Abdominal Surgery in Patients with a Ventricular Assist Device: A Single Center Experience in Israel

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ABSTRACT **Background:** Left ventricular assist devices (LVADs) are used more commonly in patients with advanced-stage heart failure. Some of these patients may require elective or urgent abdominal surgical procedures.

Objectives: To determine the outcomes of the management of LVAD-supported patients who underwent elective and urgent abdominal surgical procedures in our institution.

Methods: A retrospective review was conducted on 93 patients who underwent LVAD implantation between August 2008 and January 2017. All abdominal surgeries in these patients were studied, and their impact on postoperative morbidity and mortality was evaluated.

Results: Ten patients underwent abdominal surgical procedures. Of these procedures, five were emergent and five were elective. The elective cases included one bariatric surgery for morbid obesity, one hiatal hernia repair, two cholecystectomies, and one small bowel resection for a carcinoid tumor. The emergency cases included suspected ischemic colitis, right colectomy for bleeding adenocarcinoma, laparotomy due to intraabdominal bleeding, open cholecystectomy for gangrenous cholecystitis, and laparotomy for sternal and abdominal wall infection. All patients undergoing elective procedures survived. Of the five patients who underwent emergency surgery, three died (60%, $P = 0.16$) and one presented with major morbidity. One of the two survivors required reintervention. In total, 12 interventions were performed on this group of patients.

Conclusions: It is safe to perform elective abdominal procedures for LVAD-supported patients. The prognosis of these patients undergoing emergency surgery is poor and has high mortality and morbidity rates.

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KEY WORDS: elective surgery, emergency surgery, left ventricular assist devices (LVADs), heart failure

Heart failure continues to be a major therapeutic challenge worldwide. Heart transplantation is the best treatment offered for patients with medically uncontrollable heart and circulatory failure. A shortage of organs available for transplant has led to the successful development of an alternative to heart transplantation, the left ventricular assist device (LVAD). With growing experience and technological advancements, LVADs are implanted not only as a bridge therapy to heart transplantation, but also as a destination therapy. The outcome of this medical and technological revolution is impressive as many patients live better and longer lives [1]. The increased life expectancy of these patients has exposed them to other non-cardiac, health-related events. Thus, our study focused on the need for abdominal surgical procedures, either elective or urgent, with the objective of presenting our institution's experience in managing LVAD patients who underwent elective and emergency abdominal surgeries [2].

PATIENTS AND METHODS

This study was approved by the institutional ethics review board committee of Rabin Medical Center (approval number 0097-17-RMC). The Heart Failure Unit patient registry was accessed for data collection. Between August 2008 and January 2017, 93 patients underwent long-term LVAD implantation as either a bridge to heart transplantation or as destination therapy. The clinical records of these patients were retrospectively reviewed. Eleven patients died in the first 30 days following LVAD implantation. An additional two patients were lost to follow-up. Eighty patients were available for the study. Ten patients with LVADs (n=10) underwent abdominal surgical procedures during the study period. The procedures were divided into elective and urgent, and the data were analyzed according to the type of surgical procedures and outcomes [Figure 1]. The complications were defined as any deviation from an uneventful postoperative course, and graded according to The Clavien-Dindo classification of surgical complications [3]. The American Society of Anesthesiologists (ASA) score was used as an indicator of the patients' preoperative health [4].

RESULTS

Of the 93 patients implanted with durable LVADs who were identified in the retrospective data review, 51 (55%) received a HeartMate II (Abbott, Abbott Park, IL, USA) device, 28 (30%) received a HeartWare (HeartWare, Framingham, MA, USA), 10 (11%) received a HeartMate III, and 4 patients (4%) received other devices. Of the 80 patients who were included in the study,

Figure 1. The diagram illustrates grouping and flow of the patients in the study
LVAD = left ventricular assist devices

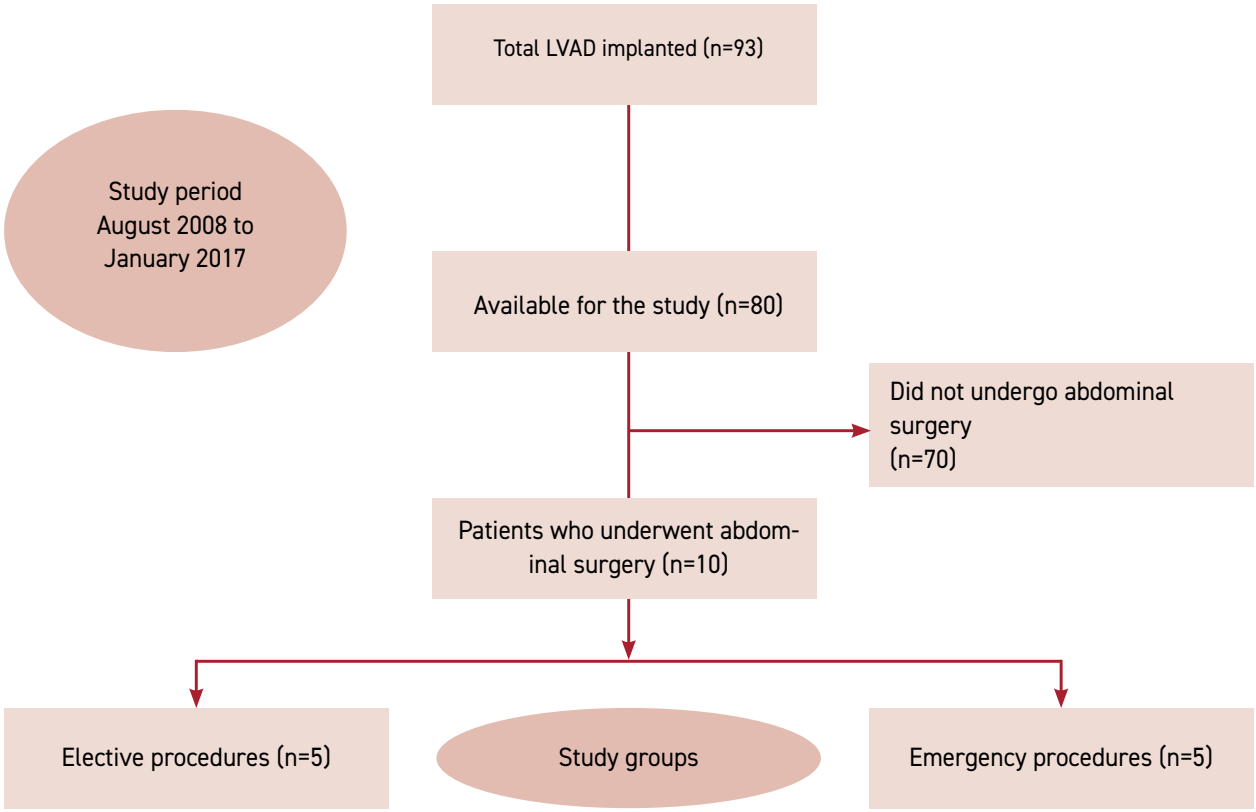

Table 1. Elective surgeries

Age, years	Sex	Surgery type	ASA grade	Indication for surgery	Complication grade (Clavien-Dindo)	Time between LVAD implantation and surgery (months)
46	Female	Lap. sleeve gastrectomy	III	Morbid obesity	0	13.6
53	Male	Lap. hiatal hernia repair	III	Symptomatic hiatal hernia with anemia*	0	16.6
60	Male	Laparotomy, intraoperative endoscopy. small bowel resection	III	GI bleeding, small bowel carcinoid	II	2.6
63	Male	Lap. converted to open cholecystectomy	III	S/P acute cholecystitis cholecystostomy	II	14. 4
66	Male	Lap. cholecystectomy with intraoperative cholangiography	III	Symptomatic cholelithiasis	0	19.9

*This patient presented with a symptomatic large hiatal hernia and anemia caused by erosions of the gastric wall, constricted by the diaphragm hiatus (Cameron lesions)
ASA = American Society of Anesthesiologists, GI = gastrointestinal, Lap = laparoscopic, LVAD = left ventricular assist device

10 underwent abdominal surgical procedures (12.5%). Of those 10, 5 required emergency surgery and 5 had elective surgery. All patients who underwent surgery were supported with fully implantable LVADs. The clinical characteristics of the patients in the two groups are shown in Table 1 and Table 2.

All patients in the elective group had some degree of functional disability, and were given an ASA score of III, indicating a severe systemic disease that is not life-threatening. All patients in the emergency surgery group were given a score of ASA IV-E, which denotes ASA class IV involving an emergency surgical procedure where a delay in surgical treatment would be life-threatening. All perioperative management in these patients was implemented by an experienced team of senior anesthesiologists, accompanied by a dedicated LVAD technician. General anesthesia was administered to all patients. During the procedure, the LVAD technician aided in programming and adjusting the pump speed and power,

Table 2. Urgent surgeries

Age	Sex	Surgery type	ASA grade	Indication for surgery	Complication grade (Clavien-Dindo)	Time between LVAD implantation and surgery (months)
55	Female	Exploratory laparoscopy	IV emergency	Suspected ischemic colitis	0	7
57	Male	*Extended right hemicolectomy	IV emergency	Bleeding adenocarcinoma of colon	IV	4
65	Female	**Open cholecystectomy, surgical hemostasis	IV emergency	Intra-abdominal bleeding	V – Exitus	15.7
66	Male	Open cholecystectomy	IV emergency	Gangrenous cholecystitis	V – Exitus	24.7
72	Male	Sterno-plasty with omental transposition	IV emergency	Wound infection around drive line	V – Exitus	17.7

*This patient underwent three additional laparotomies, one on postoperative day 7 due to suspicion of an anastomotic leak. The second laparotomy was required at 2 weeks after the first operation due to the free abdominal air. A third surgery was performed 3 weeks after the first operation due to intraabdominal bleeding
**This patient underwent four surgeries. She required an open cholecystectomy due to acute gangrenous cholecystitis and subsequently needed three operations for intraabdominal bleeding, infection, abdominal washout, and delayed closure of the abdomen
ASA = American Society of Anesthesiologists, LVAD = left ventricular assist device

according to the physiological requirements of the patient. Blood pressure was monitored with an arterial line.

Of the five elective cases, one patient underwent bariatric surgery for morbid obesity, one had symptomatic hiatal hernia, two were operated for symptomatic gallbladder disease, and one underwent small bowel resection for a carcinoid tumor causing blood loss and anemia.

All patients tolerated their respective procedures well. Neither mortality nor major morbidity was observed [Table 1]. In our series, anticoagulation was discontinued 3–5 days before elective procedures, and oral Warfarin was bridged with subcutaneous enoxaparin (Clexan®). Preoperative anemia was corrected with blood transfusions in two elective patients: a patient with a hiatal hernia with gastric erosions and a patient with a small bowel carcinoid tumor. These patients presented with chronic blood loss due to the underlying conditions, and the hemoglobin concentration of more than 10 g/dl was required prior to the procedures. Neither of these patients required postoperative blood transfusions. One elective sleeve gastrectomy patient and one elective cholecystectomy patient required postoperative blood transfusions of two packed cell units to maintain the hemoglobin levels up to 10 mg/dl. The estimated blood loss in all elective cases was reported as minimal according to the operative surgical reports. There was no clinical evidence of postoperative bleeding in these patients.

Five patients had emergency surgery including laparoscopy for suspected ischemic colitis, right colectomy for bleeding adenocarcinoma, laparotomy due to intra-abdominal bleeding, open cholecystectomy for gangrenous cholecystitis, and laparotomy for sternal and abdominal wall infection management.

For emergency procedures, therapeutic anticoagulation was counteracted with intravenous fresh frozen plasma with an INR goal of 1.5.

Preoperative anemia in three emergency surgery patients with hemoglobin levels below 10 mg/dl was corrected en route to the operating room with blood transfusions. In the emergency surgery group, one patient who showed multiple organ failure and eventually died required multiple blood transfusions. Two patients who died postoperatively after cholecystectomy also required blood transfusions.

The patients who underwent emergency surgery had substantial mortality and morbidity. Three patients died within 30 days of surgery (60%, $P = 0.16$) and one presented with a major (grade IV) morbidity [Table 2]. One of the two survivors required three additional surgical interventions to mitigate the complications. The total number of interventions was 12 for the five patients in the emergency surgery group [Table 3].

DISCUSSION

In 1994, ventricular assist devices were approved by the U.S. Food and Drug Administration in the United States for the treatment of end-stage heart failure, inotrope dependent patients, and patients with intractable arrhythmias, especially when LVEF fell below 25% [5,6]. Since then, the use of these devices has become more prevalent due to technological advances and broadening of the clinical indications [7]. In addition, the progress of continuous flow technology has led to a remarkable rise in 1- and 2-year survival rates, which have been reported as 88% and 80%, respectively [8,9]. The number of LVAD-supported patients is rising and, as expected, they may need general surgical abdominal procedures, which imposes a number of unique anesthesia related and perioperative challenges. The blood flow generated by the device is unidirectional and patient hemodynamics depends entirely on filling volume and outflow resistance. The device propels the blood from the left ventricle to

Table 3. Clinical characteristics of the 10 patients with LVADs, matched for elective and emergency surgical procedures

	Elective surgery	Emergency surgery
Number of patients	5	5
Number of surgical operations	5	12
Age (median), years	60	65
Number of patients with complications	2	4
In-hospital mortality	0	3 (60%), $P = 0.16$
Destination therapy	3	2
Type of LVAD	HeartMate II: 4 patients HeartWare: 1 patient	HeartMate II: 4 patients HeartWare: 1 patient

LVAD = left ventricular assist device

the aorta. When the impeller revolves, the blood flows from the left ventricle into the aorta, thus bypassing the failed left ventricle. Since the LVAD supports the failed left ventricle, its performance requires a high overall function of the right ventricle. The main anesthetic strategy during surgery in LVAD supported patients is to avoid hypovolemia and also to prevent or counteract right heart failure. Contrary to the heart's native response, no Starling effect is present with LVAD-driven hemodynamics; hence, the device can only pump the volume delivered to it and inadequate filling will result in decreased flow with a resulting decreased stroke volume. This preload and afterload sensitivity mandates careful attention to the administration of intravenous fluids as well as blood loss during surgery. The main goal in the perioperative management of these patients is the attenuation of sharp escalations in the arterial blood pressure by counteracting the sympathetic nervous system activity produced by laryngoscopy, intubation, or surgery itself.

Several studies have addressed this issue in the past. As early as 1995, Goldstein et al. [10] described 12 patients with LVADs who underwent non-cardiac surgical procedures. Those authors reported minimal morbidity and no mortality in their study. Subsequent studies reported the rates of non-cardiac surgical procedures in patients on mechanical circulatory support to be around 18–27%, although some studies included procedures such as dental extractions, tracheostomies, insertion of feeding tubes, catheter insertions, vascular, urologic, cataract, and other surgeries [11-14].

Due to the limited number of existing studies with relatively small sample sizes and widely heterogeneous data, some reported no postoperative deaths and others reported 30-day postoperative mortality rates ranging from 6.4 to 16.7% [15]. As a reflection of the available data, the main limitation of our study is the small number of patients, which makes interpretation of the variables such as morbidity and mortality very difficult. Unfortunately, we cannot comment on the intraoperative metabolic status of the patients, since the blood gas results were not documented in the electronic database of anesthetic reports during the study period, and were not available for the retrospective analysis.

In our experience, 12.5% (10/80) of patients with LVADs required general abdominal procedures. This number is consistent with that found in other reports. There was no mortality and minimal morbidity observed in the patients that underwent elective surgery. The patients who underwent emergency procedures had negative outcomes. They showed high mortality rates (60%), encountered major complications, required more blood transfusions, and required multiple follow-up surgeries. As expected, the patients who underwent emergency surgery had higher ASA scores of IV with an emergency nominator (E), which reliably reflects the severity of their preoperative conditions and also predicts a poor outcome. Only one patient in the emergency group who had surgery for suspected ischemic colitis did well. She underwent a normal diagnostic laparoscopy, and ruled out any abdominal pathology. She recovered without sequela. Other patients with established life-threatening abdominal emergencies had poor outcomes. Three died and one required additional surgery.

CONCLUSIONS

There is a growing population of patients with LVADs, and many of them will require general surgical interventions unrelated to their cardiac status. According to our experience, elective abdominal procedures are safe in LVAD-supported patients. The prognosis of LVAD-dependent patients who undergo emergency surgery is poor with high mortality and morbidity rates.

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Capsule

Structure of the SARS-CoV-2 spike receptor-binding domain bound to the ACE2 receptor

To better understand the initial step of infection at an atomic level, **Lan** et al. determined the crystal structure of the receptor-binding domain (RBD) of the spike protein of SARS-CoV-2 bound to the cell receptor ACE2. The overall ACE2-binding mode of the SARS-CoV-2 RBD is nearly identical to that of the SARS-CoV RBD, which also uses ACE2 as the cell receptor. Structural analysis identified residues in the SARS-CoV-2 RBD that are essential for ACE2 binding, the majority of which either are highly conserved or share similar side chain properties with those in the SARS-CoV RBD. Such similarity in structure and sequence strongly indicate convergent evolution between the SARS-CoV-2 and SARS-CoV RBDs for improved binding to ACE2, although SARS-CoV-2 does not cluster within SARS and SARS-related coronaviruses. The epitopes of two SARS-CoV antibodies that target the RBD are also analysed for binding to the SARS-CoV-2 RBD, providing insights into the future identification of cross-reactive antibodies.

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Capsule

Statin therapy is associated with lower prevalence of gut microbiota dysbiosis

Microbiome community typing analyses have recently identified the *Bacteroides*2 (Bact2) enterotype, an intestinal microbiota configuration that is associated with systemic inflammation and has a high prevalence in loose stools in humans. Bact2 is characterized by a high proportion of *Bacteroides*, a low proportion of *Faecalibacterium* and low microbial cell densities. Its prevalence varies from 13% in a general population cohort to as high as 78% in patients with inflammatory bowel disease. Reported changes in stool consistency and inflammation status during the progression toward obesity and metabolic co-morbidities led the authors to propose that these developments might similarly correlate with an increased prevalence of the potentially dysbiotic Bact2 enterotype. By exploring obesity-associated microbiota alterations in the quantitative fecal metagenomes of the cross-sectional MetaCardis Body Mass Index Spectrum cohort (n=888), **Vieira-Silva** and colleagues. identified statin therapy as a key covariate of microbiome diversification. By focusing on a subcohort of participants that are not medicated with statins, the authors found that the prevalence of Bact2 correlated with body mass index, increasing from 3.90% in lean or overweight participants to 17.73% in obese participants. Systemic inflammation levels in Bact2-enterotyped individuals are higher than predicted on the basis of their obesity status, indicative of Bact2 as a dysbiotic microbiome constellation. The authors also observed that obesity-associated microbiota dysbiosis is negatively associated with statin treatment, resulting in a lower Bact2 prevalence of 5.88% in statin-medicated obese participants. This finding is validated in both the accompanying MetaCardis cardiovascular disease dataset (n=282) and the independent Flemish Gut Flora Project population cohort (*n*=2345). The potential benefits of statins in this context will require further evaluation in a prospective clinical trial to ascertain whether the effect is reproducible in a randomized population and before considering their application as microbiota-modulating therapeutics

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