Current Ventricular Assist Device Outcomes and Future Technology

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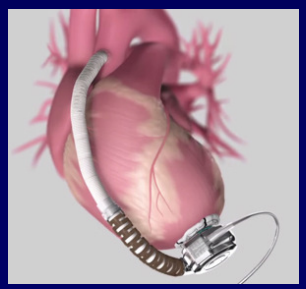
Oklahoma Heart Institution

Oklahoma Heart Institute 28th Annual Oklahoma Heart Update in Cardiology: Improving Outcomes for Cardiovascular Patients. May 5th 2017. Tulsa, OK.



CARDIOVASCULAR
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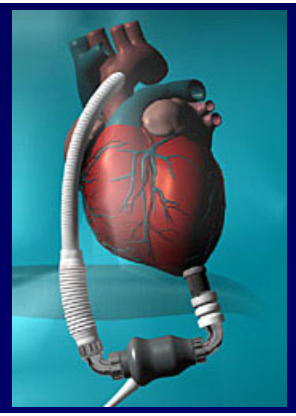


Presenter Disclosure Information

Current Ventricular Assist Device Outcomes and Future Technology

DISCLOSURE INFORMATION:

The following relationships exist related to this presentation:

Allen Cheng	**- Presenter for Thoratec and Heartware**
	- No financial relationship disclosure

Background

Heart failure remains to be a major global problem with over 26 million people suffering from heart failure around the world and approximate 6 million patients in the US alone.

Along with the aging population worldwide, the AHA estimate growth rate of heart failure patients will exceed greater than 30% in the next 10 years*.

*Forecasting the future of cardiovascular disease in the US: A policy statement from the American Heart Association Circulation. 2011 Mar 1;123[8]:933-44

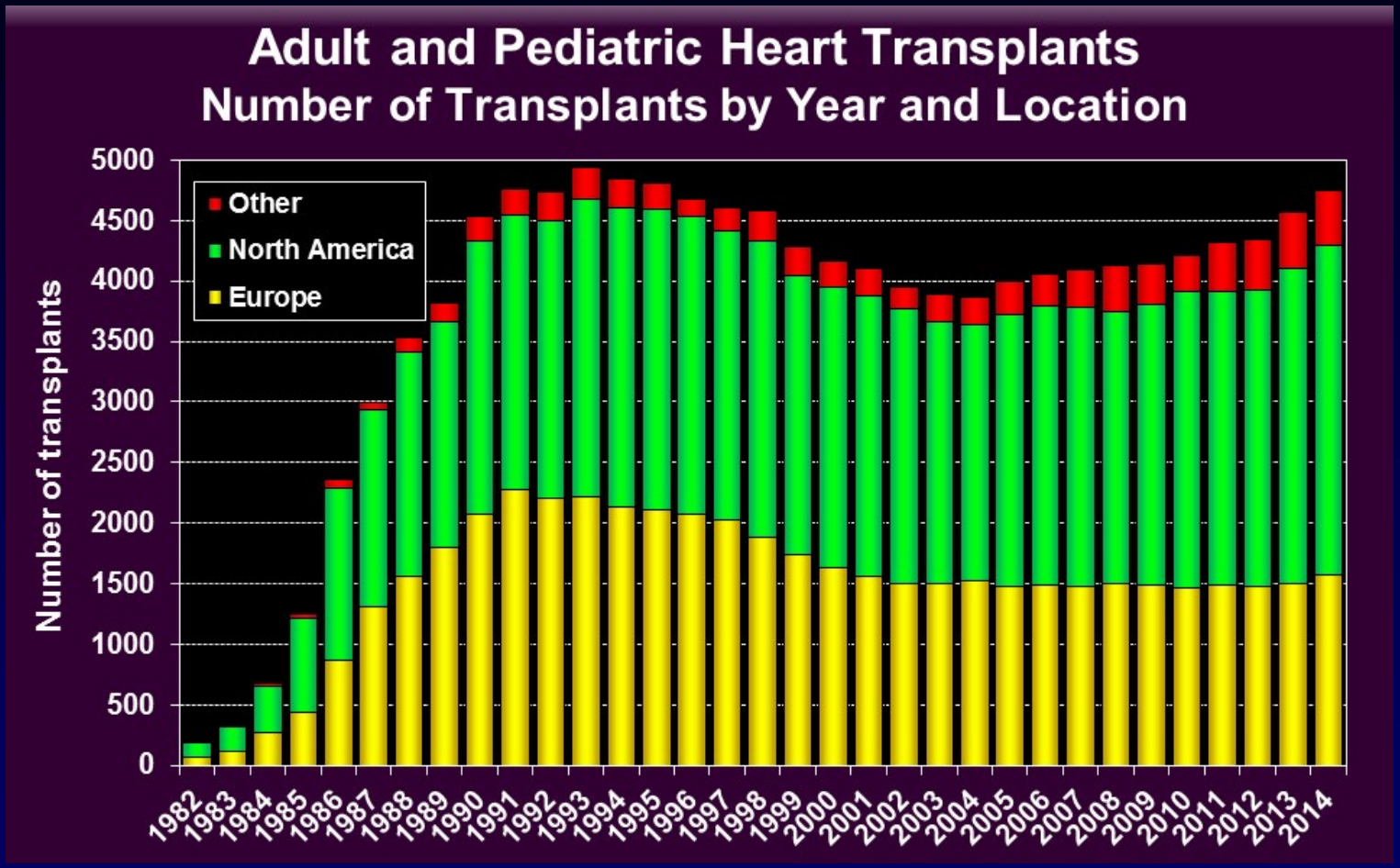
Background

Medical therapies have not been sufficient for late-stage heart failure.

Heart transplantation has been the gold standard therapy and has a 1-year survival average around 90%.

But the number of heart transplantation has been significantly limited by the number of available organ donor.

26 millions heart failure patients, 600,000 pts qualify for advance HF therapy (AHA estimate)



With the limitation of available donor organ, the number of annual heart transplantation in the US and Europe, has remained unchanged in the last two decade with only about 2500 cases a year nation-wide in the US and Europe.

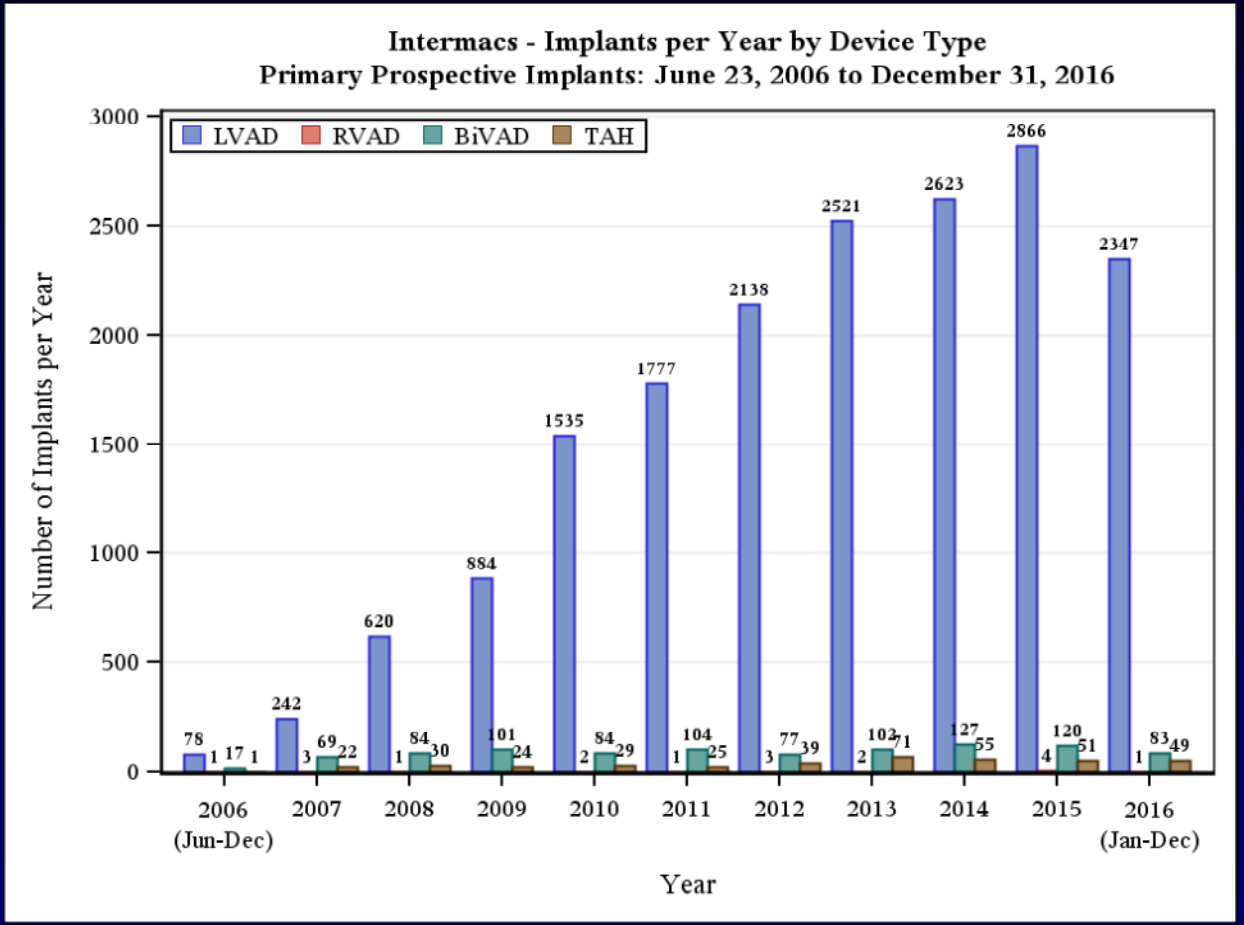
ISHLT 2016
ISHLT • INTERNATIONAL SOCIETY FOR HEART AND LUNG TRANSPLANTATION
JHLT. 2016 Oct; 35(10): 1149-1205

Background

Interagency Registry for Mechanical Assisted Circulatory Support
INTERMACS Annual Report 2016

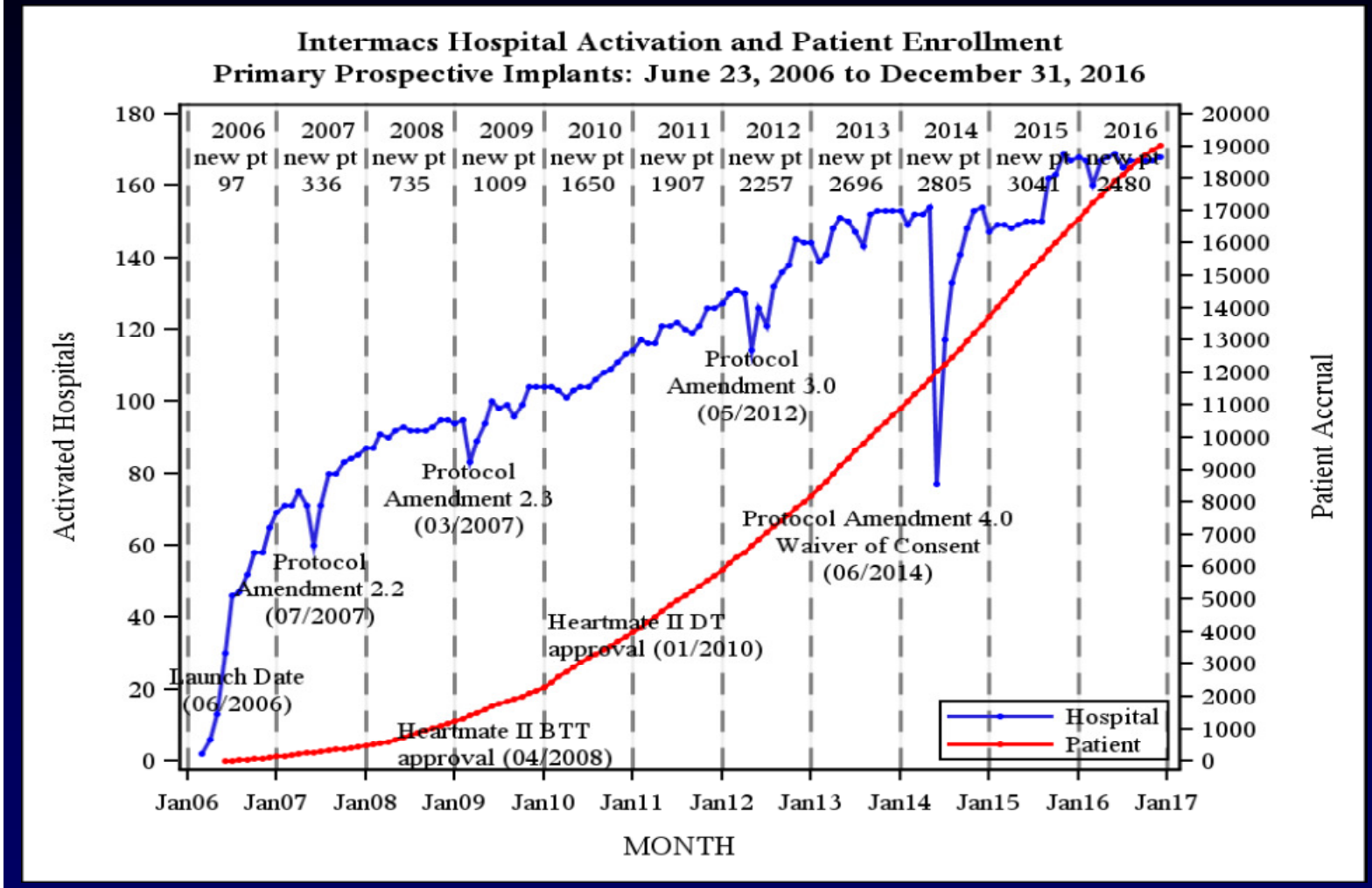
With the technological advancement in left ventricular assist device (LVAD), the use of LVAD in the US has increased significantly.

The 1-year survival rate of LVAD therapy has been shown to be comparable to heart transplantation.



https://www.uab.edu/medicine/intermacs/reports/public-statistical-reports

INTERMACS Annual Report 2016



>19000 implants
> 170 centers

https://www.uab.edu/medicine/intermacs/reports/public-statistical-reports

Benefits of Mechanical Circulatory Support

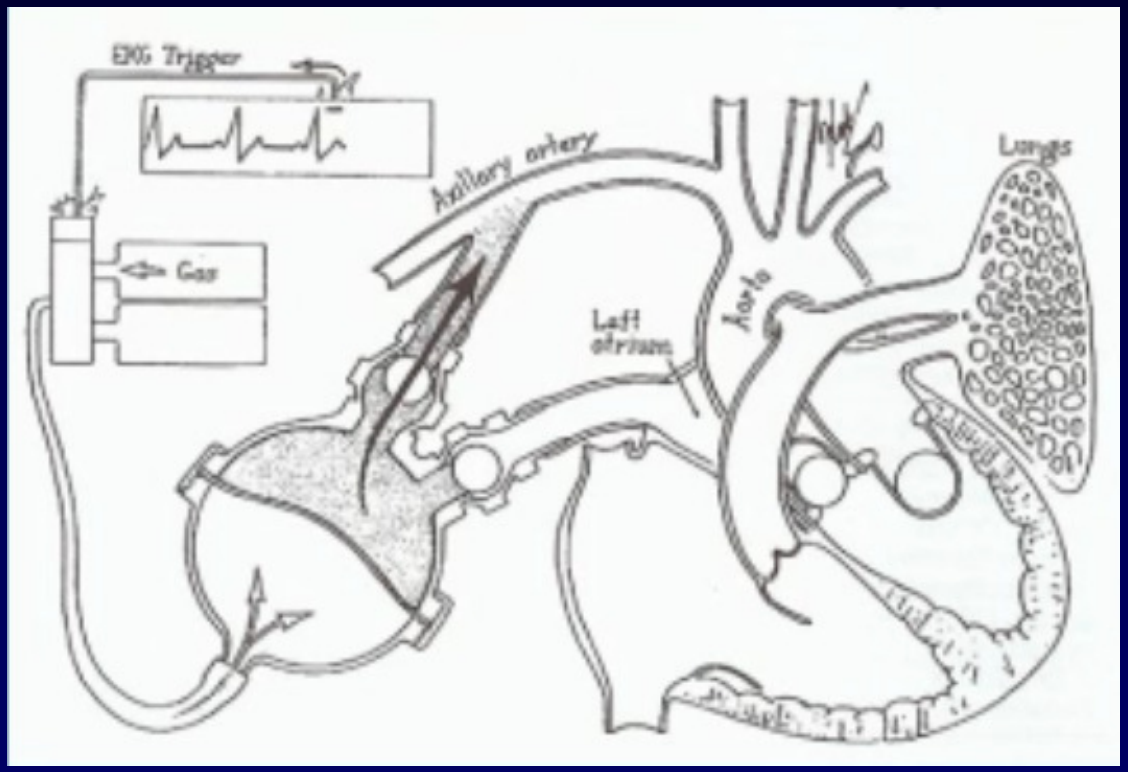
Heart transplantation vs. mechanical circulatory support

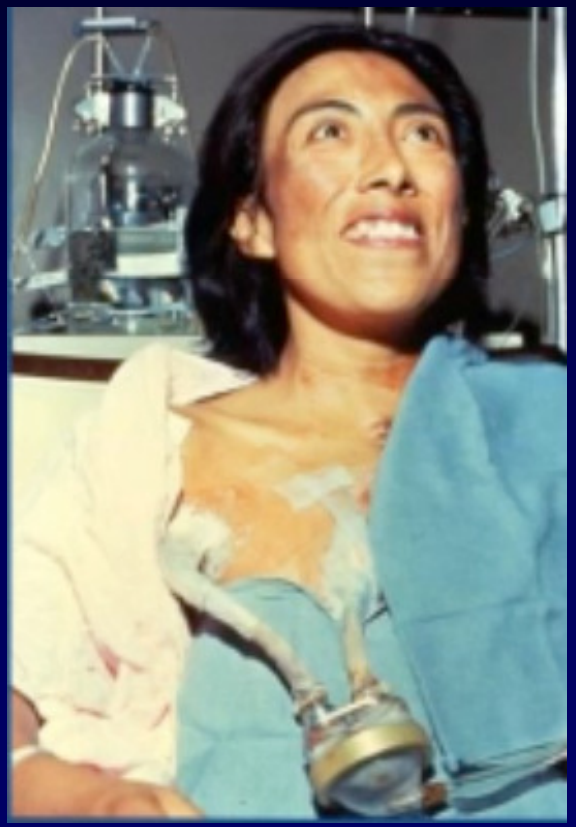
	Transplant	MCS
Wait list	Yes	No
Elective procedure	No	Yes
Risk of transmission of infectious agents	Yes	No
Need for immunosuppressive therapy	Yes	No
Monitoring for allograft vasculopathy	Yes	No
Increased malignancy risk	Yes	No
Need for surveillance biopsies	Yes	No
Rejection risk	Yes	No
Minimally invasive implantation	No	Yes
Readily replaceable	No	Yes
Amenable to technologic advancement	No	Yes
Partial support option	No	Yes
Recovery option	No	Yes
Heart transplant option	No	Yes
Lifelong anticoagulation	No	Yes
Driveline required	No	Yes

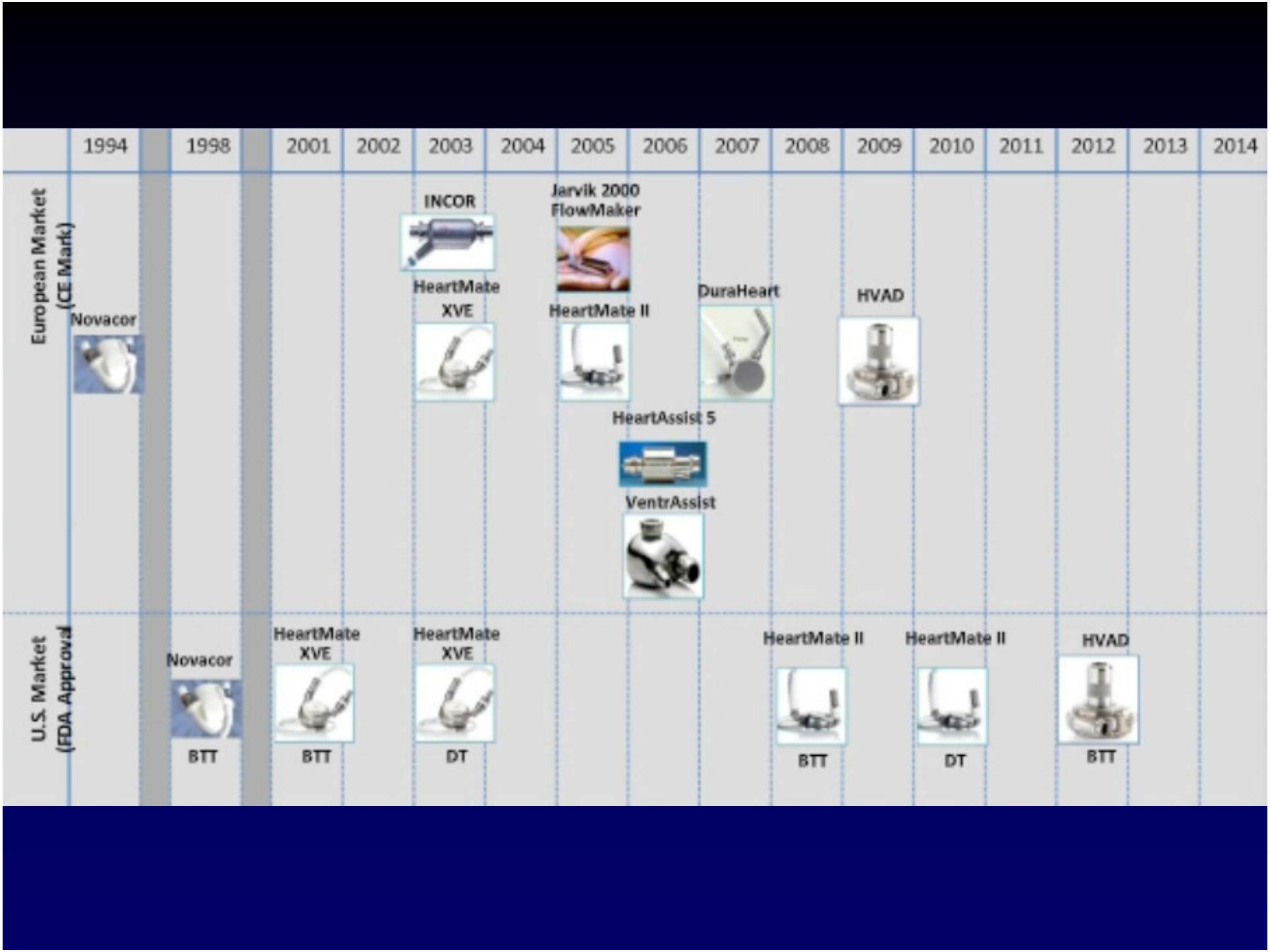
Frontline Medical News

Source: Joseph Woo, M.D.

LVAD Bridge to Recovery – 1966
Michael Debakey



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European Market (CE Mark)
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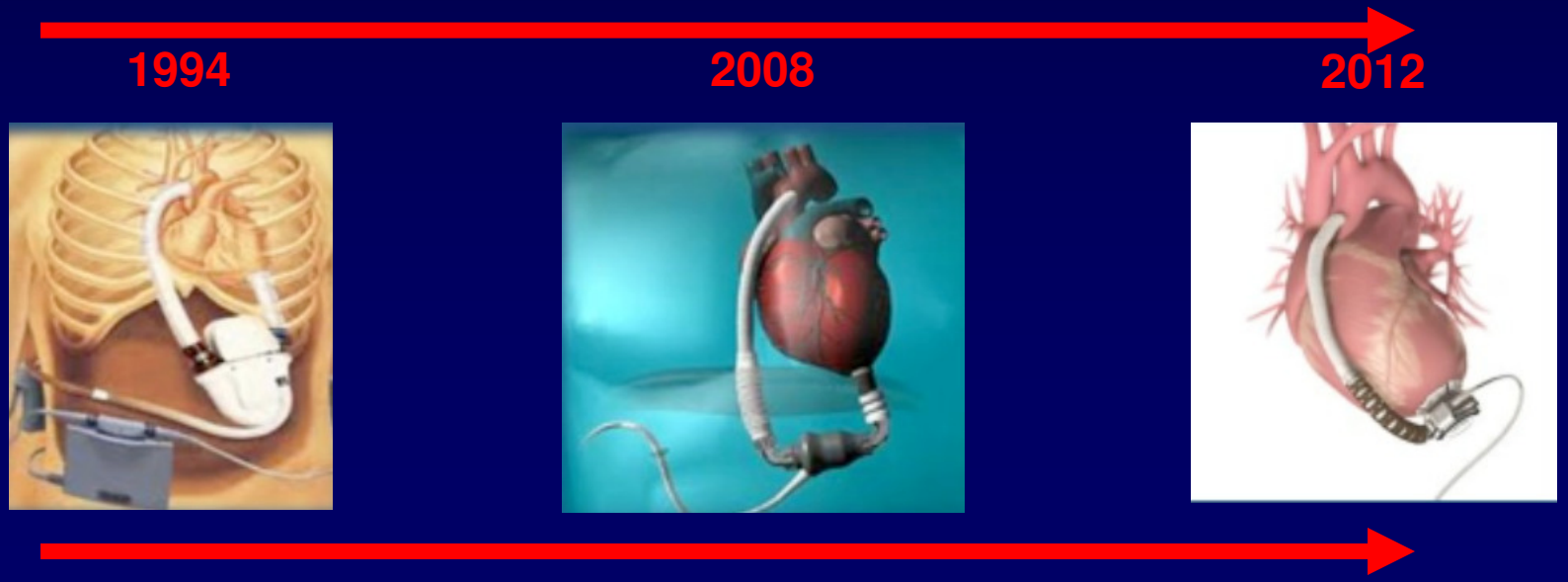
INCOR
HeartMate XVE
Jarvik 2000 FlowMaker
HeartMate II
DuraHeart
HVAD
HeartAssist 5
VentrAssist
U.S. Market (FDA Approval)
Novacor
BTT
HeartMate XVE
BTT
HeartMate XVE
DT
HeartMate II
BTT
HeartMate II
DT
HVAD
BTT

Overview

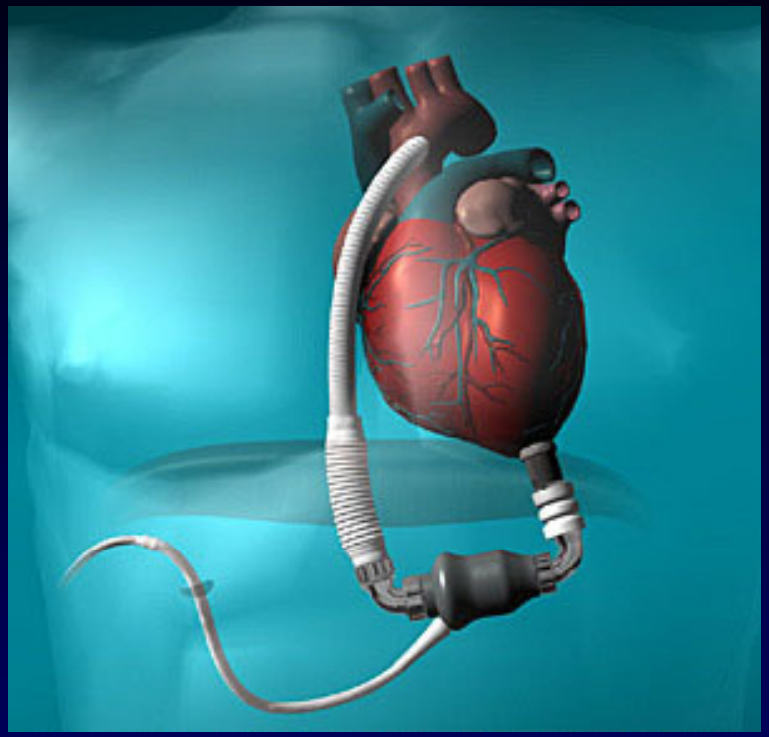
Significant progress has been made over the past decade

- Use of continuous flow devices
- Pericardial devices
- simple implant procedures (minimally invasive implants)
- Improvement in patient selection
- Shared experiences – improved outcomes
- Increased duration of successful support has resulted in alteration in transplants allocations

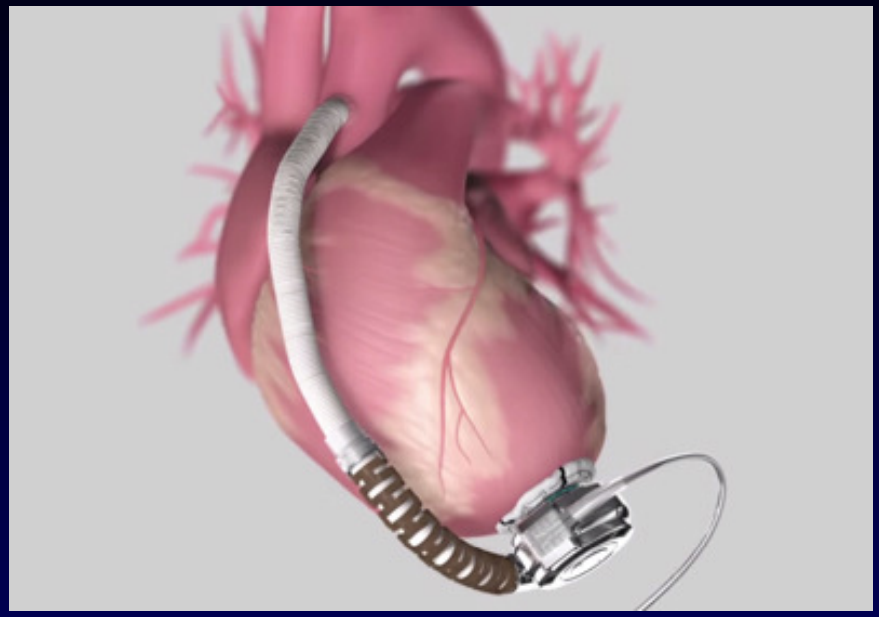


Heartmate II

Abbott
Axial-flow pump



Heartware HVAD



Heartmate XVE

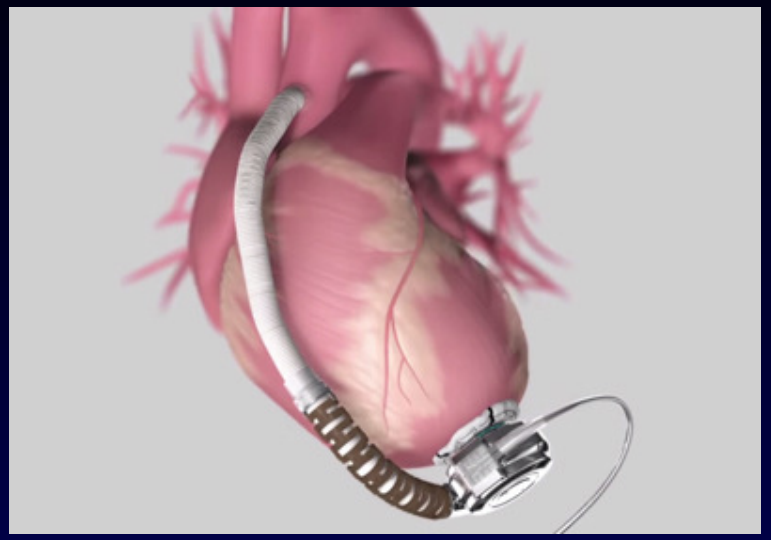
Medtronics
Centrifugal – flow pump

- Smaller
- No pump pocket needed

Multiple studies have shown HMII and HVAD are not only smaller but more reliable and durable with much less adverse events..

Uses of LVAD Support

- Provides ventricular unloading of the failing heart while supporting circulation
- Used as a bridge to heart transplant (BTT) until a donor heart is identified
- Permanent support as destination therapy (DT)
- In some patients, supports the heart as a bridge to recovery (BTR)



Intermacs

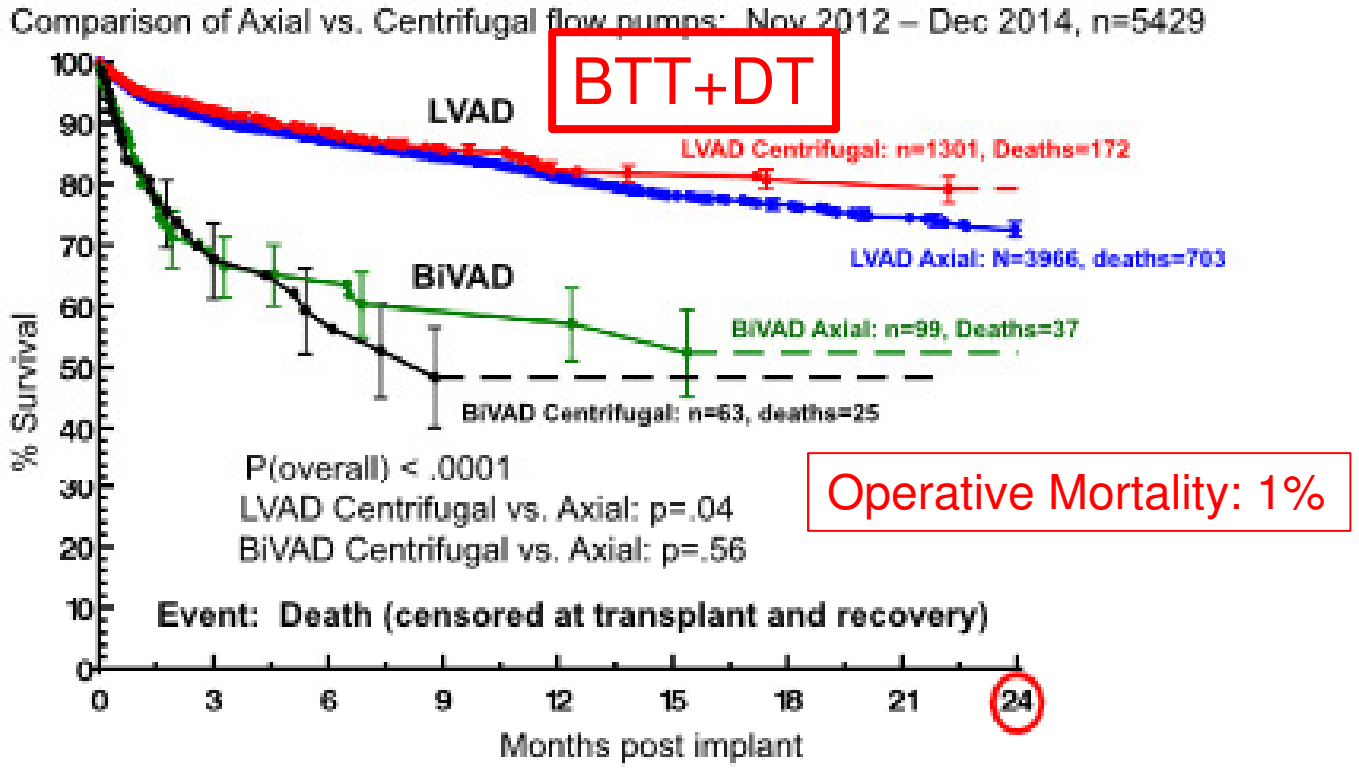
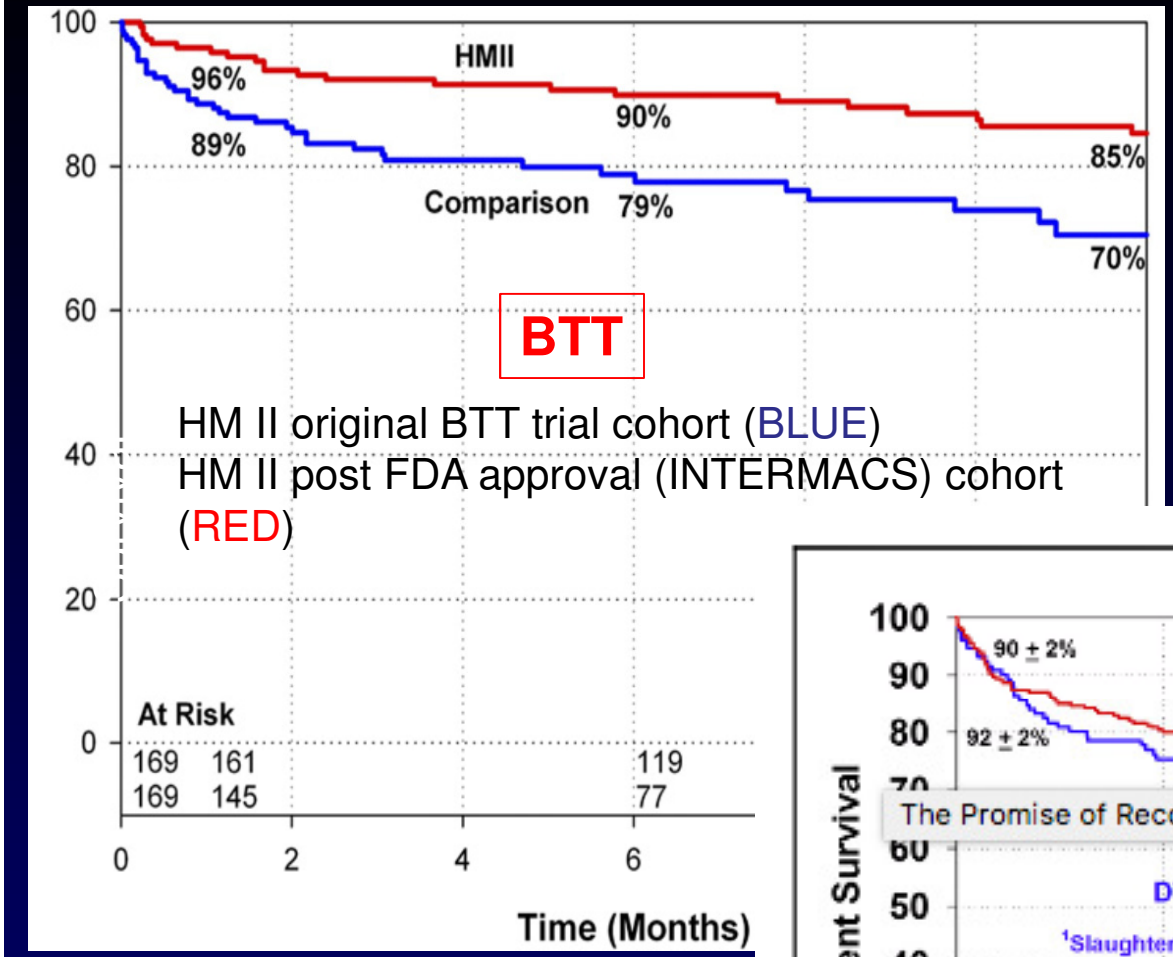


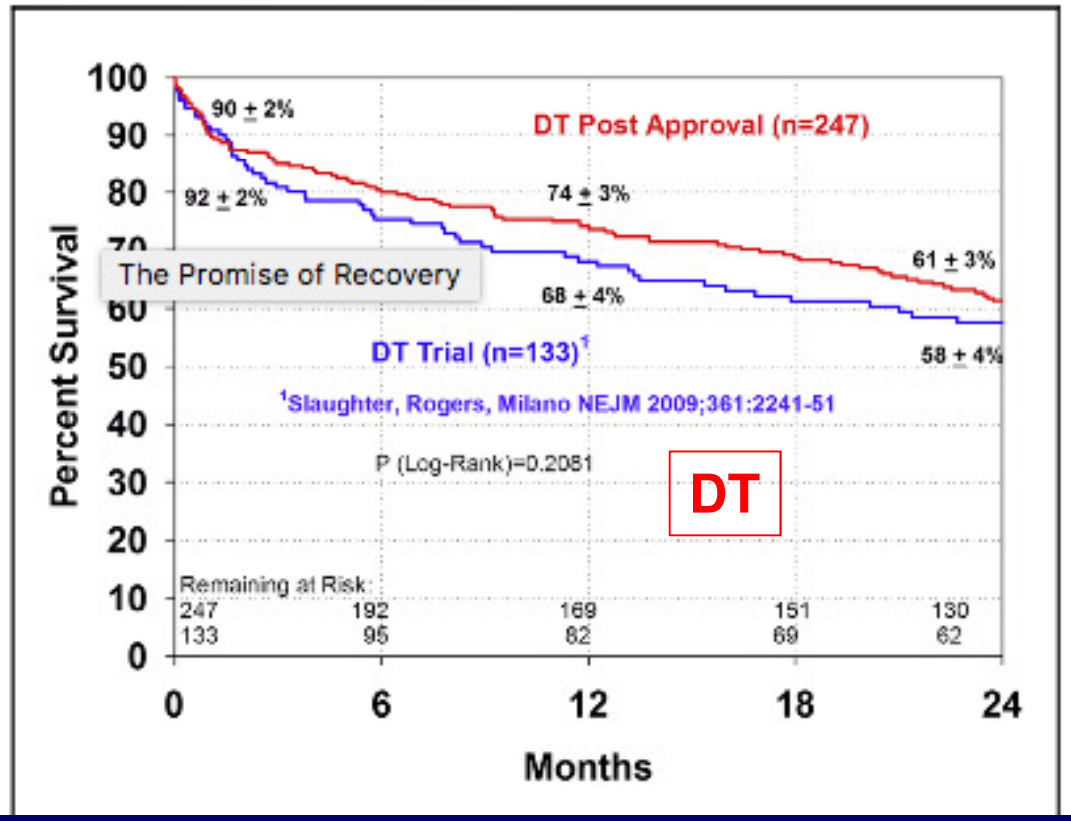
Figure 7 Actuarial survival curve for continuous-flow LVAD and BiVAD patients, stratified by pump type. The depiction is as shown in Figure 6.

Kirklin et al. Seventh INTERMACS annual report. *JHLT*. 2016;34:1495-1504



HM II original BTT trial cohort (BLUE)
HM II post FDA approval (INTERMACS) cohort (RED)

Starling RC et al. JACC 2014



Jorde UP et al. JACC 2014:1751-7

Long-term mechanical circulatory support (destination therapy): On track to compete with heart transplantation?

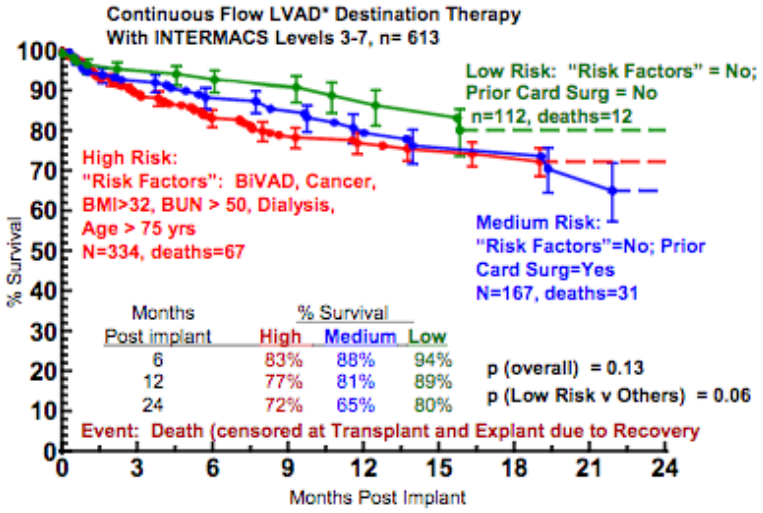
James K. Kirklin, MD,[a] David C. Naftel, PhD,[a] Francis D. Pagani, MD, PhD,[b] Robert L. Kormos, MD,[c] Lynne Stevenson, MD,[d] Marissa Miller, DVM, MPH,[e] and James B. Young, MD[f]

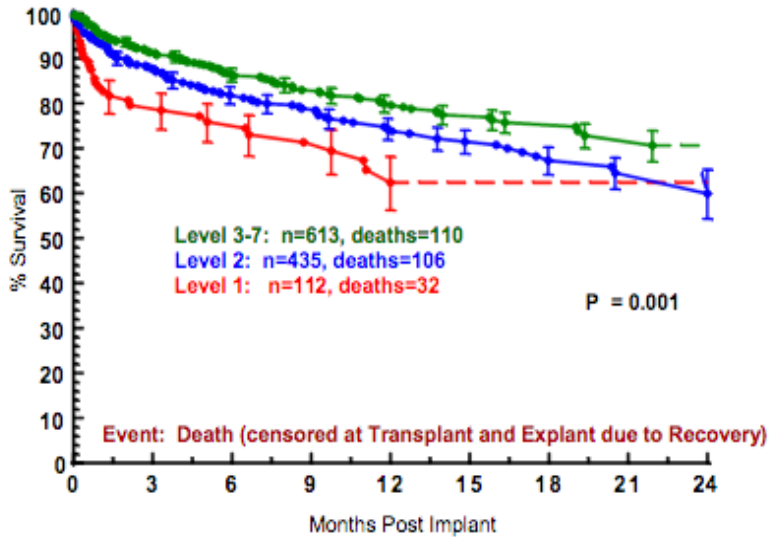
J Thorac Cardiovasc Surg 2013;144:584-603)

INTERMACS database

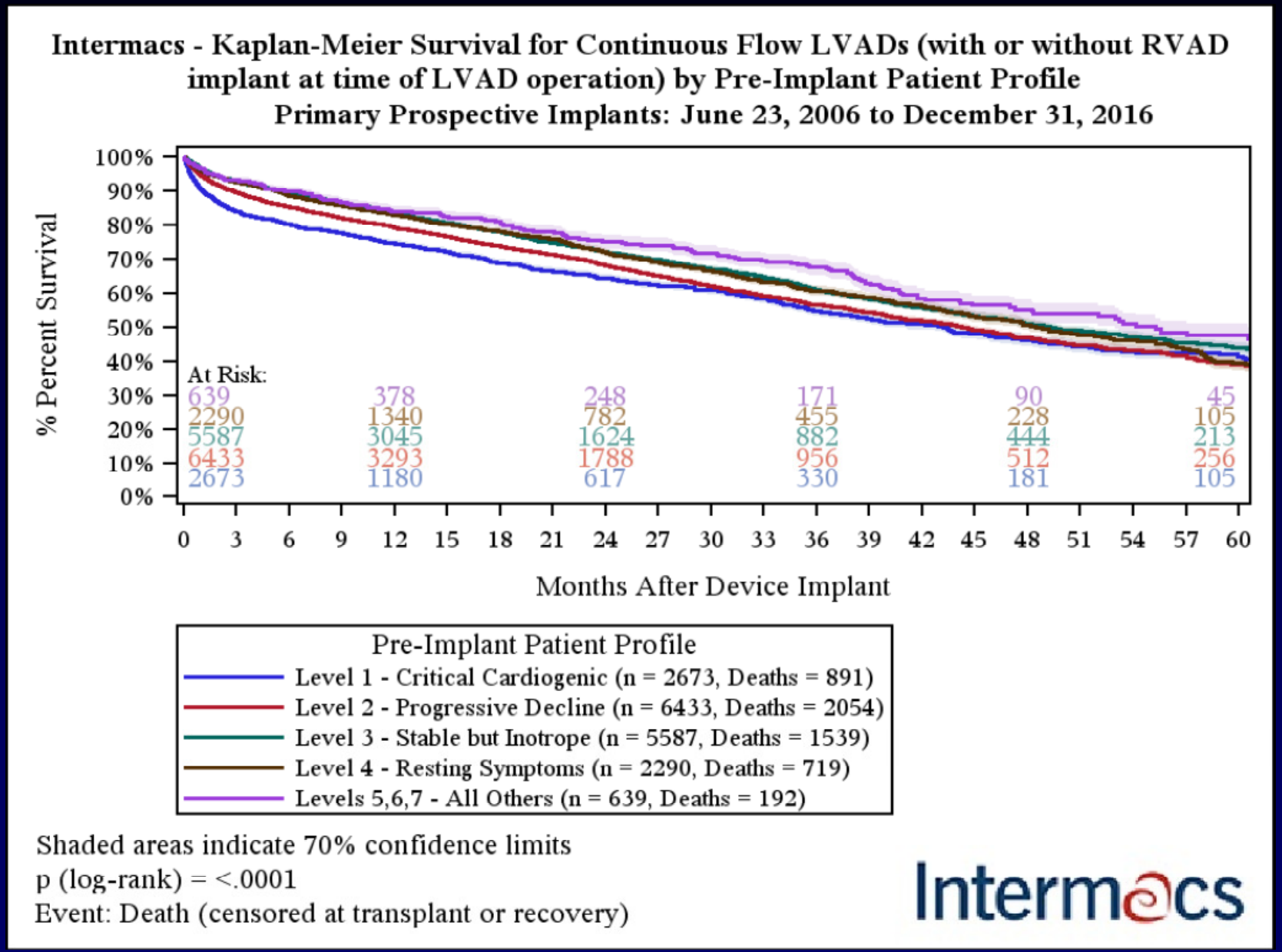
Results: By multivariable analysis, risk factors ($P < .05$) for mortality after DT included older age, larger body mass index, history of cancer, history of cardiac surgery, INTERMACS level I (cardiogenic shock), dialysis, increased blood urea nitrogen, use of a pulsatile flow device, and use of a right ventricular assist device (RVAD). Among patients with a continuous flow LVAD who were not in cardiogenic shock, a particularly favorable survival was associated with no cancer, patients not in cardiogenic shock, and blood urea nitrogen less than 50 mg/dL, resulting in 1- and 2-year survivals of 88% and 80%.

Conclusions: (1) Evolution from pulsatile to continuous flow technology has dramatically improved 1- and 2-year survivals; (2) DT is not appropriate for patients with rapid hemodynamic deterioration or severe right ventricular failure; (3) important subsets of patients with continuous flow DT now enjoy survival that is competitive with heart transplantation out to about 2 years. (J Thorac Cardiovasc Surg 2012;144:584-603)

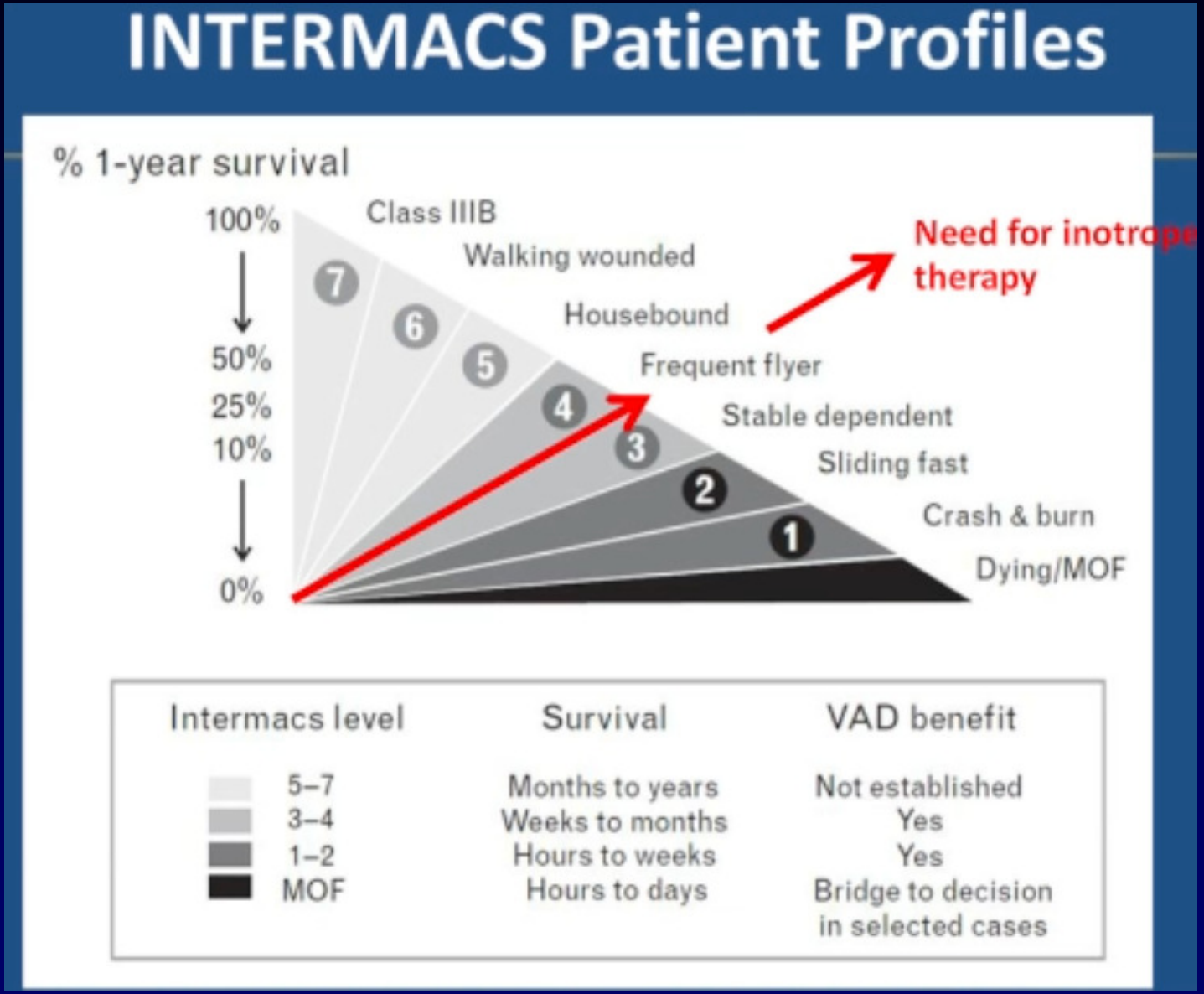




Early Referral



Early Referral



ADULT CARDIAC

Survival on the Heart Transplant Waiting List: Impact of Continuous Flow Left Ventricular Assist Device as Bridge to Transplant

Jaimin R. Trivedi, MD, MPH, Allen Cheng, MD, Ramesh Singh, MD, Matthew L. Williams, MD, and Mark S. Slaughter, MD

Division of Thoracic and Cardiovascular Surgery, University of Louisville, Louisville, Kentucky

(Ann Thorac Surg 2014;98:830–4)

UNOS Database
Propensity Match Study
Impact of LVAD on wait list survival

Does Left Ventricular Assist Device Support Improve Survival on the Heart Transplant Waiting List?

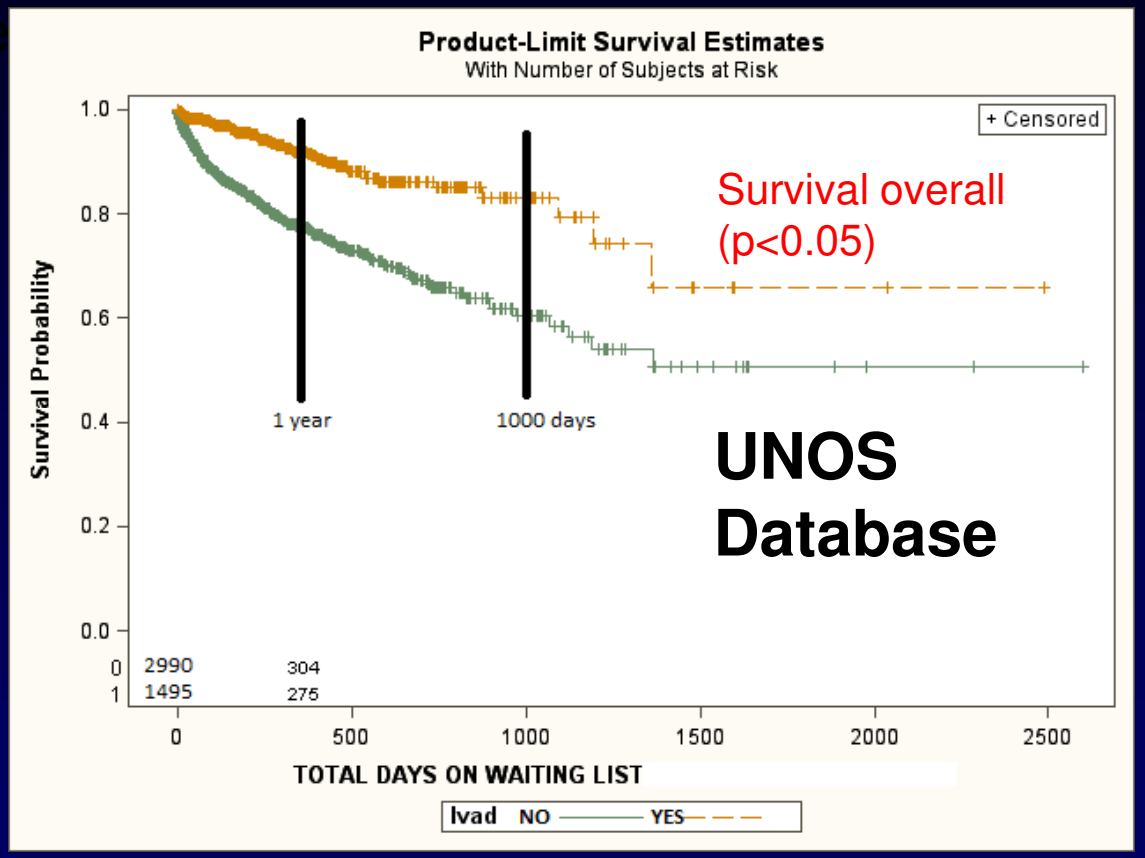
UNOS database Analysis:

Survival in Prope

Patients supported with HM II LVAD for BTT demonstrated an improved survival in patients on waiting list

Potential additional benefits

- Improved survival with LVAD could allow improved allocation of donor organs
- Improved quality of life while on waiting list compared non-LVAD patients



Trivedi J., Cheng A, Slaughter MS et al . Presented at STSA Annual Meeting 2013. Annal of Thoracic Surgery 2014;98:830-4.

ASAIO Journal 2014

The Association of Pretransplant HeartMate II Left Ventricular Assist Device Placement and Heart Transplantation Mortality

Cheng A, Slaughter MS et al ASAIO J 2014 May-Jun;60(3):294-9.

Table 2. Association between pre-heart transplant implantation with Heart Mate II LVAD and post-heart-transplant all-cause mortality, UNOS (2004 – 2010)

Time after transplantation (days)	Time-dependent Cox proportional hazard regression models			
	Unadjusted		Multivariable-adjusted	
	HR (95% CI)	P-value	HR (95% CI)	P-value
30	1.29 (0.83 – 2.01)	0.26	1.23 (0.79 – 1.95)	0.36
30 – 365	1.40 (0.93 – 2.13)	0.11	1.31 (0.85 – 2.01)	0.22
≥ 365	0.39 (0.18 – 0.84)	0.02	0.36 (0.16 – 0.77)	0.01

UNOS Database

Conclusion:

Continuous-flow LVAD pre-transplant placement is associated with improved long term (> 1year) survival after heart transplantation, possibly due to better organ functions before transplant secondary to the LVAD support.

Early Outcomes With Marginal Donor Hearts Compared With Left Ventricular Assist Device Support in Patients With Advanced Heart Failure

Erin M. Schumer, MD,* Mickey S. Ising, MEng,* Jaimin R. Trivedi, MD, MPH, Mark S. Slaughter, MD, and Allen Cheng, MD

Department of Cardiovascular and Thoracic Surgery, University of Louisville, Louisville, Kentucky

LVAD wait-list and post-transplant survival vs. Transplant with Marginal Heart

Annal of Thoracic Surgery 2015;100:522-7

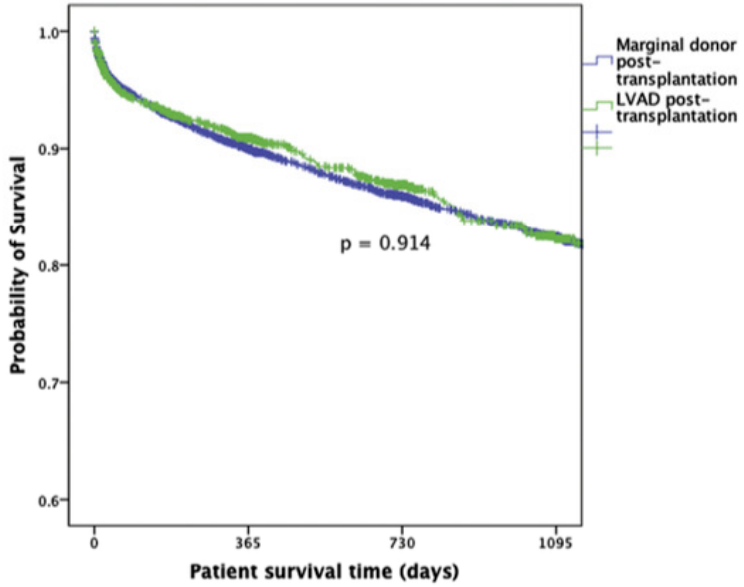


Fig 4. Kaplan-Meier survival analysis comparing all-cause mortality for post-transplantation survival for patients implanted with a left ventricular assist device (LVAD) and recipients of marginal donor hearts.

LVAD post-transplant vs. Marginal Donor

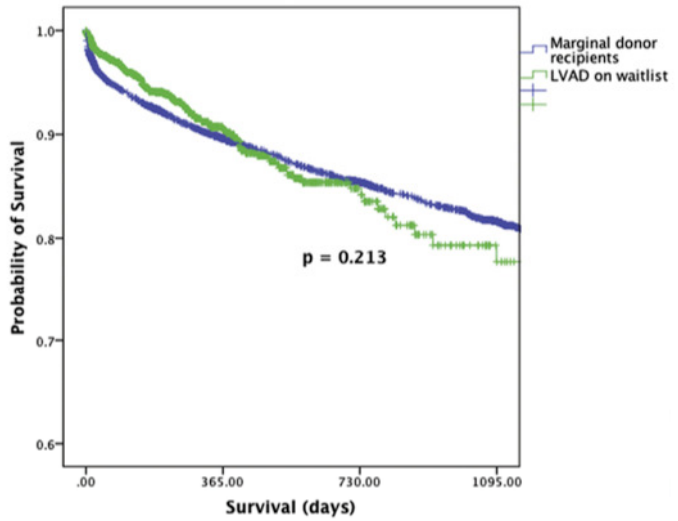


Fig 3. Kaplan-Meier survival analysis comparing all-cause mortality for continuous flow left ventricular assist device (LVAD) pre-transplant recipients and recipients of marginal donor hearts post-transplantation.

LVAD on waitlist vs. Marginal Donor

Conclusions. There was no significant difference between waiting list survival of patients with LVAD support as BTT and post-transplant survival of recipients with marginal donor hearts. There could be clinical benefits for using LVAD support as BTT to allow time for better allocation of optimal donor hearts as opposed to transplantation with a marginal donor heart.

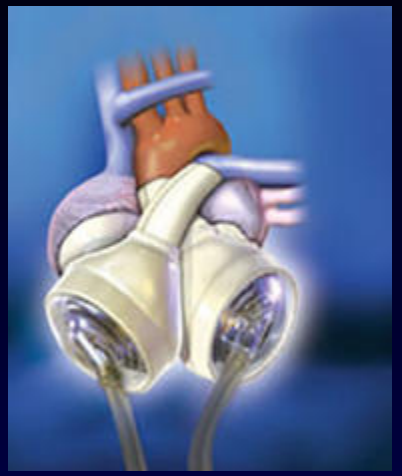
DOI 10.1111/jocs.12823

TRANSPLANTATION AND MECHANICAL SUPPORT
ORIGINAL ARTICLE

WILEY Journal of Cardiac Surgery

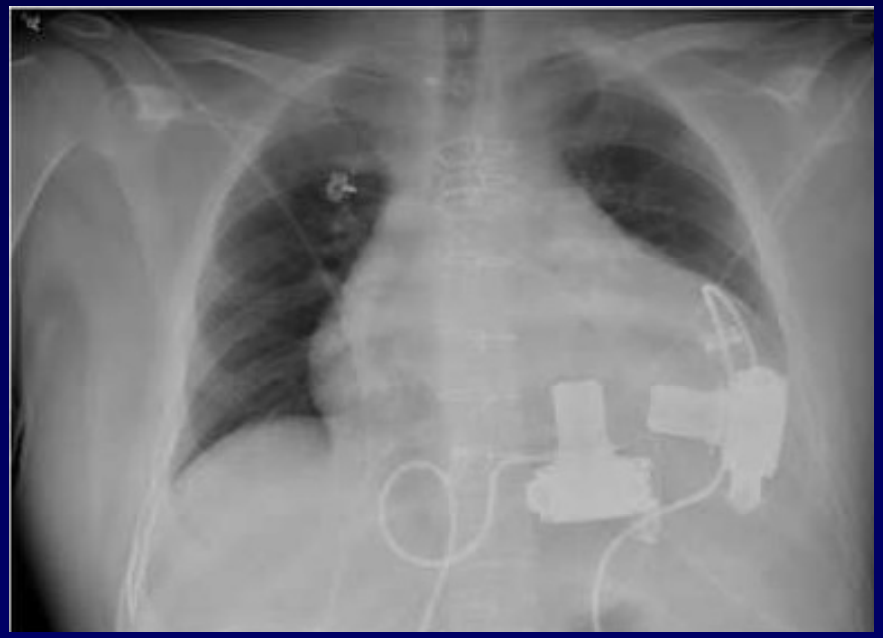
Comparison of total artificial heart and biventricular assist device support as bridge-to-transplantation

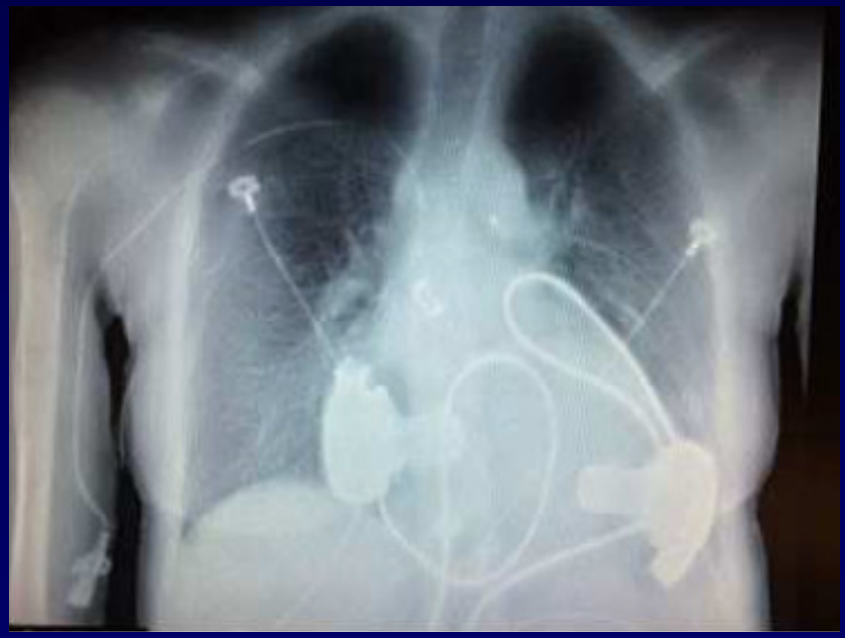
Allen Cheng, M.D.* | Jaimin R. Trivedi, M.D., M.P.H. |
Victor H. Van Berkel, M.D., Ph.D. | H. Todd Massey, M.D. | Mark S. Slaughter, M.D.

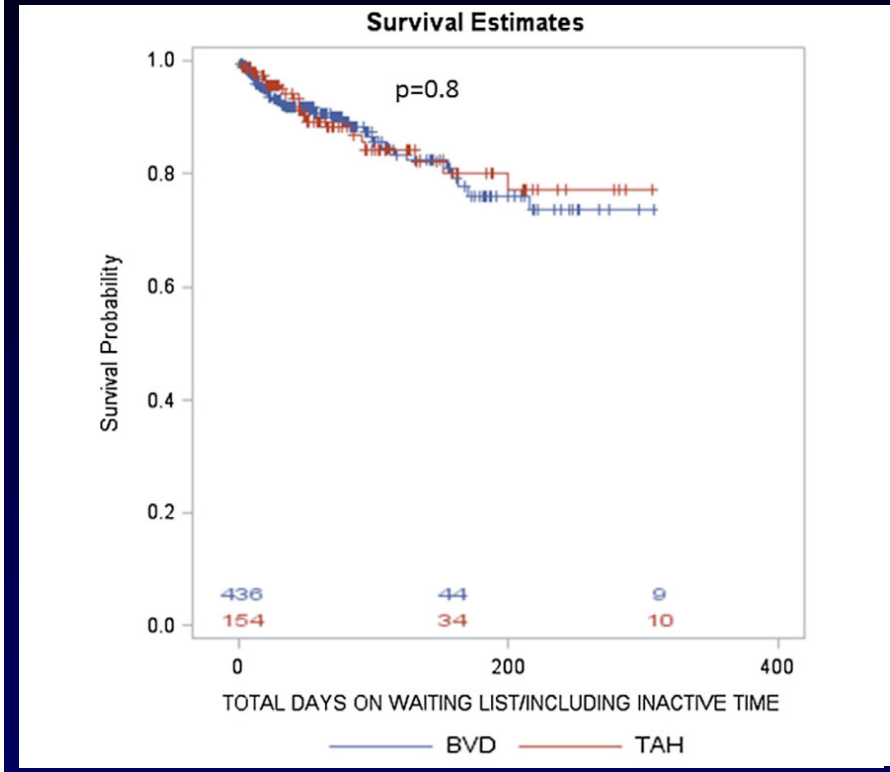


Cheng et al. *J Card Surg.* 2016 Oct;31(10):648-653

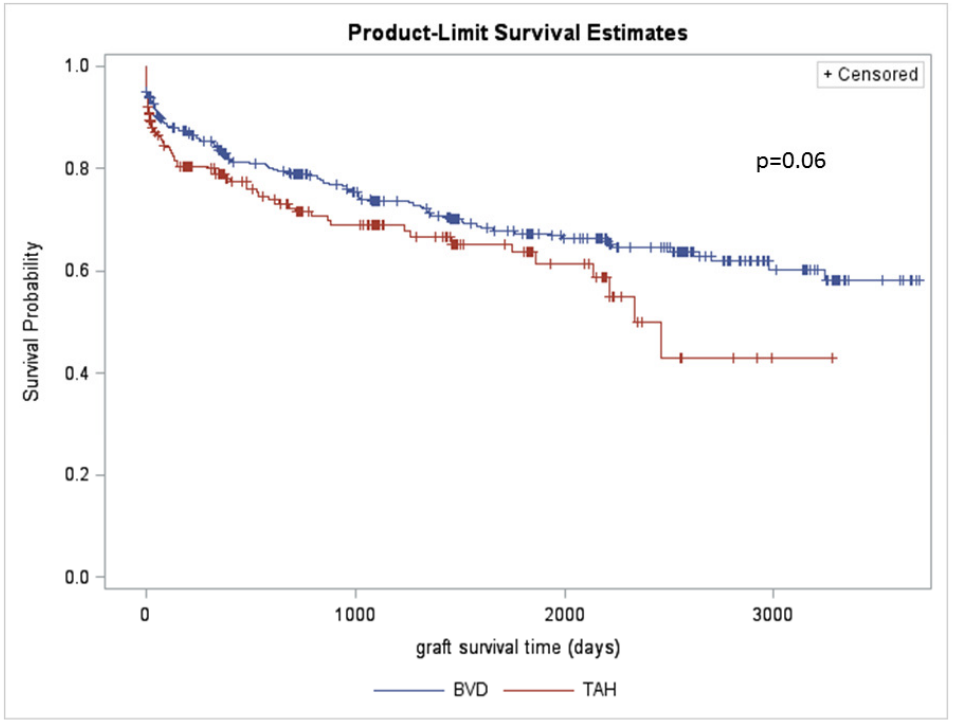
Biventricular Heart failure - BiVAD







Wait–list Survival

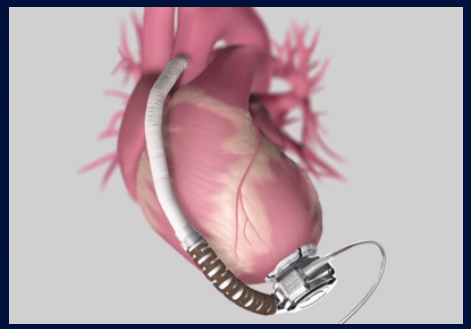


Post-transplant Survival

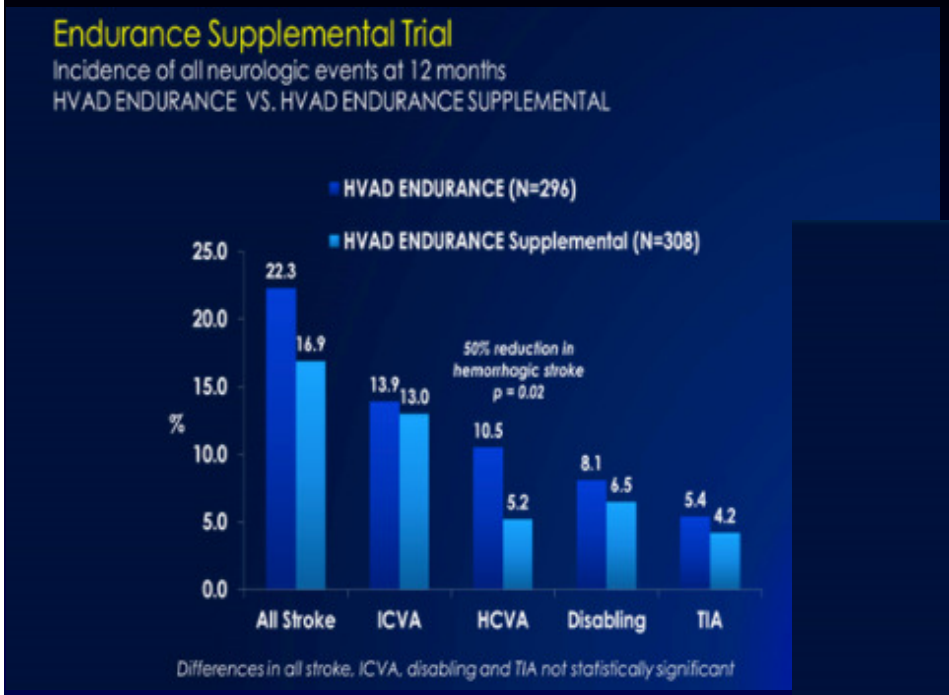
Cheng et al. *J Card Surg*. 2016 Oct;31(10):648-653

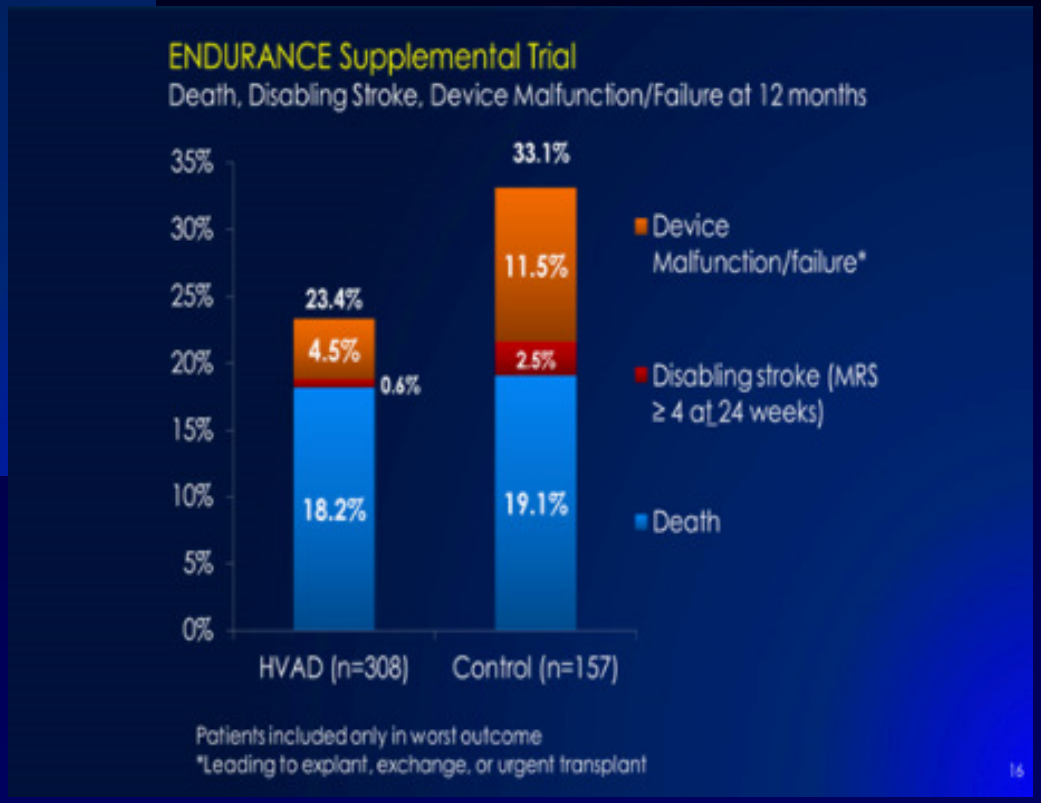
ENDURANCE Supplemental Trial: HeartWare HVAD for the Treatment of Patients with Advanced Heart Failure Ineligible for Cardiac Transplantation

Carmelo Milano, Joseph Rogers, Antone Tatooles, Geetha Bhat, Mark Slaughter, Emma Birks, Nahush A Mokadam, Claudius Mahr, Jeffrey Miller, Valluvan Jeevanandam, Keith Aaronson, and Francis Pagani



ISHLT 2017 San Diego CA



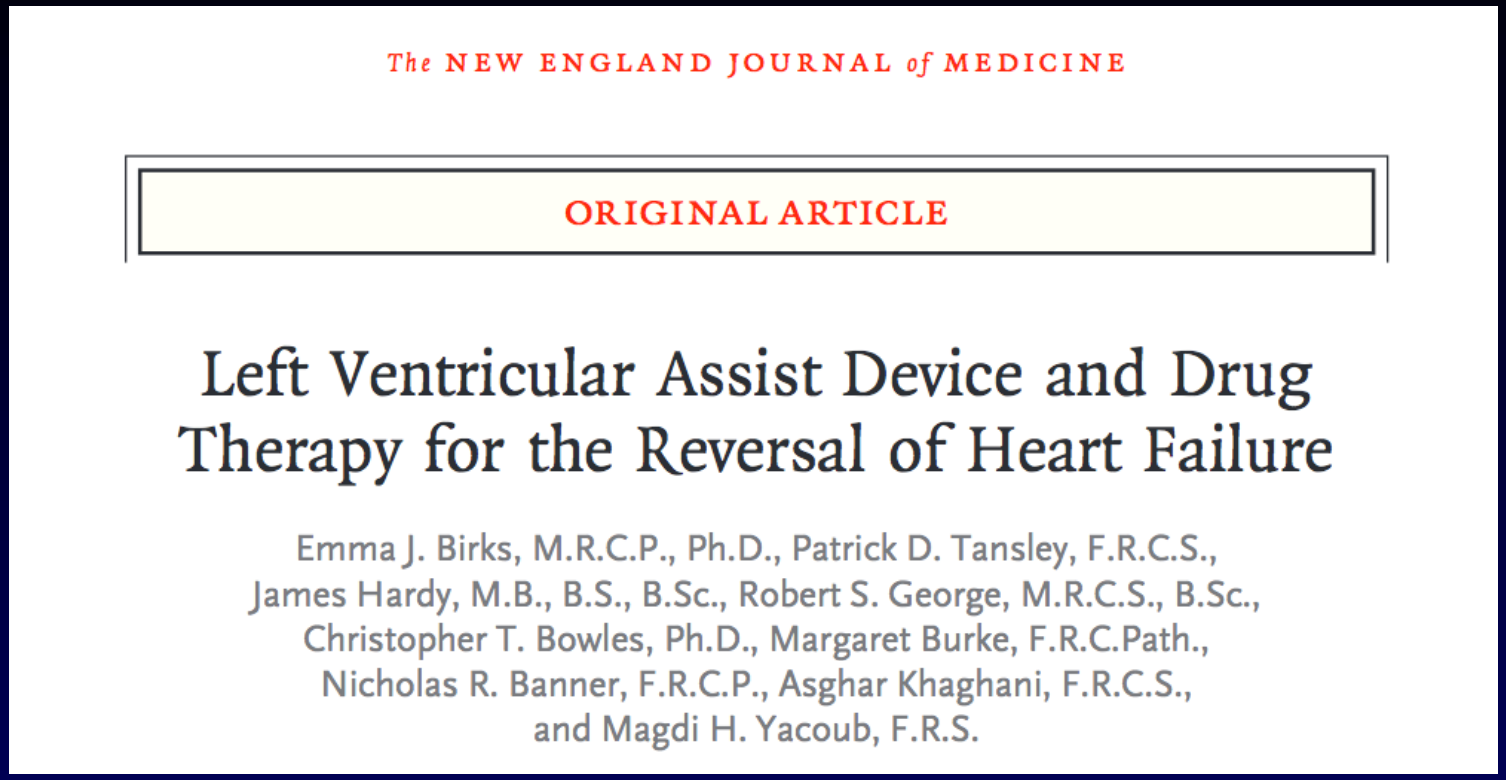


Conclusion:

HVAD proved to be statistically superior (by an absolute difference of 9.2%) to HMII with respect to freedom from death, disabling stroke, device exchange at 12 months.

LVAD Bridge to Recovery

- Effects of chronic mechanical unloading with LVAD
  - Decrease myocardial cytokines
  - Decreased neurohormonal activation
  - Up-regulation B-receptor density
  - Normalization Ca transport
  - Decrease wall stress & LVEDP
  - Decrease MR & PCWP
  - Decrease LVEDD
  - Reverse remodeling



Bridge To Recovery

Birks EJ et al. N Engl J Med. 2006 Nov 2;355(18):1873-84.

- 15 HF patients identified and support with LVAD along with a specific drug regimens.
- 11/15 patients experienced myocardial recovery with LVAD explanted; of 9 surviving patients, 89% were free of recurring HF 4 years after LVAD explant
- LVAD plus specific pharmacologic therapy resulted in sustained reversal of HF in select patients

Left Ventricular Assist Device as a Bridge to Recovery for Patients With Advanced Heart Failure

Djordje G. Jakovljevic, PhD,[a] Magdi H. Yacoub, MD, PhD,[b] Stephan Schueler, MD, PhD,[c] Guy A. MacGowan, MD,[c] Lazar Velicki, MD, PhD,[d] Petar M. Seferovic, MD, PhD,[e] Sandeep Hothi, PhD,[f] Bing-Hsiean Tzeng, MD, PhD,[g] David A. Brodie, DSc,[h] Emma Birks, MD, PhD,[i] Lip-Bun Tan, DPhil[j]

ABSTRACT

BACKGROUND Left ventricular assist devices (LVADs) have been used as an effective therapeutic option in patients with advanced heart failure, either as a bridge to transplantation, as destination therapy, or in some patients, as a bridge to recovery.

OBJECTIVES This study evaluated whether patients undergoing an LVAD bridge-to-recovery protocol can achieve cardiac and physical functional capacities equivalent to those of healthy controls.

METHODS Fifty-eight male patients—18 implanted with a continuous-flow LVAD, 16 patients with LVAD explanted (recovered patients), and 24 heart transplant candidates (HTx)—and 97 healthy controls performed a maximal graded cardiopulmonary exercise test with continuous measurements of respiratory gas exchange and noninvasive (rebreathing) hemodynamic data. Cardiac function was represented by peak exercise cardiac power output (mean arterial blood pressure × cardiac output) and functional capacity by peak exercise O_2 consumption.

RESULTS All patients demonstrated a significant exertional effort as demonstrated with the mean peak exercise respiratory exchange ratio >1.10. Peak exercise cardiac power output was significantly higher in healthy controls and explanted LVAD patients compared with other patients (healthy 5.35 ± 0.95 W; explanted 3.45 ± 0.72 W; LVAD implanted 2.37 ± 0.68 W; and HTx 1.31 ± 0.31 W; $p < 0.05$), as was peak O_2 consumption (healthy 36.4 ± 10.3 ml/kg/min; explanted 29.8 ± 5.9 ml/kg/min; implanted 20.5 ± 4.3 ml/kg/min; and HTx 12.0 ± 2.2 ml/kg/min; $p < 0.05$). In the LVAD explanted group, 38% of the patients achieved peak cardiac power output and 69% achieved peak O_2 consumption within the ranges of healthy controls.

CONCLUSIONS The authors have shown that a substantial number of patients who recovered sufficiently to allow explantation of their LVAD can even achieve cardiac and physical functional capacities nearly equivalent to those of healthy controls. (J Am Coll Cardiol 2017;69:1924-33)

JACC 2017;69:1924-33

Conclusion:

With specific bridge-to-recovery protocol, recovered patients with LVAD explanted can achieve the same cardiac and physical function capacities when compared to the healthy subjects.

Sponsored by Thoratec

Remission From Stage D Heart Failure (RESTAGE-HF) Trial: A Prospective Multi-Center Study of Myocardial Recovery

Design: prospective, multi-center (40 subjects from 6 sites), observational study

Primary Endpoint: % of subjects (hypothesis > 10%), treated with a standardized LVAD and a pharmacologic recovery protocol, is free from MCS or heart transplant at one year post-LVAD explant when achieving the following minimum explanting criteria within 18 months post-implant:

1. LVEDD < 60mm, LVESD < 50 mm, LVEF > 45%
2. LVEDP or PCWP ≤ 15 mmHg
3. Resting cardiac index (CI) > 2.4L/min/m^2
4. ±Maximal oxygen consumption with exercise (mVO2) > 16 ml/kg/min

Site	Investigator	Study Coordinator
University of Louisville	Emma Birks, Allen Cheng, Mark Slaughter	Terry Blanton
University of Utah	Stavros Drakos, Josef Stehlik, Craig Selzman	Ashley McCormick, Jennifer Strege
Cleveland Clinic Foundation	Randall Starling	Barbara Gus
University of Penn	Eddie Rame	Judy Marble
Montefiore Medical Center	Snehal Patel	Johanna Oviedo
University of Nebraska	Brian Lowes, John Um	Stacy Fickbohm, Tamara Bernard

Louisville Recovery Protocol

Standardized LVAD unloading and drug therapy protocols attempting to increase the "remission" rate and to enhance LV remodeling

• Aggressive attempt to optimize pump speed in all LVAD patients for maximal LV unloading starting earlier on.

•Close and routine followup with Echo. Echo obtained at 6 weeks, 4 months, 6 months and 1 year.

•Low speed echo (HMII 6000rpm, Heartware 1800rpm) for 5 mins and 5 mins to evaluate underlying cardiac function.

•Combined with standardized regime of optimal targeted drug therapy to enhance reverse remodeling and to reduce fibrosis

•Pt with improve LV function, LVAD explantation will be perform.

Drug Name	Maximum Dose	Frequency
Lisinopril (ACE)	40mg	daily
Carvedilol (BB)	25mg	three times daily
Spironolactone (ARB)	25mg	daily
Digoxin	125 micrograms	daily
Losartan (Angiotensin)	150mg	daily

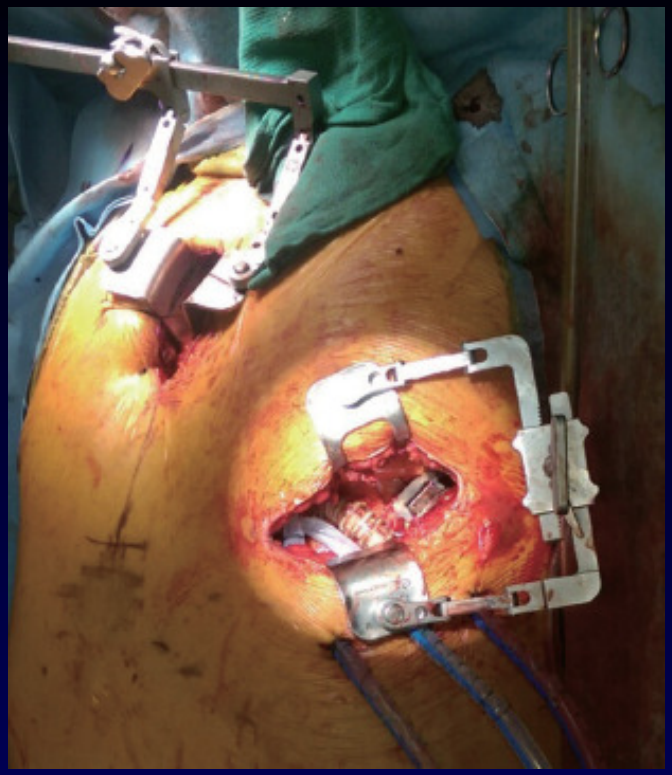
Original Article on Cardiac Surgery

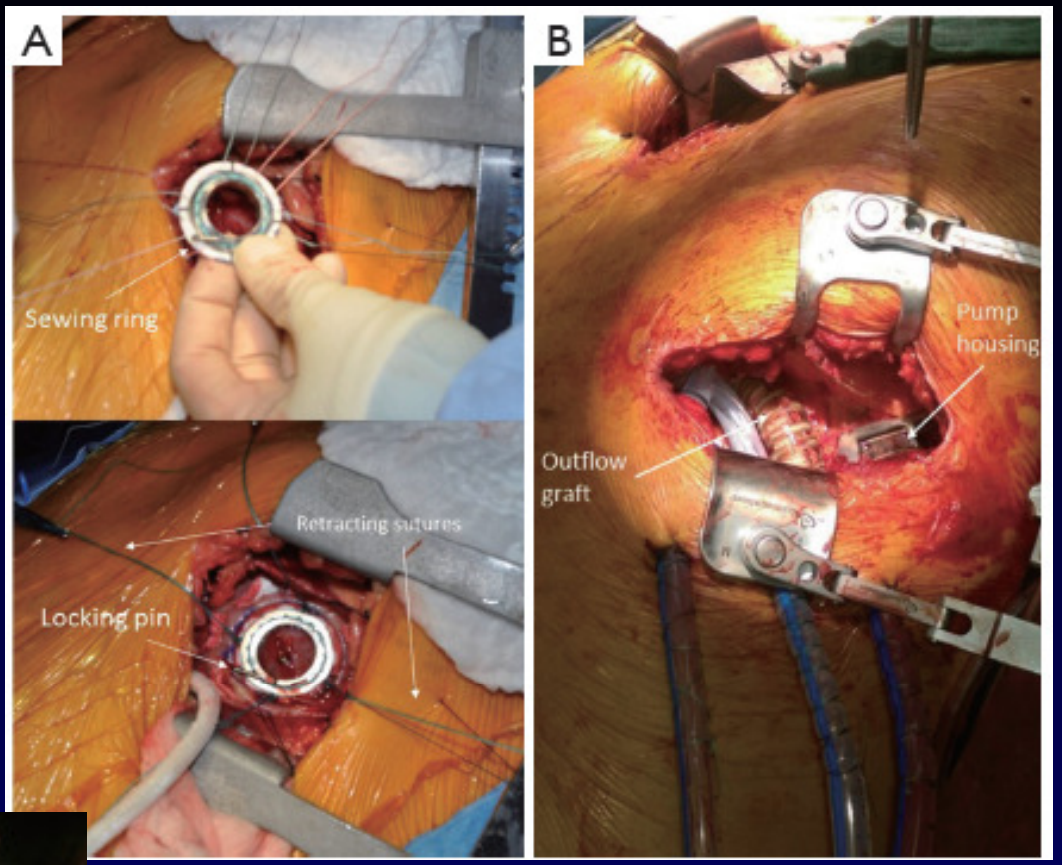
Minimally invasive left ventricular assist device placement

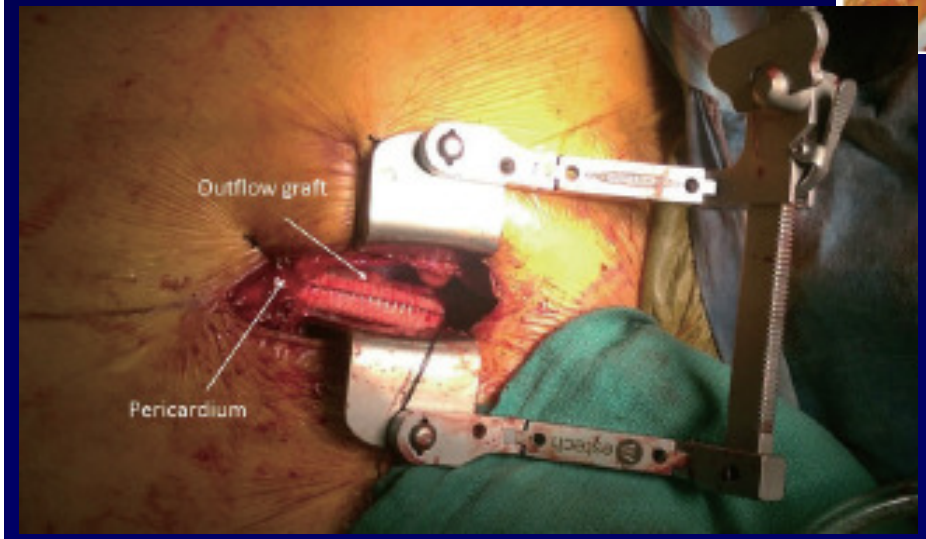
Allen Cheng

Department of Cardiovascular and Thoracic Surgery, University of Louisville, Louisville, USA

Correspondence to: Allen Cheng, MD. Department of Cardiovascular and Thoracic Surgery, University of Louisville, 201 Abraham Flexner Way, Suite 1200, Louisville, KY 40202, USA. Email: allenchengcs@gmail.com.




A
Sewing ring
Retracting sutures
Locking pin
B
Pump housing
Outflow graft


Outflow graft
Pericardium

Original Article on Cardiac Surgery

Minimally invasive left ventricular assist device placement

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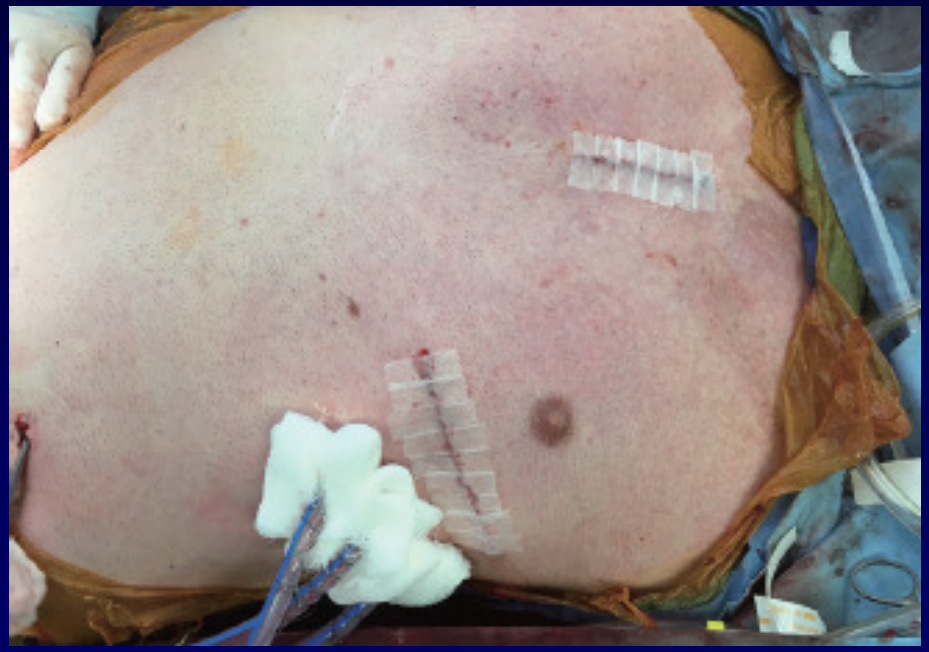
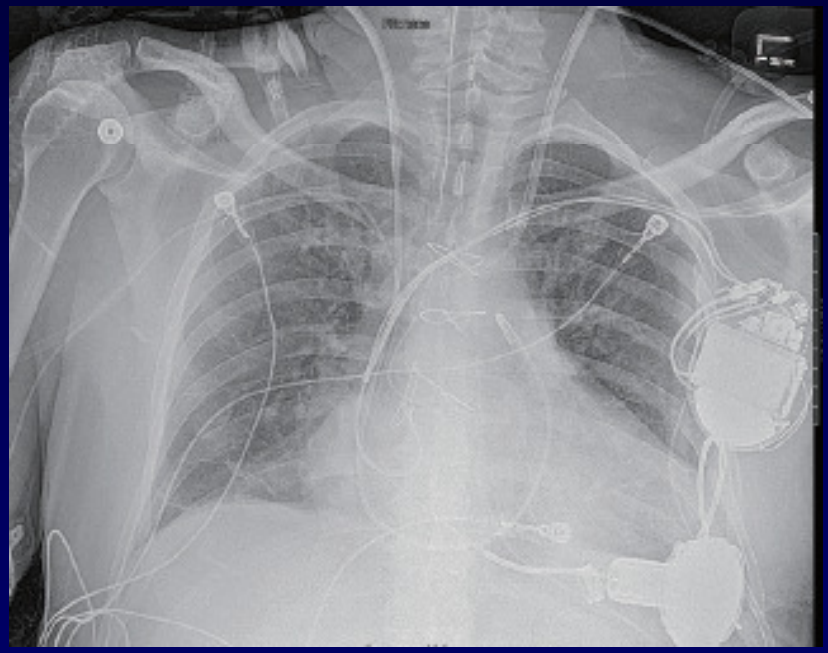




With the smaller incision, the bleeding and wound infection risk is lower

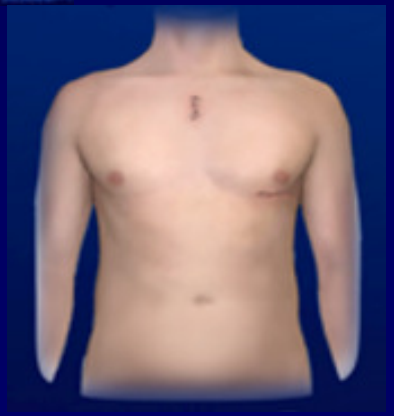
A Prospective, Controlled, Un-blinded, Multi-Center Clinical Trial to Evaluate the Thoracotomy Implant Technique of the HeartWare HVAD® System in Patients with Advanced Heart Failure: Results of the LATERAL Trial

M.R. Danter, E.C. McGee, M. Strueber,
Simon Maltais, N.A. Mokadam, G.M. Wieselthaler,
K. Leadley, S.W. Boyce, and A. Cheung

ISHLT 37th Annual Meeting and Scientific Sessions
April 5-8th 2017, San Diego, CA

HVAD Lateral

HVAD LATERAL Thoracotomy Trial
Prospective, single-arm, muti-center study
N= 145 patients
30 sites



Kaplan Meier Survival

Days of Support	0	90	180	365
Patients at risk	145	128	105	53
Cumulative Events	0	6	11	14
Survival Rate	100%	95.7%	91.8%	88.6%

hVAD Lateral

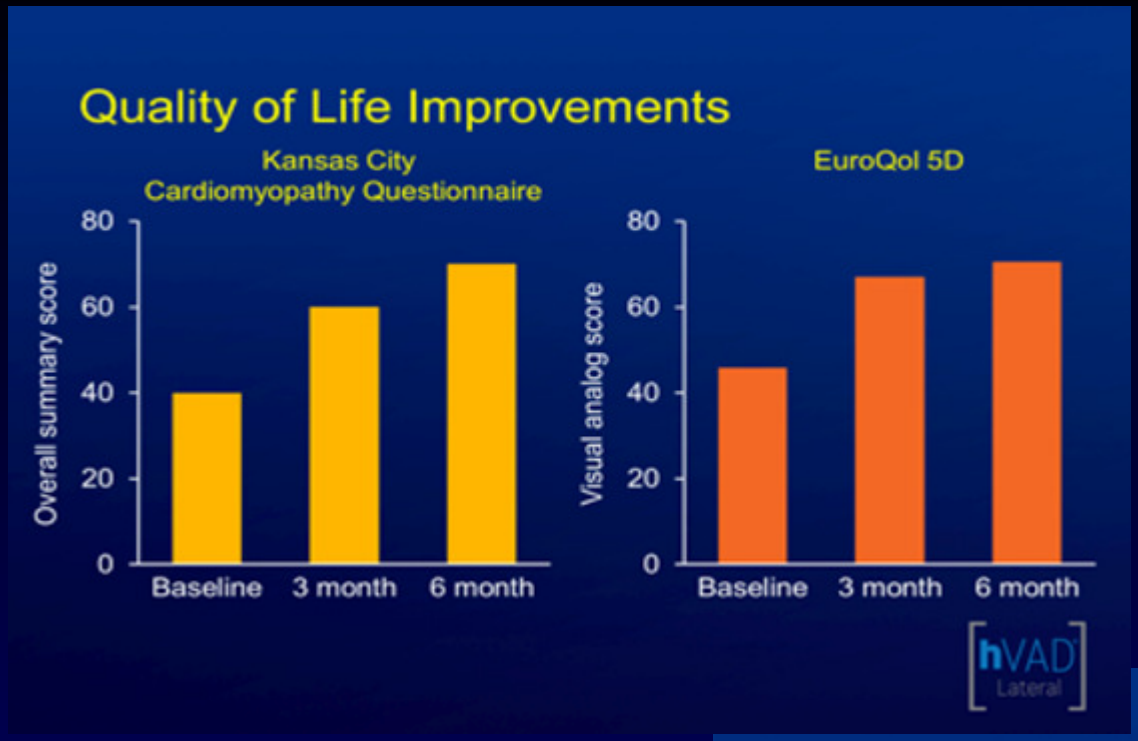
360 Link

Key Adverse Events at 30 Days

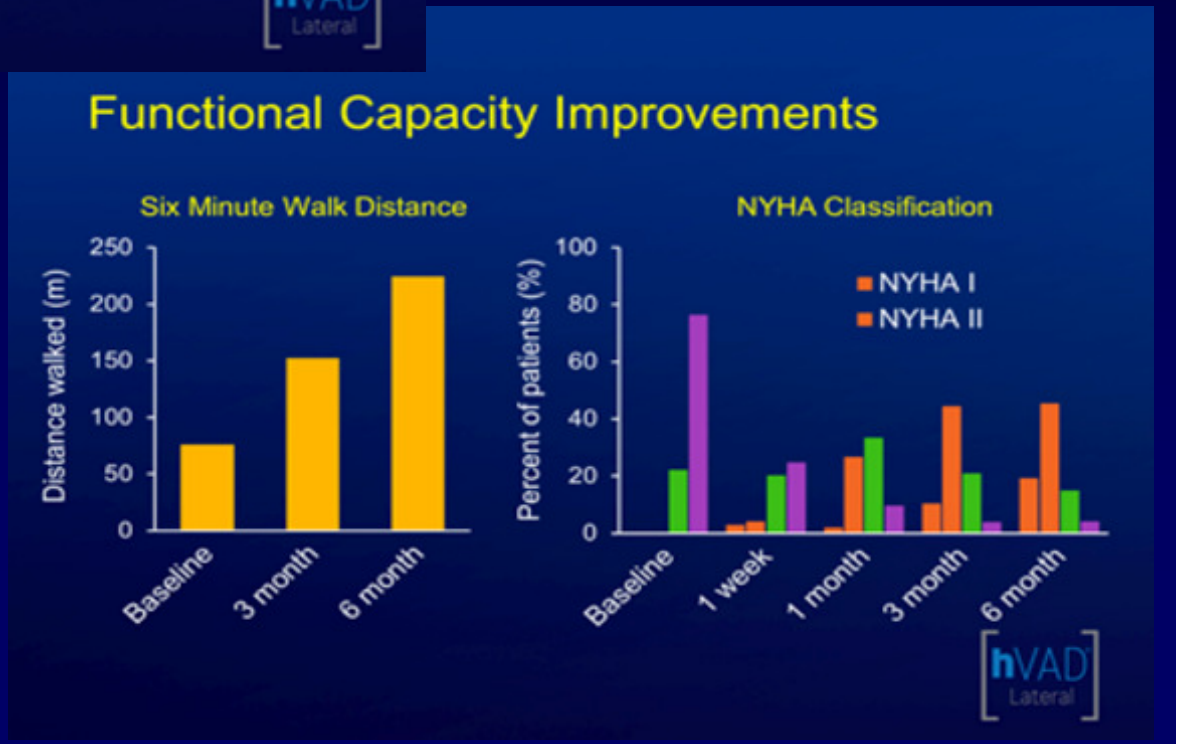
	Lateral (n=145)	HVAD BTT+CAP (n=382)
Bleeding:		
Requiring re-operation*	3.4%*	11.5%
Requiring transfusion	9.0%	13.9%
Gastrointestinal	4.1%	3.9%
Device malfunction/failure	6.2%	5.2%
Driveline infection	1.4%	2.6%
Line Sepsis	0.0%	(3.9%)
Myocardial Infarction	0.0%	0.3%
Stroke		
HCVA	2.1%	2.9%
ICVA	2.1%	1.8%
TIA	0.7%	1.6%
Right Heart Failure	22.1%	23.3%
Requiring RVAD	0.7%	2.6%
Cardiac Arrhythmia	22.1%	23.3%
Ventricular Arrhythmia	13.8%	9.2%

BTT+CAP data is historical, not a study control. The data are presented for perspective only.
* Statistically significant reduction, $P<0.05$.

HVAD Lateral



Sustained Improvement in Quality of Life And Functional Capacity



What's coming?

What are the upcoming new LVAD devices?

What is the next best thing…..

CARDIOVASCULAR INNOVATION • INSTITUTE

HeartMate III

Designed to be Hematologically-Compatible

Leverages Fully Magnetically Levitated Technology

Features

- Approved in Europe. Latest Trial is completed in the US.
- Expected US approval end of 2017
- Fully Magnetically Levitated Centrifugal-flow pump.
  - Large pump gaps designed to reduce blood trauma
  - Artificial pulse
- Textured blood contacting surfaces
- Wide range of operation
  - Full support (2 – 10 L/min)
- Advanced Design for Surgical Ease
  - Engineered apical attachment
  - Modular Driveline
- Designed for an Active Lifestyle
  - Pocket Controller

*In development. Not approved for clinical use.

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

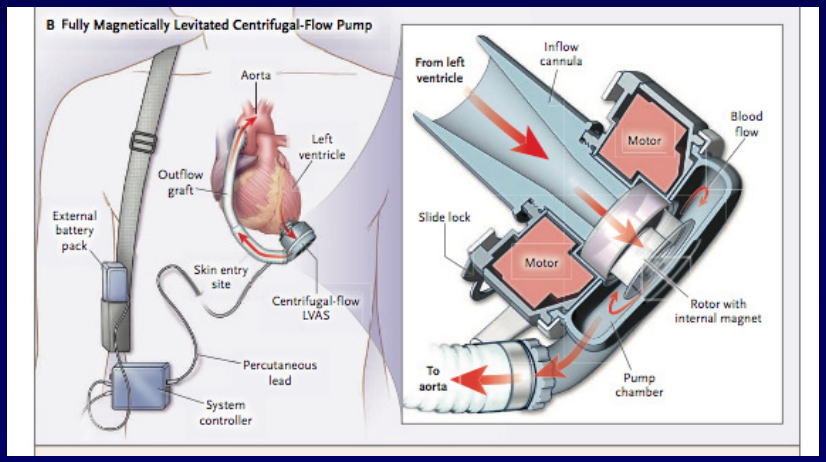
A Fully Magnetically Levitated Circulatory Pump for Advanced Heart Failure

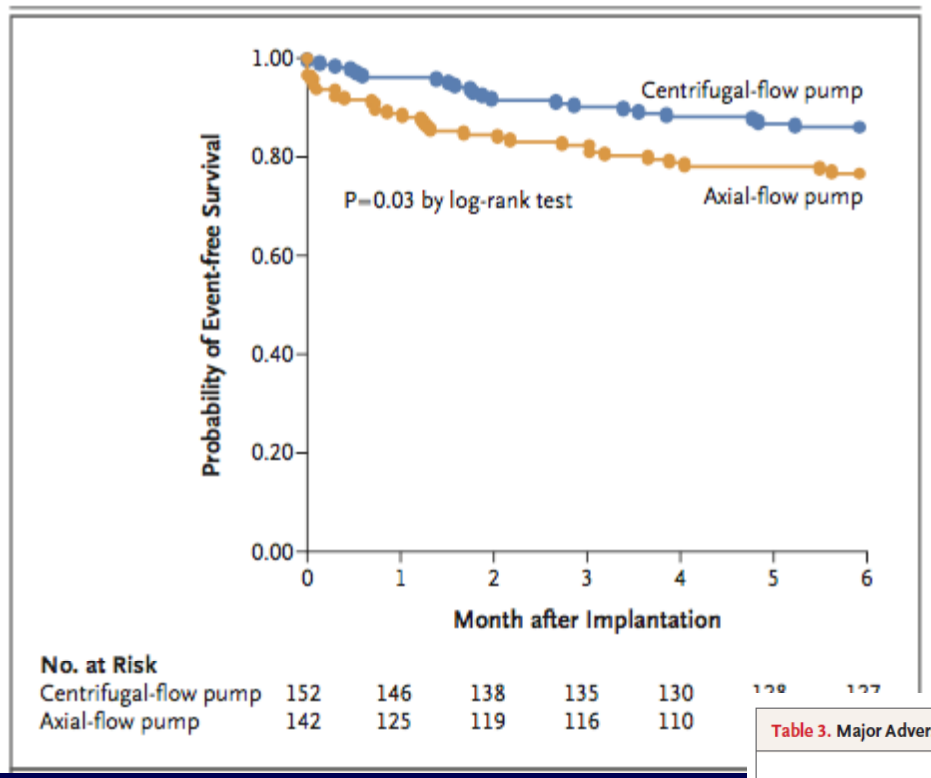
Mandeep R. Mehra, M.D., Yoshifumi Naka, M.D., Nir Uriel, M.D., Daniel J. Goldstein, M.D., Joseph C. Cleveland, Jr., M.D., Paolo C. Colombo, M.D., Mary N. Walsh, M.D., Carmelo A. Milano, M.D., Chetan B. Patel, M.D., Ulrich P. Jorde, M.D., Francis D. Pagani, M.D., Keith D. Aaronson, M.D., David A. Dean, M.D., Kelly McCants, M.D., Akinobu Itoh, M.D., Gregory A. Ewald, M.D., Douglas Horstmanshof, M.D., James W. Long, M.D., and Christopher Salerno, M.D., for the MOMENTUM 3 Investigators*

N Eng J Med 2017;376:440.50

HeartMate III

Multi-center Randomized Trial
1:1 HM3 vs HM2
294 patients





N Eng J Med 2017;376:440.50

Table 3. Major Adverse Events in the Per-Protocol Population.*

Event	Centrifugal-Flow Pump Group (N=151)		Axial-Flow Pump Group (N=138)		Relative Risk (95% CI)	P Value
	no. of patients with events (%)	*no. of events*	*no. of patients with events (%)*	*no. of events*		
Suspected or confirmed pump thrombosis	0	0	14 (10.1)	18	NA	<0.001
Stroke						
Any stroke	12 (7.9)	12	15 (10.9)	17	0.73 (0.35–1.51)	0.39
Hemorrhagic stroke	4 (2.6)	4	8 (5.8)	8	0.46 (0.14–1.48)	0.18
Ischemic stroke	8 (5.3)	8	9 (6.5)	9	0.81 (0.32–2.05)	0.66
Disabling stroke	9 (6.0)	9	5 (3.6)	5	1.65 (0.57–4.79)	0.36
Other neurologic event†	9 (6.0)	9	8 (5.8)	8	1.03 (0.41–2.59)	0.95
Bleeding						
Any bleeding	50 (33.1)	100	54 (39.1)	98	0.85 (0.62–1.15)	0.29
Bleeding requiring surgery	15 (9.9)	15	19 (13.8)	21	0.72 (0.38–1.36)	0.31
Gastrointestinal bleeding	24 (15.9)	47	21 (15.2)	36	1.04 (0.61–1.79)	0.87
Sepsis	14 (9.3)	19	9 (6.5)	10	1.42 (0.64–3.18)	0.39
LVAS drive-line infection	18 (11.9)	21	9 (6.5)	11	1.83 (0.85–3.93)	0.12
Local infection not associated with LVAS	46 (30.5)	57	36 (26.1)	58	1.17 (0.81–1.69)	0.41
Right heart failure						

HeartMate X

Ultra-Compact, Highly Versatile VAD = New patient populations

Features

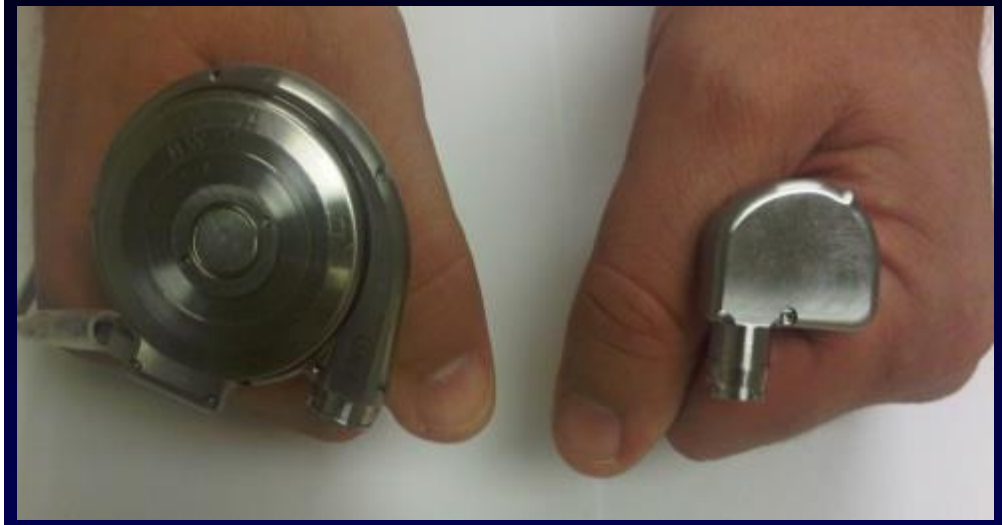
- Utilizes proven HeartMate II bearing technology
- Partial to Full support (8 L/min) in ultra-compact size
- Highly energy efficient
- Miniaturized patient peripherals
- Left and/or right side assistance

Expected Benefits

- Potential to meet the needs of earlier stage patients
- Potential for minimally invasive implantation
- Potential for multiple configurations (LVAD, RVAD, BiVAD)
- Very small, full support pump, can be use in various configuration, including as a RVAD and BiVAD, and will allow minimally invasive approaches.

*In development. Not approved for clinical use.

Heartware HVAD® and MVAD® Pump: Side-by-Side Comparison



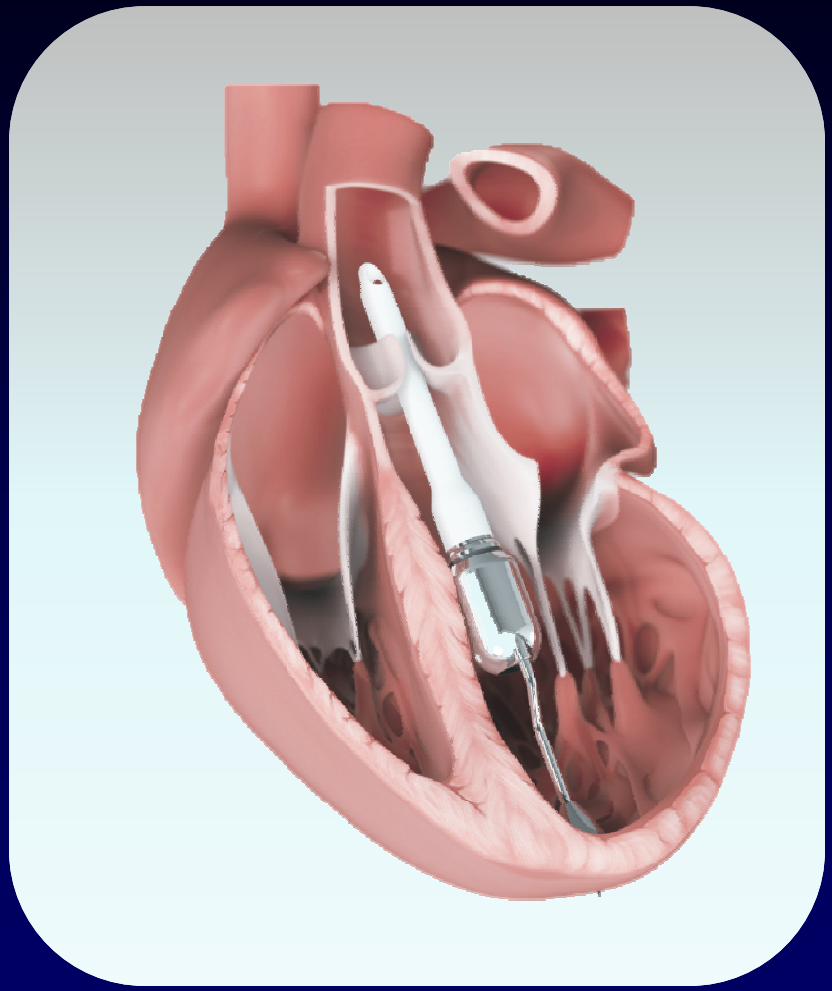
- Significantly smaller in size (Half the size of HVAD)
- Able to provide Full support
- Trial started in Europe – (On hold) Increase in thromboembolic events, but sources found per Medtronics
- Trial in US soon

Parameter	HVAD	MVAD
Pump Type	Centrifugal	Axial
Weight	160 g	58 g
Pericardial Volume	50 cc	15 cc
Priming Volume	15 cc	5 cc
Inflow OD	Same	Same

CAUTION – Investigational Device. Limited by United States law to investigational use. Exclusively for Clinical Investigations.

Transapical Cardiac Assist (Longhorn)

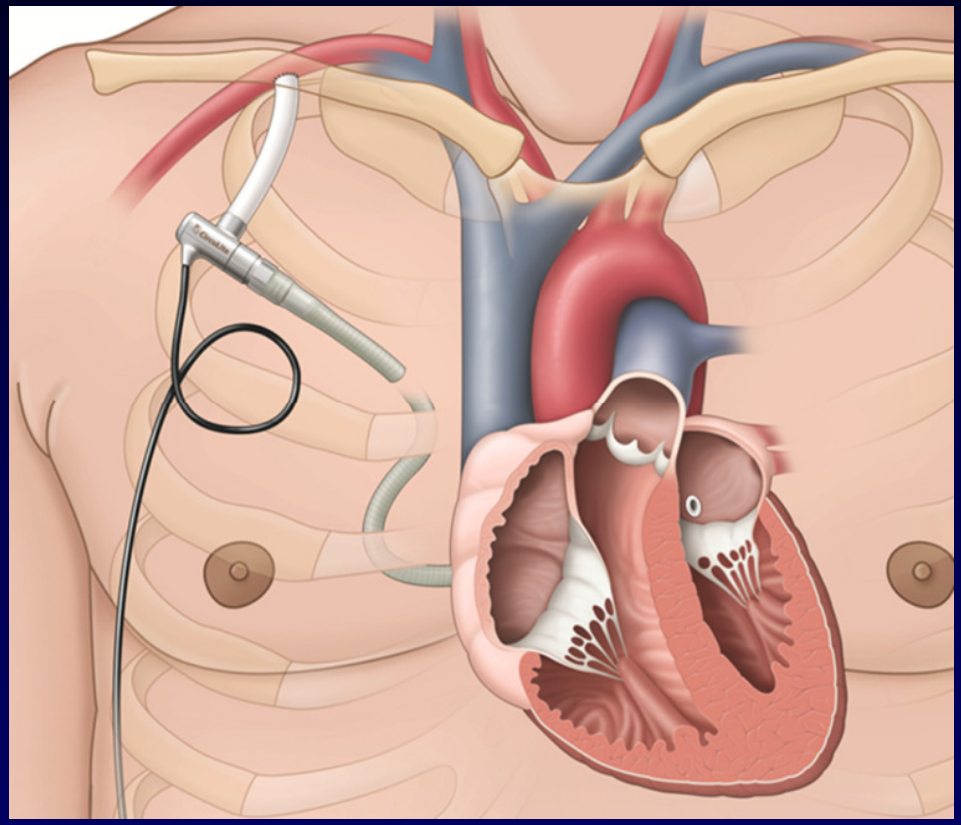
- Design based on MVAD Pump platform
- Transapical placement, pump cannula sits across aortic valve
- Axial design, continuous flow
- In vitro studies demonstrate no intraventricular or aortic valve thrombus
- Aortic valve seals around cannula with minimal to no regurgitation



- A variation of MVAD. Implant through the LV apex, pump rest in the left ventricle.
- No outflow anastomosis needed.
- Small Thoracotomy and off-pump.

CAUTION – Investigational Device. Limited by United States law to investigational use.
Exclusively for Clinical Investigations.

CircuLite Surgical System



Partial support pump

Pump in subcutaneous pacemaker-like pocket

Inflow cannula done via small right sided mini-thoracotomy into the PV

ideal for less sick pts.

- Reduce Left Atrial and ventricular pressure - offloading
- Reverse end-organ dysfunction, BTT.
- Off-pump procedure
- Extubation in OR possible

Energy Source

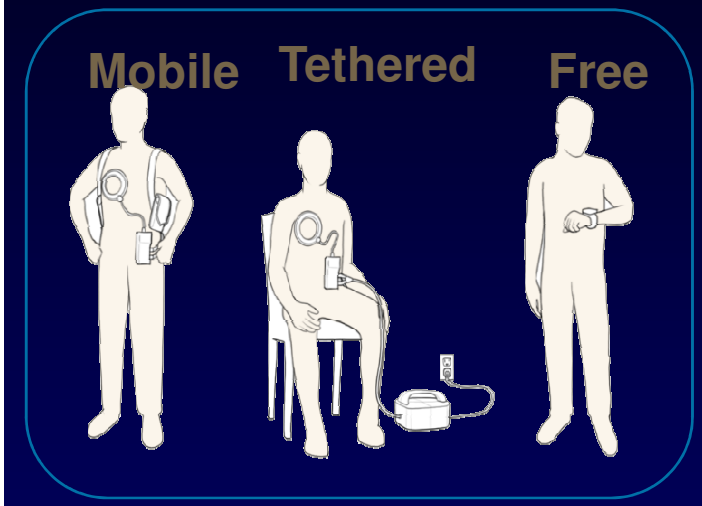
Current:

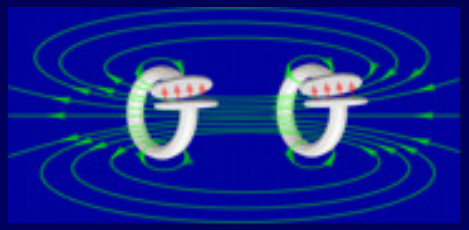
- Lithium ion batteries
- External driveline
- System controller
- “tethered” at all times
- Affect quality of life and not ideal

Fully Implantable System*

Breakthrough technology to advance mechanical circulatory support.

HeartMate





HeartWare

- Partnership with Dualis MedTech GmbH, a spin-off of the German Aerospace Centre (DLR)
- Competency in coil designs, biocompatible materials, and RF telemetry systems complement internal development effort
- Configuring technology for HVAD/MVAD

Forgiving Energy Transfer

- High-efficiency, user-friendly wireless energy transfer across a distance.
- Eliminates the driveline and "around the clock" worn equipment.

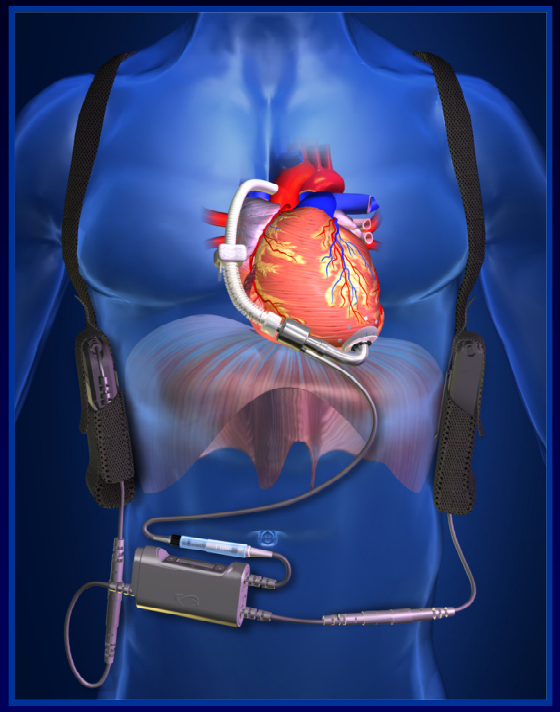
Pt happier without external battery, system controller, risk of driveline infection, fracture driveline, frequent visit to hospital.

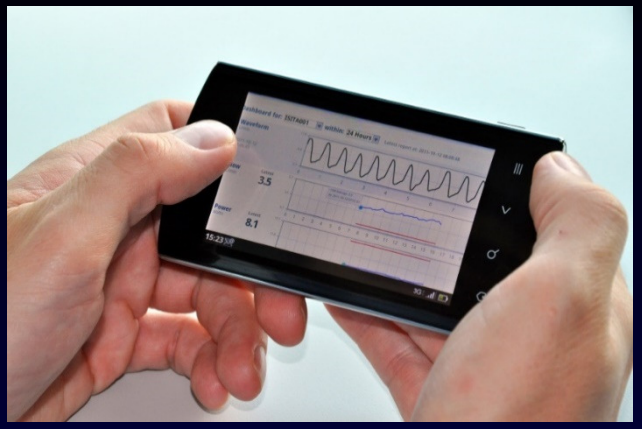
- **WREL (Wireless Resonant Energy Link)**

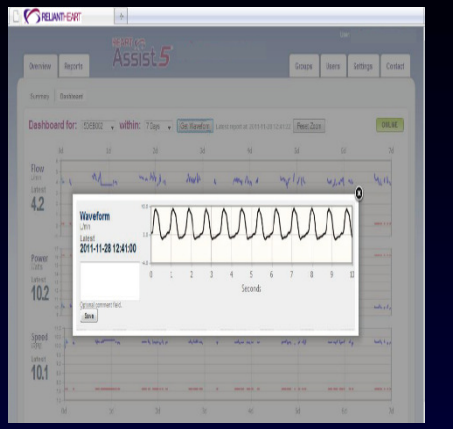
Other option. A home system. Energy transmit at home. At least untether at home. Do daily activity freely at home.

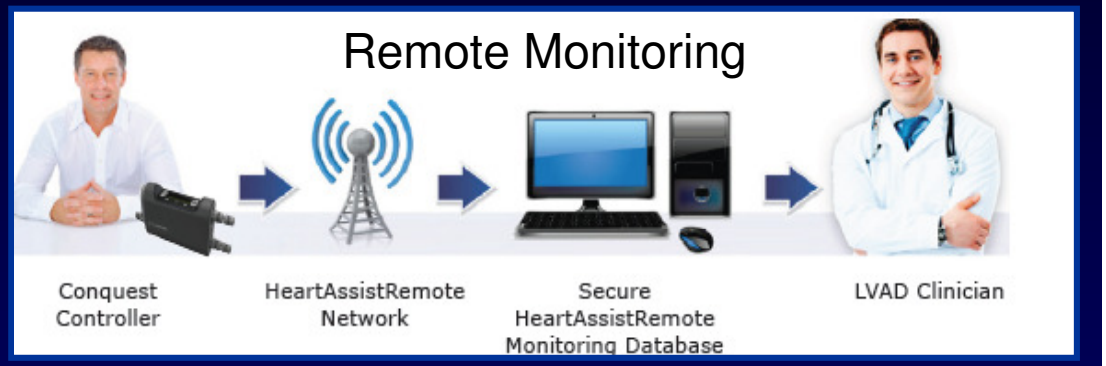
HEART Assist 5

VAD System









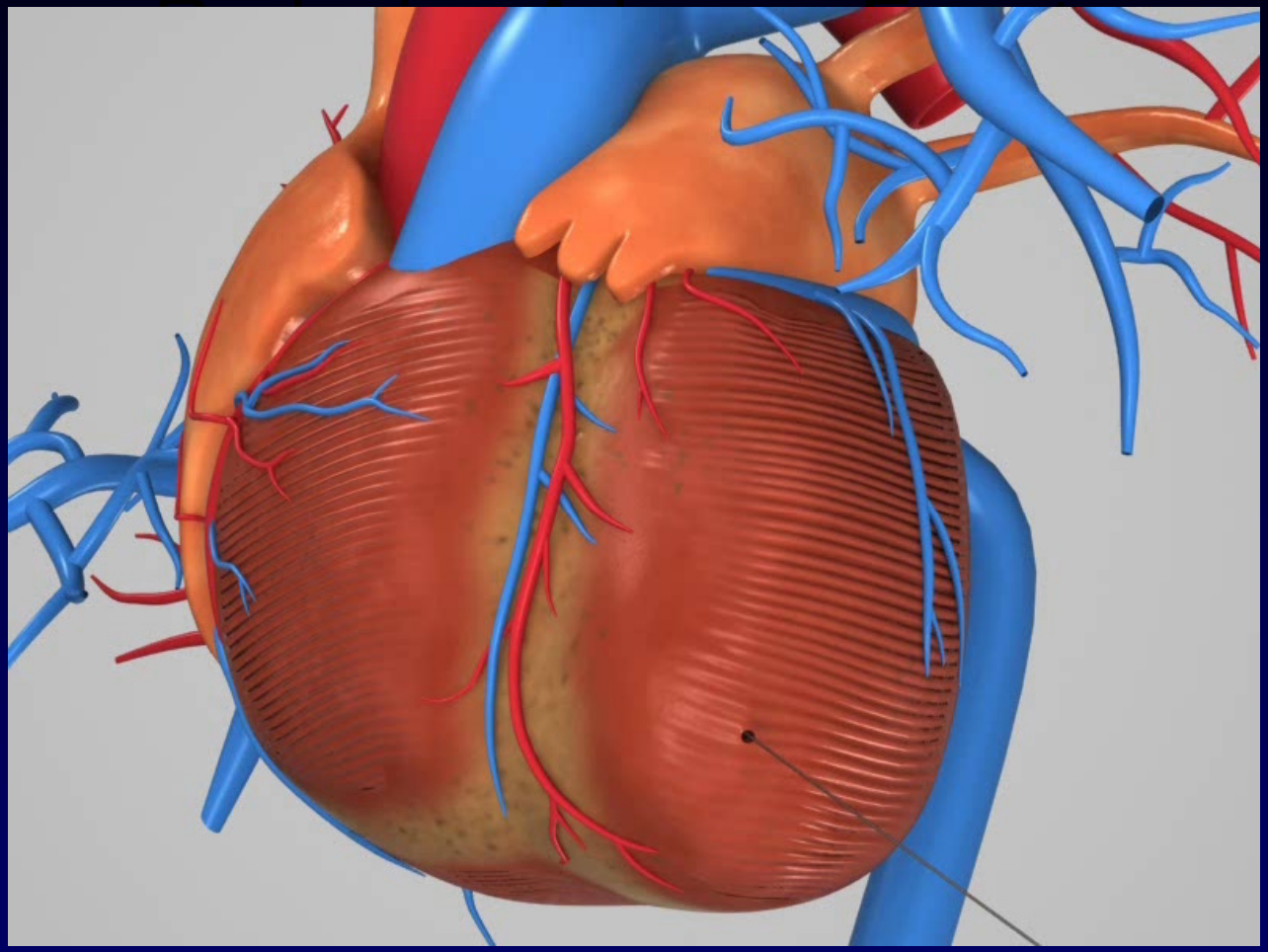
Often time, we have to get data from pts.

Hospital visit

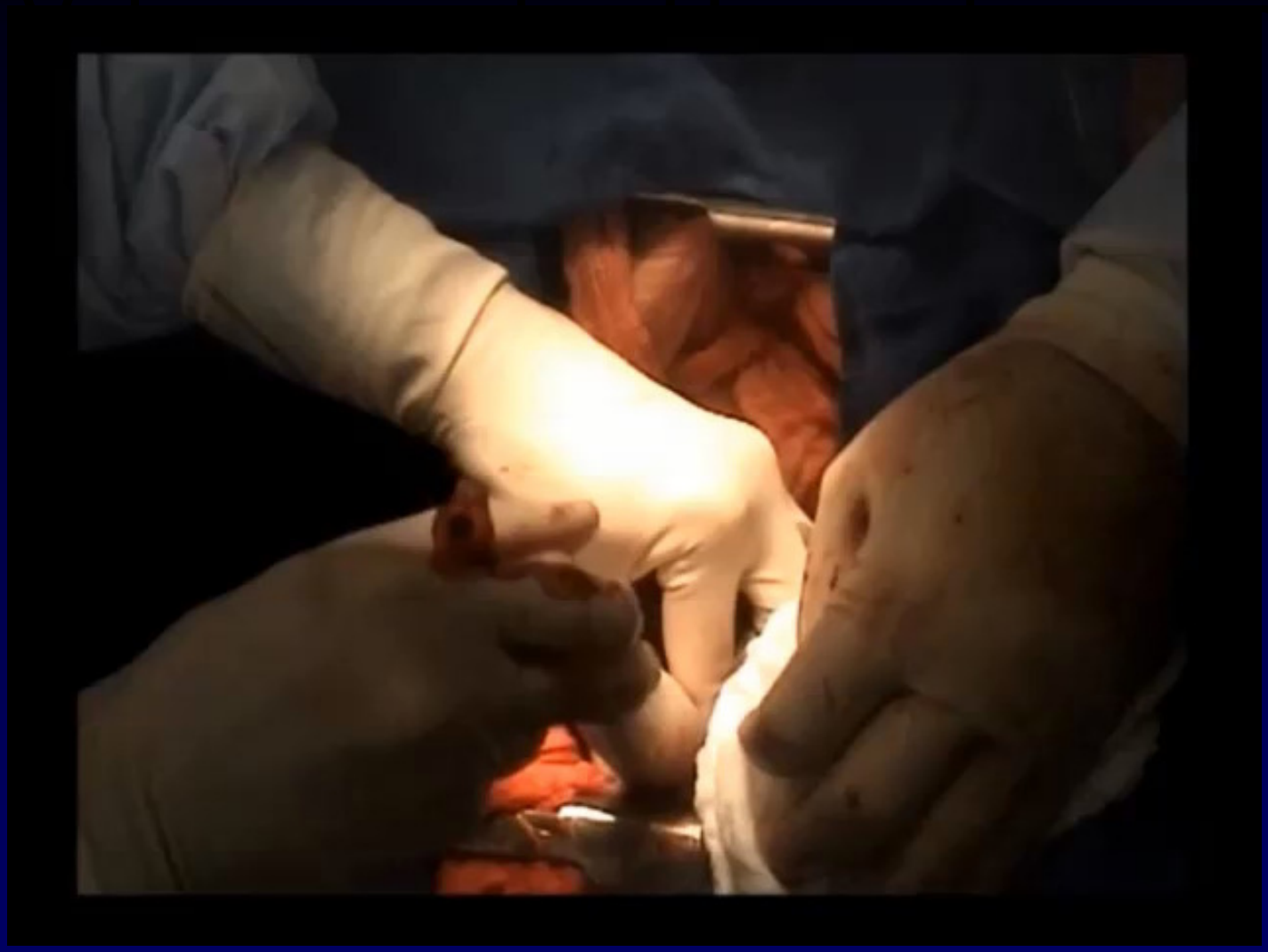
Ability to transmit information remotely to nurse coordination or physician

Allow long distant monitoring, identify trends and make intervention without having pt travel back to the hospital and before major problem happens.

LV Apex Access:



A single tool. LV apex and ventricle access. Sealed valve. No suture needed. Skin to skin in less than 30 mins.



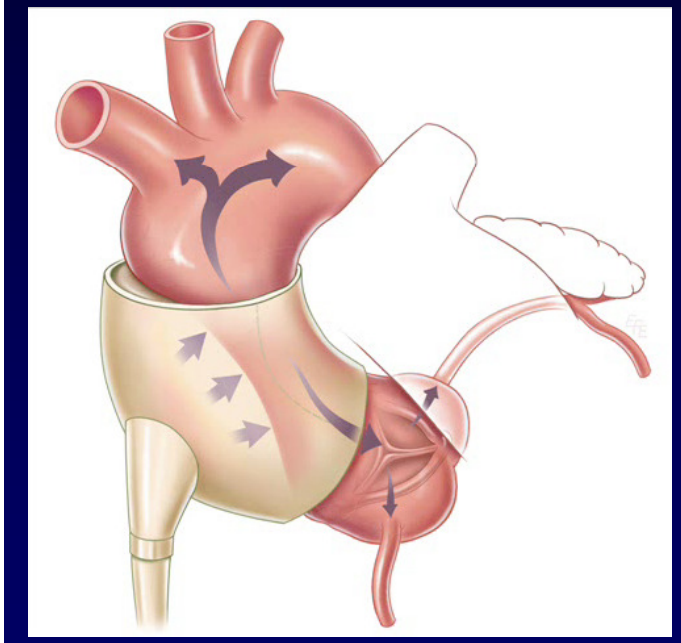
Real time. Screw in. Core ventricle. Complete hemostasis. Off-pump. No need to fibrillate heart or give adenosine. Pump is in in less than 10 mins.

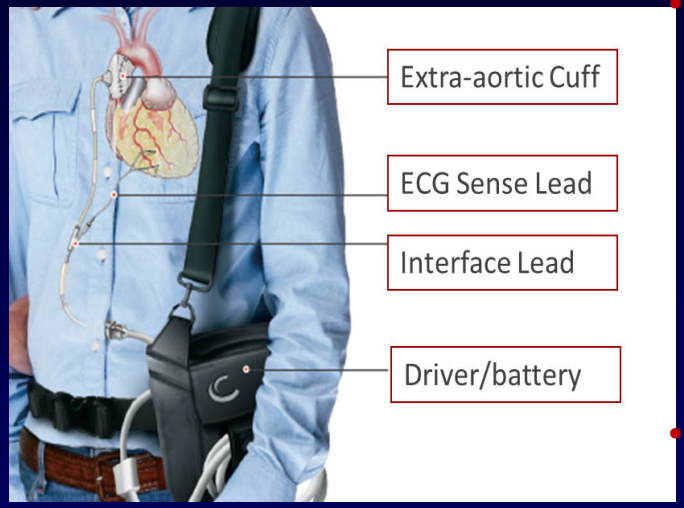
ASAIO Journal 2014 Case Re

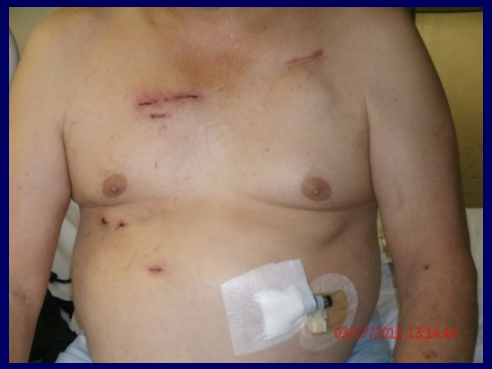
Extended Extra-Aortic Counterpulsation With the C-Pulse Device Does Not Alter Aortic Wall Structure

Allen Cheng, Gretel Monreal, Matthew L. William, Michael Sobieski II, and Mark S. Slaughter

C-PULSE Sunshine Heart







- Inplantable, Extraaortic, nonblood contact, counter-pulsation device. Works like an IABP with the ECG sensing lead. Pt can go home with it. Can be place minimally invasively and off-pump.
- On-Off ability to disconnect (patient comfort and convenience)
- earlier hospital discharge (4-5 days)
- Extra-vascular: no need for anticoagulation

Conclusions

Heart failure remains to be a global problem with increasing number of patients every year.

The shortage of donor organ has and will limit the number of heart transplantations worldwide.

Conclusions

The current ventricular assist device outcomes are good and are continuing to improve.

The use of ventricular assist device is increasing at a rapid rate in the US and Europe due to its demand, excellent outcomes and advancement in technology.

Conclusions

Emerging new technology is smaller and lighter (potentially better performance)

Implantation technique is improving with "minimally invasive" approaches and off-pump implantion.

External components are smaller and wireless energy transfer is in development (improve patient quality of life and reduce adverse event)

Conclusions

Current and future developments of LVADs will continue to improve survival, reduce adverse events and improve overall patient quality of life.

Thank you