Ventricular Assist Devices to Treat Heart Failure: Indications and Outcomes

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Management Algorithm for Patients with Cardiogenic Shock

Patient with Cardiogenic Shock

PAC

Remains hypotensive, elevated cardiac filling pressures, low CO, UOP < 30 cc/hr; MCS candidate

IABP or percutaneous VAD

Continuous support

Adequate response and likely to recover

Inadequate response and likely to recover

Inadequate response, unlikely to recover

Transplant candidate?

Yes and stable
List for transplant, consider surgically implanted LVAD, BiVAD

No
DT LVAD

Yes and stable
List for transplant + surgically implanted LVAD/BiVAD

Paracorporeal VAD or ECMO

Optimize volume status, pharmacotherapy including vasodilators and inotropic agents

The role for mechanical support in cardiogenic shock, AHA Publication, 2009
Short term Device options

- Bridge to recovery
- Bridge to decision

- ECMO
- Tandem Heart
- IABP
- AbioMed 5000
- Centrimag
- Impella

Balloon Counterpulsation

Physiologic Benefits
- Enhanced coronary blood flow
- LV unloading
- Increased cardiac output

Heart Failure
- Unresponsive hypotension
- Failure of standard medical therapies
- Progressive end-organ dysfunction
- Bridge to other therapy

AMI
- Adjunct to thrombolytic therapy to improve IRA patency rates
- Provide hemolytic stability in patients receiving thrombolytic therapy
- Post-infarct angina
- Mitral regurgitation
- Ventricular tachycardia

Thrombolytics

PCI

J Am Coll Cardiol 1997; 29: 1459-67
Potential Indications/Utility of Short-term VAD/Percutaneous MCS Devices

- Acute cardiogenic shock
- Chronic decompensated heart failure
- Post-cardiotomy
- Hemodynamically assisted high risk coronary interventions
- Supported percutaneous valve repair/replacement
- Supported ventricular arrhythmia ablation

ECMO for Cardiac Failure

**ECMO Indications**
- Hypoxemic respiratory failure
- Hypercapnic respiratory failure
- Cardiac arrest
- Failure to wean from bypass
- Intractable VT
- BTT or bridge to VAD
- Systematic Review
  - 67 papers
  - 1966-2008
  - Mostly case reports and single center series (n=5-169)
  - Cardiac indications

**Physiology Effects**
- Immediately stabilize circulation
- Improve end organ perfusion
- Overall survival comparable between ECMO + LVAD versus LVAD alone
- Clinical indicators of poor outcome after ECMO: consider VAD implantation carefully
  - Elevated blood lactate levels
  - Elevated LFTs

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<table>
<thead>
<tr>
<th>Condition</th>
<th># Reports</th>
<th>Median Survival (%)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Arrest</td>
<td>24</td>
<td>25</td>
<td>0-88</td>
</tr>
<tr>
<td>Cardiogenic Shock</td>
<td>20</td>
<td>41</td>
<td>13-78</td>
</tr>
<tr>
<td>Post-cardiotomy</td>
<td>15</td>
<td>36</td>
<td>19-67</td>
</tr>
<tr>
<td>Myocarditis</td>
<td>5</td>
<td>73</td>
<td>40-83</td>
</tr>
<tr>
<td>Post-tx cardiac dysfunction</td>
<td>2</td>
<td>57, 91</td>
<td></td>
</tr>
</tbody>
</table>

*Cardiac cases are VA ECMO for shock

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J Intensive Care Med 26: 13-26
Levitronix Centrimag

- Newer generation
- Centifugal pump
- Continuous flow
- Extracorporeal
- Impellar within the pump rotates in contact-free manner
- Increased durability
- Minimal thrombus formation and hemolysis of RBCs

Meta Analysis of Percutaneous VAD vs IABP

Eur Heart J 2009; 30: 2101-08
The Evolution of Durable MCS Devices

<table>
<thead>
<tr>
<th>Device</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoratec PVAD</td>
<td><img src="Image1.png" alt="Thoratec PVAD Image" /></td>
</tr>
<tr>
<td>Thoratec HeartMate II LVAS</td>
<td><img src="Image2.png" alt="Thoratec HeartMate II LVAS Image" /></td>
</tr>
<tr>
<td>HeatWare HVAD (Investigational)</td>
<td><img src="Image3.png" alt="HeatWare HVAD Image" /></td>
</tr>
</tbody>
</table>

The Jargon of VAD Therapy: Indications

<table>
<thead>
<tr>
<th>Indication</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge to Recovery/Explantation</td>
<td>Intended for short term support for a condition that is anticipated to reversible</td>
</tr>
<tr>
<td>Bridge to Bridge</td>
<td>Intended for short term support (typically inserted in an emergent situation) until a more permanent device can be implanted</td>
</tr>
<tr>
<td>Bridge to Transplant</td>
<td>Intended for short- to intermediate-term support in patients actively listed for transplantation</td>
</tr>
<tr>
<td>Bridge to Decision</td>
<td>Device inserted to support a patient in whom the ultimate therapy is not able to be determined at the time of implantation. Device may be used for short or long-term support.</td>
</tr>
<tr>
<td>Destination Therapy</td>
<td>Device inserted with the intention of long-term support in patients who are not candidates for transplantation</td>
</tr>
</tbody>
</table>

- Indications sometimes not clearly defined at implantation
- Indications may change during therapy
HeartMate II BTT Clinical Trial
Competing Outcomes Analysis (n=133)


Destination Therapy Trials

Figure 1. Survival Rates in Two Trials of Left Ventricular Assist Devices (LVADs) as Destination Therapy. The curves labeled 2009 are those reported by Slaughter and colleagues in this issue of the Journal; those labeled 2001 were reported for the REMATCH trial.

HeartMate II Clinical Study
Actuarial Survival
Primary + CAP cohorts (n=194)

Actuarial Survival with Centrifugal Continuous Flow Pump (HVAD)

Aaronsen KD. Circulation 2012; 125:3191-3200
Competing Outcomes: HVAD Trial

INTERMACS: Implant Volume by Type
INTERMACS: Survival by Device Type

Kirklin JK, J Heart and Lung Transplant 2012 Feb;31(2):117-26

INTERMACS: Survival with CF vs PF LVADs

Kirklin JK, J Heart and Lung Transplant 2012 Feb;31(2):117-26
INTERMACS: Survival with CF Pumps Based on Device Strategy/Indication

Kirklin JK, J Heart and Lung Transplant 2012 Feb;31(2):117-26

INTERMACS: Survival with CF Pumps for BTT Indication

Kirklin JK, J Heart and Lung Transplant 2012 Feb;31(2):117-26
INTERMACS: Survival with CF Pumps for DT Indication

![Graph showing survival rates for INTERMACS patients.](image)

Kirklin JK, J Heart and Lung Transplant 2012 Feb;31(2):117-26

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**INTERMACS Risk Level for VAD Implantation**

<table>
<thead>
<tr>
<th>PROFILE-LEVEL</th>
<th>Official Shorthand</th>
<th>General time frame for support</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEVEL 1</td>
<td>Critical cardiogenic shock despite escalating support&lt;br&gt;“Crash and burn”</td>
<td>Hours</td>
</tr>
<tr>
<td>LEVEL 2</td>
<td>Progressive decline with inotrope dependence&lt;br&gt;“Sliding fast”</td>
<td>Days to week</td>
</tr>
<tr>
<td>LEVEL 3</td>
<td>Clinically stable with mild to moderate inotrope dependence&lt;br&gt;Stable but Dependent</td>
<td>Weeks</td>
</tr>
<tr>
<td>LEVEL 4</td>
<td>Recurrent, not refractory, advanced HF that can be stabilized with intervention&lt;br&gt;“Frequent flyer”</td>
<td>Weeks to few months, if baseline restored</td>
</tr>
<tr>
<td>LEVEL 5</td>
<td>Exertion intolerant&lt;br&gt;“Housebound”</td>
<td>Weeks to months</td>
</tr>
<tr>
<td>LEVEL 6</td>
<td>Exertion limited&lt;br&gt;“Walking wounded”</td>
<td>Months, if nutrition and activity maintained</td>
</tr>
<tr>
<td>LEVEL 7</td>
<td>Advanced Class III</td>
<td>Not currently indicated</td>
</tr>
</tbody>
</table>

Patient Functionality and QoL
HeartMate II Clinical Trials Program

6 Minute Walk Distance

Minneapolis Living with Heart Failure

NYHA Functional Class

Kansas City Cardiomyopathy Score

J Am Coll Cardiol 2010; 56: 1826-34

Total Artificial Hearts
Severe Biventricular Failure

Syncardia TAH

Abiocor II TAH (investigational)
Total Artificial Heart as BTT

Figure 2. Overall Survival Rate from the Time of Study Entry to the Termination of the Study among the Patients Who Received a Total Artificial Heart According to Protocol and the Controls.

VAD Complications

- GI bleeding
- Hemolysis
- Device thrombosis
- Stroke
- RV failure
- Acquired coagulopathy
### Risk Scores for Mortality After VAD

<table>
<thead>
<tr>
<th>Variable*</th>
<th>OR/Risk Score</th>
<th>Variable§</th>
<th>OR/Risk Score</th>
<th>Variable¶</th>
<th>OR/Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platlet count ≤ 148</td>
<td>7.7/7</td>
<td>UOP &lt; 30 mL/hr</td>
<td>3.9/3</td>
<td>Respiratory failure &amp; sepsis</td>
<td>11.2/1</td>
</tr>
<tr>
<td>Serum albumin ≤ 3.3 g/dL</td>
<td>5.7/6</td>
<td>CVP &gt; 16 mm Hg</td>
<td>3.1/2</td>
<td>Preexisting RHF</td>
<td>3.2/1</td>
</tr>
<tr>
<td>INR &gt; 1.1</td>
<td>5.4/4</td>
<td>Mechanical ventilation</td>
<td>3.0/2</td>
<td>Age at implant &gt; 65 yrs</td>
<td>3.0/1</td>
</tr>
<tr>
<td>Vasodilator therapy</td>
<td>5.2/4</td>
<td>PT &gt; 16 seconds</td>
<td>2.4/2</td>
<td>Acute postcardiomyotomy</td>
<td>1.8/1</td>
</tr>
<tr>
<td>Mean PAP ≤ 25 mm Hg</td>
<td>4.1/3</td>
<td>Reoperation</td>
<td>1.8/1</td>
<td>Acute infarction</td>
<td>1.7/1</td>
</tr>
<tr>
<td>AST &gt; 45 U/mL</td>
<td>2.6/2</td>
<td>WBC &gt; 15,000/mm³</td>
<td>1.1/0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hematocrit ≤ 34%</td>
<td>2.9/2</td>
<td>Temperature &gt; 101.5°F</td>
<td>0/0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No intravenous inotropes</td>
<td>2.9/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DT Therapy Risk Score* | BTT Risk Score§ | BTT Risk Score¶
--- | --- | ---
Low risk: 0 to 8 | Low risk: < 5 | Low risk: 0
Medium to high risk: 9 to 19 | High risk: ≥ 5 | High risk: ≥ 1
Very high risk: > 19

*Adapted from Lietz et al.
§ Adapted from Oz et al.
Ŧ All patients met hemodynamic criteria consisting of CI < 2.0 with LAP or PCWP > 20
¶ Adapted from Deng et al.


### Current National INTERMACS Distribution of Patient Profiles

- **Profiles**
  - Profiles: 1, 2, 3, 4, 5, 6, 7
  - % Patients: 0, 10, 20, 30, 40, 50
  - (n=420)

Pagani F et al. ISHL 2008
Survival Stratified by INTERMACS Profile

Overall Survival

Group 3 vs 1: p = 0.011
Group 3 vs 2: p = 0.065
Group 2 vs 1: p = 0.18

Months post-LVAD

INTERMACS Profiles

Group 1

Group 2

Group 3

Numbers at risk
Baseline 6 mos 12 mos 18 mos 24 mos 30 mos 36 mos
Group 1 28 10 9 6 5 3 3
Group 2 49 25 12 7 7 7 4
Group 3 24 18 6 5 5 4 3


Pre-operative Risk for In-Hospital Death

Destination Therapy Registry
Years 2002-2005, n=208

Probability In-Hospital Death

Very High

High

Medium

Low

Pre-Operative Cumulative Risk Score

Leitz et al. ISHLT 2006
When to Refer Patients for Advanced Heart Failure Therapies (Tx/VAD)

- NYHA Class III-IV despite optimal medical and CRT therapy
- Worsening renal function
- ACE-I/BB intolerance d/t hypotension or renal function
- Dependence on IV inotropes or IABP
- > 1 hospitalization for HF in 1 year

→ LVEF < 35%
OR
→ Refractory ventricular arrhythmias
OR
→ Refractory angina
OR
→ Restrictive cardiomyopathy

AND

Conclusions

- Percutaneous VADs provide superior hemodynamic support but survival benefit not proven compared with balloon pumps
- Newer generation durable MCS pumps are smaller with fewer moving parts and greater longevity
- Survival is worse when VAD devices are implanted in unstable, crashing patients
- TAH should be considered for patients with severe biventricular failure
- Bleeding, thrombosis, and infection remain challenges with MCS device therapies
- Recognizing when to refer patients for advanced HF therapies is key to good outcomes!