Left ventricular assist devices (LVADs) are frequently implanted as permanent (bridge to destination [BTD]) or temporary (bridge to transplantation [BTT]) cardiac support. When LVAD patients are discharged to home, they are very likely to require emergency medical services (EMS), but there is very little literature on out-of-hospital emergency care for patients with LVADs. We present two typical cases of LVAD patients for whom EMS was called. In the first case, the patient was in an ambulance two hours distant from our university hospital when a pulsatile system malfunctioned. In the second case, EMS was called to an unconscious LVAD patient. Emergency reference cards, training programs for emergency medical staff, and a 24-hour emergency hotline for the local VAD team are advisable. **Key words:** left ventricular assist device; emergency medical services; prehospital care

**INTRODUCTION**

The implantation of ventricular assist devices (VADs) has evolved over the past 20 years in patients with end-stage heart failure, and technical and medical progress has increased the use of implantable left ventricular assist devices (LVADs) in particular. Following the first LVAD implantations in the 1960s, technology has progressed from large, bulky, first-generation systems with pulsatile flow (pulsatile LVADs) to second- and third-generation LVADs with continuous flow (cf-LVADs). Because of very good one-year survival,^3^ small size, better durability, easier implantation, and better quality of life (QoL), second- and third-generation LVADs are now being used not only as a bridge to transplantation (BTT) but also more frequently as permanent support (bridge to destination [BTD]).^2^ Quality of life has become one of the most important issues for patients provided with an LVAD, and living at home contributes importantly to QoL.^3^ The rate of readmission for LVAD patients is high, with three admissions per patient year.^5^ As a higher percentage of permanent support and longer time on the LVAD will increase the risk for out-of-hospital emergencies, leading to more EMS calls, EMS will be faced with LVAD patients in life-threatening situations where fast and correct handling would improve outcome. Nevertheless, there is very little literature on out-of-hospital emergency care for patients with LVADs.^3^ Based on two case reports, we highlight the importance of this matter.

**CASE REPORTS**

**Case 1**

A 36-year-old man suffering from idiopathic dilated cardiomyopathy was provided with a pulsatile HeartMate XVE (Thoratec Corp., Pleasanton, CA) as an LVAD for BTT. The patient was discharged to home in stable condition after a hospital stay of 97 days. He was scheduled for routine follow-up visits every three to four weeks. After 562 days on support, he called the outpatient department to report that water had entered the vent filter the evening before while he was showering. It was decided that the LVAD system should be checked and an ambulance was called for the two-and-a-half-hour trip to our university hospital. Thirty minutes into the trip, the LVAD made unusual noises and then failed. The paramedics monitored the patient’s oxygen saturation, which decreased significantly (99% to >59%) and then was not measurable. There was no time for the paramedics to measure blood pressure as the patient showed signs of cardiogenic shock (cold, sweaty, pallid). The LVAD controller emitted constant alarms (flashing yellow battery, red heart, and yellow wrench, indicating a serious problem) and showed no calculated flow. As no emergency card was provided with the system and the paramedics were not trained in handling the device, they were overwhelmed by the situation. Oxygen was given (6 L/min) and the patient himself was able to disconnect the system from the power supply and connect it to the hand pump, which he himself pumped until the helicopter ambulance arrived. Further monitoring was done with a
12-lead electrocardiogram (ECG) as the regular ECG showed ventricular rhythm, oxygen saturation was established (99%), and an arterial line was placed for invasive blood pressure measurement (mean pressure 60 mmHg). The LVAD alarm stopped and a reasonable flow was displayed (2.5 L/min). Intravenous fluid (250 mL crystalloid volume) was given. The patient was admitted to the hospital, where he was put on pneumatic support for the LVAD, was listed for highly urgent heart transplantation, and successfully underwent transplantation after 646 days on the LVAD.

Case 2

A 60-year-old man suffering from idiopathic dilated cardiomyopathy was provided with a Berlin Heart IN-COR (cf) (Berlin Heart AG, Berlin, Germany) as LVAD for BTT. The postoperative course was complicated by recurrent pulmonary and urinary tract infections, followed by a severe thromboembolic stroke that ruled out BTT (the patient became a permanent LVAD candidate). Initially there was complete right-sided hemiplegia and mobilization was almost impossible. Neurologic function improved very little, but after 199 days in the intensive care unit, the patient was transferred to the ward and neurologic rehabilitation intensified. After a total hospital stay of 245 days, he was finally discharged to home with his LVAD and nursing care for his neurologic deficits. Routine visits to our outpatient department every third week documented no adverse events and neurologic status remained stable. The patient had been at home for 175 days when his wife called emergency medical services (EMS) because the patient had been at home for 175 days when his wife called emergency medical services (EMS) because the system was emitting alarm signals and her husband was unconscious. When EMS arrived, the patient had no palpable pulse or other signs of life. Neither oxygen saturation (by pulse oximetry) nor blood pressure was measurable and an electrocardiogram (ECG) showed a flat line for 5 minutes. The LVAD controller constantly emitted an alarm (EF 40) and no calculated flow was displayed. EMS was uncertain whether to start cardiopulmonary resuscitation (CPR); the patient’s wife found the emergency VAD telephone number and the paramedics called our LVAD specialist. Because of the poor prognosis and according to his wife’s wishes, CPR was not attempted. The patient was pronounced dead after 420 days on LVAD support.

DISCUSSION

We present two cases that illustrate the importance of LVAD management in prehospital care. In 2010, the American Heart Association (AHA) published new guidelines for CPR, but the section on special circumstances for cardiac arrest includes no recommendations for patients with VADs. EMS may be overwhelmed when LVAD patients are at risk for cardiac arrest or the device fails. As early as 2002, Bramstedt and Simeon published “The challenges of responding to ‘high-tech’ cardiac implant patients in crisis.” This report devotes a section to LVADs and total artificial hearts (TAHs) and recommends that “emergency medical technicians should be aware of such technology and the potential malfunction and complications that can trigger a call for their service.” The authors provide useful lists of signs and symptoms that LVAD patients may display, possible causes, and recommended actions. Patel et al. report a patient with LVAD and sustained ventricular fibrillation treated by a 360-J biphase shock. The authors highlighted the expected increase in the demands that this patient population will make on EMS and the importance of “developing protocols and procedures to guide prehospital management of implanted cardio defibrillators’ malfunction, ventricular fibrillation in LVAD patients, and care of LVAD patients in general.”

Technical malfunction and failure, driveline disconnection or completely discharged batteries, and pump thrombosis will lead to life-threatening situations for LVAD patients. As to technical failure, a distinction must be made between the old pulsatile LVADs (see case 1) and the new cf-LVADs (see case 2). In the pulsatile devices, LVAD failure was reported to be up to 17.9% and 72.9% at one and two years, respectively. After two years of LVAD support, our patient with the pulsatile HeartMate XVE had a high risk of device failure. Pulsatile devices are still used and emergency medical staff must be trained to handle device failure. It was the high incidence of failure in pulsatile devices that led to the development of cf-LVADs. In the newer generation of cf-LVADs, the rate of device failure has decreased dramatically to 1.9%, but it can still happen. The incidence of fatalities due to incorrectly connected batteries was reported in the HeartMate II trial to be 0.7% of BTT patients, and 4% of BTD patients died from incorrect replacement of batteries. Life-threatening pump thrombus occurred in 1.4% to 8.6%.

Paramedics have to be aware of problems that might occur and should know how to monitor an LVAD patient and how to handle life-threatening device failure. All of these factors point to a need to train EMS staff to deal with LVAD emergencies. For years, the German Heart Centre in Berlin, one of the high-volume assist device centers with a high percentage of BTDs, has regularly offered training for EMS personnel. The paramedics are familiarized with the important components of LVADs, how they work, the different LVAD systems available on the market, adequate monitoring of LVAD patients (ECG, time to capillary refill, placement of an arterial line for invasive blood pressure measurement if needed), the most important alarms, and the information on emergency cards. At the Medical University of Graz, special LVAD scenarios are...
included in paramedical training, and when an LVAD patient is discharged home, there is intensified training for EMS teams in the patient’s vicinity. The Vienna Assist Group confronted paramedics with a simulated emergency situation involving VAD peripherals mounted on a dummy, and concluded that better component labeling and emergency reference cards are important tools for paramedics. Further, paramedics have to be aware that if, as in the second case, there is a possibility of cardiac arrest, CPR has to be started and continued until further information has been obtained by calling a VAD specialist and/or acquiring further diagnostic data. We must note that there is no consensus among VAD centers as to whether CPR should be started immediately in an LVAD emergency situation. Ideally, if an LVAD patient is discharged to home, the local EMS team should be informed by the VAD specialists as to the patient’s directives.

In the first case, technical failure, which can always happen with LVAD home care, created a stressful situation for all involved. This could be have been avoided with better training for paramedics (especially the local EMS team if an LVAD patient is discharged to home) and availability of precise information (either from the patient himself or herself, reference cards, or the VAD specialist by telephone) to determine the further course.

If the device fails, a checklist on how to handle the problem should be available and should cover the following points: First, the paramedic should check whether the LVAD is working (by auscultation, for a continuous or a pulsatile noise depending on the LVAD device). If the system is not working, it should be confirmed that the system controller cable is connected to the LVAD, both batteries are properly inserted into the battery clips, and the system controller power cables are connected to a power base. If the condition persists, power should be disconnected and either hand pumping started or a restart of the LVAD attempted by reconnecting the power cable to the controller. As soon as possible, the help of a specialist should be sought. If the pump is not working and the paramedic has to restart the system, opinions vary on how long to wait before restarting the device. According to our experience, a safe restart is possible after a 3-minute wait.

Monitoring of LVAD patients is another challenge for EMS. One problem is obtaining accurate measurements of blood pressure and oxygen saturation when diminished pulse pressure can render conventional blood pressure measurement and pulse oximetry unreliable. Time to capillary refill, placement of an arterial line for invasive blood pressure measurement, and measurement of the mean blood pressure by vascular ultrasound are possible alternatives. Unless a TAH is in use, ECG monitoring will always provide an accurate reading.

We suggest that attention to the following points can improve the prospects for patients with LVAD-related out-of-hospital emergencies:

1. Caregivers should be sensitized to this topic. Increasing survival of patients supported by LVAD at home means that these patients will increasingly need EMS help. It is of utmost importance that the local EMS be given details on any LVAD patient who is discharged to home.

2. Paramedics should have more intensive training on handling LVAD emergencies. As Bramstedt and Simeon suggested, product training for paramedics and emergency medical technicians is essential as they have the potential to significantly affect patient outcome in crisis situations. There should be at least a short lecture on the basic function of LVADs, if possible with a demonstration with a dummy or an LVAD patient.

3. LVAD outpatients should have emergency reference cards at hand; as reported by Geidl et al., these cards should have simple basic instructions for first aid for LVAD patients including a step-by-step procedure to find and solve a problem, with important emergency instructions highlighted in red. With better-trained paramedics and an emergency reference card, the patient in our first case would not have been forced to operate his own machine.

4. There should be a 24-hour hotline for LVAD outpatients with the number on the emergency reference card or even on a peripheral component of the LVAD so as to be readily available to the EMS team. According to the AHA guidelines in the special circumstance section where it says, “call specialist,” a long search for a telephone number, as in our second case, can create an unacceptable delay.

**CONCLUSIONS**

As a result of miniaturization and increased reliability of available LVADs, and improved patient selection and perioperative management, the number of patients supported by an LVAD is increasing, meaning that these patients more often need EMS assistance. Patient care would be improved with appropriate training, guidelines, and protocols.

**References**

