Mechanical Assistance for Acute Heart failure

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Mechanical Assists available

• Short term (Centrifugal pumps)
  – LVAD
  – RVAD
  – BiVAD
  – ECLS (ECMO)

• Long term
  – Pulsatile (Thoratec PVAD, Syncardia TAH)
  – Axial flow (HeartMate II)
  – Centrifugal (HeartWare)
The Levitronix® CentriMag VAS is designed to provide temporary support for patients suffering potentially reversible cardiogenic shock.

FDA approved for up to 30 days of use.
Cannulation
Outcomes of a multicenter trial of the Levitronix CentriMag ventricular assist system for short-term circulatory support

Ranjit John, MD, a James W. Long, MD, b H. Todd Massey, MD, c Bartley P. Griffith, MD, d Benjamin C. Sun, MD, e Alfred J. Tector, MD, f O. Howard Frazier, MD, g and Lyle D. Joyce, MD a

J Thorac Cardiovasc Surg 141:932-9;2011

TABLE 3. Survival by group

<table>
<thead>
<tr>
<th>Group</th>
<th>30 d (n = 38)</th>
<th>Discharge (n = 38)</th>
<th>6 mo (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>18 (47%)</td>
<td>16 (42%)</td>
<td>12 (32%)</td>
</tr>
<tr>
<td>RVAD (n = 12)</td>
<td>7 (58%)</td>
<td>5 (42%)</td>
<td>4 (33%)</td>
</tr>
<tr>
<td>PMICS (n = 14)</td>
<td>7 (50%)</td>
<td>7 (50%)</td>
<td>6 (43%)</td>
</tr>
<tr>
<td>PCCS (n = 12)</td>
<td>4 (33%)</td>
<td>4 (33%)</td>
<td>2 (17%)</td>
</tr>
<tr>
<td>LVAD (n = 8)</td>
<td>3 (38%)</td>
<td>2 (25%)</td>
<td>2 (25%)</td>
</tr>
<tr>
<td>BVAD (n = 18)</td>
<td>8 (44%)</td>
<td>8 (44%)</td>
<td>6 (33%)</td>
</tr>
</tbody>
</table>

All times are measured from device removal; all data are numbers of patients with percentages. RVAD, Right ventricular assist device; PMICS, post–acute myocardial infarction cardiogenic shock; PCCS, postcardiomyopathy cardiogenic shock; LVAD, left ventricular assist device; BVAD, biventricular assist device.
The Tandem Heart is inserted percutaneously transeptal. It provides temporary support for patients suffering potentially reversible cardiogenic shock. It is intended to be used up to 7 days.
Randomized comparison of intra-aortic balloon support with a percutaneous left ventricular assist device in patients with revascularized acute myocardial infarction complicated by cardiogenic shock

Holger Thiele*, Peter Sick, Enno Boudriot, Klaus-Werner Diederich, Rainer Hambrecht, Josef Niebauer, and Gerhard Schuler

European Heart Journal (2005) 26, 1276–1283

- IABP = 20
- Tandem Heart = 21
The Impella 2.5 is inserted percutaneously. The Impella 5 is inserted surgically. Both provide temporary support for patients suffering potentially reversible cardiogenic shock. It is intended to be used up to 7 days.
The Impella 2.5 and 5.0 devices for ST-elevation myocardial infarction patients presenting with severe and profound cardiogenic shock: The Academic Medical Center intensive care unit experience*

Annemarie E. Engström, MD; Ricardo Cocchieri, MD; Antoine H. Driessen, MD; Krischan D. Sjauw, MD; Marije M. Vis, MD; Jan Baan, MD, PhD; Mark de Jong, RN; Wim K. Lagrand, MD, PhD; Jos A. P. van der Sloot; Jan G. Tijssen; Robbert J. de Winter; Bas A. S. de Mol; Jan J. Piek; José P. J. M. Henriques, MD, PhD

Crit Care Med 2011 Vol. 39, No. 9

- At 30 days - alive
  - 6/23 (26%) Impella 2.5
  - 6/12 (50%) Impella 5
• At 30 days - alive
  – 11/29 (38%) Impella 5
  – 13/32 (41%) ECLS
ECLS (ECMO)

• Modified mobile cardiopulmonary bypass
  – Easy to insert
  – Fast
  – Bed side
  – Both circulatory and respiratory support

However

– Does not unload LV (afterload increased)
– Patient is relatively immobilized
VA ECMO
ECMO and CPR

ECMO No CPR ~ 40%-60%

ECPR survival to discharge ~ 20%
Patients Need to be referred Early, before irreversible End Organ Failure Exist
Adult Primary Implant Enrollment: n = 6561
Implants: June 2006 – June 2012

- Continuous Flow Intracorporeal LVAD Pump
- Pulsatile Flow Intracorporeal TAH
- Pulsatile Flow Intracorporeal LVAD Pump
- Pulsatile Flow Paracorporeal LVAD Pump

<table>
<thead>
<tr>
<th>Year</th>
<th>Cont Intra Pump</th>
<th>Puls Intra TAH</th>
<th>Puls Intra Pump</th>
<th>Puls Para Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>0</td>
<td>1</td>
<td>78</td>
<td>18</td>
</tr>
<tr>
<td>2007</td>
<td>0</td>
<td>22</td>
<td>260</td>
<td>60</td>
</tr>
<tr>
<td>2008</td>
<td>458</td>
<td>23</td>
<td>181</td>
<td>73</td>
</tr>
<tr>
<td>2009</td>
<td>860</td>
<td>24</td>
<td>53</td>
<td>69</td>
</tr>
<tr>
<td>2010</td>
<td>1570</td>
<td>29</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>2011</td>
<td>1765</td>
<td>21</td>
<td>3</td>
<td>55</td>
</tr>
<tr>
<td>2012</td>
<td>862</td>
<td>16</td>
<td>1</td>
<td>14</td>
</tr>
</tbody>
</table>

J Heart Lung Transplant 2013;32:141–156
NOTE: This figure includes only the heart transplants that are reported to the ISHLT Transplant Registry. As such, the presented data may not mirror the changes in the number of heart transplants performed worldwide.
When is medical therapy not enough?
Episodes of Acute Exacerbation of Heart Failure

Progression of HF is often quite difficult to predict. Progression may occur quickly. Eventually, Patients may not be viable candidates for advanced Treatment.
Timing of VAD

- Too early
- Window of opportunity
- Too late

Conservative therapy

VAD therapy
Medical therapy of heart failure
Snake disease progression

Pacemakers in HF
Delay disease progression

But: NEVER CURE!!!
Pulsatile Devices

Thoratec®: Paracorporeal VAD

Syncardia Total Artificial Heart
Continuous Flow Devices

• Adequate end organ perfusion in normal blood flow
Axial Flow Pumps

HeartMate II

- magnetically suspended
- Small
- Silent
- Valveless
- 7,000-12,000 RPM
- Afterload dependent
- Can deliver up to 10 lit/min
Centrifugal Pumps

HeartWare

- magnetically levitated
- Small
- Silent
- Valveless
- 2,000-3,000 RPM
- Afterload dependent
- Can deliver up to 10 lit/min
Intended Use

- Bridge to transplant
- Bridge to recovery
- Long term therapy
- Bridge to decision
Bridge to Transplantation

- Was the initiative to those devices
- Most require LVAD only
- About 10% will require additional RVAD
Bridge to Recovery

• Currently unpredictable results
• It is yet to be discovered who are the patients that will recover and will not fail shortly after removal of device
Long Term Therapy

- Lack of donors and successful long term support as bridge, opened a new era
REMATCH study

Randomized Evaluation of Mechanical Assistance for the Treatment of CHF

The New England Journal of Medicine

Long-term Use of a Left Ventricular Assist Device for End-stage Heart Failure


- 129 patients (68 – LVAS, 61 – optimal medical)
- Mean age: 66 ± 9 years
- 48% reduction in risk of death
- 1 year survival: 52% vs. 25%
- 2 year survival: 23% vs. 8%
- Improved quality of life at 1 year
Improved Survival in LVAD Trials

Months
0 6 12 18 24
Percent Survival
0 10 20 30 40 50 60 70 80 90 100
HM II BTT Starling JACC 2011
HM II BTT Pagani JACC 2009
HM II BTT Miller NEJM 2007
HM II DT Slaughter NEJM 2009
VE DT LVAD REMATCH Rose NEJM 2001
XVE DT LVAD Slaughter NEJM 2009
Novacor DT LVAD INTrEPID Rogers JACC 2007
OMM REMATCH Rose NEJM 2001
OMM INTrEPID Rogers JACC 2007
INTERMACS Report 2013
HeartMate II Continuous Flow LVAD

Adult Primary LVADs & BIVADs, DT and BTT, n = 6274
Implants: June 2006 – June 2012
Survival by Pump Type

The risk factor analysis for survival is restricted to continuous flow pumps

Overall p < 0.0001

Event: Death (censored at transplant and recovery)

Months post-implant

Kirklin, Naftel, Kormos et al JHLT 2013;2:141-56
ADULT HEART TRANSPLANTS
Kaplan-Meier Survival by Age Group
(Transplants: January 1982 - June 2010)

HALF-LIFE 18-29: 12.2 years; 30-39: 12.0 years; 40-49: 11.1 years; 50-59: 10.0 years;
60-69: 8.9 years; 70+: 7.4 years

All pair-wise comparisons are statistically significant at p < 0.01 except 18-29 vs. 30-39 (p=0.8452)
### Baseline INTERMACS Profiles

<table>
<thead>
<tr>
<th>INTERMACS Profile</th>
<th>HeartMate II (n=169)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41 (24%)</td>
</tr>
<tr>
<td>2</td>
<td>63 (37%)</td>
</tr>
<tr>
<td>3</td>
<td>33 (20%)</td>
</tr>
<tr>
<td>4</td>
<td>21 (12%)</td>
</tr>
<tr>
<td>5-7</td>
<td>11 (7%)</td>
</tr>
</tbody>
</table>

61% of patients in the study were in profile 1 or 2.

**Profile Description**

- **1**: Critical cardiogenic shock
- **2**: Progressive decline
- **3**: Stable, but inotrope dependant
- **4**: Recurrent advanced heart failure
- **5**: Exertion tolerant
- **6**: Exertion limited
- **7**: Advanced NYHA III
## Table 8. INTERMACS Clinical Profiles

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Hemodynamic Status</th>
<th>Time Frame for Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Critical cardiogenic shock, “crash and burn”</td>
<td>Persistent hypotension despite rapidly escalating inotropic support and eventually IABP, and critical organ hypoperfusion</td>
<td>Within hours</td>
</tr>
<tr>
<td>2</td>
<td>Progressive decline on inotropic support, “sliding on inotropes”</td>
<td>Intravenous inotropic support with acceptable values of blood pressure and continuing deterioration in nutrition, renal function, or fluid retention</td>
<td>Within days</td>
</tr>
<tr>
<td>3</td>
<td>Stable but inotrope dependent, “dependent stability”</td>
<td>Stability reached with mild to moderate doses of inotropes but demonstrating failure to wean from them because of hypotension, worsening symptoms, or progressive renal dysfunction</td>
<td>Elective over weeks to months</td>
</tr>
<tr>
<td>4</td>
<td>Resting symptoms, “frequent flyer”</td>
<td>Possible weaning of inotropes but experiencing recurrent relapses, usually fluid retention</td>
<td>Elective over weeks to months</td>
</tr>
<tr>
<td>5</td>
<td>Exertion intolerant, housebound</td>
<td>Severe limited tolerance for activity, comfortable at rest with some volume overload and often with some renal dysfunction</td>
<td>Variable urgency, dependent on nutrition and organ function</td>
</tr>
<tr>
<td>6</td>
<td>Exertion limited, “walking wounded”</td>
<td>Less severe limited tolerance for activity and lack of volume overload, fatigue easily</td>
<td>Variable urgency, dependent on nutrition and organ function</td>
</tr>
<tr>
<td>7</td>
<td>Advanced NYHA III “symptoms, placeholder”</td>
<td>Patient without current or recent unstable fluid balance, NYHA class II or III</td>
<td>Not currently indicated</td>
</tr>
</tbody>
</table>

INTERMACS indicates Interagency Registry for Mechanically Assisted Circulatory Support; IABP, intra-aortic balloon pump; and NYHA, New York Heart Association. Adapted from Alba et al.  

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Fifth INTERMACS annual report: Risk factor analysis from more than 6,000 mechanical circulatory support patients

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

Table 3  Implants: June 2006–June 2012, Adult Primary Continuous-Flow LVADs and BiVADS, DT and BTT (n = 5,436)

<table>
<thead>
<tr>
<th>Risk factors for death</th>
<th>Early hazard</th>
<th></th>
<th>Constant hazard</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hazard ratio</td>
<td>p-value</td>
<td>Hazard ratio</td>
<td>p-value</td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (older)</td>
<td>1.69</td>
<td>&lt;0.0001</td>
<td>1.30</td>
<td>0.003</td>
</tr>
<tr>
<td>Body mass index (higher)</td>
<td>1.47</td>
<td></td>
<td>1.25</td>
<td>0.01</td>
</tr>
<tr>
<td>Clinical status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilator</td>
<td>1.65</td>
<td>0.009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of stroke</td>
<td>1.69</td>
<td>0.009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERMACS Level 1</td>
<td>2.45</td>
<td>&lt;0.0001</td>
<td>1.30</td>
<td>0.003</td>
</tr>
<tr>
<td>INTERMACS Level 2</td>
<td>1.89</td>
<td>0.0004</td>
<td>1.25</td>
<td>0.01</td>
</tr>
<tr>
<td>Destination therapy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-cardiac systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.22</td>
<td>0.02</td>
<td>1.82</td>
<td>0.005</td>
</tr>
<tr>
<td>Creatinine (higher)</td>
<td>2.22</td>
<td>0.002</td>
<td>1.10</td>
<td>0.008</td>
</tr>
<tr>
<td>Dialysis</td>
<td>1.10</td>
<td>0.002</td>
<td>1.25</td>
<td>0.01</td>
</tr>
<tr>
<td>Blood urea nitrogen (higher)</td>
<td>1.10</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right heart dysfunction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVAD in same operation</td>
<td>3.73</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right atrial pressure (higher)</td>
<td>1.36</td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilirubin (higher)</td>
<td>1.08</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascites</td>
<td>1.32</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical complexities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of cardiac surgery</td>
<td>1.34</td>
<td>0.02</td>
<td>1.50</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Concomitant cardiac surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Independent risk factors for failure

BIVAD, biventricular assist device; BTT, bridge to transplant; DT, destination therapy; INTERMACS, Interagency Registry for Mechanically Assisted Circulatory Support LVAD, left ventricular assist device; RVAD, right ventricular assist device.
Heart Failure Related Quality of Life
Kansas City Cardiomyopathy Questionnaire

Early Trial (N=133) vs. Mid Trial (N=281)

Pts Tested:
- Mid Trial: 245, 201, 187, 160, 128, 76

P < 0.001 over time
P = 0.063 between groups

Park S et al Circ-HF Jan 2012
## Adverse Events – INTERMACS

### Table 5  Implants: June 2006–June 2012

<table>
<thead>
<tr>
<th>Adverse event</th>
<th>Pulsatile (n = 594)</th>
<th>Continuous (n = 5,358)</th>
<th>Pulsatile/Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Events</td>
<td>Rate</td>
<td>Events</td>
</tr>
<tr>
<td>Device malfunction</td>
<td>119</td>
<td>3.26</td>
<td>660</td>
</tr>
<tr>
<td>Bleeding</td>
<td>630</td>
<td>17.28</td>
<td>3895</td>
</tr>
<tr>
<td>Cardiac/vascular</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right heart failure</td>
<td>90</td>
<td>2.47</td>
<td>737</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>2</td>
<td>0.05</td>
<td>30</td>
</tr>
<tr>
<td>Cardiac arrhythmia</td>
<td>254</td>
<td>6.96</td>
<td>1919</td>
</tr>
<tr>
<td>Pericardial drainage</td>
<td>64</td>
<td>1.75</td>
<td>251</td>
</tr>
<tr>
<td>Hypertension(^b)</td>
<td>118</td>
<td>3.24</td>
<td>351</td>
</tr>
<tr>
<td>Arterial non-CNS thrombosis</td>
<td>14</td>
<td>0.38</td>
<td>74</td>
</tr>
<tr>
<td>Venous thrombotic event</td>
<td>59</td>
<td>1.62</td>
<td>289</td>
</tr>
<tr>
<td>Hemolysis</td>
<td>23</td>
<td>0.63</td>
<td>299</td>
</tr>
<tr>
<td>Infection</td>
<td>832</td>
<td>22.81</td>
<td>3302</td>
</tr>
<tr>
<td>Neurological dysfunction</td>
<td>139</td>
<td>3.81</td>
<td>754</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>108</td>
<td>2.96</td>
<td>582</td>
</tr>
<tr>
<td>Hepatic dysfunction</td>
<td>48</td>
<td>1.32</td>
<td>247</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>206</td>
<td>5.65</td>
<td>1038</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>18</td>
<td>0.49</td>
<td>74</td>
</tr>
<tr>
<td>Psychiatric episode</td>
<td>87</td>
<td>2.39</td>
<td>425</td>
</tr>
<tr>
<td>Total burden</td>
<td>2811</td>
<td>77.07</td>
<td>14927</td>
</tr>
</tbody>
</table>

CNS, central nervous system.

\(^a\)Adverse event rates (events/100 patient months) in the first 12 months after implant for primary left ventricular assist device with implant device strategy bridge to transplant, bridge to candidacy, and destination therapy.

\(^b\)With current reporting, identification of hypertension with continuous-flow pumps is unreliable.
The Most Difficult Group

• Ambulatory patients with advanced heart failure (INTERMACS profile 4-7)

• Factors known to be associated with worsening prognosis should be taken into account.

• Risk models need to be developed
Advanced Heart Failure: Prognostic markers

Clinical markers predicting poor outcome:

– Inability to walk one block without shortness of breath.
– HF related hospitalizations in past 6 months.
– Diuretic dose > 1.5 mg/kg/d.
– Serum sodium < 136 mmol/L.
– BUN>40 mg/dL or creatinine >1.8mg/DL.
HF and Rehospitalizations

Average age of HF hosp
In community = 74-77 years

J Am Coll Cardiol 2013;61:1209–21
Estimated Survival on LVAD Support
HeartMate II Risk Score

Multivariable Risk Factors For Death after LVAD implant

- INR
- Creatinine
- Age, per 10 years
- Albumin
- Implant after May 2007
- LVAD Center Volume >=15

Hazard Ratios:
- HR 0.52
- HR 0.67
- HR 0.71 per mg/dL
- HR 1.3 per 10 yrs
- HR 1.4 per mg/dL
- HR 1.9 per sec

Percent Survival by Risk Group

Low Risk (N=168)
Medium Risk (N=206)
High Risk (N=194)

P (log-rank) < 0.001

Suggested Algorithm

Miller and Guglin: J Am Coll Cardiol 2013;61:1209–21
Timing of VAD

Conservative therapy

Too early

Window of opportunity

Too late

VAD therapy

- Stable, but inotrope dependent
- Recurrent advanced heart failure

Better “too” early than too late!