VAD Mechanical Circulatory Support in ACHD as a Bridge to Recovery/Transplant or Destination Therapy

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Surgical Management of End Stage Heart Failure

- Heart Transplantation is the Gold Standard.

BUT

There are many more people who require the surgical management of advanced heart failure than there are heart donors (<5000 worldwide per year), and each day this number continues to grow.
Do I look genetically engineered?

XENOTRANSPLANTATION

WHEN PIGS FLY!
THE ARTIFICIAL HEART IS HERE
TRAIL RIDGE ROAD   ROCKY MOUNTAIN NATIONAL FOREST, COLORADO

HIGHEST CONTINUOUSLY PAVED ROAD IN USA   12,183 FT
The Evolution of Mechanical Circulatory Support Systems

• **1966** First successful use of an LVAD for post-cardiotomy cardiogenic shock (De Bakey blood pump)
After extensive experimental work, the left ventricular bypass pump was employed in a 37 year old woman whose left ventricle was unable to resume adequate function following replacement of aortic and mitral valves.

After ten days of circulatory support her left ventricle recovered enough to resume function and the device was removed. She returned to normal activity for about six years until she was tragically killed in an automobile accident.

Spurred on by this initial success, a variety of devices, such as the intra-aortic balloon, has been created to provide hemodynamic stabilization for gravely ill patients.

A subsequent version of the DeBakey blood pump, the Baylor left ventricular assist device, was first used successfully for postcardiotomy heart failure in 1966.
The Evolution of Mechanical Circulatory Support Systems

- **1967** Clinical application of the intraaortic balloon pump (IABP) (Kantrowitz)

- **1969** First successful use of a total artificial heart (TAH) as a bridge to transplant (Cooley)

- **1978** First successful use of an LVAD as a bridge to transplant (Frazier)
Dr. Willem Kolff (1911-2009)
FATHER OF ARTIFICIAL ORGANS

DEVELOPED INTEREST IN ARTIFICIAL HEART EARLY IN HIS CAREER
Became Head of the University of Utah’s Division of Artificial Organs
1967
DR. ROBERT JARVIK WORKED IN DR. KOLFF’S LAB AND WAS ASSIGNED TO DEVELOP AN ARTIFICIAL HEART
The Evolution of Mechanical Circulatory Support Systems

- **1982** First clinical use of The Jarvik 7 TAH as “permanent” device (De Vries)
Barney Clark and the Jarvik 7 at University of UTAH

Lived 112 days
The Evolution of Mechanical Circulatory Support Systems

• 1995 First clinical use of LVAD as “permanent” device (Frazier)
• Catanese KA Outpatient LVAD Support a Destination rather than a Bridge  Annals Thoracic Surg 1996
London man gets permanent electric heart

Deutsche Presse Agentur
Heart Transplantation and MCS remain low in the Asia Pacific region (including the ACHD population)
North America, which comprises 7.5% of the world population, accounted for 55.8% of the transplants in the 2012 ISHLT Registry, whereas Asia with 62.5% of the world population, accounted for 5.7% of the Transplants.

Cost
Wide variation in Health Care Infrastructures
Multi-cultural and racial factors
Religious beliefs
Diverse Traditions

Asia: most common MCS system implanted is the HeartMate II
Australia: most common MCS system implanted is the HeartWare HVAD

50% of the patients coming to transplant in Australia are on MCA
Proportion of ACHD transplants relative to all transplants

Proportion of ACHD transplants supported With MCS relative to all ACHD

USE of MCS in Heart Failure for ACHD Patients

OPTN SRTR data from 1987-2012

- 47,160 adult transplant recipients, 1,213 (2.6%) had CHD
- Proportion of ACHD transplants recipients relative to all adult transplant increased yearly, with concomitant increase in MCS for ACHD yearly
- MCS used in 83 patients (6.8%) with CHD as compared to 8,625 (18.8%) patients without CHD
- No difference in 30 day mortality between MCS and non MCS patients with ACHD, but both had higher short term mortality than adults without CHD

GALAPAGOS ISLANDS

STUDY OF EVOLUTION
A DATA BASE LIKE INTERMACS

INTERAGENCY REGISTRY FOR MECHANICALLY ASSISTED CIRCULATORY SUPPORT (JUNE 2006)

- IDEAL FOR STUDY OF THE EVOLVING LANDSCAPE OF MCS IN THE USA
- SPONSORED BY THE NATIONAL HEART, LUNG, AND BLOOD INSTITUTE IN PARTNERSHIP WITH CENTER FOR MEDICARE SERVICES AND THE FOOD AND DRUG ADMINISTRATION
- UNDER STEWARDSHIP OF JAMES KIRKLIN
Other MACS registries, but newer and fewer patients

J-MACS 2010

EUROMACCS 2009
The image compares two generations of implantable pumps: the **1st Generation** HeartMate I (pulsatile) and the **2nd Generation** HeartMate II (continuous flow).
SINCE 2010, >99% of USA IMPLANTS = CONTINUOUS FLOW TECHNOLOGY

2nd GENERATION

Axial Flow

3rd GENERATION

Centrifugal Flow

From heart To body

Impeller Driveline
Second Generation VADs

- The key mechanical element was the implementation of a valveless axial pump with a rotary motor as the only moving part in the system.
- More specifically, the design introduced an internal rotor in the axial path of flow that was suspended via blood-immersed bearings (i.e., the rotor is in direct contact). The theoretical benefit of this design was further reduction of prothrombotic sites and minimization of wear and tear associated with multiple moving parts.
- Efficiency was further enhanced with elimination of the reservoir chamber and inflow/outflow valves.
The HeartMate II
2nd generation device

FDA APPROVED FOR BRIDGE TO TRANSPLANT 2008
The pump used in the Jarvik 2000 booster VAD for adults (left) is being developed for children (center) and infants (right).

FDA APPROVED FOR CLINICAL TRIAL AS BTT and DESTINATION(2012)
The critical distinguishing factor between the second- and third-generation LVADs is the employment of contact versus noncontact bearings, respectively. The latter employs the technology known as magnetic levitation (MAGLEV), which allows for rotation without friction or wear. The goal of this design is to further minimize prothrombotic sites while enhancing efficiency and durability.
HeartWare HVAD

3RD GENERATION DEVICE

FDA APPROVED BRIDGE TO TRANSPLANT NOV 20, 2012
HeartMate III
3rd generation

FDA APPROVED FOR BRIDGE TO TRANSPLANT AUG 28, 2017
HOW DO ADULTS WITH CHD and LVADs COMPARE WITH THOSE ADULTS ON LVAD SUPPORT WITHOUT CHD?
Utilization and Outcomes of Ventricular Assist Device Support in Adult Congenital Heart Disease: An Analysis of the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS)


The Journal of Heart and Lung Transplantation
Volume 35, Issue 4, Pages S151-S152 (April 2016)
DOI: 10.1016/j.healun.2016.01.420
Survival of adults with and without CHD on Continuous Flow device

INTERMACS DATA

VanderPluym et al

Not Congenital, n=12231
deaths=3242

<table>
<thead>
<tr>
<th>Month</th>
<th>% Survival</th>
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<tbody>
<tr>
<td></td>
<td>NonCong</td>
</tr>
<tr>
<td>1</td>
<td>95%</td>
</tr>
<tr>
<td>6</td>
<td>87%</td>
</tr>
<tr>
<td>12</td>
<td>80%</td>
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<tr>
<td>36</td>
<td>59%</td>
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<tr>
<td>48</td>
<td>48%</td>
</tr>
<tr>
<td>60</td>
<td>42%</td>
</tr>
</tbody>
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Congenital, n=59
deaths=16
While VAD utilization is much less common in ACHD, the survival outcomes are similar to non-ACHD patients even in the setting of complex congenital disease.

1 year survival for ACHD VAD: 72%
Almost half (44%) of the high complexity lesions were D-TGA following the Atrial Switch operation: easy implant?

25% were palliated Single Ventricle circulation: more difficult but good results!
It’s indispensable for optimum pump placement

Both TEE and Epicardial ECHO together are additive in usefulness

Optimal cannula placement occurs when the inflow cannula is directed towards the AV valve

Liberal resection of the moderator band, RV trabeculae, and the papillary muscles is necessary to ensure unobstructed flow when placed in the right ventricle
A BIT OF BAD NEWS  ADVERSE EVENTS

- STROKE
- DRIVELINE, PUMP, POCKET INFECTION
- GASTROINTESTIONAL BLEEDING
- PUMP THROMBOSIS  RARE
- ADVERSE EVENT RATES DECLINING WITH NEWER GENERATION DEVICES
LVAD For Failing Single Ventricle

Use of a HeartWare Ventricular Assist Device in a Patient With Failed Fontan Circulation

Robert A. Niebler, MD, Nancy S. Ghanayem, MD, Tejas K. Shah, MD, Andrea De La Rosa Bobke, CPNP, Steven Zangwill, MD, Cheryl Brosig, PhD, Michelle A. Frommelt, MD, Michael E. Mitchell, MD, James S. Tweddell, MD, and Ronald K. Woods, MD

Herma Heart Center, Children’s Hospital of Wisconsin; Department of Pediatrics, Section of Critical Care, Medical College of Wisconsin; Department of Pediatrics, Section of Cardiology, Medical College of Wisconsin; and Department of Cardiothoracic Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin

We present a successful case of the use of a HeartWare ventricular assist device as a bridge to transplantation in an 11-year-old with a hypoplastic left heart and failed Fontan circulation.

Heart Transplantation for ACHD: The Destination?
The artificial heart is very effective as a bridge to transplant, but the number of people that can be saved with human hearts is limited. A perfect artificial heart could save many more patients.

Robert Jarvik
Durable Mechanical Circulatory Support gained acceptance as long term “Destination Therapy” in the USA.
129 patients in NYHA class 4 CHF and who were ineligible for heart transplant

68 received MCS
61 received medical therapy
LVAD “Destination” Therapy
REMATCH Trial

Results
48% reduction in the risk of death from any cause in the group that received LVAD vs medical therapy (MT)

Survival
1 year LVAD 52%   MT 25%
2 year LVAD 23%   MT 8%
Approval of the HeartMate II for Destination Therapy in 2010 by FDA opened the door for increased surgical impact on heart failure over heart transplantation alone. BULKY, PRONE TO INFECTION and PUMP FAILURE
Approval of the HeartMate II for Destination Therapy in 2010 by FDA, opened the door for increased surgical impact on heart failure over heart transplantation alone.
Medtronic HeartWare HVAD System APPROVED for Destination Therapy

FDA clears HVAD for patients with End Stage Heart Failure
SynCardia TAH implant May 22, 2011, Texas Children’s Hospital

17 y/o Jordan Merecka

Complex CCTGA, Biventricular failure
Bridge to successful Transplant

FDA approved 2004 BTT
Total Artificial Heart for Failed Fontan

Successful Use of the Total Artificial Heart in the Failing Fontan Circulation

Joseph W. Rossano, MD, David J. Goldberg, MD, Stephanie Fuller, MD, Chitra Ravishankar, MD, Lisa M. Montenegro, MD, and J. William Gaynor, MD

Division of Cardiology, Department of Pediatrics, Division of Pediatric Cardiac Surgery, Department of Surgery, and Department of Anesthesia and Critical Care Medicine, The Cardiac Center, The Children’s Hospital of Philadelphia, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania

Typical left ventricular assist devices are often ineffective for the failing Fontan circulation. We report the first successful use of a total artificial heart as a bridge to transplant in a patient who had previously undergone a Fontan operation.

© 2014 by The Society of Thoracic Surgeons
Important subsets of patients with continuous flow DT now enjoy survival competitive with heart transplant out to 2 years

No cancer
No cardiogenic shock at implant
No dialysis
BUN < 50 mg/dL
No severe right heart failure

1 year survival 88%
2 year survival 80%
Heart Transplantation 80%/2years

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

James K. Kirklin, MD, David C. Nault, PhD, Francis D. Pagani, MD, PhD, Robert L. Kormos, MD, Lyne Stevenson, MD, Marise Miller, DVM, MPH,* and James B. Young, MD

Objectives: Average 2-year survival after cardiac transplantation is approximately 80%. The evolution and subsequent approval of larger pulsatile and, more recently, continuous flow mechanical circulatory support (MCS) technology for destination therapy (DT) offers the potential for usage of some patients awaiting cardiac transplantation to DT.

Methods: The National Heart, Lung, and Blood Institute Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) is a national multi-institutional study of long-term MCS. Between June 2005 and December 2011, 123 pulsatile and 1160 continuous flow pumps (35% of early primary left ventricular assist device [LVAD]) earned an initial strategy of DT therapy.

Results: By multivariable analysis, risk factors (P < 0.05) for mortality after DT included older age, larger body mass index, history of cancer, history of cardiac surgery, INTERMACS level 1 (cardiogenic shock), dialysis, for- ced ventilation, and 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 prog- nosis was seen in those with no history of cancer, those with advanced MCS, and those with a BUN < 50 mg/dL, resulting in a 1- and 2-year survival 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 subset 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)
Continuous flow blood pumps: the new gold standard for advanced heart failure?

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Keywords: Heart transplantation • Mechanical circulatory support • Heart failure • Continuous flow pump

Consider the familiar phrase ‘cardiac transplantation sets the gold standard for the treatment of severe heart failure’. Does this still ring true? For the advanced heart failure (AdHF) patient, the primary objective is to provide symptomatic relief from intolerable breathlessness, lethargy and fatigue [1]. The secondary aim, conditional upon the primary objective being met, is to extend life. Neither is accomplished easily in refractory Stage D heart failure (New York Heart Association (NYHA) IV). Conventionally, at this stage, only cardiac transplantation or palliative care options remain.
ACHD patients might not be best candidates for “Destination Therapy”

- Criteria for Destination Therapy continue to evolve as devices continue to improve
- ACHD patients who are highly sensitized or have elevated PVR should be considered for a destination VAD then reconsidered for transplant when criteria met
- Initial mortality following heart transplant is higher for ACHD, but long term outcomes are better
- Multiple previous operations, complex anatomy, single ventricle, and Failed Fontan physiology, ie., Protein Losing Enteropathy, plastic bronchitis, favor heart transplant over a VAD
- Should ACHD candidates receive preference for heart transplant donors? I believe so.
“Fighting for peace is like screwing for virginity.” – George Carlin.
Distribution of Device Strategy for ACHD and non CHD patients: INTERMACS 2008-2014

<table>
<thead>
<tr>
<th>Device Strategy (Pre-implant)</th>
<th>Primary Diagnosis</th>
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<tbody>
<tr>
<td></td>
<td>Congenital Heart Disease</td>
</tr>
<tr>
<td></td>
<td>N   (%)</td>
</tr>
<tr>
<td>BTT Listed</td>
<td>39 (51%)</td>
</tr>
<tr>
<td>BTT Likely</td>
<td>17 (22)</td>
</tr>
<tr>
<td>BTT Moderate</td>
<td>6 (8%)</td>
</tr>
<tr>
<td>BTT Unlikely</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Destination Therapy</td>
<td>10 (13%)</td>
</tr>
<tr>
<td>BTR</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Rescue Therapy</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Totals</td>
<td>76 (100%)</td>
</tr>
</tbody>
</table>
VAD recipients with ACHD were more likely to have a Bridge to Transplant strategy (45 vs 28%, \( p<0.001 \)) than non-ACHD, and destination therapy was less frequent in ACHD patients compared to non-ACHD patients (16 vs 37%, \( p<0.001 \))
What Does The Future Hold?

**HEART HEALTH**
Permanent artificial heart could eliminate the need for transplants
By [Melinda Carstensen](https://www.melindacarstensen.com)
Published March 24, 2016
[Fox News](https://www.foxnews.com/)

Costs must decrease, patient selection has to be refined, and technology has to advance to point where external driveline is avoided (transcutaneous energy transfer system)
PARADIGM SHIFT

In the future, patients will be given a VAD when it is clinically needed; most patients will stay on the device, and those who experience device complications will undergo transplantation along with patients who are not suitable for device implantation in the first place... i.e. ACHD patients

In that way, good candidates can be listed for transplantation after full evaluation, and the limited organ supply can be allocated most appropriately.
COST IS STILL A HUGH ISSUE!

DESTINATION THERAPY NOT APPROVED
Quality Adjusted Life Year (QALY) still above 100,000 USD
By 2015, 50% of MCA devices implanted in the USA were implanted for “Destination” Therapy

2017 INTERMACS REPORT
ONLY TIME WILL TELL
Royal Mecca clock, Mecca, S.A.
World’s largest clock tower
Sister Cities since 1992
Queenstown
Aspen

THANK YOU!