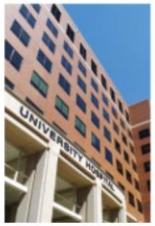
VAD Awareness
Emergency Department Physicians

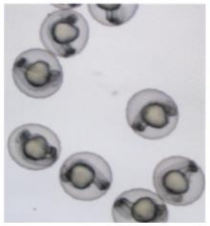
Department of Mechanical Circulatory Support

UAB MEDICINE










Objectives

Identify indications for use of mechanical circulatory support

Discuss the management of the patient with a durable ventricular assist device such as Heartmate II, HeartMate 3, or Heartware HVAD device

Discuss the physical assessment of the VAD patient and VAD parameters

Discuss emergency management of the VAD patient

Discuss UAB specific safety measures in caring for a VAD patient

UAB has been VAD Certified since 2008

MCSD Program achieved a Disease Specific Care (DSC) Certification for Destination Therapy in December 2008.

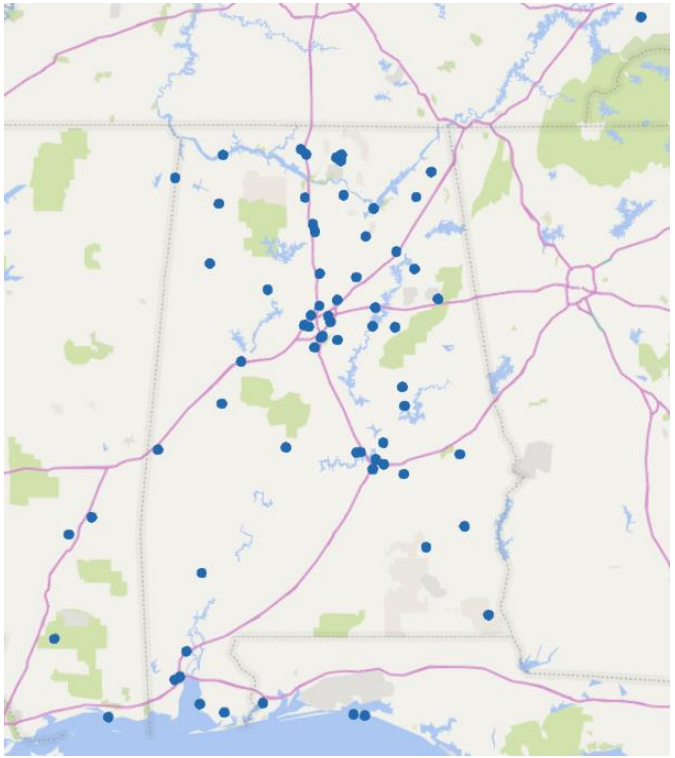
- UAB's most recent Joint Commission certification review was completed in August 2021.
  - One finding: ED MD, Anesthesia MD and care manager did not have recent VAD education but provided care for a VAD patient.

UAB is the only center in the state of Alabama offering adult cardiac transplant and mechanical circulatory support services

Where our 105 UAB VAD patients live…

- Alabama
- Tennessee
- Mississippi
- Florida
- Georgia

UAB is the only VAD center in Alabama, however there are 5 centers in GA, 1 in MS, and 4 in TN. Many additional patients travel through our state to enjoy our beaches. Any of patients may present to the emergency room.



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INTRODUCTION

- **Left ventricular assist devices (VADs) are increasingly used in the management of patients with end stage heart failure.**
- **The devices are continuous-flow pumps.**
- **Specific features of these devices include:**
  - Pulseless blood flow
  - Need for anticoagulation
  - Presence of an external drive line connecting to an electrical power source
  - Bleeding tendencies with high rate of developing arteriovenous malformations in mucosal surfaces
  - Acquired von Willebrand's disease

CONTINUOUS-FLOW DEVICES

- **These non-pulsatile devices are placed in the thoracic cavity with blood flowing through an inflow cannula in the apex of the left ventricle (LV) to the pump, and returning back through an outflow cannula in the ascending aorta**
- **Continuous-flow devices unload the failing ventricle through the action of an impeller that rotates at high speeds.**
    - Impeller- connected by a small driveline to a controller that is typically externalized to the right or left upper abdomen.
    - The controller is connected to an external power source. Some controllers also have a short term use internal battery for safety.

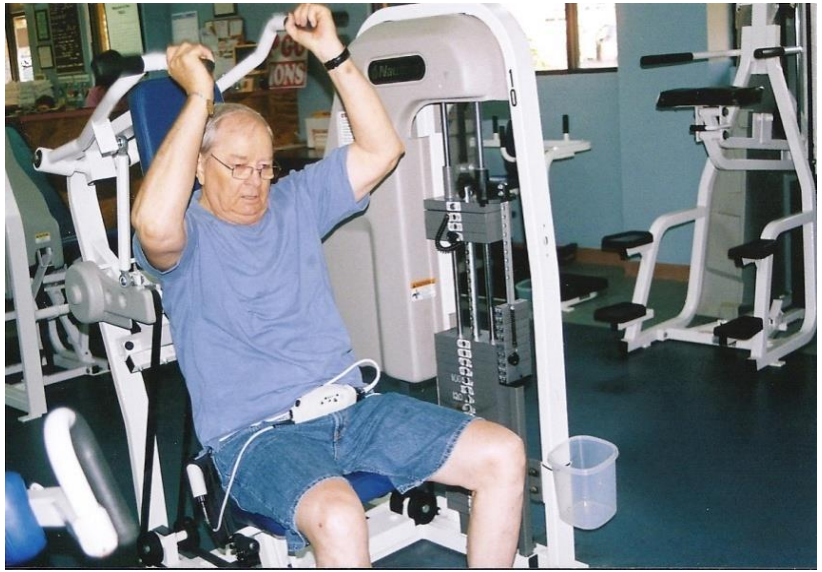
VAD Types

- **Second generation devices – The HeartMate II VAD system with axial flow no longer implanted as a primary device, but few patients remain on support**
- **Third-generation devices – The Medtronic (HeartWare) HVAD, and the Abbott HeartMate 3 are third-generation centrifugal flow devices.**
    - As of June 2021 the Medtronic HVAD is no longer manufactured and therefore no longer implanted. However, there are thousands of patients with ongoing support globally.
- **VAD improved designs ensure long durability, optimization of blood flow through the device to minimize risk of thrombus formation and hemolysis, compact size, and simplified surgical implantation.**

Living with a VAD:

A VAD does not cure Heart Failure, but assists the affected ventricle. With timely intervention, most NYHA Class IV patients treated with MCS improve to Class I or II*

LVAD patients are active in the community, traveling, returning to work, and yes, some even exercise.



(approximately 1 year after VAD implant)

Identifying the VAD Patient and Safety Considerations

PRE-Emergency Room Notification

- In most circumstances, the patient or caregiver will notify the VAD Coordinator on call 24/7 of the emergency situation. The VAD Coordinator in turn, notifies the Advanced Heart Failure Attending and the ED Charge Nurse of the emergency situation, pending arrival time and specific VAD related interventions requested by the VAD team.
- Discussion and collaboration with knowledgeable clinicians having training in mechanical circulatory support (eg, a specialized VAD team) is extremely important. This facilitates awareness of potential patient-specific and device-specific problems and avoidance of pitfalls that may arise in the emergency treatment as well as coordination of care in the post ED visit plan.

Levels of competency:

VAD Aware: basic understanding of VADs and general safety; not proficient in managing equipment; 24/7 caregiver still required.

- **At the end of this educational module, you will be VAD Aware – no badge required**

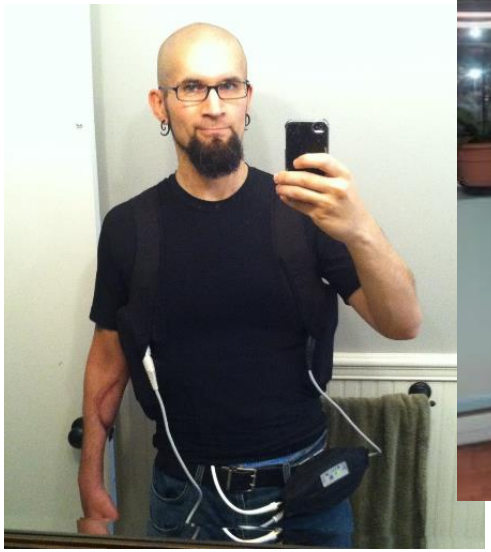
VAD Competent: 4 hour class and annual skills competency; taught how to care for VAD patient and perform emergency procedures (RNs on HLTICU, CICU, ICVU, ER, CP Rehab, CCT, and ANMs/Shift Leads in UED)

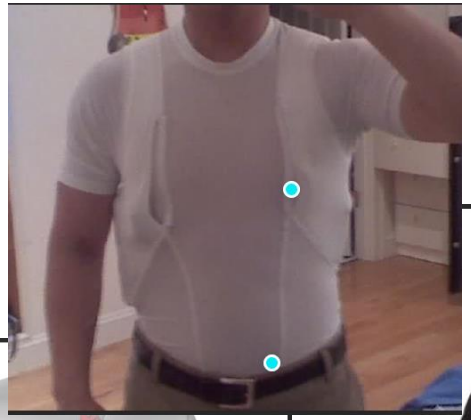
VAD Provider: general management of VAD patients (NPs & Fellows)

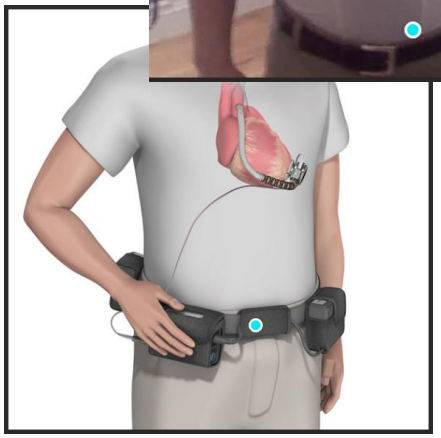
VAD Expert: additional advanced training and can support procedures with sedation, troubleshoot, or assist with implant (VAD specialists, VAD Coordinators, Perfusionist or Advanced Heart Failure Cardiologist or Surgeon)

***Color changes with each competency season

Outfits of a VAD Patient:







ALWAYS be careful when removing or cutting clothes with someone who has, or possibly has, a VAD. Do not cut/disconnect/damage the driveline!!

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VAD Patients Always Need with Them:

1. Trained Caregiver OR VAD Competent Staff Member

A trained giver is required at home 24/7 and should remain with them in the ED

2. Backup Equipment: (Backup controller and 2 batteries)

Brought from home with patient and placed in a new bag in the ED

Key VAD Safety Points:

Do NOT disconnect/reconnect cables or batteries from the VAD, unless you have been trained

Be mindful of VAD equipment if assisting moving the patient- do not let the VAD equipment fall or get pulled

Ensure Backup Equipment is present.

Take the VAD Emergency Backup Equipment with the patient wherever they go! (i.e. VAD backup equipment needs to be in the same room as the patient)

Ensure either the trained caregiver or VAD Competent staff member is with or near the patient at ALL times

NO MRI, NO wanding or metal detectors on patient or the VAD Equipment
(magnetic interference may cause the electronic components to malfunction or fail)

LVAD Patient Assessment

Vital Sign Assessment

- Patients who are hemodynamically stable with an LVAD should be evaluated in the same manner as other patients, with the exception that the LVAD team or coordinator should be consulted.
- Heart rate is dependent on the patient's rate and rhythm, though many patients with an LVAD may have a pacemaker or implantable cardioverter defibrillator(ICD). Heart sounds are obscured by the “hum” of the VAD therefore rhythm and rate should be assessed with ECG only.
- Blood pressure measurement depends on whether a palpable pulse is present. A continuous flow LVAD will not typically produce a palpable pulse on its own, but patients may have enough ventricular function to produce pulsatile flow and a pulse. If a palpable pulse is present then a NIBP may be used. The standard method is to obtain a Doppler measurement and the first sound is considered the MAP, not systole. If neither of these methods provides a measurement then an arterial catheter should be inserted. Target MAP is 70-85 mmHg.
- Pulse oximetry may be difficult to obtain in either a palpable or non-palpable pulse patient and may be unreliable if a measurement is displayed. A low reading commonly reflects low pulsatility.

Pump Function Monitoring

VADs provide continuous displays of pump parameters: **speed** (revolutions per minute [RPM]), **flow** (L/minute), **power** (watts [W]), and **pulsatility index** (PI)

“Normal” is specific to the patient. The patient should be able to tell you where their “numbers” normally run. **Parameters or “numbers” outside their usual trend requires further investigation.**

- **Pump speed** – Pump speed is measured in RPM, and is adjusted with echocardiography to allow adequate left ventricular (LV) filling without development of suction (excessive emptying) with some aortic valve opening and no more than mild mitral regurgitation. *This is the only parameter that can be adjusted*.

- **Pump flow** – Pump flow is measured in L/minute, and is dependent upon the pump speed setting and the pressure gradient across the pump (ie, preload and afterload). Pump flows are calculated from the pump speed and power use, with higher pump speeds and power resulting in higher displayed flows. However, these *flows are only estimates and are not measured* by a flow sensor.

Pump Function Monitoring

- **Pump power** – Pump power is measured in watts (W). Generally, there is a linear relationship between pump power and pump flow.
  - Increases in LV preload and high pump speed settings increase pump flow and increase power consumption.
  - Reductions in power consumption are typically due to reduced preload or reduced pump speed, but may occur with inflow cannula thrombosis
  - The presence of aortic insufficiency also necessitates increased power consumption to generate increased pump flow.
  - **An abrupt increase in power output may indicate pump thrombosis or malfunction.**

- **Pulsatility index** – The PI is a dimensionless measure of the extent of LV pulsatility. The pulsatility index is inversely related to the amount of assistance provided by the pump. A low pulsatility index typically indicates either low intravascular volume or minimal native cardiac function. It is affected by LV preload, afterload, contractility, heart rate, and rhythm, as well as by pump speed.

LVAD Specific Assessment

Issues specific for the implanted device should be noted. These include the type of device, implantation date, pump speed, pump flow, pump power, and pulsatility index. Normal pump parameters are provided in the table below.

Operating parameters for continuous flow left ventricular assist devices

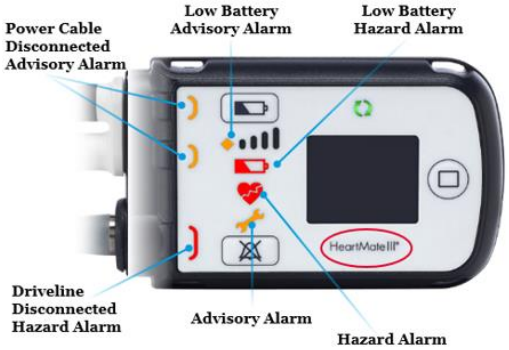
LVAD trade name (rotor design)	Pump speed (RPM) Usual clinical range (full range)	Pump flow (L/minute)	Pulsatility index (flow pulsatility)	Pump power (W)
HeartMate III (centrifugal)	5000 to 6000 (3000 to 9000)	4 to 6	3.5 to 5.5	4.5 to 6.5
HeartWare HVAD System (centrifugal)	2800 to 3200 (1800 to 4000)	4 to 6	2 to 4	3 to 7
HeartMate II (axial)	8000 to 10,000 (6000 to 15,000)	4 to 7	5 to 8	5 to 8

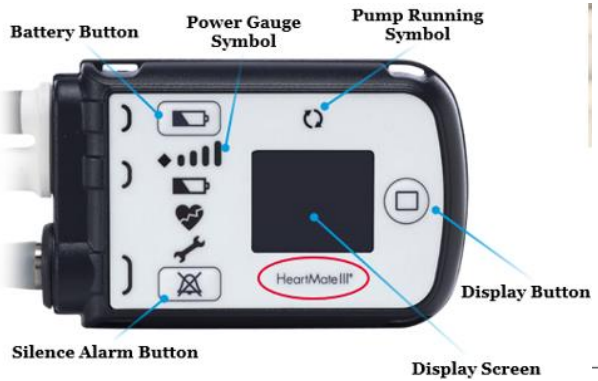
LVAD: left ventricular assist device; RPM: revolutions per minute; W: watts.

The location of the externalized driveline on the abdominal wall is also noted. Previous history of difficulties with VAD function, any VAD-related complications (eg, thromboembolism, infection, mucosal bleeding), and adequacy of device function for the individual patient's current clinical status should be noted.

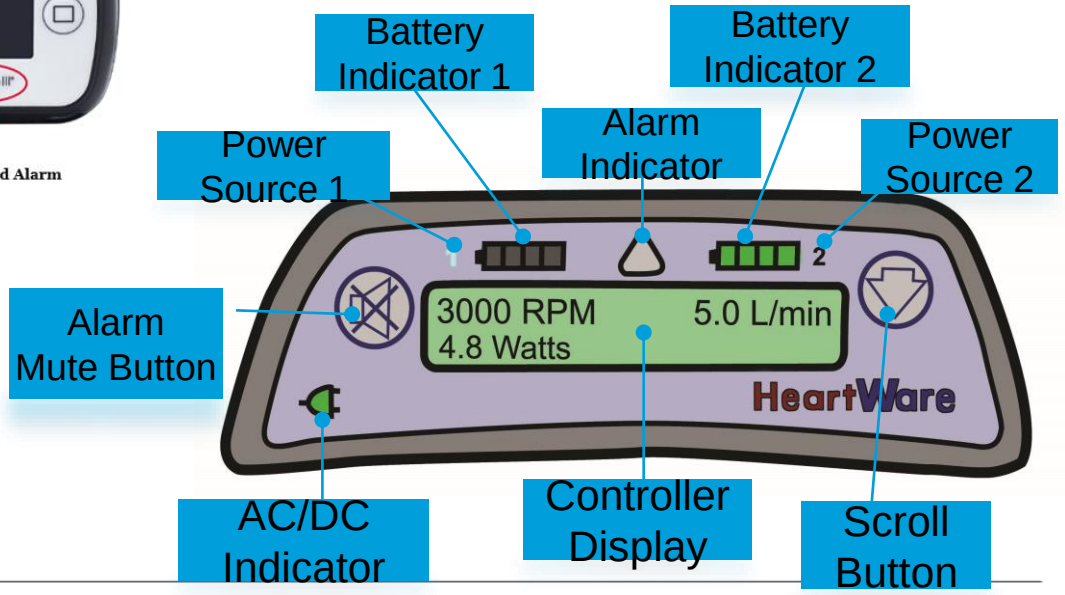
VAD Parameters/Alarms Found on Patient's VAD Controller

HeartMate II or 3 Controller





Heartware HVAD Controller



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Differential Diagnosis

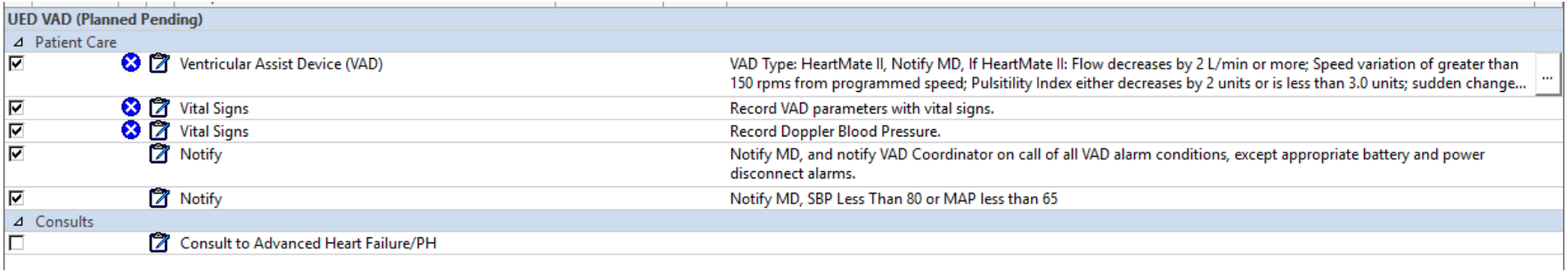
Most cardiovascular clinical issues with HVAD patients can be grouped in four distinct categories based on waveforms characteristics.

- **Low Flow/ Low Pulsatility**
  - Arrhythmia, Hypovolemia, Tamponade, Inflow Obstruction, Outflow graft obstruction, RV failure
- **Low Flow/ High Pulsatility**
  - Hypertension, RPM too low, Continuous suction
- **High Flow / Low Pulsatility**
  - AI, Thrombus, Hypotension/vasodilation
- **High Flow/ High Pulsatility**
  - Hypervolemia, LV recovery

Placing Orders in the ED

Initiate the UED VAD Powerplan:

Enter device type & speed (pt can assist with telling you what is programmed)



UED VAD (Planned Pending)		
⊿ Patient Care		
☑	Ventricular Assist Device (VAD)	VAD Type: HeartMate II, Notify MD, If HeartMate II: Flow decreases by 2 L/min or more; Speed variation of greater than 150 rpms from programmed speed; Pulsitility Index either decreases by 2 units or is less than 3.0 units; sudden change...
☑	Vital Signs	Record VAD parameters with vital signs.
☑	Vital Signs	Record Doppler Blood Pressure.
☑	Notify	Notify MD, and notify VAD Coordinator on call of all VAD alarm conditions, except appropriate battery and power disconnect alarms.
☑	Notify	Notify MD, SBP Less Than 80 or MAP less than 65
⊿ Consults		
☐	Consult to Advanced Heart Failure/PH	

Additional typical VAD orders include:

CXR and ECG

Labs: CMP, CBC w/diff, PT/INR, LDH, BMP, UA

If suspected thrombus include: plasma free Hgb, haptoglobin

Common Complications

Common VAD Complications

Bleeding

Infection

Thrombosis

Stroke

Recurrent CHF

RV failure

Renal failure

Aortic insufficiency

Hypertension

Intracranial bleed

arrhythmia

- LVAD patients will likely present to the ED with increasing frequency. Approximately half of patients with a newly placed LVAD present to the ED within the first month after implantation, and patients present on average 7 times to the ED within the first year postimplantation

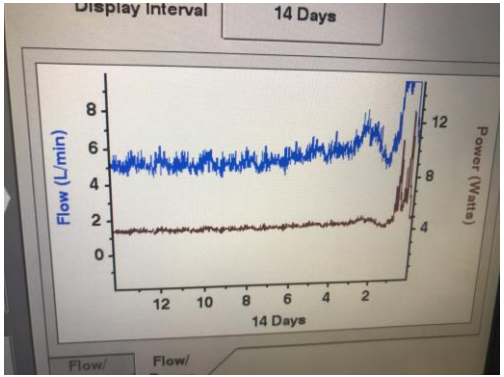
- Bleeding, infection/sepsis, actual or suspected pump thrombus and stroke are the leading causes of ED visits at UABH.

Actual or Suspected Pump Thrombus

Possible presentation:

- VAD alarms
  - -high power, low flow, pump stops
- Abnormal pump parameters:
  - -high power, high flows or
  - -power and flow trending in opposite directions
- Hemolysis
  - -Tea colored urine
  - -LHD 1.5-2 X normal
  - -Haptoglobin
- **Pump at risk of sudden stoppage**

Intermittent rise and fall in flow and power may represent an intermittent thrombus obstruction



Flow- 10.2
Power- 9.8
Typical presentation with both power and flow elevated suddenly.

TABLE 1. Possible clinical contributors to device thrombogenesis[7]

Surgical
Inflow cannula
Malapposition
Angulation
Pump pocket depth (can affect inflow cannula apposition and/or angulation)
Device management
Anticoagulation
Absent or shortened heparin bridge
Inadequate INR target
Too little time within therapeutic INR range
Antiplatelet
Insufficient ASA dosing
Bleeding
Destabilizes anticoagulation/antiplatelet therapy consistency
Thrombus detection
Biomarkers (eg, LDH and haptoglobin)
Insensitive
Actionable thresholds not standardized
Power spikes (unclear link to clotting)

INR, International normalized ratio; *ASA*, acetylsalicylic acid; *LDH*, lactate dehydrogenase.

Risk Factors for pump thrombosis

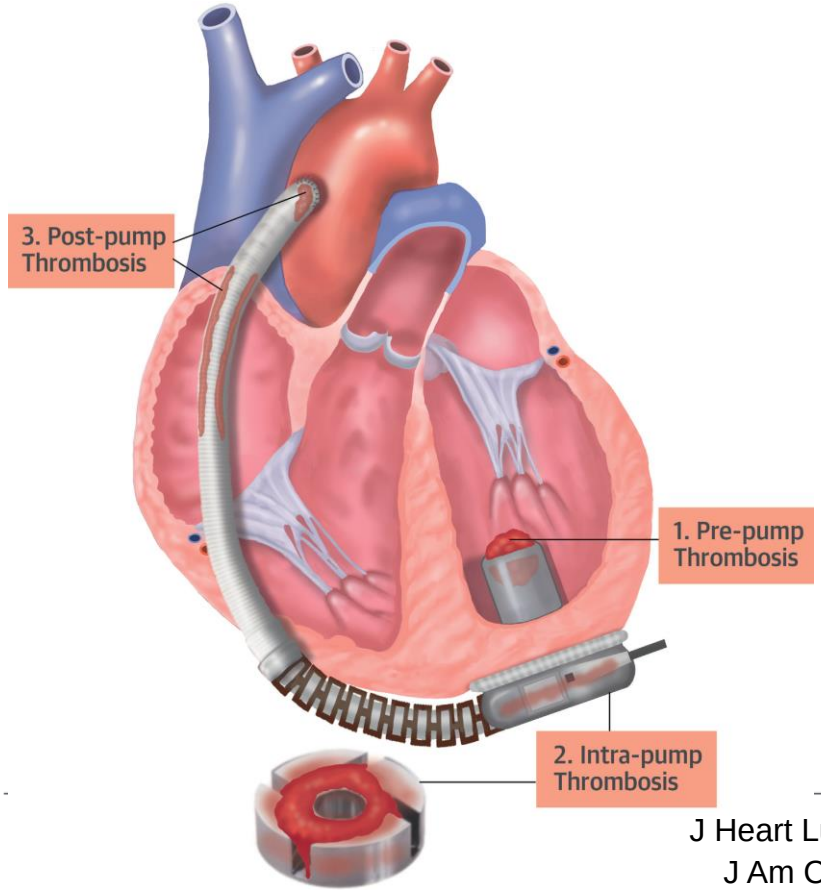
- Hypertension
- Infection
- Low VAD flows
- Missed anticoagulation
- DM2
- A fib

Patient management is important for Success!

Early detection and treatment

2015 Mar;149(3):667-73

LVAD device thrombosis: Diagnosis



Event which the pump or its conduits contain a thrombus that could lead to circulatory failure

Inflow cannula, Pump itself or Outflow Graft

Treatment:

- In collaboration with the VAD team, consider heparin infusion.
- Support HF symptoms including inotropes or vasoactive agents
- VAD team member at bedside in case of pump stoppage
- NPO in case of emergent surgical intervention
- Type and cross for PRBCs for OR

J Heart Lung Transplant 2015;34:1535–1541
J Am Coll Cardiol. 2016;67(23):2758–68.

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Bleeding and VADs

Patients are on lifelong anticoagulation with goal INR of 2.0–3.0 as well as aspirin

Acquired von willibrand factor deficiency due to high shear stress associated with LVAD circulation

Most common source is mucosal surfaces

-GI tract

-Nasopgharyngeal

15-30% of VAD patients develop significant GI bleeds

33-50% of GI bleed are due to AV malformations

- Throughout GI tract, most commonly in small bowel
- Due to the continuous device flow and decreased pulse pressure

Management of Bleeding

Resuscitation of patients with significant hemorrhage with LVAD includes product replacement and reversal agent administration. However, reversing anticoagulation should be weighed with the risk of thrombotic complications, and consultation with the LVAD specialist is recommended.

Vit K, FFP and prothrombin complex concentrates can be considered

Significant transfusion can also increase afterload and exacerbate underlying heart failure. However, hemodynamically unstable patients due to bleeding require resuscitation with blood products.

Management of Stroke

Stroke is also associated with a 4–18 fold increase in mortality in patients with an LVAD.

Patients are at high risk due to thrombus formation with severe heart failure, the greater incidence of atrial fibrillation, and the presence of a foreign mechanical device.

High systolic blood pressure, prior stroke, and postoperative infections are the greatest risk factors for a neurologic event.

A systolic blood pressure >100 mm Hg is associated with over a 2.5-fold higher risk of stroke, with a 19% increase in stroke risk with every 5 mm Hg increase in systolic blood pressure

Stroke management is the same as a non-VAD patient.

- Call Code Stroke and hemodynamically support patient
- Ensure HF MD is aware and work collaboratively with Neuro colleagues on treatment plan
- Bed placement is more difficult and requires the VAD team engagement if patient to be placed in Neuro ICU for coordination of VAD competent staff.

Management of Infection/Sepsis

- Infections increase the risk of thrombosis, stroke, intracerebral hemorrhage, and GI bleeding
- The driveline and VAD pump pocket are the most common infectious sites
- Laboratory assessment includes blood cultures, complete blood cell count, lactic acid, and inflammatory markers, as well as driveline samples
- Chest radiograph is also recommended, but definitive imaging includes CT with contrast to evaluate for deep space infection.
- Central venous access may be required. Fluid resuscitation is needed in patients with severe toxicity due to sepsis, and except for those with severe right ventricular failure, volume overloading is unlikely.
- Antibiotics should include coverage for gram-positive and gram-negative species, as well as methicillin-resistant *S. aureus*. Discussion with the LVAD specialist and Adv HF attending is recommended

Fluid and hemodynamic management

Pumps are preload dependent and afterload sensitive. It is important to maintain adequate preload and normotensive status.

- Target for mean arterial pressure (MAP) is within approximately 10 percent of the patient's normal MAP, but no lower than 70 to 80 mmHg

Maintenance of hemodynamic stability in a patient with a VAD depends on providing adequate preload, maintaining afterload, maintaining adequate heart rate and rhythm, pump speed, and preventing any hemodynamic changes that would compromise RV function.

These are the main determinates of flow through the pump (ie, the pressure gradient across the pump) and total pump output.

Fluid and Hemodynamic Management

Specific preventive strategies to maintain optimal hemodynamics include the following:

- Maintenance of intravascular volume status is necessary to provide adequate preload for optimal VAD function. A VAD will only pump the volume delivered to it. Thus, factors that decrease preload will decrease pump flow and LV output. Such factors include anesthetic agents, dehydration, hemorrhage, dysrhythmias, and lateral decubitus and reverse Trendelenburg position.
- Also, high intrathoracic pressures due to excessively large tidal volumes or high intra-abdominal pressures may decrease venous return, thereby decreasing volume delivered to the VAD.

- When VAD flow exceeds the available LV preload, the walls of the LV near the inflow conduit can collapse and limit VAD inflow. Although the VAD may temporarily decrease its speed to compensate for decreased preload in these circumstances, such a suction event may precipitate ventricular arrhythmias or hemodynamic deterioration.

Fluid and Hemodynamic Management

- Increases in afterload will decrease pump flow and reduce VAD output.
  - Severely increased afterload may lead to stasis within the VAD and acutely increase risk of thrombus formation, particularly if anticoagulation is inadequate during the perioperative period.

- Hypotension should also be avoided. In the setting of euvolemia, vasopressors are often used to maintain MAP at 70 to 80 mmHg.
  - reduced afterload increases pump flow, significant or prolonged hypotension may injure perfusion-dependent end-organs. In one retrospective study, MAP <70 mmHg for greater than 20 minutes was associated with acute kidney injury in patients with a nonpulsatile

Fluid and Hemodynamic Management

- Maintain adequate heart rate and rhythm – Arrhythmias causing clinically significant tachycardia or bradycardia interfere with optimal VAD function and can reduce pump flow. **Management of arrhythmias in these patients is similar to that for patients without a VAD.**

  - Adequate RV function must be assured by minimizing PVR since output from the RV determines the volume ultimately ejected by a left-sided VAD. Thus, increases in PVR due to hypoxemia, hypercarbia, pain, alpha-agonist vasopressors, hypothermia, and/or acidosis should be avoided.

- While adequate preload is desirable, overaggressive fluid resuscitation is avoided since this may cause RV distention and worsen RV function, thereby compromising LV filling and as a result VAD inflow .

- If increasing CVP and/or hypotension with increasing vasopressor requirements are present, as well as low PI and low flow/power on the VAD monitor, then RV failure should be suspected and further investigated. Treatment may require inotropic support (eg, milrinone, epinephrine) in addition to vasopressor agents to treat hypotension. In some cases, pulmonary vasodilator therapy may be necessary.

ACLS for the VAD patient

Table. Basic Differences in Performing Resuscitation in Patients With Mechanical Circulatory Support

Mechanical Support Type	Perfusion (Pulse Check)	ECG	Defibrillation/ Cardioversion	Chest Compressions	ACLS Drugs
p-RVAD	Pulsatile	Present	Acceptable	Acceptable	Acceptable
p-LVAD	Pulsatile	Present	Acceptable	Acceptable	Acceptable
p-BiVAD	Pulsatile	Present	Acceptable	Acceptable	Acceptable
cf-RVAD	Pulsatile	Present	Acceptable	Acceptable	Acceptable
cf-LVAD	Absent pulsatile	Present	Acceptable	Acceptable	Acceptable
cf-BiVAD	Absent pulsatile	Present	Acceptable	Acceptable	Acceptable
TAH	Pulsatile	Absent	Unacceptable	Unacceptable	Unacceptable

ACLS indicates advanced cardiovascular life support; BiVAD, biventricular assist device; cf, continuous flow; LVAD, left ventricular assist device; p, pulsatile; RVAD, right ventricular assist device; and TAH, total artificial heart.

Management of Cardiac Arrest

Cardiac arrest is challenging to diagnose in a patient with a nonpulsatile VAD. **The first step in management is to ensure adequate airway and breathing, similar to patients without a VAD. Next steps include:**

- Determine if the VAD is working (checking for the sound of the characteristic VAD hum).
- **Hum Present**: begin chest compressions if clinically indicated i.e. severe hypotension (<50 mmHg) or absent BP with P_{ETCO2} <20 mmHg. Consult Advanced Heart Failure
- **Hum Absent/VAD not functioning**: support patient as clinically indicated (assume no flow through the VAD) Emergent collaboration with the VAD expert to determine the probable cause of the VAD malfunction and troubleshooting.
- Prolonged VAD cessation ≥30 min may result in thrombus within the device, and catastrophic embolism may occur upon resumption of VAD function.
- Conventional evaluation of return of adequate circulation may not be present in patients with a nonpulsatile flow VAD, since there may be no pulse even after successful resuscitation. Providers may need to rely on signs of circulation or invasive monitoring to assess ROC.
- If electrocardiogram (ECG) indicates VT/VF cardiovert or defibrillate as appropriate.
- At UAB, staff are advised to NOT begin compressions in a VAD patient unless ordered by MD.

Management of Cardiac Arrest

In a patient with a functioning nonpulsatile VAD, causes of severe hypotension include:

- Hypovolemia
- RV failure
- Inflow or outflow cannula obstruction,
- Tamponade
- Sepsis

Check laboratory results for other causes of cardiac arrest (eg, hypoxemia, hypoglycemia) as soon as possible.

Consider other hemorrhagic or embolic causes of coma (eg, stroke, which can occur in approximately 11 percent of VAD-supported patients)

MCS Department Contacts:

VAD Office: call 975-0420 or email

VAD Coordinators: page “VAD Coordinator on Call” 24/7 Dial “0” or 934-3411

VAD Specialists: pager 9219 (7 days a week)

Heart Failure MDs: page “Advanced heart failure” Attending

Industry/Society Sponsored Resources

Mylvad.com

https://www.cardiovascular.abbott/us/en/hcp/products/heart-failure/left-ventricular-assist-devices/heartmate-3/education-training.htmlMedtronic.com

https://www.medtronic.com/us-en/healthcare-professionals/education-training.html

ICCAC.global

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https://iccac.global/highlights/emergencyguide