VIA MEDICA

REVIEW ARTICLE

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Critical considerations in management of patients with left ventricular assist device in an Emergency Department practice

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Medical Research Journal 2022;
Volume 7, Number 2, 170–175
10.5603/MRJ.a2022.0025
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ISSN 2451-2591
e-ISSN 2451-4101

ABSTRACT

In recent years, mechanical circulatory support has become an increasingly used treatment strategy for end-stage heart failure. Due to technological progress and higher availability of this therapy, the number of patients receiving left ventricular assist devices (LVAD) is increasing. A natural consequence of this is occurrence of complications related to this therapy. A patient presenting to an emergency department (ED) expects the highest level of care. Emergency department staff should have basic knowledge and skills to provide initial diagnostic and therapeutic interventions for patients with LVAD in life-threatening conditions. The most common reasons for patients with LVADs presenting to the ED are bleeding, heart rhythm disorders, stroke, or infections. This article aims to present the basic information that may be useful during the first medical contact in an emergency department. The authors have discussed the issue of diagnosis, and differences in laboratory findings and indicate where to best seek help. The article is dedicated to physicians, nurses, and paramedics working in emergency departments.
Key words: left ventricular assist device, emergency department, heart failure, emergency treatment, emergency nursing

Med Res J 2022; 7 (2): 170–175

Introduction

Heart failure (HF) syndrome was first described as endemic 25 years ago. Today in most countries, a growing and aging society is the cause of the increasing number of patients suffering from HF [1]. Despite considerable progress in pharmacological treatment and technological advancement, which encompasses implantable cardiac devices, the prognosis in advanced HF remains poor [2].

A meta-analysis published in 2019 encompassed 1.5 million patients with all HF types. It was estimated that the survival rate for patients with HF 1 year, 2 years, 5 years, and years after the incident was respectively 87%, 73%, 57%, and 35% [3]. Heart transplantation is assumed to be the golden standard in treating acute HF. However, technological advancement allowed for the introduction of the left ventricular assist device (LVAD) as a target or temporary method while waiting for a donor [4]. Published in 2016, the European Register EUROMACS included over 2500 LVAD implantations and almost 10000 patients' observation notes [5]. Among German patients in 2015, there were 915 LVAD implantations, which is an increase of 36.6.% compared to 2005.

As the number of patients with implanted LVAD systems is growing, healthcare professionals working in both pre- and in-hospital services need to be ready to make appropriate therapeutic decisions. This might be difficult for personnel not familiar with this device. The lack of knowledge may lead to wrong decisions. The European Resuscitation Council and the American Heart Association guidelines published in 2015 gave special consideration to treating patients with LVAD systems. However, the current literature does not describe preferable treatment of patients with LVAD comprehensively. It

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is especially challenging for emergency medical service (EMS) teams to treat unconscious patients, who are not able to provide information on their medical condition. A patient with a new generation LVAD system that provides continuous flow has no palpable pulse. The need for training programs for EMS, featuring treatment of patients with LVAD systems, has been previously highlighted [6].

This review aimed to introduce the issue of LVAD patients who present to an emergency department (ED) to all healthcare providers who may be involved in the care and treatment process.

Epidemiology

Mechanical circulatory support (MCS) is a viable long-term treatment option for patients with end-stage heart failure. Currently, according to the guidelines of the European Society of Cardiology, indications for LVAD implantation are bridging therapy leading to Improvement, Candidacy, Transplantation, or Direct/Destination Therapy (still not available in Poland) [7].

American researchers reviewed medical documentation from January 2011 to July 2015 to identify all individuals with LVAD admitted to ED. They found 81 patients with full medical records. As many as 283 visits were registered. There were 3.49 ED visits per patient. The researchers described also the most common reasons for admissions. These were any sort of bleeding (18%), chest pain (14%), severe dizziness, and collapse (13%). As many as 36% of patients were discharged with no need to be admitted to a hospital. In another research, a cohort of patients for whom the number of ED admissions amounted to 292 in a three-year period was presented. Only 16 patients (5.5%) were transported by EMS. The rest were able to arrive on their own [8, 9]. It is difficult to compare these data to Poland. To the best of the authors' knowledge, the issue of LVAD patients within emergency care has not yet been examined in Poland.

Basic information about LVAD

A left ventricular assist device is a centrifugal pump suspended in a magnetic field. The device is implanted into the apex of the heart. There it collects blood from the left ventricle and pumps it into the ascending aorta via an effluent graft.

The pump is supplied by an external controller. The driveline that goes from the pump to the external controller passes through the abdominal wall on the right side of the umbilicus. A patient has two power connections to the controller, but only one is active. This solution is necessary to allow the exchange of the power supply (to keep it charged) with no pause in LVAD functioning. The controller and batteries are in a dedicated bag or pockets pinned to a belt. Once the batteries are removed, one should assess their charge level by clicking the dedicated button on the battery, which will activate the diodes showing the charge level.

Usually, blood flow (L/min), pump speed (rotation/min), and power consumption (W) are presented on a display. For adults, correct flow usually falls within the range of 3.5–6.5 L/min. Each result lower than 2L/min or faster than 10 L/min should be considered critically incorrect.

Differences in patient examination

Every patient who presents to an ED should be evaluated based on the ABCDE protocol. However, certain elements differ when compared to patients with their own circulation.

In LVAD patients, blood flow is continuous rather than pulsatile. Therefore, measurement of blood pressure with routinely used electronic devices is not possible. To determine the patient's blood pressure, a sphygmomanometer and a Doppler ultrasound transducer should be used. A cuff is inflated and then slowly deflated while the transducer is held over the brachial artery. The pressure at which arterial flow appears and the Doppler flow sound indicates the patient's mean arterial pressure (MAP). Therefore, the Riva-Rocci measurement technique is not possible, and Korotkof tones are not audible. In patients without an LVAD, MAP > 60 mmHg usually provides adequate tissue perfusion. For LVAD patients, it is recommended to maintain the MAP value ≤ 80 mmHg with hypotensive medication [10–12].

Blood oxygen saturation is another parameter that may not be accurate because pulse oximetry depends on pulsatile blood flow. Healthcare providers must rely on direct assessment of the level of consciousness, perfusion, and general appearance. Clinical findings such as skin color and capillary refill time are reasonable predictors of the presence of adequate flow and tissue perfusion, especially in MCS, pulseless patients [13]. Finally, blood gas analysis should be ordered to accurately assess hemoglobin saturation. When auscultating the chest, a characteristic pump "humming" may be heard. This suggests that the pump is working properly. Signs and symptoms of acute heart failure, severe blood loss, or decreased perfusion should be noted. 12-lead electrocardiogram (ECG) also must be obtained to evaluate heart rhythm or signs of ischemia. Numerous electrical disturbances caused by LVAD might be present.

Patients with LVAD are sensitive to changes in afterload. Any increase in this parameter may worsen pump

function and manifest as exacerbation of heart failure. In principle, patients with a properly functioning LVAD should not present with signs of acute left ventricular failure such as pulmonary edema. Right ventricular failure symptoms, such as ascites, peripheral edema, or jugular vein distension, may be present. Pulmonary edema may occur as a result of a thromboembolic incident within the device. Point of care ultrasound is recommended to differentiate the type of shock.

The initial assessment of a device itself starts with disclosing the controller and an external power source to check whether the connection is correct. The place where the driveline passes the abdomen should be secured with a dressing and abdominal bandage — to prevent the line from being pulled out. Inspection of the skin for infection and the correct position of the line should be performed. Moreover, it is necessary to check the battery level and make sure there are not any critical alerts on the controller. A spare controller, as well as batteries and a charger, must be transported to a hospital with the patient.

Specific laboratory findings

As for any patient in an ED, laboratory tests for patients with LVAD are used to receive a differential diagnosis and to answer specific clinical questions. However, some abnormalities in laboratory tests specific to LVAD patients may be present. These include an international ratio (INR), troponin, N-terminal pro-B-type natriuretic peptide (NT-proBNP), and lactic acid dehydrogenase (LDH).

Patients with LVAD must take anticoagulant agents, vitamin K antagonists (VKAs), with the recommendation of maintaining INR between 2.0 and 3.0 (in the absence of contraindications).

Troponin can be used to diagnose acute coronary syndrome (ACS) in a patient with chest pain or new ECG changes of suspected ischemic origin. Since these patients have chronic heart failure, troponin levels may be permanently elevated [14]. Therefore, the diagnosis of ACS should rather consider the dynamics of troponin.

In a diagnosis of right ventricular failure, NT-proBNP may be helpful in addition to clinical presentation. However, NT-proBNP should correlate with the previous result, defined shortly after LVAD implantation. It was shown that unloading of the failed left ventricle was associated with a decrease in NT-proBNP levels. However, it remained in the abnormal range (mean 2.090 pg/mL) [15]. The authors of the same study also indicated that C-reactive protein concentration was permanently elevated (11.9 mg/L).

Lactate dehydrogenase concentration can be helpful in the diagnosis of hemolysis and thrombosis. Concentration higher than 2.5 times above the upper limit is characteristic of thrombosis within the pump [15].

Common issues to manage in an ED

Table 1 outlines the most common reasons for admissions of LVAD patients to an ED [16].

Heart Rhythm Disorders

Even with a properly functioning device, an irregular or too fast heartbeat will still affect the function of the right ventricle and atria.

Patients with LVAD have residual left ventricular fraction. Therefore, to prevent life-threatening rhythm disorders, a cardioverter-defibrillator should be implanted. Nevertheless, rhythm disturbances may still occur and cause deterioration of the general condition.

Specific types of arrhythmias that occur in patients with LVADs are the ones caused by device components that mechanically irritate the left ventricular wall. Hypovolemia should always be considered a leading cause of arrhythmias, especially recurrent or refractory.

Heart rhythm disorders may be masked by a properly functioning device. Patients may only complain of fatigue, nausea, or dizziness due to otherwise fatal arrhythmias. Atrial and ventricular arrhythmias are relatively common. Ventricular tachycardia (VT) most often results from an underlying condition such as cardiomyopathy. However, it can also result from right ventricular failure or mechanical decompression of the ventricle by a supply cannula. With mechanical support, a patient with sustained tachycardia will not present signs of instability. If an arrhythmia is detected, it should be treated

Table 1. Common reasons for admissions of LVAD patients to an emergency department

LVAD-related emergencies	LVAD complications	Non-LVAD-related emergencies
Acute heart failure	Arrhythmias	Abdominal pain
Device failure	Atrial fibrillation	Injuries
Drive system	Ventricular tachycardia	Burns
Shutdown of the pump	Ventricular fibrillation	Hypovolemia
Pump thrombosis	Bleeding	Sepsis
	Epistaxis	
	Gastrointestinal bleeding	
	Cardiac arrest	
	Pericardial tamponade	
	Infection	
	Driveline	
	Pump pocket	
	Stroke	
	Hemorrhagic	
	Ischemic	

in the same way as in patients without LVAD. Cardioversion of atrial fibrillation is recommended in patients with rapid ventricular rates, as well as VT that results in poor device flows or hemodynamic compromise [17]. Recurrent VT should prompt consideration of a suction event. If possible, electrodes should not be placed directly above the device. Anterior-posterior positioning is advisable [20]. Patients with ongoing VT refractory to medical therapy may require catheter ablation, which should be performed by an electrophysiologist with the requisite knowledge and expertise in treating patients with mechanical circulatory support.

Cases of ventricular fibrillation were also described when the patient reported only minor symptoms such as dizziness and visual changes [18]. This can be treated by defibrillation. In this case, analgosedation must be performed.

Decrease in blood flow

Patients treated with LVAD are susceptible to complications associated with a significant decrease in blood pressure and flow. This is largely due to the inability of the device to directly measure the volume of blood in the left ventricle. An attempt should always be made to identify the cause of a reduction in preload as it leads to suboptimal filling of the left ventricle. This, in turn, may cause suboptimal flow or suction in the inlet cannula. The pump then continues to spin with minimal ability to reduce speed to compensate for the reduced volume, which may cause instability.

In contrast, low flow associated with an increase in central venous pressure may suggest right ventricular failure. This condition may be caused by ventricular arrhythmias, volume overload, pulmonary embolism, persistent pulmonary hypertension, or tricuspid regurgitation. Excessive LVAD speed may also cause right ventricle overload [1, 2, 7].

Ultrasonography may be a useful tool for differentiating the cause of flow reduction. This technique allows for a quick and simple assessment of cardiac preload by evaluating the right ventricle and inferior vena cava.

Hypovolemia should be treated with fluid therapy as in any patient. Pharmacological conservative treatment with heparin may be the first-line treatment in the case of a suspected thrombosis [19].

Bleeding

A patient admitted to an ED due to external bleeding does not raise a diagnostic problem even for an inexperienced clinician. Gastrointestinal (GI) bleeding or epistaxis are common presentations in the ED. The most challenging group of patients is the one with acute delirium, headache, or neurological symptoms. These patients always require an urgent diagnosis for subarachnoid hemorrhage. In this context, patients with head trauma also require imaging to exclude intracranial injury. Gastrointestinal bleeding occurs in approximately one-third of patients with LVADs [12, 20, 21].

Bleeding results from the overlap of several mechanisms related to the presence of the device and its specific work. First, continuous blood flow promotes vascular malformations. Angio ectasia is the most common identified cause of GI bleeding (33%). Second, an increased prevalence of acquired von Willebrand disease has been observed in patients, which has a direct impact on an increased risk of bleeding. Third, patients with LVADs take chronic anticoagulants [22–25].

Management in an ED is the same as for a typical patient. Active GI bleeding requires endoscopic evaluation to find the source and stop the bleeding [26]. Administration of vitamin K, fresh frozen plasma, or prothrombin complex concentrate should be considered to reverse the effects of anticoagulants. Octreotide may also be effective as additional treatment [27].

The treatment of choice for massive bleeding with symptoms of hemorrhagic shock is emergency blood transfusion. However, it should be highlighted that this procedure may exclude patients from heart transplantation. Therefore, low-leucocyte and irradiated products should be chosen. In stable patients, greater restriction in blood transfusion and consultation with a cardiothoracic surgery center is recommended [28].

Vascular incidents in CNS

Stroke is the leading cause and predictor of death in patients with LVAD [29]. The incidence of stroke is approximately 17%, and it increases in the postoperative period and persists for up to 9 to12 months. Hemorrhagic stroke is more common [29].

It is recommended to evaluate coagulation parameters and to administer reversal agents, similarly to GI bleeding. In addition, it is necessary to assess whether the pump is working properly and if there is no dysfunction indicating the formation of a clot in it. A computed tomography scan and angiography of the head and neck should be performed on each patient. A neurologist and neurosurgeon consultation should then be ensured, and appropriate treatment instituted depending on the patient's condition and the type and nature of a stroke [17].

Cardiac arrest

The issue of chest compressions for patients with LVAD remains controversial. There was a common belief that a cannula may be misplaced or the connection may be fractured. However, it has not been determined if there is any benefit to chest compressions before restarting the pump if it fails. Initiation of cardiopulmonary resuscitation (CPR) in the pre-hospital environment

must be warranted in this situation if the device does not work properly despite numerous attempts to turn it on.

There is a lack of high-quality scientific data to support the safety of chest compressions in this group of patients. However, some retrospective studies and literature reviews suggest that chest compression is not as unsafe as previously thought [30].

In first aid, chest compressions must be delivered to every unconscious person with abnormal breathing. Advanced providers, however, should consider capnography to evaluate perfusion. It has been estimated, that an E_TCO_2 value lower than 20 mmHg in an unresponsive, correctly intubated patient with an LVAD may be a reasonable indicator of poor systemic perfusion and should prompt providers to start chest compressions [13]. Cardiopulmonary resuscitation should be performed according to advanced life support protocol. Defibrillation, as well as any recommended medications, are administered in compliance with algorithms for sudden cardiac arrest with no harm [17, 31].

Driveline infections

Driveline infection can be a critical problem and lead to serious consequences. Early recognition and aggressive surgical approaches to driveline infections are essential to minimize associated morbidities [32]. Factors that increase the risk of infection include increased BMI, younger age, and exposed driveline velour [33]. The education of a patient and their family on driveline care and hygiene is an important factor in reducing the risk of infection [32]. The most commonly isolated bacteria are gram-positive *cocci* and *pseudomonas*. In the case of localized infection, cultures should be taken. For localized infections at the exit site, antibiotics should be administered, and the patient should be closely monitored during this time. In the case of infection involving the entire canal or the presence of an abscess, the exit site of the driveline should be changed through the skin. In critical cases, the entire device may need to be replaced [32].

Where to seek experts' consultation?

There are 6 facilities in Poland where LVAD therapy is promoted. These are Poznań, Warszawa, Gdańsk, Kraków, Wrocław, and Zabrze. The authors advise establishing contact with an LVAD center as soon as possible to prevent medical errors. The contact details for the LVAD coordinator should be visible on the controller. Family members play an essential role in gathering medical history. Moreover, it has become a standard practice in the United Kingdom to inform local EMS and ED if a patient with an LVAD resides in their operating area. Training and 24-hour medical consultation have also been offered. This enables early contact to be made with the LVAD team in critical situations [34, 35].

Conclusions

Left ventricular assist device patients require a non-standard approach to standard problems. Knowledge of basic issues regarding LVAD patient care can prevent dangerous consequences of overlooking a major complication.

Funding: *None.*

Conflict of interests: *None.*

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