunction	No	3.7 l min^{-1}	No
8	Yes	Yes	Unclear	No	5.2/4.9 l min^{-1}	No

CPR

we considered chest compression an extreme "saving" measure, an ultimate modus operandi, to perform when all CPR actions have failed.

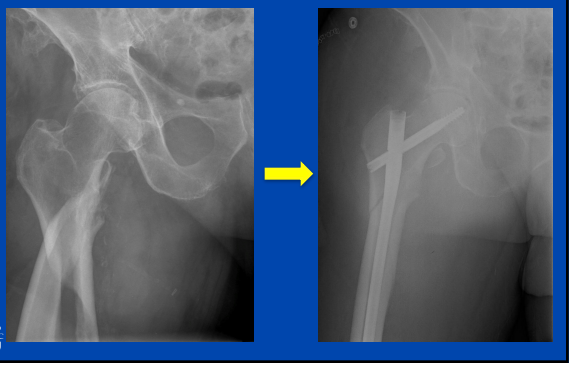
International Journal of Cardiology 168 (2013) 5143–5148

Anticoagulation/Antiplatelets



MAYO CLINIC

Return to case



Hospital course

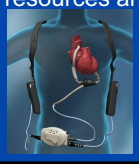
- OR: Awake art line, GETA
  3 RBC, 1 plat, phenyl gtt, extubated
- ICU: PICC, Phenyl → Vaso +/- NE x 2 d
  FFP for oozing w INR 2.4
- POD 2, 3: 1 U RBC each day
- POD 3: Left ICU
- POD 4: Warfarin
  - Heparin gtt (POD 5-6)
  - Highest INR 3.7 (POD 9)
- POD 8: Xfer rehab
- POD 20: Home w home health services

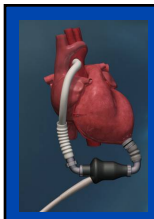
Outline

- Recent Case
- LVAD basics
- LVAD anticoagulation, physiology, and acute management
- NCS & LVADs
- LVAD perioperative considerations
- Conclusions

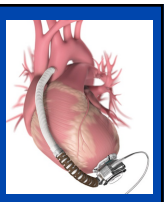
Conclusions

- LVADs are becoming increasingly prevalent
- More LVAD pts are presenting for NCS
- Thorough understanding of LVAD physiology is necessary
- LVAD pts can safely undergo NCS at centers with appropriate resources and multidisciplinary support





MAYO CLINIC



Questions?

Barbara.David@mayo.edu