HISTORICAL PERSPECTIVES OF MECHANICAL CARDIAC ASSIST

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Abington-Jefferson Health Systems
PROGRAM

• Past – From inception to clinical use

• Present – Devices, patients & outcomes

• Future – Technology, management & directions
THE BEGINNING
EARLY HORIZON OF CARDIAC SURGERY

- 1949 - Bailey, Harken surgically treat mitral stenosis
- 1954 - Gibbon introduces the heart-lung machine
- Late 50’s - multiple tissue substitutes/homografts in desc aorta
- 1960 - Starr’s caged ball valve
1962. . .Kennedy is President, declares that man will land on the moon this decade, and faces nuclear war with the Cuban missile crisis.

- John Glenn orbits the earth
- 1st Kmart is opened
- Wilt Chamberlain scores a 100 pts in a game
- 3 Boeing 707’s have fatal crashes
- The Rolling Stones debut & Marilyn Monroe dies
- Mariner2 flies by Venus, transmitting 1st data from another planet.
- Watson, Crick & Wilkins win the Nobel prize in medicine for the structure of DNA
- Norman Shumway is transplanting animal hearts...
EARLY PIONEERS

• 1964- U.S. Artificial Heart Program (LBJ)
  • Drs. DeBakey and Kolff

• “The Heart is a Pump”

• NHI morphs into NHLBI

• 1967 – Barnaard, Shumway lead the world into heart transplantation
HISTORY- MCS/DT

• VADs began as an additive technology
  • Transplant List Mortality was too high
  • “Assist” was the key word
    • “Whether permanent, mechanical, orthotopic replacement of the heart will be feasible or practical remains a moot question” Cooley 2001

Cooley -1969
w/Liotta heart
First Generation Long-term VADs

“As BTT”

Thoratec Paracorporeal

WorldHeart Novacor

Thoratec HeartMate XVE
## DEATH ON UNOS HEART TRANSPLANT WAITING LIST

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</tr>
</thead>
<tbody>
<tr>
<td>Pts</td>
<td>5,401</td>
<td>5,946</td>
<td>6,286</td>
<td>6,380</td>
<td>6,971</td>
<td>7,165</td>
<td>7,291</td>
<td>7,658</td>
<td>7,540</td>
<td>7,336</td>
</tr>
<tr>
<td>Deaths</td>
<td>790</td>
<td>781</td>
<td>763</td>
<td>731</td>
<td>772</td>
<td>743</td>
<td>782</td>
<td>770</td>
<td>714</td>
<td>592</td>
</tr>
<tr>
<td>Rate per 100 yrs</td>
<td><strong>40.4</strong></td>
<td><strong>31.7</strong></td>
<td><strong>27.3</strong></td>
<td><strong>25.3</strong></td>
<td><strong>24.0</strong></td>
<td><strong>20.6</strong></td>
<td><strong>20.7</strong></td>
<td><strong>19.1</strong></td>
<td><strong>17.0</strong></td>
<td><strong>14.5</strong></td>
</tr>
</tbody>
</table>

**UNOS 2001 Annual Report**

And it worked!
LVAD SUPPORT

• From single ventricle support to biventricular support with CardioWest

• Increase in organ preservation, such as the brain and kidneys

• Removing the diseased heart

• NEJM – Reported 79% survival compared to 46% in controls

The NEW ENGLAND JOURNAL of MEDICINE

Cardiac Replacement with a Total Artificial Heart as a Bridge to Transplantation

CARDOWEST TAH: HISTORY

- Evolved from Univ. Utah / Jarvik
- Developed under CardioWest Technologies Inc.
- 1993-2002: IDE trial
- 2001: SynCardia founded
- 2003 : Approved by FDA
CARDIOWEST TAH SYSTEM

Implantable TAH
Drivelines
External Console
IMPLANTABLE TAH FEATURES

- Occupies space of diseased heart
  - Displaces 400 ml
  - Weighs 160 grams

- Blood flow path same as normal heart
  - Inflow <2 cm
  - Blood path <20 cm

- Adjustable ventricle orientation

- No surgical pocket required
FROM BTT TO DT

• Can patients survive just on the pump?
• How long can the pump last?
• Most importantly: “Who is a candidate?” and “Who is not?”

• Dr. Eric Rose, Columbia leads the first randomized device study – 20 OHT centers
FIRST DEVICE FOR RANDOMIZED STUDY

REMATCH
Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure

- Randomized clinical trial
  - Optimal medical therapy vs pulsatile flow LVAD
- Nontransplant candidates (n = 129)
  - EF ≤ 25%
  - Peak VO2 < 12 mL/kg/min
  - Or continuous infusion inotropes
- FDA approval for XVE as destination therapy

Percent Survival

- LVAD (n=68)
  - 52% at 24 months
- DMM (n=61)
  - 23% at 24 months

Months

REMATCH

• First glimpse into our future
• Cardiac replacement was the holy grail
• DT therapy enters the lexicon ...and demands a greedy algorithm from industry...the goal is no longer just txp
SLOW ADOPTION OF DT

• High infection rate
• Pump breakdown
• Size issues
• Power requirement

The answer: Continuous flow instead of a pump.

- Only one moving, but durable, part
- No volume capacitance
- Less energy requirement
- Smaller…w less surgical issues
CONTINUOUS FLOW LVAD
HEARTMATE® VE & HEARTMATE II
SIZE COMPARISON

Currently in clinical trials in Europe; not available in the U.S.
HEARTMATE II LVAS

- Small, advanced blood pump, designed to improve patient outcomes and quality of life.
- 60 percent smaller pocket requirement and 44 percent shorter surgical time than older model
- Electrically powered
  - Batteries and line power
- Home discharge
HEARTMATE II – BTT RESULTS

Initial Heartmate II Outcomes (n=133)

- 79% at 6 months
- Transplantation, recovery, or ongoing device support

- Transplantation
- Ongoing device support
- Death
- Recovery
- Withdrawal

AXIAL FLOW PUMP RESULTS

Clinical Outcomes Are Similar in Pulsatile and Nonpulsatile Left Ventricular Assist Device Recipients

Erika D. Feller, MD, Erik N. Sorensen, PhD, Michel Haddad, MD, Richard N. Pierson III, MD, Frances L. Johnson, MD, James M. Brown, MD, and Bartley P. Griffith, MD

Divisions of Cardiology, Clinical Engineering, and Cardiac Surgery, University of Maryland Medical Center, Baltimore, MD

• Retrospective review – 13 pts in pulsatile; 14 pts in non-pulsatile
• Equally mixed between BTTX and DT
• Novacor, HeartMate and Jarvik devices
NEAR THE PRESENT
HISTORICAL CHANGE IN 21ST CENTURY- W HMII

- Continuous flow LVADs become the norm for BTT...& DT
- Industry responds, research explodes, registries are formed.
- Joint Commission earmarks DT for formal review
**VAD USE IN THE ELDERLY – U.S.**

- VAD use has risen steadily over the past decade and is rising exponentially (Courtesy - Thoratec)

- Although older pts have inferior survival post-VAD (37% @ 6mo), post-txp survival is acceptable (67.5% @ 5yrs) [Sandner – JHLT 2009:28]
TXP & VAD IN ELDERLY -5 YR. SURVIVAL

74% -- 59% drop

[Courtesy ISHLT Registry – L. Edwards, Apr, 2009]
THE NOW
VAD CERTIFIED CENTERS -2014

- 138 DT centers (date) are CMS approved ...
- 15 in state of PA, 10 in state of NY

- 67 approved in 2008
  - 106% growth in 6 years.

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<thead>
<tr>
<th>State</th>
<th># VAD Ctr</th>
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<tbody>
<tr>
<td>AL</td>
<td>1</td>
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<tr>
<td>AR</td>
<td>1</td>
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<tr>
<td>AZ</td>
<td>3</td>
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<tr>
<td>CA</td>
<td>13</td>
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<tr>
<td>CO</td>
<td>1</td>
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<td>CT</td>
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<td>DC</td>
<td>1</td>
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<td>DE</td>
<td>1</td>
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<tr>
<td>FL</td>
<td>6</td>
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<td>GA</td>
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<td>8</td>
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<td>IN</td>
<td>4</td>
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<td>KY</td>
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<td>3</td>
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<td>NJ</td>
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<td>10</td>
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<td>OH</td>
<td>6</td>
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<td>2</td>
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<td>OR</td>
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<td>6</td>
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<tr>
<td>WA</td>
<td>3</td>
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<tr>
<td>WI</td>
<td>3</td>
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COMPARABLE TECHNOLOGY
MEDICAL TECHNOLOGY - ICD

- Defibrillation known to save lives
- Implantable pads – a surgical procedure
- Transvenous implantation & efficacy proven

- Technology that created new patient treatment pathway
ICD GROWTH

• Transformative technology that increased the patients referred for therapy
• Explosion in cases and in the field of electrophysiology
• Massive increase in # of centers, fellowship trainees, governmental oversight.

• A DISRUPTIVE technology that also increased survival!
MEDICAL TECHNOLOGY – JOINT REPLACEMENT

• 1891 – Gluck – Ivory ball prosthesis. . .led to biocompatible materials. . .led to (1936) cobalt-chrom alloys. . .led to (1981) Charnley Teflon socket. . .

• Industry explosion, massive manpower increases, research for better prostheses

• Consumer Reports - >600,000 patients yearly!!!
“IF YOU DON’T BELIEVE...LISTEN TO CAPTAIN KIRK”

“I’m telling you, Spock, this VAD thing is the ‘Real Deal!’”
FROM BTT TO DT
**Worldwide HeartMate II® Clinical Experience**

Over 20,000 patients worldwide have now been implanted with the HeartMate II LVAS.

**Over 7,600 patients on ongoing support**

<table>
<thead>
<tr>
<th>Duration of Support</th>
<th>Number of Patients</th>
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<tbody>
<tr>
<td>≥1 year of support</td>
<td>5,128</td>
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<tr>
<td>≥2 years of support</td>
<td>3,195</td>
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<tr>
<td>≥3 years of support</td>
<td>1,795</td>
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<td>≥4 years of support</td>
<td>947</td>
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<tr>
<td>≥5 years of support</td>
<td>434</td>
</tr>
<tr>
<td>≥6 years of support</td>
<td>180</td>
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<tr>
<td>≥7 years of support</td>
<td>73</td>
</tr>
<tr>
<td>≥8 years of support</td>
<td>27</td>
</tr>
<tr>
<td>≥9 years of support</td>
<td>12</td>
</tr>
<tr>
<td>≥10 years of support</td>
<td>2</td>
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HeartMate II® System

Over 12 million days of HeartMate II support.

As of Feb 2015
*Based on clinical trial and device tracking data*  
GL-HM2-08140028(1)
HEARTMATE DT SURVIVAL BENEFIT VS MEDICAL MANAGEMENT

IMPROVED SURVIVAL IN LVAD TRIALS
PATIENT SELECTION

- DT risk score – estimate of 90-day hospital mort (Lietz, Miller- SemThCVSurg)

- Limits – older pts, exclud mech vent, iabp, small size, clin severity of HF

- Other models available
INTO THE FUTURE
TO BOLDLY GO WHERE NO MAN HAS GONE BEFORE. . .
## PROJECTIONS - U.S. POPULATION: 2000-2025

<table>
<thead>
<tr>
<th>AGE</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2025</th>
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<tbody>
<tr>
<td>65-74</td>
<td>7.0%</td>
<td>6.8%</td>
<td>7.6%</td>
<td>11.3%</td>
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<tr>
<td>75-84</td>
<td>4.9</td>
<td>5.0</td>
<td>4.7</td>
<td>6.5</td>
</tr>
<tr>
<td>&gt;85</td>
<td>1.7</td>
<td>1.9</td>
<td>2.1</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>13.6</strong></td>
<td><strong>13.7</strong></td>
<td><strong>14.4</strong></td>
<td><strong>20.1</strong></td>
</tr>
</tbody>
</table>
WHY SHOULD LVAD MANAGEMENT BE PERFORMED IN THE COMMUNITY

1. Better appreciation of the natural history of heart failure will improve outcomes clinically
   • Treatment options offered to local patients
   • Utilization of resources efficiently
   • Earlier recognition of advanced heart failure
GLOBAL EXPANSION OF HEARTMATE II®

372 HMII centers in 47 countries

<table>
<thead>
<tr>
<th>Geography</th>
<th>Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americas</td>
<td>188</td>
</tr>
<tr>
<td>EMEA</td>
<td>149</td>
</tr>
<tr>
<td>APAC</td>
<td>35</td>
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*As of April 2014*
THE COMING ASSIST OF THE FUTURE

HeartMate III™
with Full MagLev
HEARTMATE III*: FULL MAGLELV TECHNOLOGY

Key Design Feature: Fluid Dynamics (Designed to Minimize Shear Stress and Activation of Blood Components)

– The HeartMate III rotor and volute have been designed to minimize shear and avoid stasis over the entire range of operation (2 to 10 L/min).
THE “LOOK” OF THE FUTURE

Courtesy: The Crux (Discover magazine)
STILL REMAINS THE #1 PROBLEM
MI – TISSUE ENGINEERING (JACC, 2006–CHRISTMAN, LEE)
CONCLUSIONS

• Destination Therapy is additive and disruptive
• Unknown long-term benefit, but more to come with other therapies
• Technically complicated and complex psychosocially and ethically
• We’re still at the horizon.
“IN SCIENCE, THE CREDIT GOES TO THE MAN WHO CONVINCES THE WORLD, NOT TO THE MAN TO WHOM THE IDEA FIRST OCCURS.”

FRANCIS DARWIN

Thank you.

Dr. Rohinton Morris

QUESTIONS