Left Ventricular Assist Device
Objectives

• Discuss conditions to qualify for LVAD Therapy

• Discuss LVAD placement and other treatment modalities

• Describe the Thoratec Heartmate 2 and Heartmate 3 systems

• Discuss assessment changes of the LVAD patient

• Review emergency care of the LVAD patient
LVAD Exclusion Criteria

• Aortic Valve Competency
  – Sometimes valve is oversewn to allow adequate device function

• RV Function - if RV dysfunction is present must be transplant candidate
  – No PPHTN unless candidate for heart-lung transplant

• Hepatic Dysfunction - cirrhosis and portal HTN

• Renal Dysfunction - Irreversible disease vs. disease due to poor perfusion
  – Long term dialysis and creatinine > 3.0 mg/dl

• Cancer

• Psych/Social Concerns
LVAD Referral

• Symptoms
  – Recurrent admissions
  – Refractory
  – At rest

• Medications
  – Intolerance or lower doses
    • ACE-I/ARBs
    • Beta blockers
  – Increasing diuretic doses

• Unable to carry out ADLs
  – Poor nutritional status

• Hypotension
• Laboratory
  • Renal insufficiency
  • Hepatic dysfunction
  • Hyponatremia
• Pulmonary Hypertension
• RV Dysfunction
• Unresponsiveness to CRT (Cardiac Resynchronization Therapy)
• Inotropes
<table>
<thead>
<tr>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Contraindications</td>
</tr>
<tr>
<td>Presence of non-reversible end stage organ failure other than cardiac</td>
</tr>
<tr>
<td>Fixed CrCl &lt;30 mL/min and / or urine protein &gt; 3 grams/24 hours</td>
</tr>
<tr>
<td>Active metastatic carcinoma or carcinoma with a remission period &lt; 2 years (except basal cell carcinoma and prostate cancer)</td>
</tr>
<tr>
<td>Fixed pulmonary hypertension with PVR &gt; 3.5 Wood Units and TPG &gt; 15 mmHg</td>
</tr>
<tr>
<td>Moderate to severe pulmonary disease with FEV1&lt;50% predicted following bronchodilators</td>
</tr>
<tr>
<td>Significant peripheral or cerebral vascular disease</td>
</tr>
<tr>
<td>Active abuse of narcotics, alcohol, or illicit drug use in the previous 3 months</td>
</tr>
<tr>
<td>Active smoking or use of other tobacco products in the previous 3 months</td>
</tr>
<tr>
<td>Pulmonary embolus within the past 3 months</td>
</tr>
<tr>
<td>Refractory coagulopathy</td>
</tr>
<tr>
<td>Active peptic ulcer disease</td>
</tr>
<tr>
<td>Positive HIV serology</td>
</tr>
<tr>
<td>Acute Hepatitis B or C or any active or chronic parenchymal hepatic disease (case by case basis)</td>
</tr>
<tr>
<td>Documented cirrhosis unless candidate for combined heart / liver transplant</td>
</tr>
<tr>
<td>Severe psychiatric instability</td>
</tr>
<tr>
<td>Documented noncompliance</td>
</tr>
<tr>
<td>Relative Contraindications</td>
</tr>
<tr>
<td>Active infection</td>
</tr>
<tr>
<td>Insulin dependent diabetes with a HgA1c &gt; 8%</td>
</tr>
<tr>
<td>Extensive bone disease</td>
</tr>
<tr>
<td>Obesity with BMI &gt;36 kg/m²</td>
</tr>
<tr>
<td>Poor social support</td>
</tr>
<tr>
<td>History of cerebral vascular disease</td>
</tr>
<tr>
<td>Recent malignancy within the past 2 years</td>
</tr>
<tr>
<td>Active autoimmune disease</td>
</tr>
<tr>
<td>Inability to accept or receive blood products</td>
</tr>
<tr>
<td>Criteria</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>Inclusion Criteria</strong></td>
</tr>
<tr>
<td>At least 18 years of age and less than 70 years of age</td>
</tr>
<tr>
<td>NYHA Class IIIB or IV except if well supported with LVAD</td>
</tr>
<tr>
<td>Documented left ventricular ejection fraction &lt;25% and/or Cardiac index of &lt;2.2 and/or PCWP &gt;20</td>
</tr>
<tr>
<td>Optimal medical management</td>
</tr>
<tr>
<td>Not amenable to other medical or surgical treatments, as evaluated by Adv. Heart Failure Cardiologist and Cardiothoracic Surgeon</td>
</tr>
<tr>
<td>Peak VO2 &lt; 14 ml/kg/min or &lt;50% of age predicted</td>
</tr>
<tr>
<td>Absence of fixed pulmonary hypertension (TPG&lt;15) with vasodilator therapy</td>
</tr>
<tr>
<td>No significant chronic renal or hepatic disease unless eligible for heart/renal or heart/liver transplant and defined as</td>
</tr>
<tr>
<td>Serum creatinine &gt;2.5 mg/dL or CrCl &lt;30ml/min</td>
</tr>
<tr>
<td>Serum bilirubin &gt;2.0 mg/dL with increased prothrombin time (in the closure of anticoagulation) and serum transaminases greater than 3x ULN</td>
</tr>
<tr>
<td>No significant pulmonary disease (FEV1, FVC&lt;70%, and FEVi&lt;50% or TLC &lt;60 predicted and DLCO &lt;50% predicted) and corrected</td>
</tr>
<tr>
<td>If diabetic, no significant sequelae from disease defined as</td>
</tr>
<tr>
<td>Significant nephropathy, retinopathy, gastropathy, autonomic dysfunction</td>
</tr>
<tr>
<td>No active systemic disease (i.e. cancer) that will limit survival benefit from transplantation</td>
</tr>
<tr>
<td>No active infection</td>
</tr>
<tr>
<td>Unstable angina not amenable to medical therapy, coronary intervention, or revascularization</td>
</tr>
<tr>
<td>Refractory ventricular arrhythmias with storm</td>
</tr>
<tr>
<td>No significant peripheral vascular, cerebrovascular or abdominal aortic disease</td>
</tr>
<tr>
<td>Poor survival prognosis due to advanced heart disease</td>
</tr>
<tr>
<td>Availability of suitable insurance (Commercial or Medicare)</td>
</tr>
<tr>
<td>Psychosocial assessment that determined evidence of social support, ability to understand basics of transplantation and details of post-transplantation care, compliance with medical therapy, ability to undergo necessary lifestyle modifications (weight loss if needed, smoking cessation, absence from recreational drugs and alcohol for at least 3 months, maintain sodium and fluid restriction as needed, psychiatric evaluation if indicated)</td>
</tr>
</tbody>
</table>
### AHF Surgical Evaluation
- AHF Cardiology Consult
- ASO Patient Education
- BTT VAD/Transplant Labs
- AHF Surgical Consult
- Financial Coordinator Consult
- Spiritual Consult
- Social Worker Consult
- Nutritional Consult
- 6 Minute Walk (If not on Milrinone)
- Full PFT without ABG
- Chest X-ray (PA & lateral)
- Carotid Doppler Ultrasound
- CT Scan, Abdominal
- Echocardiogram – If not done in past 3 months at PHI
- Right Heart Catheterization
- CT Head w/o contrast (Advanced Age >60 & Hx of Stroke/TIAs)
- Bone Densitometry (DEXA) If not done in past 2 years
- Chest CT (all Redo Sternotomy)
- Phase 2/Education
- Transplant Coordinator Consult/Consents

### VAD Evaluation
- AHF Cardiology Consult
- ASO Patient Education
- DT VAD labs
- AHF Surgical Consult
- Financial Coordinator Consult
- Spiritual Consult
- Social Worker Consult
- Nutritional Consult
- 6 Minute Walk (if not on Milrinone)
- Full PFT without ABG
- Chest X-ray (PA & lateral)
- Carotid Doppler Ultrasound
- CT Scan, Abdominal
- Echocardiogram – If not done in past 3 months at PHI
- Right Heart Catheterization
- CT Head w/o contrast (Advanced Age >60 & Hx of Stroke/TIAs)
- Transplant Coordinator Consult/Consents
- Chest CT (all Redo Sternotomy)

### Additional Studies
- Vaccines
- Screening Mammogram – **females over 40**
- Pap Smear – **females (> 18)**
- Colonoscopy – **(>50)**
- Cardiopulmonary Stress–(except if Inotrope dependent or post VAD)
- Dental Exam (Mandible/Sinus Complete x-rays if inpt)
- Endocrine Consult/Clearance-diabetics
- Ophthalmology Consult/Clearance-diabetics
- ABI (BLE)- >50, or if pt is diabetic or Ischemic Cardiomyopathy
# INTERMACS Classification

<table>
<thead>
<tr>
<th>ADULT PROFILES</th>
<th>Current CMS - DT Functional Indication</th>
<th>IV INO*</th>
<th>Official Shorthand</th>
<th>NYHA CLASS Assumed</th>
<th>Modifier option</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERMACS LEVEL 1</td>
<td>Met</td>
<td>X</td>
<td>“Crash and burn”</td>
<td>IV</td>
<td>TCS A</td>
</tr>
<tr>
<td>INTERMACS LEVEL 2</td>
<td>Met</td>
<td>X</td>
<td>“Sliding fast” on inotropes</td>
<td>IV</td>
<td>TCS A</td>
</tr>
<tr>
<td>INTERMACS LEVEL 3</td>
<td>Met</td>
<td>X</td>
<td>“Stable” continuous inotrope dependent * Can be in hospital or at home</td>
<td>IV</td>
<td>TCA if hosp FF if home A</td>
</tr>
<tr>
<td>INTERMACS LEVEL 4</td>
<td>+ Peak $VO_2 \leq 12$</td>
<td></td>
<td>Resting symptoms on oral therapy at home</td>
<td>AMB IV</td>
<td>FF A</td>
</tr>
<tr>
<td>INTERMACS LEVEL 5</td>
<td>+ Peak $VO_2 \leq 12$</td>
<td></td>
<td>“Housebound”, Comfortable at rest, symptoms with minimum activity ADL</td>
<td>AMB IV</td>
<td>FF A</td>
</tr>
<tr>
<td>INTERMACS LEVEL 6</td>
<td></td>
<td></td>
<td>“Walking wounded”-ADL possible but meaningful activity limited</td>
<td>IIB</td>
<td>FF A</td>
</tr>
<tr>
<td>INTERMACS LEVEL 7</td>
<td></td>
<td></td>
<td>Advanced Class III</td>
<td>III</td>
<td>A only</td>
</tr>
</tbody>
</table>
LVAD Implantation Process

• Referral Phase
  – Referred to AHFC by primary cardiologist

• Evaluation Phase (2-4 weeks)
  – Testing
  – Consults with each team member
  – Selection Committee meets weekly

• Surgery Phase (~4-6 weeks)
  – Admit to CCU the day before surgery

• Outpatient Phase
  – Weekly clinic visits in AHFC (may be less frequent the further from surgery)
  – Warfarin management
LVAD Devices Worldwide

More than 20,000 patients worldwide have now been implanted with the HeartMate II LVAD.

Patients with the HeartMate II have a 2 year survival rate 7x’s greater than medical therapy alone (58%)
Indications for Use

• Bridge to Transplant
  – Non-reversible left heart failure
  – Imminent risk of death
  – Candidate for cardiac transplantation

• Destination Therapy
  – NYHA Class IIIB or IV heart failure
  – Optimal medical therapy 45 of last 60 days
  – Not candidate for cardiac transplantation

• For in-patient and out-patient use
  – May be transported via ground ambulance, fixed wing aircraft or helicopter
A surgically implanted, rotary continuous-flow device

Follows native LV pulse, pump flow varies over the cardiac cycle

Percutaneous driveline

Electrically powered
  – Batteries & line power
  – Other External Components

Fixed speed operating mode

Home discharge
Left Ventricular Assist Device – Where is it?
LVAD System

Implanted Components:
- Implantable titanium blood pump

External Components:
- System Controller
- Power Module
- Display Module
- Power Sources
  - Power Module
  - Batteries & Clips
  - Emergency Power Pack
- Accessories
Left Ventricular Assist Device – Design

• Design
  - Valve-less
  - Only one moving part (rotor)
  - Rotor spins on blood-lubricated bearings (rubies) designed for minimization of blood damage
  - All motor drive and control electronics are outside of the implanted blood pump

• Speed range: 6,000 to 15,000 rpm

• Flow range: 3 – 10 L/min
Pump Flow Principles

• Pump flow is a function of:
  – The speed of the rotor
    \[\uparrow \text{Speed} \rightarrow \uparrow \text{Flow}\]
    \[\downarrow \text{Speed} \rightarrow \downarrow \text{Flow}\]
  – The difference in pressure across the pump
    \[\uparrow \text{Pressure gradient} \rightarrow \downarrow \text{Flow}\]
    \[\downarrow \text{Pressure gradient} \rightarrow \uparrow \text{Flow}\]

At any given speed, increased B/P will decrease flow
Device Parameters

- Device parameters
  - Speed
  - Power
  - Flow
  - PI

- Monitoring
  - No single parameter is a surrogate for monitoring patient’s clinical status
  - Note baseline values
    - Trends
    - Abrupt changes
Pump Speed (RPM)

- Fixed Speed
  - Range: 6,000 - 15,000 rpm
  - Typical range: 8,000 – 10,000 rpm
  - Sensed via motor

- Low Speed Limit
  - Range: 8,000 – 10,000 rpm
  - Typical range: 400 – 800 rpm below fixed speed

- Monitoring
  - Normal:
    - Fixed set speed ±150 rpm
    - Decrease in RPM to low speed limit (PI Event)
  - Failure to maintain fixed speed in absence of PI event indicates pump, percutaneous lead or controller issue
Pump Power

- Measured in watts
- Related to pump speed and flow
- Under normal patient conditions, power should remain within a certain range for a specified speed
  - \( \uparrow \) Speed → \( \uparrow \) Power
  - \( \downarrow \) Speed → \( \downarrow \) Power
- Flow
  - \( \uparrow \) Flow → \( \uparrow \) Power (takes more work to move more blood)
  - \( \downarrow \) Flow → \( \downarrow \) Power (does not compensate for \( \uparrow \) afterload)
- Gradual power changes (hour or days) may signal a thrombus formation
- Abrupt changes need to be evaluated for cause
Flow Estimator Design

- Flow measurement does not use a sensor or flow probe (calculated value)
- Flow range 3 – 10 liters/minute
- Derived from motor power and speed providing an estimate of pump flow
  - ↓ Power → ↓ estimated Flow
  - ↑ Power → ↑ estimated Flow
- For a given speed, pump flow is linearly related to power (over a limited range)
- Flow of less than 2.5lpm is an emergent situation* (check patient for condition)
Pulsatility Index

- The Pulsatility Index (PI) is a measurement of the flow pulse through the pump (coming from the heart)

- During LV filling, increase in pressure causes an increase in pump flow (higher PI indicates better LV function)

- PI should be monitored routinely
  - A significant drop can indicate decrease in circulating blood volume
  - PI range is typically 1-10; a very high value indicates more activity from the native heart—check patient for status

- PI Event—Assumed whenever the per second PI differs from the average PI by more than 45%; reduces the risk of LV collapse
  - Pump speed is automatically reduced to the low speed limit setting to avoid suction then slowly returns to the fixed speed
  - Triggers include—change in volume status, arrhythmias, or a sudden change in power or speed
Percutaneous Lead

Damage to the percutaneous lead may cause the pump to stop

- Has 6 wires that send and receive information
- Exits the body from the right or left abdomen
- Excessive bending or kinking of driveline can cause damage
- Site should be monitored daily for signs of infection
- Gauze over insertion site changed daily
- Driveline anchor changed weekly
# Hazard Alarms

<table>
<thead>
<tr>
<th>Priority</th>
<th>System Controller Screen</th>
<th>Active Symbols</th>
<th>Alarm Means</th>
<th>To Resolve Alarm</th>
</tr>
</thead>
</table>
| **HAZARD** | Low Flow  
Call Hospital Contact  
[Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 03] | ![Heart symbol]  
![Cut-off time stamp: 03] | Pump is off. The pump running symbol is black. | 1. Check if the fixed speed setting is below 8,000 rpm AND the System Controller’s backup battery is not installed. Under these conditions, the pump can only be started from the System Monitor’s Clinical or Settings screen by pressing the Pump Start button. Otherwise, press any button on the System Controller to attempt pump start.  
2. Switch to backup System Controller and attempt to restart pump.  
| **HAZARD** | Connect Driveline  
[Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 02] | ![Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 02] | Driveline is disconnected. The pump running symbol is black. | 1. Immediately reconnect the driveline to System Controller and move the driveline safety tab on the System Controller to the locked position.  
2. If alarm persists after reconnecting the driveline, press any button on the System Controller to attempt pump start. Otherwise, check if the fixed speed setting is below 8,000 rpm AND the System Controller’s backup battery is not installed. Under these conditions, the pump can only be started from the System Monitor’s Clinical or Settings screen by pressing the Pump Start button.  
3. If driveline is connected and alarm persists, replace System Controller with pre-programmed backup System Controller. |
| **HAZARD** | Backup Battery  
[Battery icon]  
[Critical condition symbol]  
[Cut-off time stamp: 01] | ![Battery icon]  
[Critical condition symbol]  
[Cut-off time stamp: 01] | Both power cables are disconnected. | Immediately connect to a working power source (Power Module or two fully-charged HeartMate 14 Volt Lithium-ion batteries). |
| **HAZARD** | Low Flow  
Call Hospital Contact  
[Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 03] | ![Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 03] | Low flow, flow is less than 2.5 lpm | 1. Ensure that the driveline is connected to System Controller.  
2. Ensure that a power source is connected to System Controller.  
| **HAZARD** | Replace Power Immediately  
[Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 02] | ![Heart symbol]  
[Critical condition symbol]  
[Cut-off time stamp: 02] | Low Battery, Power input is extremely low with less than 5 min. remaining | Immediately connect to a working power source (Power Module or two fully-charged HeartMate 14 Volt Lithium-ion batteries). |
### Hazard Alarms

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<thead>
<tr>
<th>System Controller Screen</th>
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</table>
| Low Flow                 | ![Heart](image) | Pump is off. The pump running symbol is black. | 1. Check if the fixed speed setting is below 8,000 rpm AND the System Controller’s backup battery is not installed. Under these conditions, the pump can only be started from the System Monitor’s Clinical or Settings screen by pressing the Pump Start button. Otherwise, press any button on the System Controller to attempt pump start.  
2. Switch to backup System Controller and attempt to restart pump.  
| Call Hospital Contact    | ![Heart](image) | Driveline is disconnected. The pump running symbol is black. | 1. Immediately reconnect the driveline to System Controller and move the driveline safety tab on the System Controller to the locked position.  
2. If alarm persists after reconnecting the driveline, press any button on the System Controller to attempt pump start. Otherwise, check if the fixed speed setting is below 8,000 rpm AND the System Controller’s backup battery is not installed. Under these conditions, the pump can only be started from the System Monitor’s Clinical or Settings screen by pressing the Pump Start button.  
3. If driveline is connected and alarm persists, replace System Controller with pre-programmed backup System Controller. |

**Important!** The pump running symbol is always lit green when the pump is running.
# Hazard Alarms

<table>
<thead>
<tr>
<th>Hazard Description</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backup Battery</strong></td>
<td>Immediately connect to a working power source (Power Module or two fully-charged HeartMate 14 Volt Lithium-Ion batteries).</td>
</tr>
<tr>
<td><strong>Low Flow</strong></td>
<td>1. Ensure that the driveline is connected to System Controller.</td>
</tr>
<tr>
<td></td>
<td>2. Ensure that a power source is connected to System Controller.</td>
</tr>
<tr>
<td><strong>Replace Power</strong></td>
<td>Immediately connect to a working power source (Power Module or two fully-charged HeartMate 14 Volt Lithium-Ion batteries).</td>
</tr>
<tr>
<td><strong>Low Battery</strong></td>
<td>Low battery, power input is extremely low with less than 5 min. remaining</td>
</tr>
</tbody>
</table>

**Important!** The pump running (green) symbol is always lit green when the pump is running.
### Advisory Alarms

<table>
<thead>
<tr>
<th>Priority</th>
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<th>Alarm Means</th>
<th>To Resolve Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Connect Power</strong></td>
<td></td>
<td>One of the two power cables is disconnected</td>
<td>Promptly connect the disconnected power cable to power source (functioning Power Module or two fully-charged HeartMate 14 Volt Lithium-Ion batteries).</td>
</tr>
<tr>
<td></td>
<td><strong>Replace Power</strong></td>
<td></td>
<td>Low Battery, Power input is low with less than 15 min. remaining</td>
<td>Promptly connect to a working or different power source (Power Module or two fully-charged HeartMate 14 Volt Lithium-Ion batteries).</td>
</tr>
<tr>
<td></td>
<td><strong>Low Battery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Replace Controller Controller Fault</strong></td>
<td></td>
<td>System Controller hardware fault</td>
<td>1. Switch to the backup System Controller. 2. Provide patient with a new System Controller.</td>
</tr>
<tr>
<td></td>
<td><strong>Call Hospital Contact Controller Fault</strong></td>
<td></td>
<td>System Controller Backup Battery fault</td>
<td>Replace the 11 Volt Lithium-Ion backup battery. <strong>Note:</strong> If replacing the battery does not resolve the alarm, the System Controller may need replaced, or additional steps may be required. Call Thoratec with questions.</td>
</tr>
<tr>
<td></td>
<td><strong>Low Speed</strong></td>
<td></td>
<td>Low Speed advisory warning</td>
<td>1. Use the System Monitor to check that the fixed speed and low speed limit have been appropriately set. 2. Replace the System Controller. 3. Clinically evaluate the patient.</td>
</tr>
<tr>
<td></td>
<td><strong>Call Hospital Contact</strong></td>
<td></td>
<td>Driveline fault</td>
<td>1. Contact Thoratec to determine best next steps. 2. Use the System Monitor to silence the alarm while awaiting resolution, if needed. <strong>Note:</strong> The alarm must be active in order to access the alarm silence for this situation.</td>
</tr>
<tr>
<td></td>
<td><strong>Call Hospital Contact Driveline Fault</strong></td>
<td></td>
<td>System Controller Backup Battery not installed</td>
<td>1. Install the 11 Volt Lithium-Ion backup battery in the System Controller. 2. Obtain a new backup battery replacement kit. <strong>Note:</strong> If replacing the battery does not resolve the alarm, the System Controller may need replaced, or additional steps may be required. Call Thoratec with questions.</td>
</tr>
<tr>
<td></td>
<td><strong>Controller Clock not set</strong></td>
<td></td>
<td>Controller Clock not set</td>
<td>Use the System Monitor to set the System Controller’s internal clock. <strong>Note:</strong> Be sure the System Monitor clock is correct.</td>
</tr>
</tbody>
</table>

**Important:** The pump running symbol is always lit green when the pump is running.
## Advisory Alarms

<table>
<thead>
<tr>
<th>Action</th>
<th>Description</th>
<th>Action Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connect Power</td>
<td>One of the two power cables is disconnected</td>
<td>Promptly connect the disconnected power cable to power source (functioning Power Module or two fully-charged HeartMate 14 Volt Lithium-ion batteries).</td>
</tr>
<tr>
<td>Replace Power + Low Battery</td>
<td>Low Battery, Power input is low with less than 15 min. remaining</td>
<td>Promptly connect to a working or different power source (Power Module or two fully-charged HeartMate 14 Volt Lithium-ion batteries).</td>
</tr>
<tr>
<td>Replace Controller</td>
<td>System Controller hardware fault</td>
<td>1. Switch to the backup System Controller. 2. Provide patient with a new System Controller.</td>
</tr>
</tbody>
</table>

Important! The pump running symbol is always lit green when the pump is running.
## Advisory Alarms

<table>
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<tr>
<th>Call Hospital Contact</th>
<th>System Controller Backup Battery fault</th>
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<tbody>
<tr>
<td>Low Speed</td>
<td>Low Speed advisory warning</td>
</tr>
<tr>
<td>Driveline Fault</td>
<td>Driveline fault</td>
</tr>
<tr>
<td>System Controller</td>
<td>System Controller Backup Battery not</td>
</tr>
<tr>
<td>Controller Clock</td>
<td>Controller Clock not set</td>
</tr>
</tbody>
</table>

### Call Hospital Contact
- **Backup Battery fault:** Replace the 11 Volt Lithium-Ion backup battery.
  - **Note:** If replacing the battery does not resolve the alarm, the System Controller may need replaced, or additional steps may be required. Call Thoratec with questions.

### Low Speed
- **Low Speed advisory warning:**
  1. Use the System Monitor to check that the fixed speed and low speed limit have been appropriately set.
  2. Replace the System Controller.
  3. Clinically evaluate the patient.

### Driveline Fault
- **Note:** The alarm must be active in order to access the alarm silence for this situation.

### System Controller Backup Battery not installed
- **Note:** If replacing the battery does not resolve the alarm, the System Controller may need replaced, or additional steps may be required. Call Thoratec with questions.

### Controller Clock not set
- **Note:** Be sure the System Monitor clock is correct.

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**Important!** The pump running (図) symbol is always lit green when the pump is running.
HeartMate III
HeartMate III

Features

- Fully Magnetically Levitated
  - 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
**HeartMate 3*: Pulsatility**

**Key Design Feature: Pulsatility (Minimize stasis)**

- The large gaps also enable the rapid speed changes used by our artificial pulse feature without rotor/housing contact.

- Some potential benefits:
  - **Designed to promote washing of the pump**
    - Prevents the formation of zones of recirculation and stasis.
  - **Zero Net Change in Flow**
    - Speed ramps up and down (zero net change)

![Diagram showing rotor speed changes over time](image)

*New for HeartMate 3*
Full MagLev

• Goals
  – Use magnetic fields to create a frictionless and non-contact pump rotor
  – Rotor is levitated utilizing magnets to support all six degrees of freedom, such that the rotor essentially remains fixed except for rotation
  – Create a pump with large secondary flow paths (also known as “gaps”) for reduced shear stress on blood
A Healthy Respect for Blood. What influences Hemocompatibility?

- Designed for Hemocompatibility
  - Minimizes shear stress
  - Minimize stasis
  - Minimize activation of blood components
  - Minimize interactions between the blood and the contacting surfaces
HeartMate 3 Driveline

- Redundant Power, Communication and Ground (Return) Conductors
- System can maintain operation with a minimum of one Power and one Ground conductor
- Pins on Modular cable “live” when connected to Controller
  - Important to keep dry!
HeartMate Components

- 14 V Li-Ion Batteries and clips
- Power Module
- Mobile Power Unit
- Universal Battery Charger
- System Monitor
- Go Gear Wearable's
# Patient’s Daily Journal

|-------------|----------------------------|---------------------|-------------------------------------------|---------------------------------------------|----------------------------------------|-----------------------------------|--------------|-------------------------------|-----------|--------------------------------|----------------------|---------------------------------|---------------|---------------------------------|----------------------|
# Common Medications

<table>
<thead>
<tr>
<th>Medication Classification</th>
<th>Examples</th>
<th>What is it for?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary Vasodilator</td>
<td>Adcira, Sildenafil (Revatio, Viagra)</td>
<td>Decrease the work of the right side of the heart; preserves right heart function</td>
</tr>
<tr>
<td>Beta-Blocker</td>
<td>Anything that ends in “lol”: Coreg Carvedilol, Lopressor (Metoprolol), etc.</td>
<td>Decreases your heart rate or pulse. Heart Failure causes high heart rate/pulse which increases the damage to the heart muscle.</td>
</tr>
<tr>
<td>ACE-Inhibitor</td>
<td>Anything that ends in “pril”: Lisinopril, enalapril, ramipril, etc.</td>
<td>Prevent the blood vessels from constricting or narrowing by blocking an enzyme</td>
</tr>
<tr>
<td>ARB</td>
<td>Anything that ends in “tan”: losartan, valsartan, etc.</td>
<td>Prevents blood vessels from constricting or narrowing by blocking an enzyme</td>
</tr>
<tr>
<td>Diuretics</td>
<td>Lasix, Bumex, Diuril, Hctz, Spironolactone, etc</td>
<td>Removes excess fluid/water through urine; also removes potassium w/ the water excretion</td>
</tr>
<tr>
<td>Potassium CL</td>
<td>K-Dur, KCl, Klor-Con, K-tab, Micro-K, etc.</td>
<td>Replaces Potassium lost due to diuretics</td>
</tr>
<tr>
<td>Anti-Arrhythmics</td>
<td>Amiodarone, Digoxin</td>
<td>Prevention of abnormal heart electrical rhythms such as Atrial Fibrillation (A. fib), Ventricular Fibrillation (V. fib), Ventricular Tachycardia (V. tach)</td>
</tr>
<tr>
<td>Anti-Platlet</td>
<td>Aspirin, Plavix</td>
<td>Prevention of platelet build-up/aggregation on the LVAD pump</td>
</tr>
<tr>
<td>Anti-Coagulant</td>
<td>Warfarin</td>
<td>Prevention of the clots forming on the LVAD pump</td>
</tr>
<tr>
<td>Anti-Gout</td>
<td>Allopurinol, probenecid</td>
<td>Blocks production of uric acid by blocking the action of xanthine oxidase</td>
</tr>
<tr>
<td>Anti-Diabetic Agents</td>
<td>Insulin, metformin, glipizide, etc.</td>
<td>Control Blood Glucose level</td>
</tr>
</tbody>
</table>
## Anticoagulant protocol

<table>
<thead>
<tr>
<th>INR Ranges</th>
<th>Reasons for Anticoagulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5-2.0 (if only 1 reason to be on blood thinner)</td>
<td>LVAD</td>
</tr>
<tr>
<td>2.0-3.5 (if 2 reasons for being on blood thinner)</td>
<td>Mechanical Mitral or Aortic valve</td>
</tr>
<tr>
<td>2.5-3.5 (if 3 or more reasons for being on blood thinner)</td>
<td>Atrial or Ventricular Fibrillation</td>
</tr>
<tr>
<td></td>
<td>DVT/PE</td>
</tr>
<tr>
<td></td>
<td>Stroke</td>
</tr>
</tbody>
</table>
Patient Assessment

• Vital signs, fluid status, chest tube output
• Heart rate & rhythm
• Assess peripheral circulation for adequate perfusion
• Neuro checks
• ECHO
• 12 lead EKG
• Lab work
  – Chemistry profile
  – Liver functions
  – PTT, PT, INR
  – CBC
Device Assessment

- Pump function
  - Pump Parameters
    - Speed
    - Power
    - Flow estimation
    - Pulsatility index (PI)
  - System controller settings, alarm status
  - Review system controller event recorder log file

- Auscultate over pump
- Modular cable connection and driveline connection to system controller and locked in place
- Exit site status, immobilization of driveline
- Backup system controller available & programmed
Vital Sign Monitoring

• Blood Pressure
  – Manual Cuff and Doppler/stethoscope are usually required
  – Use manual cuff, pump to ~120-140mmHg. Slowly deflate cuff. First sound you hear is patients blood pressure or Return to Flow (RTF)
  – Target RTF=60-80.

• Pulse oximetry
  – if obtainable, may be unreliable due to the diminished pulse pressure

• ECG is unaffected by implantation
  – Many LVAD patients have implanted pacemaker/ICD
Causes of Readmission

• 6 month readmission rates for LVAD patients are ~45%

• Top Reasons:
  – Bleeding (GI)
  – Infection
  – Cardiac (Arrhythmias, Stroke)
  – Device Alarms
  – Abdominal Issues
Goals for Emergency Care

- Complete assessment and exam
- LVAD assessment
- LVAD Problem or Other

- If LVAD issue-
  - Interventions to aid with pump flow
    - Restarting the pump
    - Fluid replacement
    - BP Control

- If other- treat as indicated
Preload and Afterload Considerations

Preload driven
• Volume
• Hydration

Afterload sensitive
• Resistance
• Blood pressure
Cardiac Arrest

External chest compressions

Potential Risks

- Damage to the outflow graft or dislodgement of the LVAD inflow tract.

- Clinical judgment should be used

Direct cardiac massage

- May be effect in patients prior to mediastinal healing
24 Hour Support

LVAD/Transplant Coordinator

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