



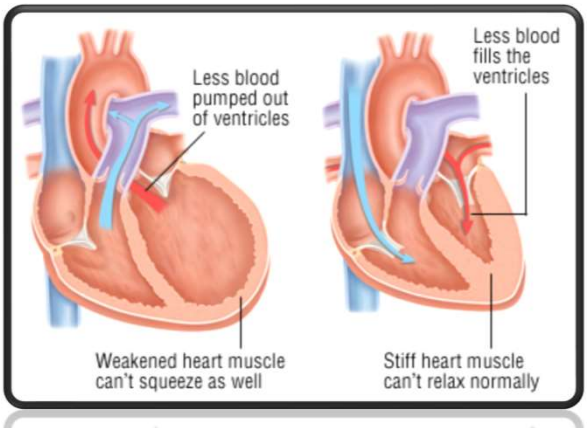
LVAD Functionality

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In this lesson, we will go over how an LVAD works using the HeartMate II as the example. As you go through the slides, think about how these concepts may apply to other ventricular assist devices you may encounter.

LVAD Candidates

- Bridge-to-Transplant (BTT)
- Destination Therapy (DT)
- Bridge to the Decision
- Bridge-to-Recovery (BTR)



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LVADs are life-saving devices for patients with end-stage cardiac disease. They offer an intermediate to a long-term solution for those with heart failure. They are most commonly used as bridge-to-cardiac transplantation or as destination therapy. The structure and function of these devices have evolved with time, and further developments and advances in this field should help to further reduce the mortality rates from advanced heart failure.

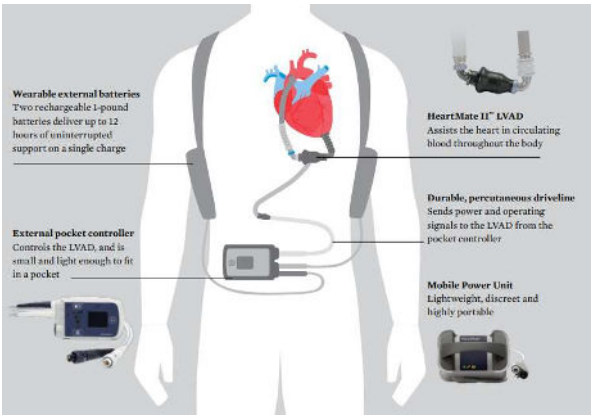
The HeartMate II, the HeartMate III, and the HeartWare, are three current and more popular FDA-approved assist devices.

As we discussed previously, Ventricular assist devices are used as therapies for the four following conditions.

1. Bridge-to-cardiac transplantation in Class 3B and Class IV heart failure patients.
2. Destination therapy is used in patients who are ineligible for cardiac transplantation.
3. Bridge-to-the-Decision LVADs have been used as a temporary measure in patients with end-organ dysfunction due to heart failure.
4. Bridge-to-Recovery provides temporary ventricular support in some Heart Failure patients, to improve myocardial function and promote recovery.

LVAD System Overview

- Surgically implanted into the Left Ventricle
- Outflow to aorta
- Driveline or Percutaneous tube
- System Controller
- Batteries



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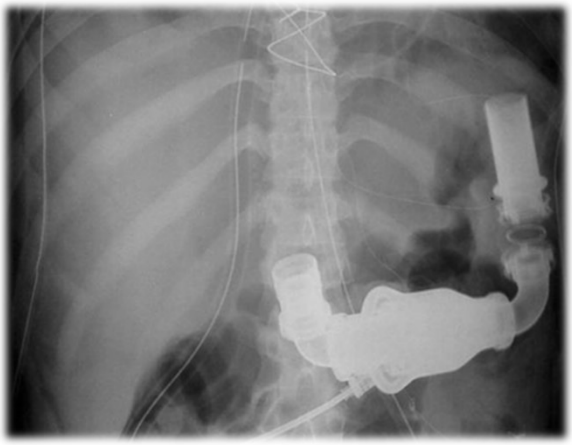
LVADs are implanted by a trained cardiac surgeon. There are components placed inside and outside the body to support the heart. These components are:

1. The HEART PUMP: Connected to the left side of your heart and moves blood from the heart to the rest of the body.
2. Power Devices: Include an external, replaceable, and rechargeable battery pack, powering the device and providing up to 12 hours of uninterrupted use. In addition, a MOBILE POWER UNIT can be plugged into an electrical socket to provide power while the individual is indoors, at rest, or asleep.
3. A DRIVELINE or percutaneous tube that Transfers power and information between the controller and the LVAD. This component is partially outside of the body. The driveline is tunneled from the device to the skin and exits through the abdominal wall. It forms the connection between the surgically implanted VAD and the controller.
4. The CONTROLLER Powers and checks the heart pump and driveline. The HeartMate II controller weighs approximately one pound and fits into a front pocket. The external controller serves to convey pump function parameters to the Pump, display alarms, and provide a way to manage the device settings. In the HeartMate II, it includes 15 minutes of emergency backup power.

Note that The generation 3 VADs (HeartMate III and HeartWare) are located in the thoracic cavity. And the Generation 2 devices are located in the intra-abdominal cavity.

Anatomic Placement

- HeartMate II: Placement in the intra-abdominal cavity
- HeartMate III and Heartware: Placement in the thoracic cavity

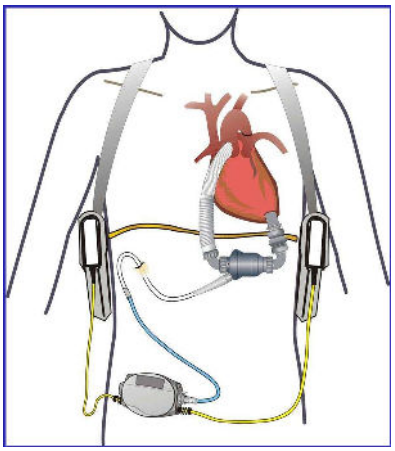


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The X-Ray in this slide shows the anatomical placement of an LVAD device. In this case, a HeartMate II is shown in the intra-abdominal cavity. When you watch the videos for the HeartMate III and the HeartWare, observe their placement in the thoracic cavity.

Important Considerations

- Axial (continuous) flow:
  - ✓ No pulse
  - ✓ No blood pressure
- One moving part: Rotor
  - ✓ Blood lubricated bearings
  - ✓ Small: 400 gm, 125 cc
  - ✓ Flows: 3 – 10 lpm
- Quiet
- Anticoagulation Meds required. Typically a combination of warfarin and aspirin
  - ✓ Goal INR 2-3
- Lower infection rates due to a smaller percutaneous driveline tube than Gen 1



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The HeartMate II is an axial-flow, rotary ventricular assist system that generates flows up to 10 liters per minute. One end of the LVAD is attached to the apex of the left ventricle; the other end of the device connects to the ascending aorta. The LVAD diverts blood from the weakened left ventricle and propels it to the aorta.

The rotor is the only moving part of these devices, making them more durable than first-generation units. These devices are smaller and easier to implant. They are quieter and also associated with lower rates of driveline infection.

Note that the LVAD Patient will not have a pulse or blood pressure.

Also, Anticoagulation medicine is required for these patients, which may include Aspirin and/or Warfrin to achieve an INR between 2 and 3.

Key Components

- HeartMate II offers small size, applicability to more patients
- The entire axial-flow pump housing that contains the rotor responsible for moving the blood through the device is about the size of a D battery

Pump Housing



Rotor

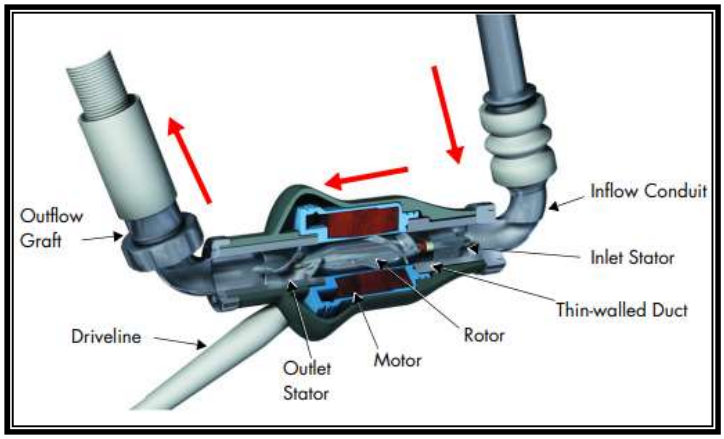


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The Heartmate II rotor is enclosed in the LVAD Pump housing. It is lubricated by the patient's blood, hence eliminating invasive maintenance and enabling a long device life before replacement is needed.

Pump Rotor and Stators

- Blood flows from the right to the left
- Begins at the inflow conduit, into the stator
- Lubricates while flowing
- Rotor propels blood to outflow bearings and stator, then to aorta
- Curvature minimizes chances of blood coagulation



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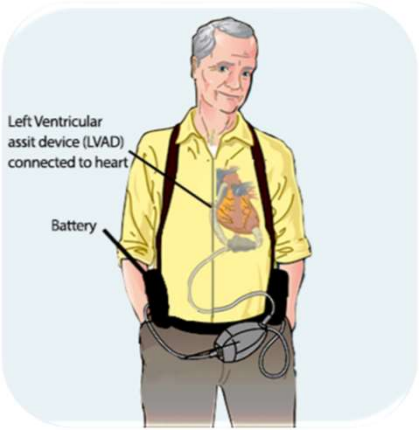
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The blood flows in this diagram from the right to the left, beginning at the inflow conduit into the stator. It Lubricates while flowing into the inflow bearings.
The rotor then propels the blood to the outflow bearings and stator, and then on to the aorta.
The curvature of the rotor is designed to minimize the chance for blood coagulation.

Patient Scenario

A 66 year old male called and stated he fell and hit his head on the bathroom counter. He was instructed to call 911 by the VAD team. What is the first thing you do?

- Neuro exam?
- What are his pump parameters?
- Patient and caregiver should know what their normal pump parameters are
- If flows are low, it may be beneficial to give fluids (slowly)
- What is his MAP?
- Transfer to local hospital for stat CT of the head and labs



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So the purpose of this lesson is to prepare you for real-world scenarios. Let's pause to think about the following:

A 66-year-old male called and stated he fell and hit his head on the bathroom counter. He was instructed to call nine-one-one by the VAD team. What is the first thing you do?
Is it a Neuro exam?
What are his pump parameters?
Remember, patients and caregivers should know what their normal pump parameters are.
If the flows are low, is it beneficial to give fluids?
What is his Mean Arterial Pressure?
Should you transfer to a local hospital for a stat CT of the head and labs?
I suggest you engage in the forum or discuss with your instructor your thoughts.
More on this later in another lesson.

System Controller – Controller + Back-up Controller

- System Controller powers and checks heart pump, driveline
- LVAD controllers weigh approximately one pound and fit into a front pocket
- External controller conveys pump function parameters to the pump and display alarm
- Includes 15 minutes emergency backup power in HeartMate II & III



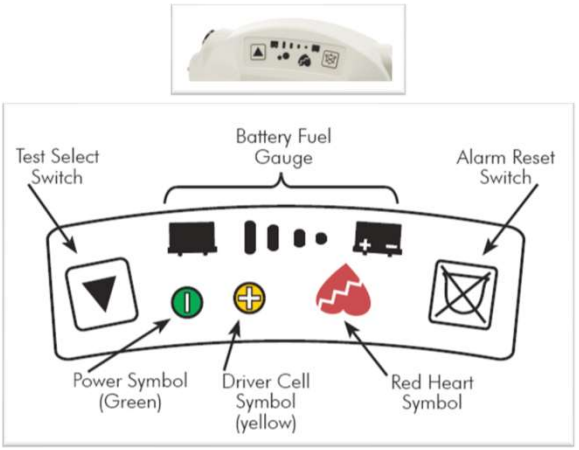


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Now, back to the mechanics of the LVAD devices. Again, the System Controller powers and checks the heart pump and driveline.
The LVAD controllers generally weigh approximately one pound and fit into a front pocket. The external controller serves to convey pump function parameters to the Pump and display alarms. It also provides a way to manage device settings. In the HeartMate II & III, it includes 15 minutes of emergency backup power.

Face of System Controller

- A small computer that manages and monitors system operation
- Uses lights, sounds, and on-screen messages to communicate with users
- Informs operating status and alarm conditions
- Driveline passing through patient's abdomen connects implanted pump to System Controller



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The System Controller is a small computer that manages and monitors system operation. The System Controller uses lights, sounds, and on-screen messages to communicate with users about operating status and alarm conditions. A driveline, which passes through the patient's abdomen, connects the implanted pump to the System Controller.

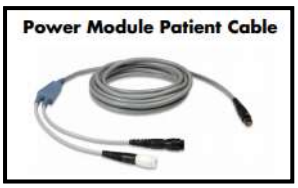
This diagram shows the switches and gauges for the HeartMate II older unit. We will discuss each one in detail during the next lesson.

Note that the switches, gauges, and controls will be similar, but different on the HeartMate III and HeartWare devices.

Power Module

- Supplies main power to LVAD
- Provides 30 minutes of backup power
- Repeats alarms generated by the System Controller
- Serves as the electrical interface between the System Controller and the Display Module





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The power module supplies the main power to the LVAD. It also provides 30 minutes of backup power. In addition, it Repeats alarms generated by the System Controller, serving as the electrical interface between the System Controller and a separate clinical Display Module

The Power Module plugs into an AC outlet. It is also used in the clinical setting when the patient requires monitoring using the System Monitor. This is just one reason why you need to bring all the components of the LVAD when you transport.

The System Controller and the Power Module are connected through the Power Module patient cable.

Battery Charger

- Calibrates, charges and tests HeartMate Lithium-Ion batteries
- For HeartMate II and III:
  - ✓ Charges up to four batteries in four hours or less
  - ✓ Monitor need for calibration and calibrates individual 14-volt batteries
  - ✓ Performs diagnostic testing on up to four batteries at a time



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The Battery Charger calibrates, charges, and tests the HeartMate Lithium-Ion batteries that are used to power the system during battery-powered operation. For the HeartMate II and III devices, the Battery Charger will:

- Charge up to four batteries in four hours or less.
- Monitor the need for calibration, and calibrate individual 14-volt batteries.
- Perform diagnostic testing on up to four batteries at a time.

The batteries are used in conjunction with the Mobile Power Unit. It is for home or clinical use when the patient does not require monitoring using the System Monitor.

BATTERIES

- 14v Li-Ion
- 6 to 10 hours of support
  - ✓ *Patients report up to 15 hours of battery power
- Up to 4-hour recharge for fully discharged battery
- 3 years or 360 charges





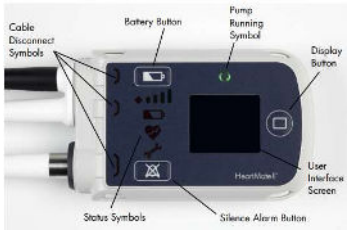
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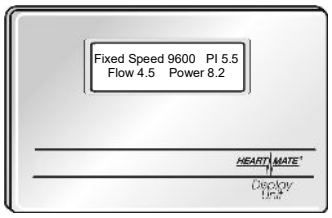
For the HeartMate II and III units, two Lithium-Ion batteries are used to power the system during battery-powered operation. Batteries are used in pairs and are inserted into a 14 Volt battery clip. When fully charged, a pair of HeartMate 14 Volt Lithium-Ion batteries can power the system for up to 10–12 hours, depending on the activity level of the patient.

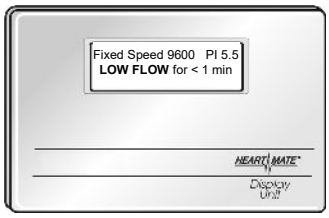
Display Module – Different Models

- Pump Mode
  - ✓ Fixed
  - ✓ Power Saver
- Pump Speed (rpm)
- Pulse Index
- Estimated Flow (lpm)
  - ✓ Too low "---"
  - ✓ Too high "+++"
- Power (watts)
- Alarm Conditions
- Highest priority displayed









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So, no matter what model unit or version the patient has, an LVAD has some type of interface to communicate with the user or caregiver.
There is also a System Monitor providing clinicians with the ability to monitor a patient's HeartMate system. It enables setting system parameters such as pump speed, assessing and tracking alarm conditions, as well as viewing and saving performance data.
During your assessment, it's imperative to get the phone number to call the LVAD manufacturer support or Clinical support if you need assistance.
You will at minimum, need to be able to determine if the unit is working properly, you may have to reset the unit, evaluate the power status, assess the display parameter readouts, and understand warning and alarm conditions.
We will address alarm conditions in the next lesson.

EMERGENCY POWER PACK (EPP)

- Single use battery pack in a plastic carrying case with a shoulder strap
- Provides battery power in the event of extended power outage
- Approximately 12 hours of support
- Must be replaced if used for a period exceeding three hours



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The LVAD also has a single-use battery pack, in a plastic carrying case with a shoulder strap. It provides battery power in the event of an extended power outage, with approximately 12 hours of support. It must be replaced if used for a period exceeding three hours.

That's the end of this lesson. Be aware that there are multiple LVADs you may encounter, with multiple versions and releases. Make sure you get the manufacturer or clinical contact information you may need right away when assessing the patient. We will discuss LVAD alarms in the next lesson.

Good studying.