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Perioperative management of non-cardiac surgery in patients on long-term left ventricular assist device support

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Abstract

Background: The shortage of donor hearts has led to the increased use of left ventricular assist devices (LVADs) as an alternative treatment for advanced heart failure. As the population of LVAD recipients grows, so does the demand for non-cardiac surgical interventions in this group. This study aims to share our experience with non-cardiac surgeries performed in patients supported by long-term LVADs.

Methods: We retrospectively analyzed 72 patients who underwent LVAD implantation at our clinic between 2017 and 2024. Among them, 53 received the HeartMate 3 (Abbott Inc., Chicago, IL) and 19 received the HeartWare (Medtronic Inc., Minneapolis, MN).

Results: Patients were followed for a mean duration of 48.5 months (range: 1-78 months). During this period, 19 non-cardiac surgical procedures were performed in 13 patients; some patients underwent more than one procedure. A total of 12 procedures were conducted under general anesthesia, while 7 was performed under sedation. No perioperative deaths, thromboembolic events, or device malfunctions occurred. Minor complications included one case of re-intubation and one surgical site infection, associated with repeated amputations in a patient with peripheral arterial disease.

Conclusion: Non-cardiac surgery in patients with long-term LVAD support appears to be safe when carefully planned. Larger studies are warranted to validate these findings.

Keywords: Left ventricular assist device, non-cardiac surgery, perioperative management, anesthesia.

Left ventricular assist device (LVAD) implantation is increasingly utilized for patients with advanced heart failure. Favorable outcomes at one and five years have contributed to the growing number of LVAD recipients, which in turn has increased the demand for both elective and emergency non-cardiac surgeries in this population.[1,2] LVADs are typically implanted either as a bridge to transplantation (BTT) or as destination therapy (DT). Patients receiving LVADs as DT are generally older and have more comorbidities, making them more likely to require non-cardiac interventions. This study aims to share our experience with non-cardiac surgeries performed in patients with long-term LVAD support.

Methods

Between 2017 and 2024, 72 patients underwent LVAD implantation at our clinic, including 53 with the HeartMate 3 (Abbott Inc., Chicago, IL) and 19 with the HeartWare (Medtronic Inc., Minneapolis, MN). The mean age of the patients was 46.6 years, and the mean follow-up period was 48.5 months (range: 1-78 months).

This study included 13 LVAD recipients who underwent a total of 19 non-cardiac procedures; some patients required multiple surgeries. A total of 12 procedures were performed under general anesthesia, and 7 were performed under sedation. Among these patients, 9 had received the HeartMate 3 device, and 4 had the HeartWare device. LVADs were implanted as a BTT in 5 patients and as DT in the remaining 8. The cohort comprised 5 female and 8 male patients, with a mean age of 45.7 years (range: 7-70 years). Detailed demographic and clinical characteristics are presented in Table 1. The study protocol was approved by the Institutional Review Board on Gaziosmanpaşa Hospital (date: 28.10.2024, number: 1942).

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Table 1. Detailed demographic and clinical information of the patients

Case	Gender	Age	Concomitant disease	Etiology	INTERMACS	LVAD type	Complication	Outcome
GA	Female	61	HT, CRF prolonged intubation	Ischemic cardiomyopathy	2	HeartMate III	Re-intubation	Under follow-up
GA								Under follow-up
VE	Male	65	DM, HT	Ischemic cardiomyopathy	3	HeartMate III		Under follow-up
VE								Mortality after 6 months
ME	Female	14		Dilated cardiomyopathy	1	HeartMate III		Heart transplant
BK	Male	15	Prolonged intubation	Dilated cardiomyopathy	2	HeartWare		Mortality after 4 years
ÜB	Male	65	PAD, DM, HT	Ischemic cardiomyopathy	3	HeartMate III	Wound infection	Under follow-up
ÜB								Under follow-up
ÜB								Under follow-up
ÜB								Mortality after 6 years
MHD	Male	67	DM	Ischemic cardiomyopathy	3	HeartMate III		Under follow-up
SNA	Female	7	End stage liver disease	Metabolic cardiomyopathy	3	HeartWare		Heart recovery
EÖ	Female	13		Dilated cardiomyopathy	1	HeartWare		Under follow-up
EÖ								Mortality after 4 years
AP	Male	46	DM	Valvular dilate cardiomyopathy	3	HeartWare		Device malfunction
HY	Male	70	PAD, HT	Ischemic cardiomyopathy	4	HeartMate III		Under follow-up
TB	Male	65	HT	Ischemic cardiomyopathy	3	HeartMate III		Under follow-up
FK	Male	69	HT	Ischemic cardiomyopathy	3	HeartMate III		Right heart failure, under follow-up
MT	Female	65	HT, DM	Ischemic cardiomyopathy	3	HeartMate III		Right heart failure, under follow-up

DM: Diabetes mellitus; HT: Hypertension; PAD: Peripheral arterial disease; CRF: Chronic renal failure; INTERMACS: Interagency registry for mechanically assisted circulatory support.

Statistical Analysis

Data were analyzed using desciptive statistics only. No inferential statistical analysis was performed due to the descriptive nature of the study.

Types of Non-cardiac Surgery (NCS)

A total of 19 procedures were performed in the 13 patients, with some patients undergoing multiple interventions. Procedures related to outflow graft complications, driveline infections requiring surgical debridement and vacuum-assisted closure, and interventions for pleural effusions (considered device-related) were excluded.

Except for three patients who presented with bleeding, all procedures were elective.

Major Procedures Requiring General Endotracheal Anesthesia

The major procedures performed under general endotracheal anesthesia included the following:

- Tracheal end-to-end anastomosis for tracheal stenosis
- Total gastrectomy for stomach cancer
- Surgical tracheostomy
- Lower limb amputations for diffuse peripheral artery disease (three procedures in one patient: Right below-knee, right above-knee, and one year later, right above-knee)
- Femoro-popliteal bypass
- Prostatectomy for benign prostatic hyperplasia
- Craniotomy and tumor excision for brain cancer
- Liver transplantation for propionic acidemia
- Surgical repair of a right humerus fracture
- Removal of an infected vascular graft in the thorax

(Detailed information is provided in Table 2).

Table 2. Major procedures requiring general endotracheal anesthesia

Procedure	Reason	Number of patients	Number of procedures
Tracheal end-to-end anastomosis	Tracheal stenosis	1	1
Total gastrectomy	Gastric cancer	1	1
Surgical tracheostomy	Respiratory issue	1	1
Leg amputation (below knee, above knee)	Peripheral artery disease	1	3
Femoro-popliteal bypass	Peripheral artery disease	1	1
Prostatectomy	Benign prostatic hypertrophy	1	1
Craniotomy and tumor resection	Brain cancer	1	1
Liver transplant	Propionic acidemia	1	1
Surgical repair of humerus fracture	Right humerus fracture	1	1
Removal of infected intrathoracic graft	Infected intrathoracic vascular graft	1	1

Minor Procedures Requiring Sedation

The minor procedures performed under sedation included the following:

- Permanent catheter placement for chronic kidney disease
- Permanent catheter placement for chemotherapy in lung cancer patients
- Gastroscopy or recto-sigmoidoscopy for gastrointestinal (GI) bleeding
- Femoral artery embolectomy
- Endometrial ablation for hypermenorrhea

(Detailed information is provided in Table 3).

Preoperative Preparation

The preoperative preparation and treatment of patients who underwent LVAD implantation and NCS in this study were coordinated by the Heart Failure Team and the relevant specialty physicians performing the non-cardiac interventions. The need for intensive care in certain patients was discussed.[3,4]

Information about the medical history of patients with LVADs presenting for NCS was obtained. During routine pre-anesthetic examination, patients were asked about LVAD-related GI bleeding, stroke, thromboembolic events, and previous infections. Auscultation was performed carefully to detect abnormal heart or diaphragm sounds that could indicate LVAD thrombosis or dysfunction. Systemic examinations and laboratory tests were conducted to evaluate recent or worsening heart failure, as well as signs of infection and sepsis. Liver and kidney functions, neurological status, hemogram, and coagulation profiles were also assessed in patients with end-stage heart failure undergoing long-term LVAD therapy.[5]

Cardiovascular medications, anticoagulants, and antithrombotic drugs used by the patients were documented. Heart failure medications were continued before surgery, while antiarrhythmic drug doses were adjusted in consultation with a cardiologist based on electrocardiogram (ECG) findings. Anticoagulant and antiplatelet drugs (warfarin and aspirin) were generally maintained for minor procedures. For major surgeries—such as orthopedic, neurosurgical, or intra-abdominal operations—warfarin was discontinued three days before surgery to reduce its effect to the lower therapeutic limit (target international normalized ratio [INR] 1-2), and aspirin was stopped five days prior. Low-molecular-weight heparin (LMWH) was administered to maintain anticoagulation coverage.[3]

Before surgery, patients were monitored for LVAD parameters, including flow rate (L/min), speed (RPM), pulsatility index (PI), and power. The heart and LVAD device functions were evaluated by a cardiologist. This assessment was used to determine the optimal LVAD RPM for each patient's ventricular function, aortic patency, and cardiac output. Pulmonary hypertension and right heart function were also evaluated. Patients with implanted cardiovascular electronic devices, such as defibrillators and pacemakers, were optimized by a cardiologist and technician prior to surgery. The defibrillator function of the implantable cardioverter-defibrillator (ICD) was planned to be disabled during the procedure.[6]

Patients fasted for 6 hours according to the classical preoperative fasting protocol and were allowed oral clear fluids until 2 hours before surgery. Since dehydration can lead to a significant decrease in cardiac output, particularly in this patient population, preoperative fluid supplementation was provided for those with potentially inadequate oral intake.[7]

Patients received 1 mg of midazolam for premedication.

Table 3. Minor procedures requiring sedation anesthesia

Procedure	Reason	Number of patients	Number of procedures
Permanent catheter placement	Chronic kidney disease	1	1
Permanent catheter placement	Chemotherapy for lung cancer	1	1
Gastroscopy/rectosigmoidoscopy	Gastrointestinal bleeding	3	3
Femoral artery embolectomy	Vascular issue (embolism)	1	1
Endometrial ablation	Menorrhagia	1	1

Anesthesia Management

Cases where sedation was applied

Pulse oximetry and rhythm monitoring were applied to patients undergoing minor interventions in the procedure room. Nasal oxygen was administered at 2-4 L/min during the procedure. Non-invasive blood pressure monitoring was generally not performed in these cases. However, for patients undergoing GI endoscopy with bleeding, non-invasive blood pressure was measured from the upper extremity using the Doppler method. Additionally, these patients were monitored with support from an experienced perfusionist, who assisted the anesthesiologist in managing the LVAD device. LVAD control was maintained by connecting the device to the desktop main control.

Patients received moderate to deep sedation depending on the nature of the procedure. The sedation level was continuously monitored and recorded. Sedative medications—including intravenous midazolam, fentanyl, and propofol infusion—were titrated to achieve the desired level of sedative analgesia and anesthesia.

After the procedure, patients were monitored in the recovery unit and then transferred to their respective wards based on their recovery scale values.

Patients who received general anesthesia

Patients taken to the operating room were monitored with a standard 5-channel ECG. After attaching the pulse oximeter, oxygen was administered via mask at 2 L/min. The LVAD was transitioned from the mobile portable control device to the desktop control panel used in the operating room and intensive care unit (ICU). Intravenous sedation was then titrated with 0.5-1 mg midazolam and 50-100 µg fentanyl.

A 3-3.5F, 6-8 cm arterial cannula was inserted into the right or left radial artery, or a 5F, 20 cm arterial cannula was inserted into the right or left femoral artery under ultrasound guidance and local anesthesia in sterile conditions. The vascular structure observed with ultrasound and the suitability of the insertion site were carefully considered, especially in patients with previous interventions.

After ultrasound evaluation of both sides, an internal jugular venous catheter was inserted. This was performed in critically ill patients receiving cardioactive drugs, patients who were awake under local anesthesia, and others following anesthesia induction.

For induction of anesthesia, midazolam (0.05-0.1 mg/kg), fentanyl (2-4 µg/kg), and thiopental (2-3 mg/kg) were administered. Muscle relaxation was achieved with rocuronium, followed by endotracheal intubation. Anesthesia was maintained with sevoflurane and fentanyl infusion.[8]

For patients with right ventricular dysfunction or pulmonary hypertension, right heart pressures were monitored using a pulmonary artery catheter inserted via the internal jugular vein under ultrasound guidance. In patients undergoing major surgery, a transesophageal echocardiography (TEE) probe was employed. In all cases, a perfusionist accompanied the anesthesiologist in the operating room to assist with LVAD management, including operation of the LVAD support console and alarm monitoring. LVAD power index and rotation RPM were adjusted according to the patient's condition by the anesthesiologist and perfusionist.

A urinary catheter was placed to monitor urine output. Body temperature was measured with an oropharyngeal probe, and anesthesia depth was monitored using bispectral index monitoring. Antibiotic prophylaxis consisted of 1-2 g of cefazolin; a second antibiotic was added in high-risk cases.

Anesthesia was maintained with an inhaled mixture of oxygen, air, and sevoflurane (0.5-1.5 MAC), alongside a continuous infusion of fentanyl (0.25-0.50 µg/kg/min). Ventilator settings for general anesthesia were adjusted to volume-control mode to prevent hypoxia, hypercarbia, respiratory acidosis, and auto-PEEP, maintaining peak inspiratory pressure between 25 and 30 mmHg. Tidal volume was set at 6-7 mL/kg, respiratory rate at 10-12 breaths/min, and PEEP at 3-6 cm H_2O. This strategy aimed to prevent excessive increases in pulmonary vascular resistance, thereby reducing the risk of right ventricular dysfunction and subsequent left ventricular failure.

For major surgeries, monitoring included TEE and LVAD support, while intravenous cardiac drugs and fluid therapy were optimized. LVAD inflow was assessed using TEE, evaluating ventricular positioning, turbulence in inflow and outflow areas, left ventricular size, mitral flow changes, and aortic valve opening. Intravascular volume status, arrhythmias, and right ventricular function were closely monitored, as these patients are highly sensitive to positioning and surgical techniques and are dependent on preload. Right ventricular width, tricuspid valve motion, and right atrial dimensions were also observed for signs of acute right heart failure. Arterial pressure was maintained between 70 and 90 mmHg, and LVAD RPMs were adjusted to maintain a flow rate of 3-3.5 L/min.[9]

When hypovolemia was detected based on TEE and pulmonary artery pressure, intravenous crystalloid boluses of 100-200 mL were administered. Norepinephrine was the first-line inotropic agent, followed by dopamine in patients requiring additional support under general anesthesia. Dobutamine, milrinone, and nitroglycerin were used if right ventricular function deteriorated during TEE monitoring. Infusions were administered as required.

Atrial fibrillation, rare ventricular ectopic beats, or chronic arrhythmias that did not compromise blood pressure or hemodynamics were left untreated. Acute rapid atrial fibrillation or ventricular tachyarrhythmias were managed with antiarrhythmic or heart rate–lowering drugs, taking care to prevent advanced bradycardia and right ventricular failure.[10]

Platelets and cryoprecipitate were prepared for patients undergoing neurosurgery, organ transplantation, or major abdominal procedures.

For femoropopliteal bypass and amputation procedures, patients were extubated in the operating room. In major surgeries, extubation was performed in the ICU. Postoperatively, patients were monitored in the ICU by an experienced cardiac surgery team specializing in the care of critically ill patients with heart failure.

Results

There were no complications in any major or minor surgery or intervention, and no early or late mortality was observed. All patients were discharged without problems. The fact that most procedures were performed electively may have positively influenced the outcomes. Only minor complications occurred: one patient required re-intubation, and one developed a surgical site infection related to repeated amputations

in a patient with peripheral arterial disease. No major complications were seen in patients undergoing large surgeries.

In proctosigmoidoscopy cases with bleeding, patients were corrected to an acceptable prothrombin time using fresh frozen plasma and vitamin K, and urgent endoscopy was performed. These three patients underwent sedation and required transfusion with erythrocyte suspension. In patients under general anesthesia, the average blood and blood product use was 1.6 units per patient, with liver transplantation and brain surgery cases increasing the average.

For patients with interrupted warfarin or aspirin therapy, LMWH, warfarin, and aspirin were restarted after extubation once bleeding was ruled out. LMWH was stopped when the INR reached the target range. In patients presenting with bleeding, the regimen was switched to aspirin and clopidogrel, keeping INR slightly below two. None of the patients experienced thromboembolic events, cerebral events, or device-related problems.

Discussion

Recently, as the number of patients receiving LVAD implantation for DT has increased, there has been a parallel rise in the number of non-cardiac interventions in these patients.[2,11] Such interventions should ideally be performed in transplantation and LVAD centers. In centers with an LVAD coordinator, the coordinator should accompany the patient, and the device control panel should be carefully monitored.[11] If no LVAD coordinator is available, a cardiac anesthesiologist or transplant surgeon familiar with these patients should provide support.

Two main considerations are important for patients undergoing major interventions. First, antiplatelet and anticoagulant therapy should be preemptively discontinued and converted to LMWH. This approach reduces preoperative and postoperative bleeding, lowers blood product usage, and helps prevent device thrombosis. This strategy is similar to the management of patients with mechanical heart valves or atrial fibrillation who are on antiplatelet or anticoagulant therapy.

In third-generation continuous-flow LVADs, the risk of thrombus formation is low.[1] Devices with a higher risk of thrombus have been withdrawn from the market. Extra attention is still required for patients living with older devices. The exclusive availability of HM3 in our country has strengthened our ability to manage these patients effectively.

In patients requiring minor interventions, procedures can often be performed while maintaining anticoagulant and antiplatelet therapy. However, for procedures such as stomach and colon resection, open cholecystectomy, open prostatectomy, major vascular interventions, and orthopedic surgeries, we recommend discontinuing warfarin and aspirin at least five days before the procedure, with anticoagulation managed using LMWH.

The second challenging group includes patients presenting with acute GI bleeding. These cases are urgent and require immediate endoscopy, which can be performed while continuing warfarin and aspirin. Rapid reversal with fresh frozen plasma and vitamin K to reduce the INR, as well as blood transfusion if needed, should be considered. For elective endoscopy, warfarin and aspirin should be discontinued, and the procedure performed under LMWH. In our series, only 3 of 19 patients (15.8%) required intervention for GI bleeding, which is lower than reported in other series.[11] Patients with GI bleeding represent a significant group due to their use of anticoagulants, antiplatelets, and continuous-flow devices.

The second important consideration is assessment of intravascular and extravascular fluid status. For minor procedures, an intravenous line is usually sufficient, without the need for arterial monitoring. The main control panel of the device should be brought into the room or operating theater, rather than relying on the pocket panel, to monitor RPM, flow, and PI. Routine monitoring of rhythm, pulse oximetry, and non-invasive blood pressure is generally adequate. Although some series recommend capnography,[12] we did not use it in any patient.

When propofol and remifentanil are used for sedation, low doses should be administered to avoid hypotension, and the infusion should be titrated accordingly. This is particularly important during GI endoscopy. An arterial line is recommended for patients at high risk of bleeding or with increased fluid requirements. Central venous access should be established and carefully monitored. In long-duration major procedures, right and left ventricular filling and septal positioning should be evaluated using TEE.

TEE is especially valuable during laparoscopic surgery, where increased intra-abdominal pressure can reduce venous return. Monitoring right ventricular and right atrial size, as well as inferior vena cava fullness, is therefore important. We suggest that TEE be used routinely in such cases.

If hypotension occurs despite high flow, the dose of vasodilators should be reduced. In conditions such as sepsis, vasopressors should be initiated. If hypotension occurs with low flow, volume loading should be administered.[13] TEE can guide management in these scenarios. Additionally, if the PI rises excessively and triggers an alarm, it may indicate elevated blood pressure, which should be corrected as needed.

Electrocautery does not interfere with LVAD function. Many of these patients have both an LVAD and an ICD, which can be advantageous. In cases of ventricular tachycardia (VT) or ventricular fibrillation (VF), the ICD may activate. For long-duration major surgeries, external defibrillator pads should be applied. VF or VT should not be feared in LVAD patients. In our series, one patient remained in VF; if the ICD does not activate, external defibrillation can be performed.

In patients with Fontan circulation and high right-sided pressures, defibrillation may not restore sinus rhythm. In such cases, defibrillation should be applied only after the right ventricle and right atrium are adequately emptied.

Blood transfusion is often necessary, particularly in patients presenting with bleeding. Literature reports a transfusion rate ranging from 12% to 41%.[14-16] In our series, 3 patients with emergency bleeding under sedation required red blood cell transfusions. Among patients under general anesthesia, the average blood and blood product use was 1.6 units per patient, with liver transplantation and brain surgery increasing the average.

Since our hospital does not have an LVAD coordinator, all procedures were performed by a single cardiac anesthesiologist. We believe that having an experienced cardiac anesthesiologist, particularly for major surgeries, contributed positively to outcomes by enabling ultrasound-guided arterial monitoring and TEE when necessary. However, another study reported that the type of anesthesiologist—cardiac or non-cardiac—did not significantly affect outcomes.[14]

In cases where the abdominal cavity must be opened, the LVAD driveline may cross the midline. General surgeons should be reminded to handle the driveline with utmost care, and, if feasible, procedures should be performed endoscopically.

Although most studies have shown that NCS does not increase mortality, Mentias et al. reported in JAMA that among over 1,000 emergency or urgent cases and 326 elective cases, the frequency of major cardiovascular events was 16.9% for emergency procedures and 7.1% for elective procedures, with mortality of 8.78%.[2] The same article noted that rates in other studies ranged from 0% to 16%, likely due to differences in inclusion criteria.[2] In their cohort, NCS was required in one out of every six LVAD patients, with a 34.2% rate of blood transfusion, increased mortality, and 37.2% rehospitalization after NCS.[2]

Although our sample size is small, we believe that performing most procedures electively and following patients with a single experienced cardiac anesthesiologist contributed positively to our outcomes, consistent with findings in other studies. The main limitations of our study include a small sample size and the absence of a control group. Additionally, as a retrospective study, it is susceptible to bias. Despite these limitations, our findings suggest that non-cardiac surgeries in LVAD patients can be performed safely with appropriate planning and multidisciplinary coordination. No anesthesia-related complications were observed. These results support a cautious yet proactive approach, although further studies are needed to confirm generalizability.

Ethics

Ethics Committee Approval: The study protocol was approved by the Institutional Review Board on Gaziosmanpaşa Hospital (date: 28.10.2024, number: 1942).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Concept: H.K., D.M.; Design: H.K., D.M.; Data Collection or Processing: M.B., O.K., K.S.; Analysis or Interpretation: M.B., A.D., O.K., K.S.; Literature Search: H.K., A.D., D.M.; Writing: H.K., A.D., D.M.

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