Original paper

Emergency abdominal surgery in patients with left ventricular assist device: short- and long-term results

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A b s t r a c t

Introduction: Emergency abdominal surgery (EAS) in patients with long-term mechanical circulatory support and strong anticoagulation is very difficult.

Aim: To present our experiences regarding the short- and long-term results of patients with a left ventricular assist device (LVAD) who underwent emergency abdominal surgery under general anesthesia at a large tertiary healthcare center.

Material and methods: The electronic medical records of 7 patients with LVAD who underwent EAS between January 1, 2010 and December 31, 2016 were retrospectively investigated in order to evaluate perioperative management and outcomes. The patients were divided into two groups based on the need for EAS procedures.

Results: Seven (9.2%) of 76 patients with LVAD underwent EAS an average of 79.1 ±79.4 days after implantation. No statistically significant differences were found between the groups with and without EAS with regard to demographic characteristics, type of device, and rate of perioperative mortality ($p > 0.05$). The indications for surgery, retroperitoneal hematoma in 2 patients and in 5 other patients; ileus, iatrogenic splenic injury associated with thoracentesis, splenic abscess, acute abdominal pain and rectal cancer surgery was a pelvic abscess in a patient who is connected to the stump. In all cases laparotomy was performed with median incision. The perioperative mortality rate was 28.6% ($n = 2$). Two patients underwent orthotopic heart transplant during long-term follow-up.

Conclusions: The EAS is not rare during LVAD treatment but is a rather complex procedure. General surgeons will be increasingly likely to encounter such patients as their numbers rise and their life expectancies are prolonged.

Key words: emergency, left ventricular assist device, general surgery.

Introduction

Although heart transplantation is very successful for the treatment of end-stage heart failure (HF), an insufficient number of donors has led to the development of ventricular assist devices (VADs). The major clinical practice areas of VADs include bridge to recovery, bridge to transplant, and bridge to decision [1].

As the utilization of left VADs (LVADs) has increased, complications related to this device and accompanying comorbidities have also become more common [2–5]. Complications unrelated to mechanical support might arise and necessitate surgical treatment, along with typical problems such as hemorrhage related to support devices, thromboembolism, and infection [5]. Pathologies originating from the abdomen involving general surgery may also occur [5, 6].

Aim

This study aimed to investigate the causes of emergency abdominal surgery (EAS) following LVAD implantation and the short- and long-term effects of such procedures on mortality.

Material and methods

Study design

The study was approved by Kartal Koşuyolu High Speciality and Training Hospital's Clinical Trial Review Board (Registration No: 2017.1/4-23). Eighty-one patients underwent LVAD implantation at our hospital between January 2010 and December 2016 due to end-stage HF. The incidence of the postoperative need for EAS in these patients, treatment, and effects on mortality were inves-

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tigated. The patients' data were evaluated and recorded from hospital archive files and automated records.

Study population

Patients older than 18 years who received LVAD implantation between January 2010 and December 2016, with complete file records, were included in the study. Patients who did not undergo EAS following LVAD implantation were allocated to group 1, while those who underwent EAS were allocated to group 2.

Anticoagulation protocol

Patients with LVADs at our institution are routinely anti-coagulated with aspirin and warfarin, with a target international normalized ratio (INR) of 1.8 to 2.5.

Data

The age, sex, comorbidities, type of LVAD, indication for LVAD location, goal of LVAD treatment, period from LVAD implantation to surgery, and antiaggregant and/or anticoagulant treatments of each patient were recorded. Preoperative laboratory data, including full blood count, blood urea nitrogen, creatinine, and INR, were collected.

Data on the indication for emergency surgery, type of anesthesia, method of intraoperative monitorization, type of surgery performed, need for intraoperative blood transfusion, duration of operation, inotropic support during surgery, total duration of intensive care and hospitalization, morbidity, and mortality were also recorded. Mortality occurring within the first 30 days of postoperative follow-up was referred to as perioperative mortality, while surgical complications observed within the same period were considered morbidities.

The primary endpoint of the study was to investigate the short- and long-term effects of EAS following LVAD implantation on mortality.

Table I. Clinical and demographic characteristics of LVAD

Parameter	Group 1 (n = 69)	Group 2 (n = 7)	P-value
Sex:			
Male	59 (85.5%)	7 (100%)	0.280
Female	10 (14.5%)	0	
Age	44.83 ±11.99	42.29 ±14.29	0.601
Diagnosis:			
DKMP	55 (79.9%)	5 (71.4%)	0.813
IKMP	11 (15.9%)	2 (28.6%)	
PKMP	2 (2.9%)	0	
RKMP	1 (1.4%)	0	
Device:			
HeartWare HVAD	26 (37.7%)	0	0.176
HeartMate II	27 (39.1%)	6 (85.7%)	
HeartMate III	11 (15.9%)	1 (14.3%)	
Excor Berlin Heart	4 (5.8%)	0	
Micromed DeBakey	1 (1.4%)	0	
30-day mortality:			
None	55 (79.7%)	5 (71.4%)	0.609
Present	14 (20.3%)	2 (28.6%)	
Orthotopic heart transplantation:			
Yes	5 (7.2%)	2 (28.6%)	0.063
No	64 (92.8%)	5 (71.4%)	

LVAD – left ventricular assist device, DKMP – dilated cardiomyopathy, IKMP – ischemic cardiomyopathy, PKMP – peripartum cardiomyopathy, RKMP – restrictive cardiomyopathy, HeartWare HVAD (HeartWare International, Inc., Framingham MA), HeartMate II (Thoratec Corp., Pleasanton, CA), HeartMate III (Thoratec Corp., Pleasanton, CA), Micromed DeBakey (MicroMed Cardiovascular, Inc., Houston, TX), Excor (Berlin Heart, Inc., Berlin, Germany).

Statistical analysis

The Statistical Package for the Social Sciences (SPSS 21 Inc., Chicago, IL, USA) software was utilized to conduct biostatistical analyses. When the data were presented in mean figures, the standard deviation was also offered; data were stated in percentages where necessary. Normally distributed data were analyzed with Student's t-test. Categorical groups were compared using the χ^2 test. The Kaplan-Meier method was used to determine the survival rates between the study groups, and the comparisons were conducted with the log-rank test. Statistical significance was set at $p < 0.05$.

Results

The cases of 76 patients at our hospital who underwent LVAD implantation due to HF between January 1, 2010 and December 31, 2016, were investigated. Five of these patients were younger than 18 years and were thus excluded from the study. In group 1, 69 patients did not require EAS during follow-up, while 7 patients in group 2 underwent EAS.

With regard to sex, 86.84% of the patients were male (n = 66) and 13.15% were female (n = 10); there was no statistically significant relationship between sex and EAS (p = 0.280). The mean age of the patients was 44.59 ±12.1 years, with no significant difference between the groups. With regard to the etiology of HF, 82.9% (n = 63) of the patients were non-ischemic while 17.1% (n = 13) were ischemic, with no significant difference between the groups (p = 0.813).

HeartMate II (Thoratec Corp., Pleasanton, CA, USA) was implanted in 33 (43.4%) of the patients, HeartWare HVAD (HeartWare International, Inc., Framingham MA, USA) was implanted in 26 (34.2%), HeartMate III (Thoratec Corp., Pleasanton, CA, USA) was implanted in 12 (15.8%), Excor (Berlin Heart, Inc., Berlin, Germany) was implanted in 4 (5.3%), and Micromed DeBakey (MicroMed Cardiovascular, Inc., Houston, TX, USA) was

Table II. LVAD patients undergoing abdominal surgery: clinical and demographic characteristics

Patient no.	Age	Sex	Comorbidities	LVAD type	Indication for LVAD placement	LVAD treatment target	Time from implantation [days]
1	58	M	–	HeartMate II	IKMP	Bridging to transplantation	35
2	35	M	–	HeartMate III	DKMP	Bridging to transplantation	2
3	35	M	–	HeartMate II	DKMP	Bridging to transplantation	90
4	53	M	DM	HeartMate II	DKMP	Destination therapy	190
5	55	M	–	HeartMate II	DKMP	Bridging to transplantation	187
6	18	M	–	HeartMate II	DKMP	Bridging to transplantation	30
7	42	M		HeartMate II	IKMP	Bridge to recovery	20

LVAD – left ventricular assist device, DM – diabetes mellitus, IKMP – ischemic cardiomyopathy, DKMP – dilated cardiomyopathy.

implanted in one. No significant difference was found between the groups for type of device (p = 0.176). The clinical and demographic characteristics of the patients are summarized in Table I.

Baseline characteristics of patients with emergency abdominal surgery

Seven (9.8%) patients received emergency abdominal surgery during long-term mechanical assistance. All of these patients were male, with a mean age of 42.29 ±14.29 years. The etiologies of end-stage HF in these patients were idiopathic cardiomyopathy (n = 5) and ischemic cardiomyopathy (n = 2). The surgical procedures were performed within 2–190 days (mean 79.1 ±79.4 days) after LVAD implantation (Tables II, III).

Preoperative results

Five patients requiring urgent laparotomy were using aspirin and warfarin and the INR value was between 2.27 and 1.8. In 2 patients, warfarin and aspirin were stopped due to retroperitoneal hematoma, and with an INR of 1.48 and 1.23. Preoperative values of hematocrit, platelet count, creatinine, INR, and aPTT are summarized in Table IV.

Intraoperative results

In our patients, the pump chamber was at the preperitoneal space and the abdominal cavity was not opened. The location of the driveline outlet was determined according to the patient's preference. The driveline's skin under the curve was known to be able to make laparotomies later and to reduce the most possible infection. The drivelines were removed from the lower right quadrant in 6 patients and left lower quadrant in 1 patient (Figure 1). In all cases laparotomy was performed with a median incision without xiphoidal extension. When entering the abdominal cavity, care was taken to protect the pump chamber and the drive line.

Table III. Emergent abdominal surgical procedure types and intraoperative management

Patient no.	Preoperative disposition	Diagnosis	Surgical procedures	Surgical time [min]	Intraoperative management			
					Anesthesia	Monitoring	Blood products	Inotropic support
1	Intubated, in ICU	Ileus	Loop ileostomy	70	General	Arterial/CVL	1 RBCP 2 FFP	
2	Awake, in ICU	Iatrogenic splenic injury after thoracentesis	Splenectomy	60	General	Arterial/CVL	4 RBCP 2 FFP	Yes
3	Awake, on patient floor	Splenic abscess	Splenectomy	80	General	Arterial	1 RBCP 3 FFP	
4	Awake, in ICU	Acute abdomen	Explorative laparotomy	40	General	Arterial/CVL	2 RBCP 1 FFP	Yes
5	Awake, in ICU	Acute abdomen (operated rectal cancer, stump leak)	Explorative laparotomy + abscess drainage	70	General	Arterial	–	
6	Awake, in ICU	Retroperitoneal hematoma – ACS	Abdominal decompression laparotomy	80	General	Arterial/CVL	4 RBCP 2 FFP	Yes
7	Intubated, in ICU	Retroperitoneal hematoma – ACS	Abdominal decompression laparotomy	70	General	Arterial/CVL	3 RBCP 2 FFP	Yes

ICU – intensive care unit, CVL – central venous line, ACS – abdominal compartment syndrome, RBCP – red blood cells packed, FFP – fresh frozen plasma.

Table IV. Preoperative findings in patients

Patient no.	HCT (%)	aPTT [s]	INR	Platelet count [× 10^3/µl]	Creatinine [mg/dl]
1	25.4	62.9	1.96	162	1.4
2	17	35	1.8	114	0.8
3	36.5	64	2.27	279	0.94
4	26.8	44.6	2.2	57	3.57
5	29.7	42	1.91	111	0.76
6	21.7	41.7	1.48	239	0.8
7	17.5	29.5	1.23	136	2.27

HCT – hematocrit, aPTT – activated partial thromboplastin time, INR – international normalized ratio.

The surgical indications for surgery were abdominal compartment syndrome related to retroperitoneal hematoma in 2 of 7 patients, ileus in 1 patient, iatrogenic splenic injury related to thoracentesis in 1 patient (Figures 2 A, B), splenic abscess in 1 patient, acute abdomen in 1 patient, and pelvic abscess related to stump leakage in a patient with operated rectal cancer.

The retroperitoneal hematoma in the patients had giant size and caused abdominal compartment syndrome. Surgical intervention aimed at removing the intended compartment from the center. Both patients underwent abdominal decompression. In the patient who was operated on for ileus, segmental small bowel ischemia was detected and ileostomy was performed after resection. Percutaneous drainage and antibiotherapy failed and surgical drainage was performed in the patient who developed a pelvic abscess due to rectal stump leak.

All procedures were performed under general endotracheal anesthesia. Intraoperative monitoring was performed with arterial lines in 7 (100%) patients and central venous lines in 5 (71.4%).

Six (85.7%) patients received red blood cell transfusions in the operating room; all patients received transfusions within the first postoperative 24 h. Six patients were administered fresh frozen plasma (FFP) during the procedure. There was no additional coagulation support other than FFP. None of the patients required platelet transfusions. Four (57.1%) patients required intraoperative inotropic support.

Postoperative follow-up

Mortality was observed in 2 (28.6%) of the 7 patients (case numbers 4, and 7) within the first postoperative 30 days. Two patients (case numbers 2 and 6) underwent orthotopic heart transplant (OHT) during long-term follow-up. One of these patients survived for 39 months following transplantation, and the other still survives after undergoing transplantation 2 months ago. Case 5 was diagnosed with mid-rectal cancer after examinations were performed because of rectal hemorrhaging following LVAD implantation (Figure 3 A). An elective Hartmann's procedure was performed under general anesthesia following neoadjuvant therapy, and a pelvic abscess related to stump leakage developed during the postoperative follow-up period (Figure 3 B). Percutaneous drainage and antibiotherapy failed. This patient was taken into emergency surgery and received drainage. As

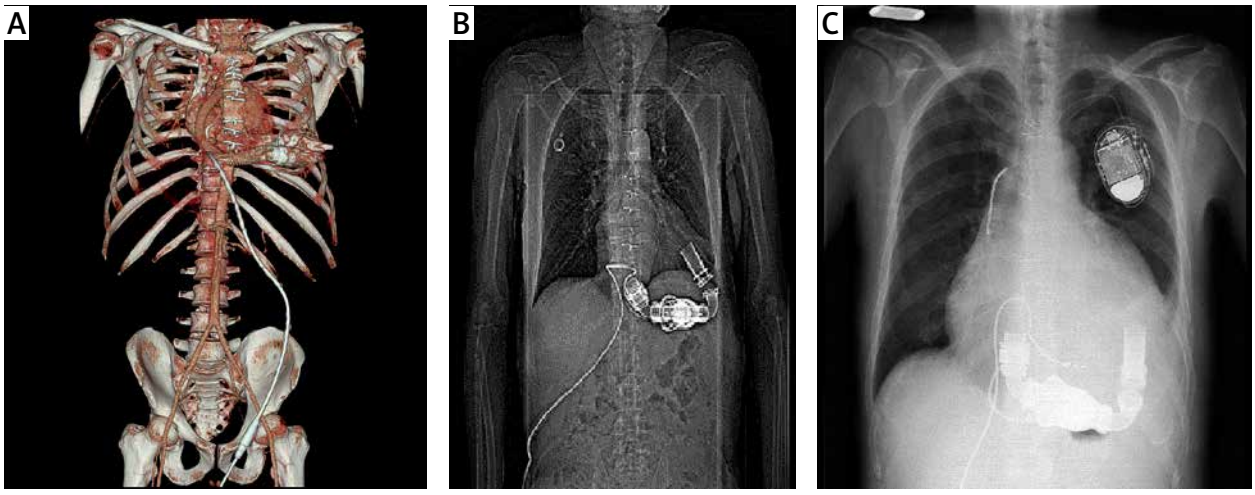

Figure 1. Computed tomography and posterior anterior chest X-ray scout film shows the location of the LVAD and LVAD driveline in the chest and abdomen

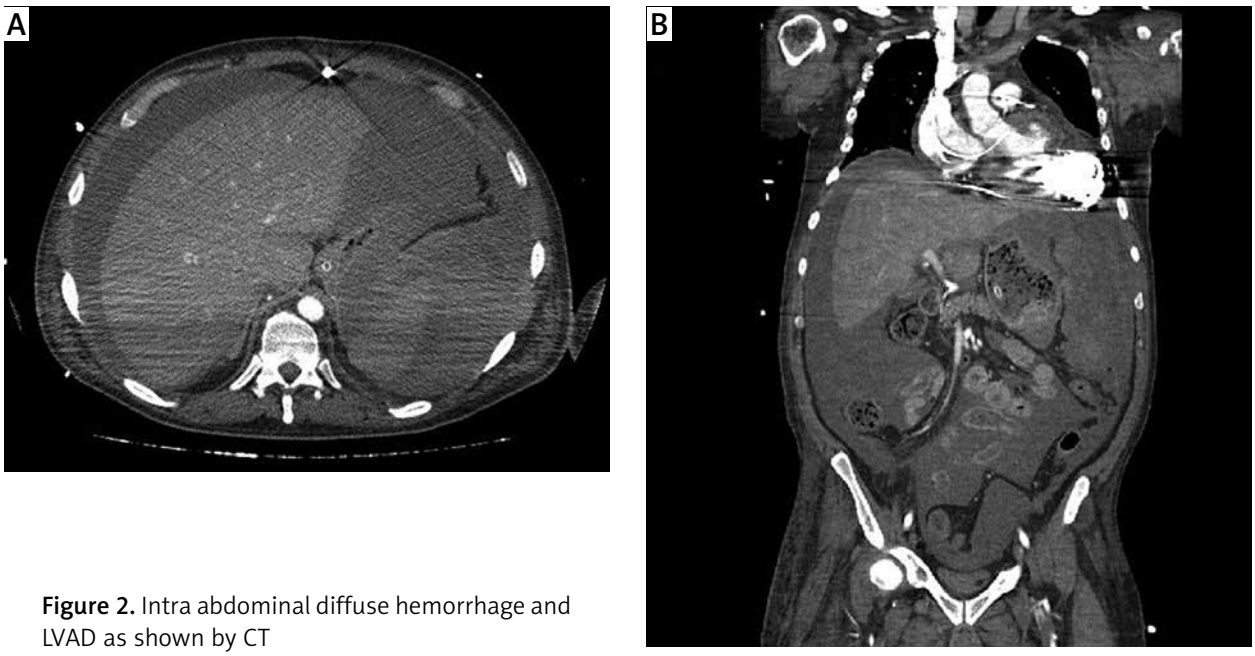

Figure 2. Intra abdominal diffuse hemorrhage and LVAD as shown by CT

his final pathological evaluation showed T3N2 (Stage IIIC), adjuvant chemotherapy was initiated. There was no radiographic distant (computed tomography, position emission tomography and abdominal ultrasonography) organ metastasis before the surgery. Liver metastasis was not detected intraoperatively. A metastasis measuring approximately 3 cm was detected in hepatic segment 4A during the 25th month of follow-up (Figure 3 C), and the patient received radiofrequency ablation therapy. The patient died of multiorgan failure in the 29th month following LVAD implantation. Case 1 died of multiorgan failure in the 3rd month following LVAD implantation. Case 3, however, has been on the waiting list for approximately 16 months since the LVAD implantation. Postoperative complications and long-term follow-up results are summarized in Table V.

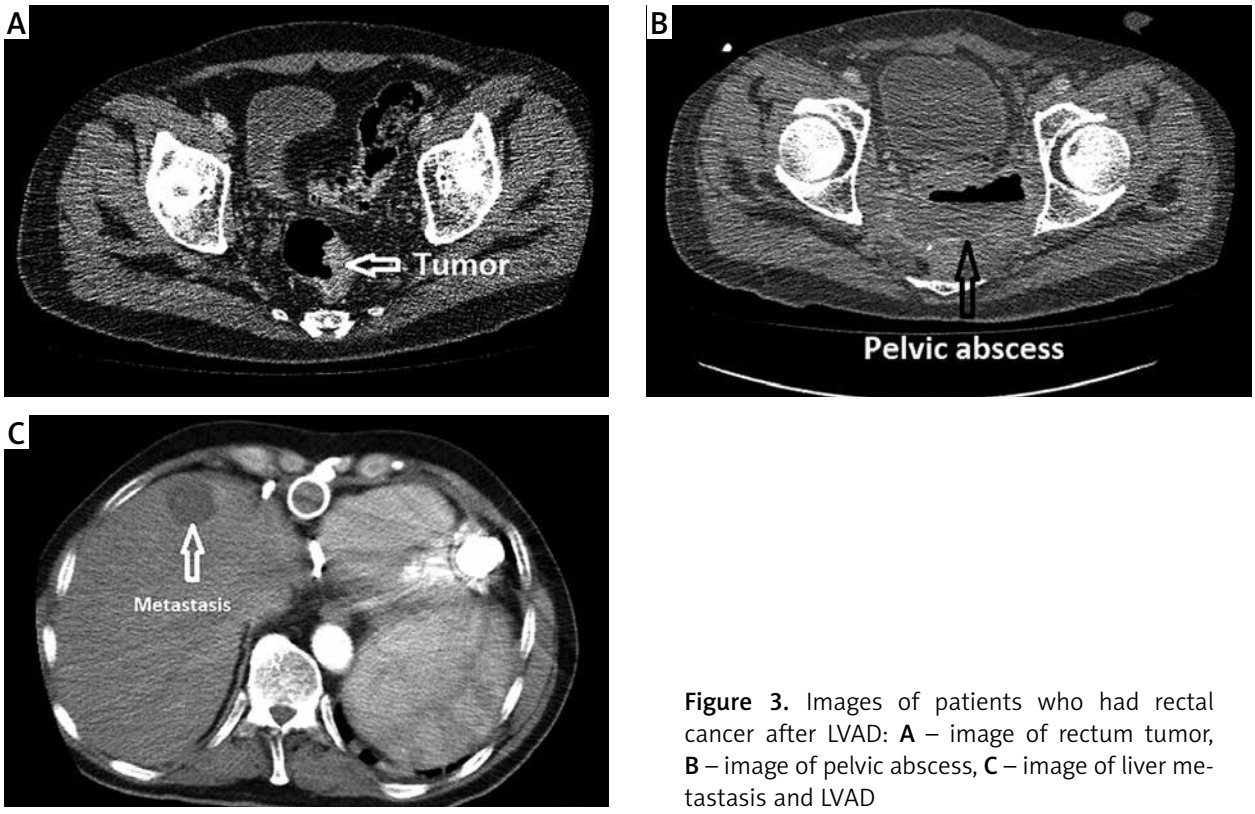

Figure 3. Images of patients who had rectal cancer after LVAD: **A** – image of rectum tumor, **B** – image of pelvic abscess, **C** – image of liver metastasis and LVAD

Table V. Postoperative complications and follow-up

Patient no.	Length of stay intensive care [days]	Length of stay in hospital [days]	Complications (30-day)	Mortality (30-day)	Heart transplantation	Late outcome
1	35	50	Wound infection	No	No	Death 3 months after LVAD implant
2	2	15	No	No	Yes	Orthotopic heart transplantation – alive
3	3	26	No	No	No	Ongoing LVAD support (480 days)
4	4	4	MOF	Yes	No	Operative death
5	3	21	Wound infection	No	No	Death 18 months after LVAD implant
6	5	34	No	No	Yes	Death 39 months after heart transplant
7	37	66	MOF	Yes	No	Operative death

LVAD – left ventricular assist device, MOF – multiple organ failure.

Survival

Mortality occurred in 43 of the 76 patients (56.6%) within the period covered by the study, including 16 who died within 30 days. The period of mean survival was 650.6 ±94.3 days in group 1 and 556.3 ±248 days in group 2, with no statistically significant difference between the groups (log rank; $p = 0.813$). After excluding the patients who died within 30 days, the mean survival was 813 ±107.8 days in group 1 and 773.6 ±308.3 days in group 2, with no significant difference between the groups (log rank; $p = 0.939$).

Discussion

The LVAD implantation has become more common as a bridge to transplantation or a destination treatment for end-stage HF. Accordingly, the number of LVAD implantations has increased and survival has been prolonged in patients with HF [1]. As these patients live longer, the likelihood of non-cardiac surgery increases [3]. Such surgical procedures range from exodontias to malignancy removals [4, 5].

Many authors have predicted that more patients with LVAD will undergo noncardiac surgical procedures, given the technological advances and increased use of LVAD. About 20% (range: 4–33%) of patients with VAD have required NCS [7–10]. Arnaoutakis *et al.* reported that they had undergone a general surgical procedure in 47 (26%) of 173 LVAD patients [5].

Studies on non-cardiac surgical procedures in these complicated patients have been limited to small case studies or isolated case reports focusing on experiences in surgery or anesthesia [5]. In a systematic review, Davis *et al.* reported that the rate of perioperative mortality was in the 6.4–16.7 interval in studies covering more than 20 patients [11]. These authors, however, did not report mortality rates for patients with emergency procedures.

Bhat *et al.* reported in 2012 that 36 (32.7%) out of 110 patients with LVAD underwent non-cardiac surgery, 9 of which were emergency procedures. Five of these 9 (4.5% of the LVAD patients) underwent EAS (two ischemic bowels, a necrotic bowel, a bowel obstruction, and a bleeding gastric ulcer) and their 30-day mortality rate was 60% ($n = 3$) [12]. Morgan *et al.* reported that 20 (23.2%) out of 86 patients with LVAD needed non-cardiac surgical procedures, but only 3 (3.4%) were emergencies, including 2 (2.3% of the LVAD patients) laparotomies and one drainage due to a knee abscess [4]. Arnaoutakis *et al*. stated in their 2013 study that 21 (12.1%) out of 173 patients with LVAD needed emergency surgery, all of which, except for one, were laparotomies. The 30-day mortality rate in the patients undergoing EAS was 9.5% [5].

Garatti *et al.* reported that 11 (14.2%) out of 77 patients with LVADs over a period of 19 years had 12 non-cardiac surgical procedures and only 1 (1.2%) received EAS; this case received OHT during the long-term follow-up period [13]. In 1994, Goldstein *et al.* reported that 1 (3.5%) out of 28 patients with LVAD needed EAS due to gastric ulcer bleeding. No complications during the follow-up period were mentioned, other than hypotension [14].

In the present study, 7 (9.2%) out of 76 patients over age 18 with LVAD implantation required EAS during a 6-year follow-up period, and the mortality rate within the first 30 days was 28.6%. Two of the 5 patients who survived beyond 30 days underwent OHT during long-term follow-up. One of these patients lived for 39 months following transplantation and the other still survives after transplantation.

There are publications reporting the technical difficulty of the incision. The driveline also loops across the abdomen and exits in the abdominal wall. The surgeon needs to be aware of these factors and be flexible with the location of the incision [15, 16]. We assessed the location of the drivelines with radiologic imaging. Laparotomy, as it allows the placement of the drive line, was performed with midline incision. Two patients who un-

derwent splenectomy had difficulty in surgical technique due to incision.

Laparoscopic procedures were performed in this patient population. Pneumoperitoneum has been reported to be safe [17].

The difficulties in emergency abdominal surgeons under LVAD can be listed as follows. The first is that the surgery is under anticoagulation and antiaggregant therapy. Ideally, the pre-surgery INR value should be adjusted. At EAS, however, this condition has to be done during and after the surgery. The second is the choice of an incision, because the surgeon has to protect the pump chamber and driveline when entering the abdomen. Laparoscopy may be preferred in elective or minor EAS (acute apathisitis, cholecystitis etc.). However, if urgent major surgery is performed, laparotomy may be inevitable. In this case, the surgeon should choose the most appropriate incision according to abdominal pathology and driveline course. Third, early postoperative morbidity and mortality of patients requiring urgent surgery are high. For this reason, general surgery, cardiac and transplant surgery, and anesthesia should be experienced as multidisciplinary and patient management.

Our study had some important limitations, first and foremost being the small number of patients. Second, the study had a retrospective observational design. Third, the study population was heterogeneous as it included patients with various pathologies, such as ileus, iatrogenic splenic injury, and retroperitoneal bleeding. The results of this analysis, however, are nonetheless important for various reasons, most significantly because they include the short- and long-term outcomes for pathologies involving the abdomen in isolation, necessitating emergency surgical procedures. Moreover, this study may be instructive for perioperative management by general surgeons working at centers where LVADs are not implanted, who might encounter such patients under emergency conditions.

Conclusions

The increased utilization of LVADs for the treatment of end-stage HF and the technological developments of these devices has led to increased numbers of patients in this situation, with prolonged lifespans. This is accompanied by a parallel increase in the rate of non-cardiac surgical procedures in such patients. Emergency abdominal surgical interventions after LVAD implantation remain particularly challenging and complex. In LVAD patients, abdominal surgery is not rare, but it can be said to carry a high mortality risk.

Conflict of interest

The authors declare no conflict of interest.

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