
NORA PBLD

Endoscopy in Patients with an LVAD- Anesthetic Management Challenges

Stem:

A 55 year old patient has been admitted to the ER to the GI floor with an LVAD(heartmate II as DT for NICM) with a history of shortness of breath and a decreasing hemoglobin and having tarry stools. He weighs 170 lbs. His BMI is 27. His hemoglobin on admission is 6.5. He has been volume resuscitated and transfused three units of packed cells and his Hb is now 9.0gm/dl. INR on admission is 2.0. He has a history of non-sustained V-tach and has a CCID in place. His past medical history is significant for diabetes, hypertension and asthma.

Vitals are stable and his heart rate of 84bpm, Blood pressure is 80/65 with and oxygen saturation is 96% on room air. He last blood sugar was 175 mg/dl.

He finished his bowel prep 6 hours ago and has been NPO since then.

His EKG shows a normal sinus rhythm with intraventricular conduction defects and occasional unifocal PVCs. His last ECHO showed an EF of 15% prior to his LVAD. Post procedure ECHO showed global hypokinesia and his aortic valve opens during the cardiac cycle.

Medications include Carvedilol, Lisinopril, metoprolol, metformin, Insulin, Coumadin and albuterol as needed. His Coumadin was stopped following presentation to the hospital and he was started on Heparin. He has had general anesthetics in the past and his airway examination is unremarkable. His asthma has been well controlled and there have been no recent admissions for flare up. He denies OSA.

1. What are some of the challenges in providing care to this in non-operating room locations such as the GI Endoscopy suite?
2. Should this patient be done in a remote site or should he be scheduled in the main OR?
3. What are your preoperative concerns?
4. How would you monitor this patient?
5. How would you come up with a safe anesthetic plan?
6. How would you manage his hemodynamics during the procedure?
7. The screen shows short runs of VTach. How will you manage it?
8. At the end of the procedure, the patient does not wake up. What is your differential diagnosis?

Discussion:

What are challenges in providing anesthesia in non-operating room locations such as the GI Endoscopy suite?

There has been an exponential growth in NORA procedures and there is a need to realize that they present challenges in both the organizational aspects and the administration of anesthesia. The anesthesiologists are forced to work outside their comfort zone forcing them to think outside the box. The challenges the anesthesiologist face is due to the unfamiliar environment and surroundings (from the main ORs), non-availability of some critical equipment and paucity of space. Patients presenting to the remote site are in addition older, have a higher ASA-PS class and not uncommonly have not had their comorbidities addressed. The conduct of anesthesia is further challenging due to limited access to the airway due to shared airway or barriers to easy and ready access, increasing complexity of the procedures being performed outside of the operating room and the increasing patient acuity.[1-3]

Details and protocols must be worked out, such as how the room is set up, what monitors are needed (ASA standards), what to do in a code, whom to call for help or how to transfer care after the procedure is finished or in an emergency. The ASA addressed this issue in their Statement on Nonoperating room anesthetizing locations: Committee of Origin: Standards and Practice Parameters (Approved by the ASA House of Delegates on October 19, 1994, and last amended on October 16, 2013)[4] and Standards for Basic anesthesia monitoring: Committee of Origin: Standards and Practice Parameters (Approved by the ASA House of Delegates on October 21, 1986, last amended on October 20, 2010, and last affirmed on October 28, 2015)[5].

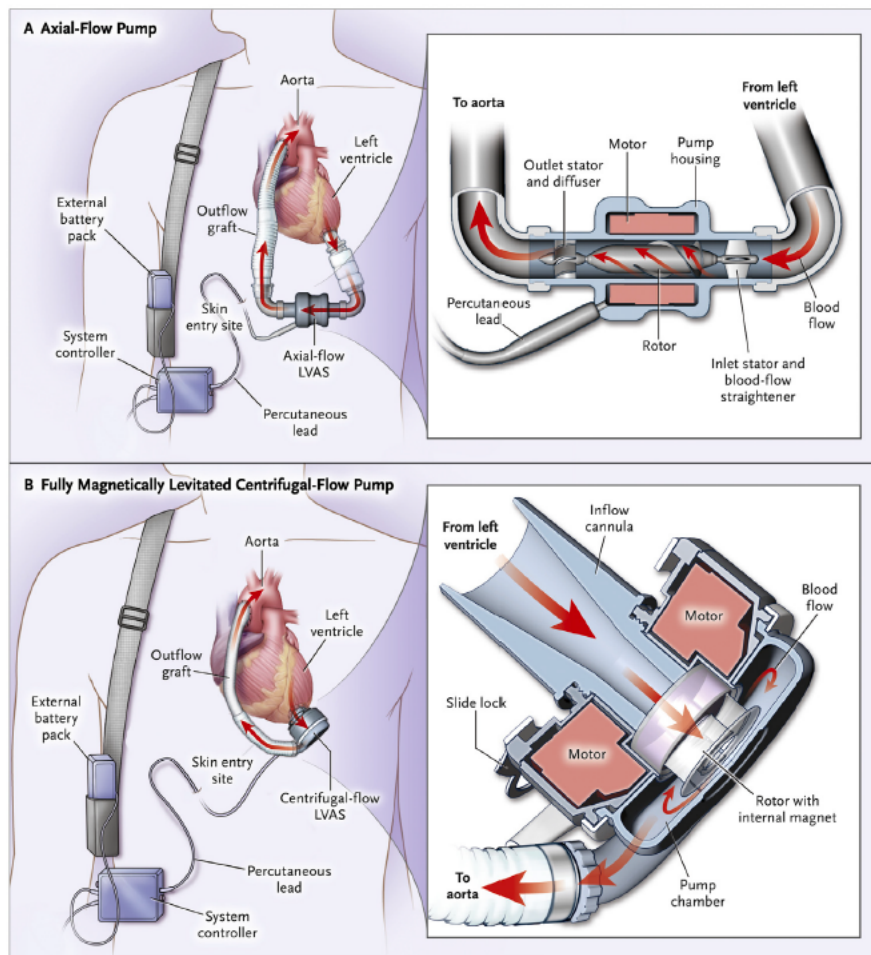
Nearly all patients who receive Mechanical Cardiac Support (MCS) have end-stage systolic heart failure. Although there are only a limited number of approved devices, they differ in the indications for their placement, their configuration, and the means by which they pump blood. Long-term MCS devices suitable for non-hospitalized patients are placed largely for 1 of 2 indications[6]:

1. Bridge to transplantation refers to patients awaiting heart transplantation whose heart failure progresses despite medical therapy. In such cases, MCS is used as a bridge until a donor organ becomes available.
2. Destination therapy refers to patients with advanced systolic heart failure who are not candidates for transplantation because of factors such as comorbidities or advanced age. In this population, MCS is the destination itself, as opposed to transplantation, and patients will typically live the remainder of their lives on mechanical support.

This latter population is growing rapidly, with some patients being supported for many years. These 2 designations are fluid. Patients can have their status changed from bridge to transplantation to destination therapy or vice versa on the basis of clinical changes

Clinical research into mechanical circulatory support systems dates back to the 1960s, with the first reported successful human implantation of a left ventricular

assist device (LVAD) for postoperative heart failure. Early ventricular assist devices were typically extracorporeal pumps. Investigators during the 1970s and 1980s focused their efforts on the development of implantable pulsatile pumps to reduce some of the risks associated with the external machines. In 2001 the HeartMate VE was introduced. Implantable small rotary (continuous-flow) blood pumps have revolutionized mechanical circulatory support since the first human implantation in 1998. Hemolysis has not been shown to be a clinically relevant event in patients supported with axial flow devices unless it is associated with pump thrombosis. Blood exposure to high shear stress contributes to the development of acquired von Willebrand disease in LVAD patients.



- A) The axial-flow pump. Blood enters at one end of the rotor and is driven along the axis of the rotor to the outflow of the pump. (B) The fully magnetically levitated centrifugal-flow pump. Blood enters at the central axis of the rotor and is driven outward centrifugally to the outflow of the pump. Both pumps are considered to be continuous-flow pumps (rather than pulsatile-flow pumps) because blood flow is continuous and not interrupted, although the centrifugal-flow pump incorporates rapid changes in rotor speed to create an intrinsic artificial pulse. LVAS, Left ventricular assist system.[7]

The HeartMate II is one of the most commonly used types of LVAD. It is an axial, electromagnetic, continuous flow pump. The pump is usually positioned in an abdominal pocket in the sub-xiphoid area between the peritoneum and abdominal muscles. The inflow to the device is through a cannula that is placed at the apex of the left ventricle and the outflow cannula is connected to the ascending aorta. A driveline that provides power and allows control to the device is brought out through the skin of the abdominal wall to an external power source and control unit. Adverse events and device replacement are less frequent in the continuous flow group as compared to the pulsatile flow devices.

The HeartMate 3 is a centrifugal continuous-flow pump; blood enters at the central axis of the rotor and is driven outward centrifugally to the outflow of the pump. The rotor is magnetically levitated and thus has no mechanical bearings, in contrast to the HeartMate II; this design eliminates friction between device components.

Heartware HVAD Pumps[8]:



1. Miniaturized HeartWare HVAD pump. (Courtesy of Heartware, Inc, Miami Lakes, FL)

Blood is forced through the pump by the rotating impeller using hydrodynamic and centrifugal forces. The electromagnetic coupling between motor magnets within the impeller and motor stators in the front and rear housings provide rotational energy to the impeller. Blood flow through the pump at a constant rotational speed (range 1800–4000 rpm) depends on the differential pressure across the pump. This system is a preload- and afterload-dependent one, and the difference between LV and aortic pressures is the most important determinant of flow through the pump.[8]

The most common adverse events within the first 30 days after LVAD implantation is nonsurgical bleeding. The most commonly reported sources of bleeding are epistaxis, GI tract bleeding, bleeding of the mediastinum and thorax, and intracranial hemorrhage. The location of bleeding may vary depending on time from operation, with thoracic or mediastinal bleeding having higher, but diminishing, risk in the early postoperative period, with a delayed risk of GI tract bleeding. GIB after LVAD implantation to vary between 18-40%.[9]

What are your preoperative concerns?

This Patient presenting to the endoscopy suite needs to be evaluated by an anesthesiologist. A careful history should be elicited. The anesthesiologist should initiate a discussion regarding the proposed procedure with the LVAD team (generally comprised of a cardiac surgeon, LVAD nurse, and perfusionist, among other medical professionals). The LVAD team can provide a wealth of information

with regards to a particular patient's LVAD, including the current settings, the duration of the implantation, and any complications associated with the LVAD. Patient co-morbidities should be evaluated and in this case his hemodynamics, coagulation status and diabetes. The clinical scenario indicates a significant gastrointestinal blood loss, and the patient should receive immediate supportive measures (volume resuscitation). An intravenous proton-pump inhibitor should be considered, given the possibility of an upper gastrointestinal acid-related disorder.

The health records should be assessed to ascertain the presence of any drug allergies and medication history. Prior hospitalizations and surgeries, and any adverse outcomes following previous sedation and anesthesia should be elicited and documented. A careful assessment of the airway should be done even in cases that normally would not need airway instrumentation. In addition, a focused examination of the heart, lungs and neurological status should be documented. The NPO status should be confirmed.

Investigations:

A review of lab results is vital to patient care. Coagulation studies should be performed pre-procedure and ensure that his heparin has been discontinued at least 4-6 hours prior to the procedure.

With the history of ongoing bleeding and a potential for major blood loss, a baseline hemoglobin or hematocrit, as well as a type and crossmatch of both packed cells and coagulation factors should be obtained.

The preoperative evaluation should also focus on identifying any other underlying end-organ dysfunction such as renal and hepatic dysfunction, which can be common in LVAD destination therapy (DT) patients. Serum electrolyte, Creatinine and blood urea nitrogen (BUN), LFT, serum albumin and blood sugar should be checked prior to the procedure.

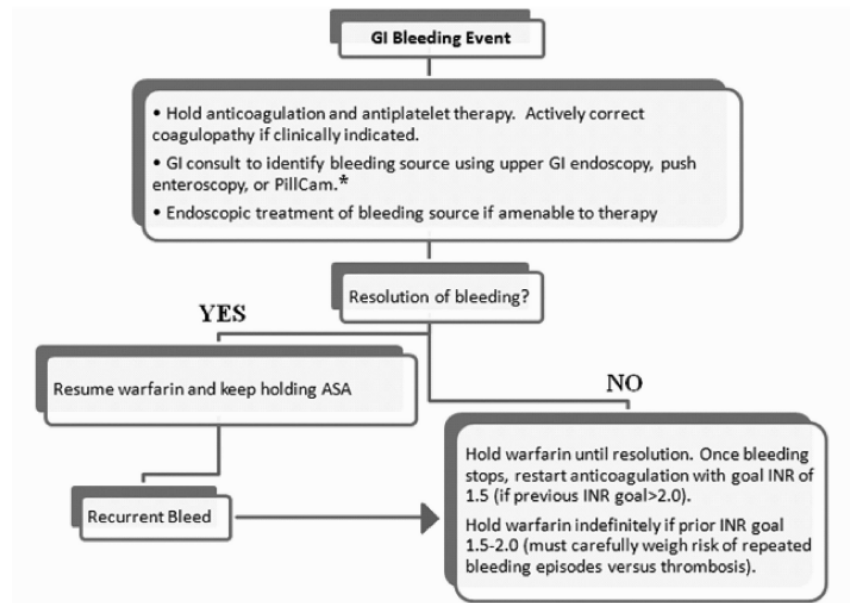
Coagulation:

In general, the rate of gastrointestinal bleeding is significantly higher for patients who receive nonpulsatile LVADs. There are 3 proposed mechanistic theories for the pathophysiology of GIB with continuous flow VADs:

1. Coagulopathy
2. Acquired von Willebrand disease
3. Lack of pulsatility leading to angioectasias

Even though the HeartMate II and other LVADs have been designed to minimize the risk of thrombosis, the constant exposure of blood to foreign materials means that patients require some degree of chronic anticoagulation.[10] The goal is to maintain an INR of 1.5 to 2.0. The most common anticoagulant used is warfarin with addition of an antiplatelet medication such as aspirin at 325 mg by mouth daily. Clopidogrel may be used if device thrombosis is of concern or if patients are unable to tolerate aspirin.[11]

The Duke Algorithm for the evaluation and treatment of gastrointestinal (GI) tract bleeding (the Duke approach)[10]



Patients with LVADs can develop acquired von Willebrand Disease (AVWD). This occurs because the large von Willebrand factor multimers are cleaved by the flow through the LVAD. Diagnosis may be difficult. A trial of desmopressin if may be effective in only 10% of the time. They have been reported to normalize after removal of the device.

Angioectasias are also increasingly recognized in patients with both pulsatile or nonpulsatile LVADs. The narrow pulse pressure may result in hypoxia of intestinal tissue with subsequent vascular dilatation and angioectasia formation.

The PTT in this patient may be elevated for a couple of possible reasons.

- one related to the patient's LVAD
- Related to the patient's lupus.

If the patient has an anti-phospholipid antibody this can be associated with a paradoxical increase in PTT but the occurrence of a clinical thrombophilia.

In non-emergent situation, the patient should be bridged to heparin (like in this case). In emergent cases, we may need to administer fresh frozen plasma to partially reverse the effects of a patient's anticoagulation. *Vitamin K should be not be administered because of the risk of pump thrombosis.* The degree of anticoagulation reversal should be agreed on with the LVAD team.

His baseline electrocardiogram (ECG) should be obtained. The rhythm and rate should be noted, as well as any signs of previous infarction or ischemia or arrhythmias. An echocardiogram provides important information to the anesthesiologist regarding the patient's myocardial contractility, left ventricular function, and integrity of the valves. In patients with an LVAD, it is important to know if the aortic valve opens with each ventricular contraction

AICDs and PPMs:

In addition to the LVAD, many of these patients also have automated internal cardioverter- defibrillators (AICDs), which should be turned off just before coming to the operating room, and external defibrillator pads should be applied. In emergency settings where reprogramming cannot be accomplished in a timely fashion, the use of bipolar cautery only or the use of a magnet may be considered.

Pacemakers: recommendations for managing pacemakers in the setting of electrosurgical procedures

	Pre-procedure	During procedure	Post-procedure
Universal recommendations	1. Assess the type of implanted cardiac device, its location, the reason for the patient's need for the device and dependence on the device. 2. Determine whether the patient is pacemaker dependent and attempt to predict whether prolonged electromagnetic current will be needed. a. If patient is not pacemaker dependent, then no reprogramming is necessary. b. If pacemaker dependent and prolonged electrocautery may be required, see specific recommendations below.	1. Closely monitor vital signs and heart rhythms with electrocardiography during the procedure. The patient should be monitored continuously via hard-wired monitoring. 2. Cardioverter-defibrillation equipment should readily available. 3. Use alternative methods to electrocautery whenever possible. 4. Apply bipolar or multipolar currents rather than unipolar currents whenever possible. 5. Whenever unipolar cautery is required, place the grounding pad on the patient in a location such that the applied current does not pass close to or through the leads of the cardiac device. 6. Minimize the strength of the electrosurgical current applied. 7. Apply the electrosurgical current intermittently and for the shortest amount of time possible. 8. External pacing can be effective. It can be set to the asynchronous mode and will be unaffected by cautery.	1. If the pacemaker or ICD was reprogrammed, restore baseline function of the device. 2. There is no need for further follow-up if the device is interrogated after the procedure.

Recommendations for managing ICDs in the setting of electrosurgical procedures

	Pre-procedure	During procedure	Post-procedure
Universal recommendations	1. Assess the type of implanted cardiac device, its location, the reason for the patient's need for the device, and dependence on the device. 2. Reprogram an ICD to inactivate tachyarrhythmia detection before procedures in which electrocautery is to be used. If unable to do so, a magnet could be used if the magnet can be secured over the pulse generator. Consult cardiology or a team specifically trained in cardiovascular implantable device management.	1. Closely monitor vital signs and heart rhythms with electrocardiography during the procedure. 2. Cardioverter-defibrillation equipment should be readily available. 3. Use alternative methods to electrocautery whenever possible. 4. Apply bipolar or multipolar currents rather than unipolar currents whenever possible. 5. Whenever unipolar cautery is required, place the grounding pad on the patient in a location such that the applied current does not pass close to or through the leads of the cardiac device. 6. Minimize the strength the electrosurgical current applied. 7. Apply electrosurgical current intermittently and for the shortest amount of time possible.	1. The ICD should be reprogrammed to its original function as soon as possible by trained personnel, including either a cardiologist or a team specifically trained in cardiovascular implantable device management.

ICD, Implantable cardioverter-defibrillator.

The American College of Cardiology Foundation/American Heart Association, American Society for Gastrointestinal Endoscopy, and Heart Rhythm Society and the American Society of Anesthesiologists all agree on these recommendations.^{1,4,5}

The adequacy of resuscitation should be ascertained prior to his anesthetic.

Providing anesthetic care to patients with LVADs for non-cardiac procedures is a challenge for both a cardiac and non-cardiac anesthesiologists.

HeartMate II LVAD is designed with specific features to minimize thromboembolic complications, including the use of biomaterials, such as titanium, polytetrafluoroethylene, and acrylics. Despite these modifications, because it is in direct contact with the blood stream, it can activate the coagulation system. Consequently, all patients are given an anticoagulation regimen.

Antibiotic Prophylaxis

Antibiotic prophylaxis should be considered for the surgical procedures if appropriate. Post-LVAD implantation sepsis has been shown to increase the length of hospitalization and in-hospital mortality rates. Discuss with your proceduralist and the LVAD team.

Monitoring the patient.

Standards ASA monitors are still required for these patients. Due to the non-pulsatile nature of the flow, oscillometric non-invasive blood pressure (NIBP) monitoring and pulse oximeters may not be reliable. If the left ventricle is poorly contractile, or if the patient is hypovolemic to the extent that it does not substantially augment the continuous extra-cardiac flow through the LVAD then there will be no detectable pulse pressure. A mean blood pressure reading can still be obtained by using a blood pressure cuff and a Doppler on the brachial artery. A NIBP monitor (Nexfin®) is available that is specifically designed to measure as low as a 5mmHg augmentation but may not be available at most institutions.

Near-infrared spectroscopy (cerebral oximetry) does not depend on pulsatile flow for its function and has been reported to be of use as a monitor of perfusion in patients with LVADs.[12] In an occasional patient, it is essential to obtain an arterial line in order to monitor these patients during the procedure. The lack of a palpable pulse can make arterial catheter placement difficult, but it can be facilitated by the use of an ultrasound.

In cases in which the pulse oximeter does not work at all or is believed to be inaccurate, one may have to do serial arterial blood gas measurements or use cerebral oximetry.[11]

A CVP is not absolutely essential for the procedure but if available can facilitate intraoperative management. It should be transduced and monitored during the procedure. All invasive monitors, should be placed using a strict aseptic technique to minimize the risk of bloodstream infections and other LVAD infections.

During the procedure, all LVADs should be connected to external power source and a nurse trained for assessing the functioning of these devices should be involved in monitoring them. Volume and inotropic therapy are the primary interventions used to correct the hypotension and/or acute heart failure that may develop during the procedure. Intraoperative adjustment of pump speed should be done only after using echocardiographic data. An increase in the pump speed to correct hypotension in the face of hypovolemia would have a counter intuitive effect and further hemodynamic compromise.

Intraoperative Management:

Even though LVADs can operate for several hours off battery power, it is advisable for even the shortest procedures to power the LVAD from its base/module. The module as shown includes a digital readout of the following parameters:

- Pump Flow
- Pump speed
- pulse index (PI)
- Pump Power



These parameters have to be interpreted within the context of the patient's overall condition. Trends and change from the baseline usually has more clinical significance than its absolute value. It is very important to realize that Pump Flow is a calculated value and is not a direct measurement. It is based on the speed and the power consumption. Increases in pump speed will increase pump power. Hence it is not reliable. The extreme case would be in the instance of pump thrombus. Here the power consumption would be very high with minimal flow resulting in an erroneously high flow estimate. For a specified pump speed, flow increases with increasing LVAD preload and decreasing LVAD afterload.

When the left ventricle contracts, the increase in ventricular pressure causes an increase in pump flow during systole. The magnitude of these flow changes is estimated and is displayed as the Pulse index (PI). The PI is thus a dimensionless value representing the degree of cardiac pulsatility, which is related to the magnitude of assistance provided by the LVAD. Pulse Index changes depending on the intravascular volume status and the contractility of the heart which depends on the LV function and afterload. So if the PI is low when the patient presents to the GI suite, this will indicate relative hypovolemia.

- Higher values indicate more ventricular filling or better contractility (pump is providing less support to the LV),
- Lower PI values indicate less ventricular filling or lower contractility.

Under ideal circumstances, when a CVP monitor is also available, it is important to maintain a CVP of around 10 to 12 and a PI of around 4 to 5.

- A low CVP (<10) with a low PI (<3) may suggest hypovolemia.
- A low CVP (<10) with a high PI (>5.5) can be seen with systemic hypertension.
- A high CVP (>12) with a low PI (<3) is generally the most worrisome combination and can suggest right ventricular dysfunction with poor filling of the left ventricle.

The electrosurgical unit grounding pad should be placed in such a manner that the path of the electrical current from the electrosurgical unit does not go through the LVAD.

Anesthetic Management

Endoscopy in LVAD patients has been performed safely under general anesthesia or deep sedation under MAC. The use of propofol, ketamine, etomidate, fentanyl, and midazolam in various combinations for sedation can be reasonably considered, as they have been safely reported in LVAD patients. The appropriate choices for anesthetic and monitoring modalities can be made on individual patient factors and the anesthesiologists comfort level.

The induction of anesthesia can be a demanding. This is due to the fact that these patients are very dependent on their preload and afterload. Before induction,

patients should be adequately hydrated to mitigate the drop in preload frequently encountered with induction.

One may use any of the induction agents if a GA is planned but it is important to titrate the medications in and it is important to remember that it may take longer to achieve a steady state given their precarious circulation.

Patients with LVADs should possibly be treated as having “full stomachs” and appropriate precautions should be taken to prevent aspiration. An adequate depth of anesthesia should be achieved before instrumentation of the airway as abrupt increase in SVR during laryngoscopy can result in a precipitously drop in the cardiac output.

Intraoperative hemodynamic management should focus on maintaining an adequate preload, avoiding abrupt changes in SVR, and maintaining right ventricular contractility and the cardiac rate and rhythm. Any type of IV fluids can be used but it requires a careful balance between maintaining preload and avoiding right ventricular failure. The LVAD is very dependent on a RV function as the latter determines the preload on the left ventricle. Fluid management should be guided by CVP measurements (when available) and the assessment of PI, and if there is any doubt about a patient’s fluid status, a TEE or a TTE should be used to assess the volume status.

In intubated patients, avoid high positive-pressure ventilation as it can significantly impede venous return and preload. Ventilator settings should be adjusted to provide adequate ventilation without generating unnecessarily high intrathoracic pressures

Patient positioning can be critical. If a change in position is required after induction, it should be done slowly and carefully while closely monitoring the hemodynamics. In most cases, when there is hypotension following reposition, intravenous fluid administration is adequate to increase preload and restore cardiac output, but occasionally the patient will need to be returned to a supine position until the hemodynamic changes can be addressed appropriately.

Vasopressors should be judiciously used in the setting of adequate cardiac output and low systemic vascular resistance. If the hypotension can be reliably attributed to low cardiac output, inotropic assistance (in the setting of right ventricular dysfunction) or the adjustment of LVAD parameters may be undertaken.

Management of cardiac arrest[6]

Tachyarrhythmias are common in patients with LVADs. Sustained VT and VF are hemodynamically unstable heart rhythms and often life threatening if not terminated. However, many VAD patients are able to tolerate VT specifically for periods of several hours or longer[13]. Patients whose systemic flow is coming primarily from the LVAD may be surprisingly stable hemodynamically, whereas some may present with circulatory collapse, usually caused by acute compromise of RV function and decreased LV filling. In addition, ventricular arrhythmia does cause a drop in VAD output, confer a risk of thrombus formation, and increase the risk of right ventricular failure when sustained.

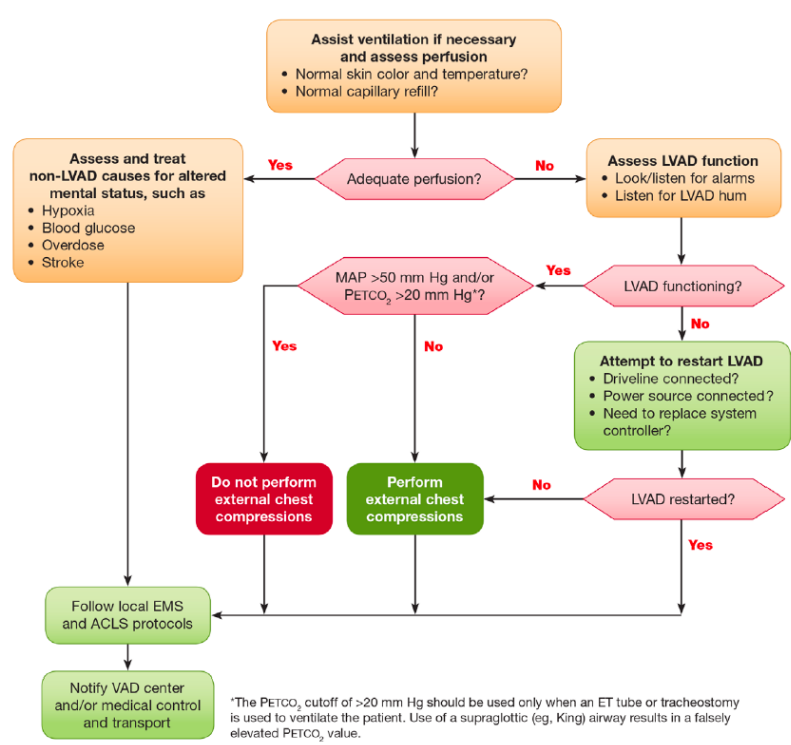
While patients with VADs can generally tolerate sustained VT and VF for a period of time, there should be an effort to place these patients back into normal rhythm, given the potential adverse consequences[13].

While early studies found increased mortality in those patients experiencing VT or VF after VAD placement, larger more recent reviews do not find VA as a risk factor for death[13].

Most patients have an implantable cardioverter-defibrillator or a cardiac resynchronization device with defibrillation capability implanted before LVAD placement, which can deliver antitachycardia pacing or cardioversion. However, in the setting of electrolyte abnormalities or acute ischemia, VT/VF may persist and compromise pump flow with subsequent clinical decompensation.

Similar to the decision made for patients without VADs, the decision to cardiovert (either chemical or electric) or to defibrillate a patient with an LVAD with VT or VF is based on the adequacy of mental status and perfusion. Except for patients who have a Total Artificial Heart, cardioversion and defibrillation should be performed for the same indications as used in the general population, with the understanding that perfusion in these patients does not equate to a palpable pulse.

Atrial tachyarrhythmias such as atrial fibrillation usually do not affect RV function adversely except when preexisting RV function is truly marginal.



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