PROBLEM-BASED LEARNING DISCUSSION

Ventricular Assist Device And Non-Cardiac Surgery

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Objectives

Understand different types of LVADs.
Understand unique perioperative concerns regarding patients with LVADs undergoing non-cardiac surgery.
Understand pharmacologic support of right ventricular failure.

Case Presentation: Preoperative

A 52 year old male presents for elective left lower leg vascular surgery. Past medical history is significant for ischemic cardiomyopathy with biventricular dysfunction requiring LVAD insertion six months prior. Other medical issues include congestive heart failure, hypertension, diabetes, prostatic hypertrophy, and hypercholesterolemia. Medications include amiodarone, aspirin, atorvastatin, carvedilol, dipyridamole, enalapril, finasteride, glimeperide, and lansoprazole.

What are the different types of LVADs and why are they inserted?
How do LVADs work (physiology)?
What type of anticoagulation is required and how will it be altered?
How do we assess major organ dysfunction and why is this important?
How do we assess right ventricular function and why is this important?

Case Presentation: Intraoperative

General anesthesia or regional anesthesia?
Aspiration risk?
Antibiotic prophylaxis?
Monitoring?

Depth of anesthesia monitoring?

Anticoagulation strategy?

Physiologic goals: preload?, contractility?, afterload?

Surgical positioning?

Right ventricular support?

**Case Presentation: Postoperative**

Unique concerns?

**Discussion**

As the number of patients with end-stage cardiac disease rises and organs available for transplantation continue to be in scare supply, additional therapeutic modalities have arisen. One approach has been the implantation of LVADs in patients as either a bridge to transplantation or as an alternative to transplantation (destination therapy) in patients who are not transplant candidates. With increased experience and improvements in technology, patients are being discharged home with LVADs with improvements in major organ function, right ventricular function, exercise tolerance, and overall health status. It can be anticipated that with increased LVAD utilization, more of these patients will present for procedures requiring anesthetic intervention.

There are three types of LVADs currently used:
Heartmate® (Thoratec Corporation): Implantable, no anticoagulation required.
Novacor® (World Heart): Implantable, anticoagulation required.
Thoratec® (Thoratec Corporation): External, anticoagulation required.

In general, LVADs function well as long as there is sufficient intravascular volume (and RV function) to fill the pump, yet management must be individualized. LVADs are typically set to eject as soon as the blood chamber is full. Thus, the faster the device fills, the faster it pumps, and the higher the pump output. Hypovolemia results in slow pump filling, decreased LVAD output, and hypotension. Consequently, the goal of fluid management is to maintain normal or slightly elevated intravascular volume. Markedly increased SVR impairs forward flow, resulting in incomplete pump emptying, which leads to stagnation of blood in the pump and increased risk of thrombosis. Therefore, maintenance of normal or slightly low SVR is desirable. Inotropes, vasodilators, and vasopressors are administered as needed to achieve optimal hemodynamics.

While optimal LVAD function depends on adequate volume to fill the pump, effective RV function is necessary to deliver volume to the LVAD. For a wide variety of reasons, LVADs increase risk of RV failure. High output from an LVAD will increase RV preload and may cause RV failure in patients with underlying RV dysfunction. LV decompression by an LVAD causes leftward interventricular septum shift, resulting in altered RV geometry, increasing RV compliance, and decreasing RV contractility. Tricuspid regurgitation can result from a combination of papillary muscle displacement...
from interventricular septum shift and tricuspid annulus distortion. Lastly, while an LVAD will reduce RV afterload and may improve RV function in patients with normal PVR, patients with fixed, elevated PVR may experience increased RV afterload due to increased right-sided flows.

While no anticoagulation is required for the Heartmate, these patients are usually taking anti-platelet agents. The Heartmate and Thoratec systems have hand-pump backup (Novacor does not). Physiologically, the LVAD replaces the pumping function of the left ventricle and hopefully provides adequate systemic perfusion to prevent major organ system failure. The basic design of an LVAD is simple and straightforward: a conduit drains from the left ventricular apex to a pump (implantable or external) and pump outflow is directed through a conduit into the ascending aorta. Bioprosthetic, unidirectional valves are present within the conduits to maintain integrity of forward flow. LVADs do not provide oxygenation of blood nor removal of waste products.

The preoperative clinical status of an LVAD – supported patient depends primarily on the amount of end-organ damage sustained during low-output states prior to LVAD implantation, post-implantation complications, and the present surgical problem. Many LVAD – supported patients are ambulatory and otherwise uncompromised. Others may exist with varying degrees of co-existing organ dysfunction. Careful preoperative evaluation of all major organ systems is essential because any deterioration in the perioperative period may preclude full recovery or disqualify a patient from later heart transplantation.

While LVADs do not specifically contraindicate any anesthetic agent/technique, the anesthetic plan must consider the potentially dysfunctional, unassisted RV. Thus, optimizing RV preload, afterload, and contractility are important. Anesthetic drugs chosen should be appropriate for the planned operation and should take into account any pathophysiology of major organ systems. Implantable LVADs likely increase risk of aspiration. Extubation criteria are the same as in any other patient. Regional anesthetic techniques may be appropriate, depending on numerous factors (anticoagulation, surgery, surgeon, etc.). Obviously, potential benefits must be weighed against potential risks. The impact of ventilation and heart-lung interactions should also be considered.

Spontaneous ventilation under anesthesia may promote venous return yet may also result in hypercarbia, elevated pulmonary artery pressure, and right ventricular failure. Controlled ventilation is therefore preferable. Mechanical ventilation causes positive swings in intrathoracic pressure, which usually helps to unload the failing left ventricle by decreasing left ventricular transmural pressure. This relationship, however, does not apply to the LVAD patient. High intrathoracic pressure may serve only to decrease venous return and increase pulmonary vascular resistance.

Invasive hemodynamic monitoring is not mandatory for all procedures and such devices must be individualized. CVP monitoring may help detect RV failure (CVP, LVAD output) and/or guide fluid management. Oximetric pulmonary artery catheter monitoring (mixed venous oxygen saturation) may yield additional insight into oxygen extraction and overall perfusion. One may also calculate SVR: 

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SVR = \frac{\text{MAP} - \text{CVP}}{\text{LVAD output}} \times 80 \text{ dynes-sec-cm}^{-5}
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PACs may assist pharmacological management of RV failure and/or pulmonary hypertension and can be used to assess mixed venous oxygen content/saturation. TEE remains the intraoperative monitor of choice when evaluating hemodynamics, particularly with regard to evaluation of the failing right ventricle.
HR and BP are not reliable indicators of the depth of anesthesia in LVAD-supported patients. The LVAD-supported patient’s pulse rate is the rate of the LVAD ejection (linked to pump filling). Thus, intraoperative tachycardia is not a reliable sign of light anesthesia nor is its absence indicative of adequate depth of anesthesia. Likewise, hypertension may be more related to volume status (LVAD output) than depth of anesthesia. Therefore, processed EEG monitoring may help with anesthetic titration. The effect of surgical positioning on venous return must be considered because adequate preload is the most important factor in maintaining LVAD output. Trendelenberg position will abruptly increase venous return to the heart, resulting in increased rate of LVAD filling/pumping/output/pulse rate/blood pressure. Reverse Trendelenberg position will have opposite effects. In general, fluid management must be individualized, and inotropes/vasodilators/vasopressors should be used as necessary to continuously create optimal hemodynamics.

Cardiovascular collapse in LVAD patients is treated with standard ACLS protocols. However, one should never perform chest compressions on a LVAD-supported patient because intracardiac cannulae dislodgement is lethal. The Novacor is electrically well-shielded and will not be affected by defibrillation or electrocautery. However, the Heartmate may be reset to a fixed-rate mode by electrocautery and potentially damaged by external defibrillation.

Thromboembolism remains a serious complication in LVAD supported patients. The Heartmate’s blood chamber is designed with an anti-thrombogenic surface which encourages neointimal ingrowth and therefore does not require full anticoagulation with coumadin (yet these patients will be taking anti-platelet agents). Despite this, approximately one out of every five patients supported with a Heartmate will experience a thromboembolic complication. The Novacor’s smooth polyurethane-lined blood chamber mandates anticoagulation (INR maintained at 2.5 – 3.5 times normal). Despite this, approximately two out of every five patients supported with a Novacor will experience a thromboembolic complication. Usually Novacor/Thoratec patients discontinue regular anticoagulation (coumadin) preoperatively and maintain perioperative anticoagulation with intravenous heparin. In most cases, heparin infusions are not routinely discontinued preoperatively and surgeons/anesthesiologists must determine a safe anticoagulation regimen for the perioperative period, taking a number of important issues into account. Obviously, scrupulous attention to hemostasis is required. Blood products (PLT, FFP, CRYO, etc.) may or may not be used in order to decrease anticoagulation levels toward the lower limits of recommendations yet it is not advisable to completely reverse anticoagulation in Novacor/Thoratec supported patients. Frequent assessment of the coagulation system (PT, PTT, PLT, INR, etc.) is important to appropriately balance the risks between hemorrhage and thrombus formation. Adherence to strict aseptic techniques is mandatory for all invasive procedures and prophylactic perioperative antibiotics are routinely employed. While LVAD patients frequently develop infections at their implantation site or along the drive-line tunneled through their skin, infection of the LVAD itself is usually a catastrophic complication, as they are very large foreign bodies that cannot be adequately sterilized with antibiotics.
References


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