Review Article

Perioperative Management of Patients with Durable Left Ventricular Assist Devices Undergoing Non-Cardiac Surgery

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Abstract

Patients receiving durable left ventricular assist devices (LVADs) for advanced heart failure present growing perioperative challenges, with nearly one-third undergoing non-cardiac procedures most often in emergent or urgent contexts. This article reviews critical management strategies, emphasizing the importance of multidisciplinary collaboration. Device characteristics and operating principles are detailed, focusing on pump types, control parameters, and unique physiological responses in LVAD-supported patients. Preoperative assessment entails comprehensive echocardiographic evaluation, management of coexisting implantable cardioverter defibrillators (ICDs), and tailored anticoagulation regimens. Warfarin discontinuation and perioperative heparin bridging, consideration of acquired von Willebrand syndrome, and preemptive transfusion planning are highlighted to address bleeding risks. Infection prevention includes strict sterile technique and timely administration of prophylactic antibiotics targeting skin flora and device-specific pathogens. Intraoperatively, vigilant monitoring of device parameters and hemodynamics, invasive arterial blood pressure assessment, and selection of anesthesia approaches are outlined. Special attention is given to LVAD preload and afterload dependencies, right ventricular support, positioning, and arrhythmia management. Acute complications, including suction events, device malfunction, and modified cardiopulmonary resuscitation protocols are addressed, underscoring differences from standard cardiac arrest care. The postoperative phase demands careful ICU management, prompt resumption of anticoagulation, and restoration of ICD settings. As LVAD utilization increases, non-cardiac anesthesiologists are required basic understanding in device physiology, monitoring, anticoagulation, and infection prevention to optimize outcomes for this complex patient population.

Keywords: left ventricular assist device; perioperative; non-cardiac surgery

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1 Introduction

An increasing number of patients receive durable left ventricular assist devices (LVADs) for the treatment of advanced heart failure. Around 30% of LVAD recipients will require non-cardiac surgery, necessitating care from non-cardiac anesthesiologists (1). The majority of these procedures are emergent or urgent, with abdominal surgery being the most common. Both elective and non-elective surgeries are associated with elevated risks of major adverse cardiovascular events and increased mortality (2). Although these patients are ideally managed in specialized centers, the urgency of some procedures may necessitate admission to non-specialized hospitals. While effective communication with a specialized center is of utmost importance, a thorough understanding of key perioperative management principles will facilitate the process and can improve patient care.

2 Device Characteristics

LVADs currently used in clinical practice are categorized as second- or third-generation devices. All provide continuous flow but differ primarily in pump design. The second-generation device, HeartMate II (HMII, Abbott, Abbott Park, IL, USA), utilizes an axial-flow pump. Third-generation devices include the HeartMate 3™ (HM3, Abbott, Abbott Park, IL, USA) and HeartWare™ HVAD™ (HW, Medtronic, Minneapolis, MN, USA), both of which employ centrifugal-flow pumps. The HM3, featuring a magnetically levitated centrifugal-flow pump, is the only LVAD currently approved for clinical use in both the EU and the USA.

The main components of an LVAD include an inflow cannula, which drains blood from the left ventricle; a pump; and an outflow cannula, which returns blood to the ascending aorta. The driveline exits the body through the abdominal wall and connects the pump to the controller, supplying electrical power and transmitting device operational data. The controller is powered by either a pair of rechargeable batteries or an external power source. Key components of an LVAD are schematically depicted in Figure 1.

Key parameters displayed on the monitor include pump speed, power, flow, and pulsatility index (PI). Pump speed, set by LVAD teams, represents the rotor speed in revolutions per minute. Pump power is the product of voltage and current applied to the motor and correlates with pump flow. The device estimates pump flow using a power-flow curve specific to the device and the set pump speed. A low-flow alarm is triggered if the estimated flow falls below 2.5 L/min. Because the device pumps blood against the pressure gradient between the left ventricle and the aorta, power (and thus flow) varies throughout the cardiac cycle—reduced during diastole due to higher pressure differences and increased during systole as intraventricular pressure rises. The flow variability is graphically represented in Figure 2. This variability is quantified by the PI, calculated as the difference between maximum and minimum power divided by mean power over 15-second intervals. The PI under stable conditions reflects cardiac contractility, with increased contractility resulting in greater oscillations of intraventricular pressure throughout the cardiac

cycle. These pressure variations produce corresponding changes in flow and power, leading to elevated PI values.

Sudden deviations from the average PI exceeding 45% trigger PI events. Such events may arise from abrupt alterations in left ventricular preload or afterload, as observed during coughing, sneezing, emergence bucking, or patient repositioning. Additionally, atrial fibrillation can induce significant beat-to-beat variability in left ventricular preload, contributing to PI events. PI events do not generate an alarm but are recorded in the device history and warrant further clinical investigation when frequent. A critical concern during PI events is ventricular suction, a condition characterized by severe left ventricular underfilling that causes the ventricular wall to obstruct the inflow cannula. To mitigate this, the pump responds to a PI event by reducing speed to its lower limit, thereby relieving the suctioned ventricular wall, before gradually returning to the preset speed. This cycle repeats with each PI event, and frequent occurrences may consequently reduce overall pump flow. It is essential to recognize that left ventricular underfilling may result from hypovolemia or right ventricular failure. Management with intravenous fluids will alleviate hypovolemia but exacerbate right ventricular failure, underscoring the need for comprehensive hemodynamic assessment in patients experiencing frequent PI events to guide appropriate treatment.

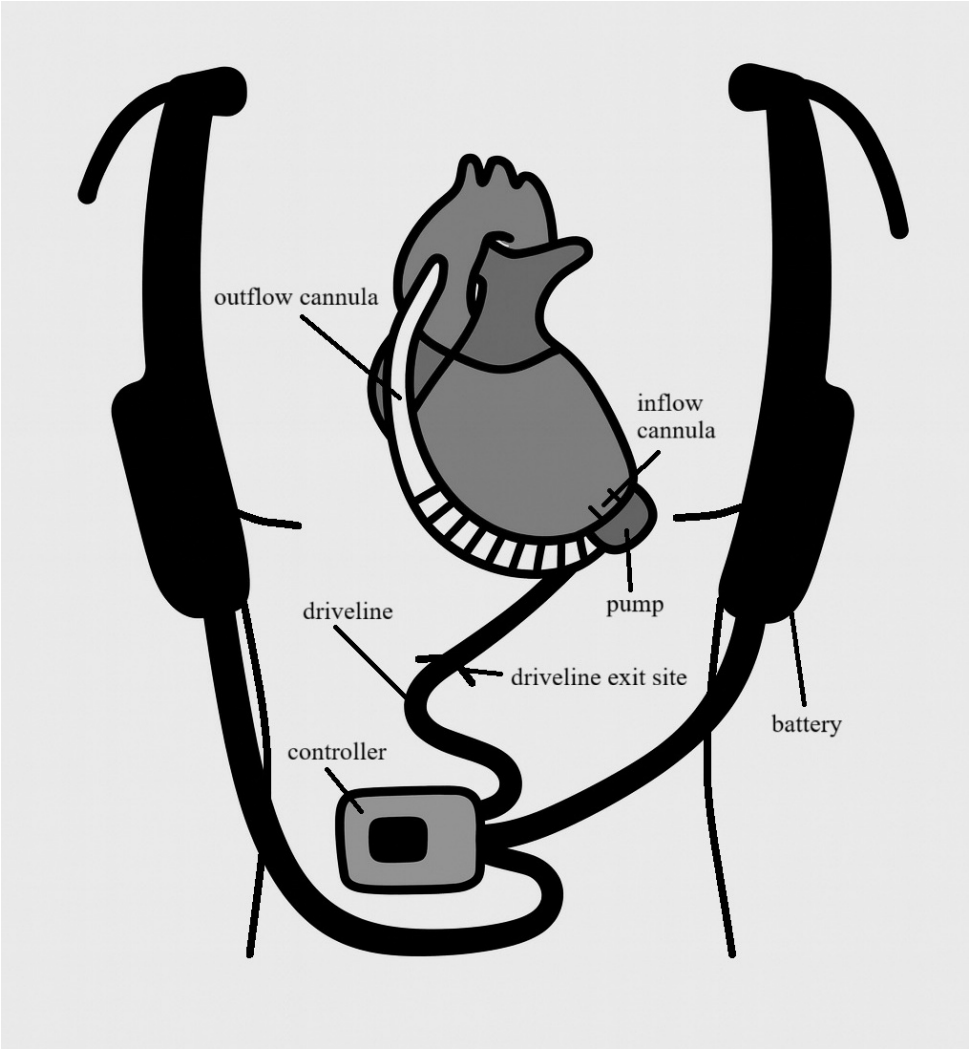

Figure 1. Schematic representation of a left ventricular assist device showing the inflow cannula, pump, outflow cannula, driveline, controller, and power source.

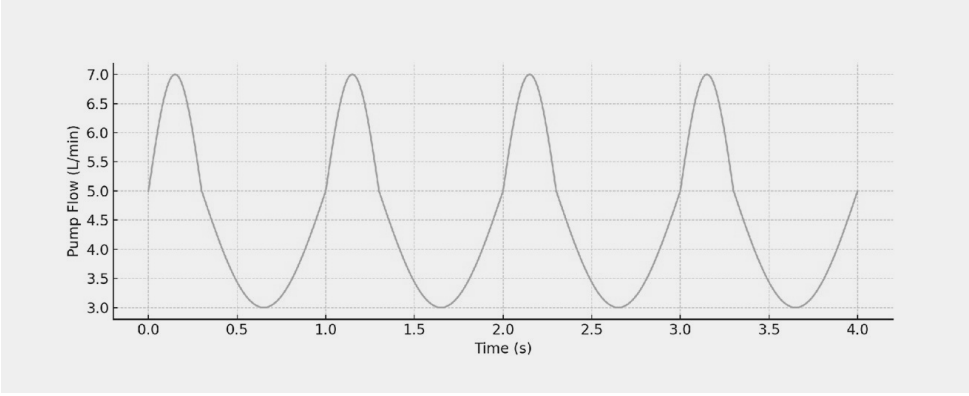

Figure 2. Graphical representation of flow variability through the left ventricular assist device across the cardiac cycle, depicting four consecutive cycles. Flow rate reaches its maximum during systole and its minimum during diastole.

3 Preoperative Management

Because the LVAD exclusively supports the left ventricle, both hemodynamic stability and LVAD performance are highly dependent on the function of the right ventricle. Hence, an up-to-date echocardiogram should be obtained, with focus on right ventricular function. Position of interventricular septum, flow profiles of the inflow and outflow cannulas, valves and presence of intracardiac thrombi should also be assessed (3).

Most LVAD recipients carry an implantable cardioverter defibrillator (ICD). In procedures with potential electromagnetic interference, antitachycardia pacing and defibrillation functions must be disabled. Non-pacing-dependent patients may be managed by placing a magnet over the device, whereas pacing-dependent patients require device reprogramming to asynchronous mode. In emergencies where reprogramming is not feasible, a magnet should be used, bearing in mind that the pacemaker remains in synchronous mode. Adhesive defibrillator pads should be applied when the ICD is inactive (4).

Patients with LVAD are maintained on long-term anticoagulation therapy with warfarin, targeting an international normalized ratio (INR) of 2–3. Patients carrying HW and HMII devices are additionally treated with aspirin. However, recent evidence demonstrating a reduced risk of bleeding without an increase in thromboembolic events has led to the recommendation against the routine use of aspirin in patients with HM3 devices (5). For elective surgeries, warfarin should be discontinued five days prior and bridged with continuous intravenous unfractionated heparin to achieve an activated partial thromboplastin time (aPTT) of 50–60 seconds once INR falls below 2. Heparin should be stopped 2–4 hours before the procedure. In emergencies requiring rapid warfarin reversal, factor concentrates are preferred to reduce INR to approximately 1.5. Vitamin K is best avoided due to potential difficulties in re-establishing therapeutic INR postoperatively (6).

Nearly all patients with LVADs develop acquired von Willebrand syndrome. The increased shear stress within the pump leads to unfolding of von Willebrand factor multimers, making them susceptible to proteolytic cleavage by the ADAMTS13 enzyme. This results in reduced functional activity despite elevated antigen levels. Additionally, platelet dysfunction is common among LVAD recipients (7). Due to these factors, increased bleeding risk should be anticipated, and appropriate blood products should be crossmatched in advance.

Although patients with magnetically levitated devices experience overall fewer major adverse events when compared to other devices, the incidence of device-related infections remains the same. The driveline exit site is the most vulnerable to infections (8, 9). Strict sterile technique during skin preparation and draping around device components minimizes infection risk. Prophylactic antibiotics should be administered before surgical incision. There are currently no specific guidelines for perioperative antimicrobial prophylaxis in LVAD patients undergoing non-cardiac surgery. Consequently, high-risk protocols should be applied. The choice of antimicrobial agent should be tailored to the anticipated pathogens at the surgical site. For most surgical procedures, coverage against gram-positive bacteria is essential, with cefazolin frequently employed as the

agent of choice, while in abdominal procedures antimicrobial prophylaxis may warrant gram-positive, gram-negative and anaerobic coverage.

4 Intraoperative Management

During patient transfer, the device should be powered by rechargeable batteries; once in the operating room, power should switch to an electrical outlet. There are easily accessible videos provided by the manufacturer as part of patient education program, covering HM3 system components and how to safely operate them. They are intended for patients and caregivers, but can be of great help to medical personnel not familiar with the device. The patient or educated members of the family can assist in operating the device safely.

Continuous monitoring of pump speed, power, flow, and PI is essential. Due to continuous flow physiology, automated noninvasive blood pressure measurements are unreliable. Invasive arterial blood pressure monitoring should be established before induction, preferably using ultrasound guidance. Mean arterial pressure (MAP) is the value of interest. Since absent pulse can make pulse oximetry unreliable, frequent blood-gas analysis may be required. Placement of a central venous catheter can assist in fluid management, monitor right ventricular function, and facilitate administration of vasoactive medications.

General anesthesia is most commonly employed when local anesthesia is insufficient. Although there are several case reports of successful neuraxial anesthesia (10, 11), it is generally avoided due to anticoagulation requirements and significant preload reduction following sympathectomy.

LVADs are preload-dependent and afterload-sensitive. Maintaining adequate preload is critical, as hypovolemia or bleeding-induced volume loss can precipitate hypotension and decreased pump flow. Patient positioning, such as reverse Trendelenburg, can reduce preload and should be managed carefully. Pneumoperitoneum and high positive end-expiratory pressure (PEEP) can impair venous return; thus, intra-abdominal pressure during laparoscopic procedures should not exceed 12 cmH_2O. Because left ventricular preload depends on right ventricular function, measures should prevent increased pulmonary vascular resistance—avoid hypoxemia, hypercarbia, acidosis, and elevated airway pressures. Steep Trendelenburg position can cause sudden increase in venous return, leading to right ventricular volume overload. Elevated afterload can reduce pump flow. Furthermore, uncontrolled hypertension increases risk for pump thrombosis, ischemic and hemorrhagic stroke, aortic insufficiency, right ventricular failure, subendocardial ischemia and ventricular arrhythmias. However, low MAP risks end organ damage and is associated with inferior survival (12). Thus, MAP should be maintained between 70 and 90 mmHg.

Arrhythmias can also compromise pump flow. In cases with preserved hemodynamic stability patients can be managed with antiarrhythmics. Reversible causes, such as electrolyte abnormalities, acidosis or suction events due to underfilled left ventricle, should be addressed. In cases of hemodynamic compromise, electrical cardioversion with standard pad placement is indicated. Of note, ventricular tachycardia and ventricular fibrillation may not cause hemodynamic instability if left ventricular preload is maintained.

Severe left ventricular underfilling can cause inflow cannula obstruction by collapsing myocardium, resulting in a suction event characterized by a marked drop in pump flow, hypotension, and possibly ventricular arrhythmias. Reduced left ventricular filling can be caused by hypovolemia, right ventricular failure or tamponade. Management includes reducing LVAD speed and administering intravenous fluids or, in case of right ventricular failure, inotropic support.

Cardiopulmonary resuscitation in LVAD patients differs from standard protocols. Absence of a pulse is not a reliable indicator of cardiac arrest due to non-pulsatile flow; perfusion adequacy must be assessed. If there are signs of inadequate perfusion, device function should be assessed by auscultating for a LVAD hum over the left chest. If the device is not functioning, it is necessary to check the connections and energy supply. If the issue is not resolved, the controller should be changed. Although chest compressions carry risks of device damage and dislocation and are relatively contraindicated, the American Heart Association recommends initiating compressions when there is sustained MAP below 50 mmHg and end-tidal carbon dioxide partial pressure is under 20 mmHg despite following the aforementioned algorithm. It is important to consider that, in addition to the risk of device damage, substantial retrograde flow may occur through the non-functioning device during chest compressions, which can diminish systemic circulation and potentially compromise the success of resuscitation (13).

5 Postoperative Management

Most patients require postoperative intensive care unit admission. Early extubation is preferable due to the beneficial effects of spontaneous ventilation on right ventricular function, provided adequate ventilation and oxygenation are maintained. ICDs reprogrammed before surgery must be restored to preoperative settings. Continuous intravenous unfractionated heparin should be restarted once bleeding risk is acceptable and continued until therapeutic INR is achieved with warfarin.

6 Conclusion

Most non-cardiac anesthesiologists do not routinely encounter patients with LVADs. However, as device implantation becomes more common, the likelihood of managing these patients in non-cardiac settings increases. While close collaboration with LVAD specialists remains essential, understanding basic device physiology, monitoring specifics, and common therapeutic interventions can reduce clinician stress and simplify care for this complex patient population.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

Author Contributions

All authors contributed to the literature search, analysis, drafting, and revision of the manuscript. All authors have read and approved the final version of the manuscript.

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