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Examination of a patient with left ventricular assist device in an emergency condition — proposal for adaptation of the ABCDE examination algorithm

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ABSTRACT

Heart failure is becoming a medical issue that concerns more and more patients. The most effective treatment method is heart transplantation, however, more people are waiting for the procedure than there are available donors. The improvement of left ventricular assist device (LVAD) method was possible because of the joining forces of technological and medical advances. In recent years more patients have undergone the LVAD treatment. It has been a considerable challenge for medics in prehospital conditions. Device malfunction, bleeding, chest pain, or collapse pose a threat to life for those patients.

The aim of this paper was to adjust the ABCDE examination algorithm to be applied for patients with LVAD. Additionally, the author has described the method in detail. The article itself and the modification of the algorithm are based on the analyses of available source literature.

The biggest challenge for medics who examine patients with LVAD is a lack of pulse and inability to measure the pressure in a classical method. The most visible differences in the examination scheme have been observed in points C and E.

The authors have identified the need for simulation-based trainings dedicated to medical staff working in prehospital conditions. Additionally, a special system informing emergency services about LVAD patients living in their area should be implemented.

Key words: examination, prehospital care, left ventricular assist device, clinical assessment, emergency medicine.

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Introduction

According to the statistics of the Polish Cardiac Society (PCS), heart failure (HF) is a medical problem that affects between 600,000 and 700,000 people in Poland. About 10% of them are over 70 years old [1, 2]. Due to the progress in pharmacology, electrotherapy, and cardiac surgery, significant improvement in diagnostics, treatment, and prognosis for patients with HF has been observed in the last several decades. However, the disease is still a significant social problem. Korewicki et al. [3] compared the problem of HF to epidemics, due to its prevalence, unfavorable prognosis, and economic consequences. In the European Society of Cardiology (ESC) guidelines for HF, the 21st century is defined as the age of heart failure.

The golden standard of treatment for patients suffering from advanced HF is heart transplantation (HTx). This method allows for long-term survival, which is defined as 50% within ten years after surgery. For comparison, the annual survival of patients qualified for urgent transplantation is less than 50%. Since 1985,

2373 HTx have been performed in Poland. The number of heart transplants was increasing steadily until 2004, whereas in subsequent years, the number of procedures decreased. In 2020, 145 HTx were performed. In the same year, 471 patients were waiting for a new organ. It means that only 30% of those who need, received organ transplantation. The average waiting time of patients who received heart transplantation in 2020 was 362 days. During the waiting time, 93 patients died, including three recipients under 18 years old. The problem which markedly affects the lower number of transplantation procedure is a lack of a sufficient number of organ donations [4].

Rapid technological development and miniaturization of technology accelerated the development of devices mechanically supporting the heart. These may be an effective alternative to pharmacological treatment, as a bridge to transplantation. These devices include, among others, a left ventricular assist device (LVAD).

The number of patients with LVAD is increasing and has reached 2500 implants per year in 2016 in the United States [5]. LVAD therapy is becoming more and more common in Poland and Europe. People suffering from HF often also suffer from other chronic diseases. Therefore, this group of patients is particularly at risk of life-threatening situations, requiring contact with the emergency medical system. The physical examination of such patients, although it does not vary from the commonly accepted ABCDE scheme, may arouse many ambiguities. The limits of routine vital sign assessment have previously been emphasized [6].

The authors aimed to familiarize the reader with the knowledge of LVAD systems used in Poland and to point out the essential activities that should be taken into account during the patient examination.

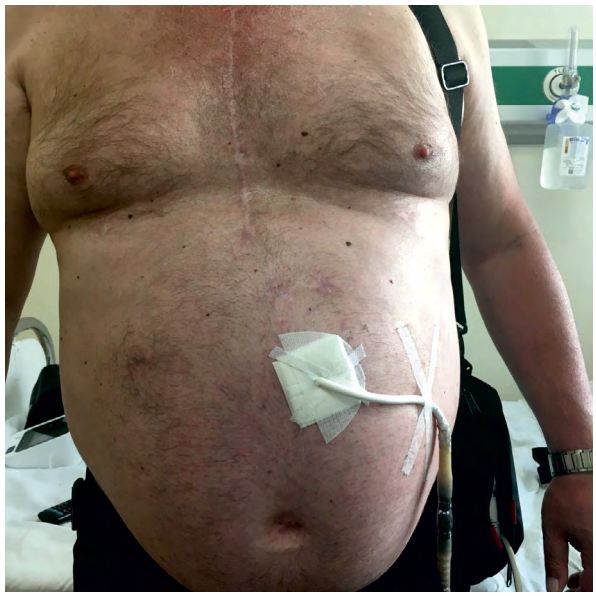

Figure 1. Left ventricular assist device (LVAD) driveline leaving the body

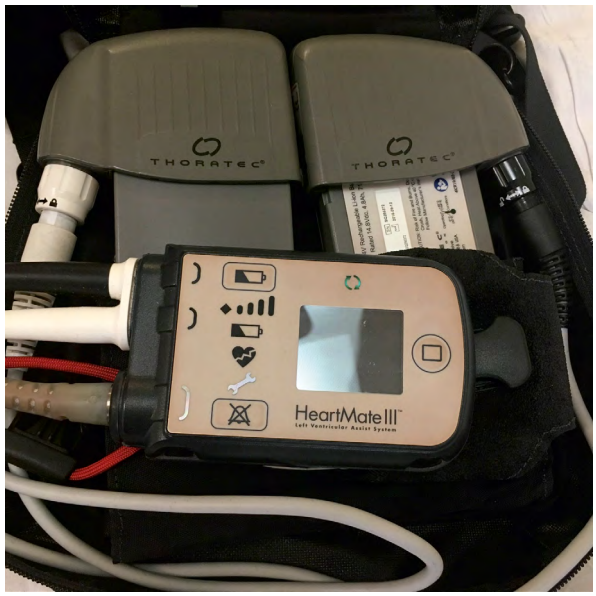

Figure 2. Left ventricular assist device (LVAD) controller and battery set

Material and methods

LVAD system

The LVAD system is an electrically driven mechanical pump, which is used for long-term maintenance of heart function and blood flow in patients with critical HF. It provides adequate mechanical circulatory support in patients with resistant HF, significantly improves comfort and quality of life (QoL). It consists of several elements, regardless of the manufacturer: the implantable pump, the controller (a cable connecting both elements), battery, charger, adapter to the socket. The device and the place where the driveline leaves the body were presented in Figures 1–2.

The device is implanted between the left rib arch and peritoneum. The cardiac surgeon places a ring around the apex. Then using a trocar, cuts a hole in the heart muscle and connects the pump (Fig. 3–5). On the other side of the device, the blood is pumped with an effluent graft, which is sewn into the ascending aorta. Thus, the device works by collecting blood from the left ventricle and pumping it into the ascending aorta. It should be noted that for the cardiovascular system to function efficiently, the right ventricle function must be maintained.

The construction is based on a centrifugal pump suspended in a magnetic field. A control cable — driveline, powers it. This cable leads through the skin on the

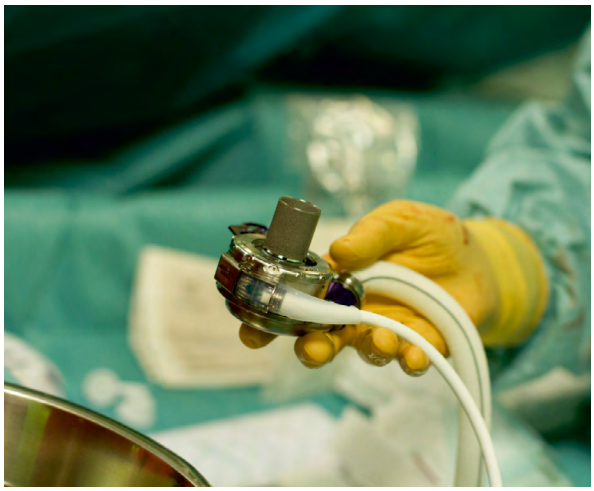

Figure 3. Left ventricular assist device (LVAD) pump prepared for implementation

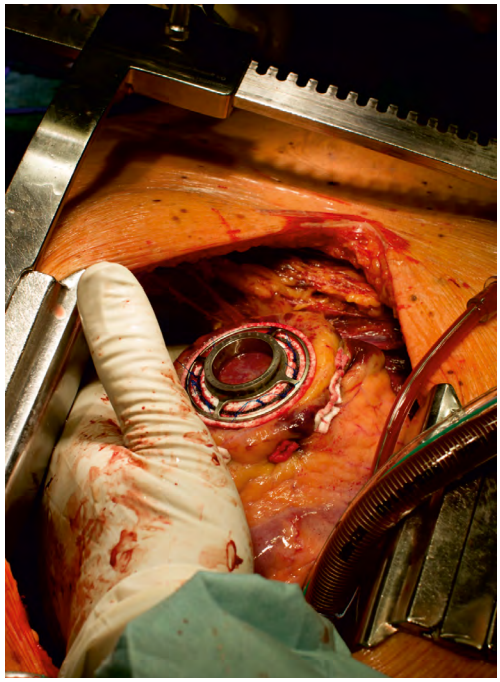

Figure 4. The metal ring implanted into the apex of the heart

abdominal surface to the controller. The patient wears the controller directly on the body surface. The device is equipped with two batteries. This allows maintaining continuous operation for 17 hours, depending on a manufacturer. Blood flow in the pump is possible because of the hydrodynamic rotor suspended in the magnetic field. In this process, the risk of damage to the blood's morphotic components is minimized. An average estimated flow rate slower than 2 l/min or faster than 10 l/min may indicate abnormal operation of the device, abnormal hematocrit of the patient's blood, or a clotted duct obstruction.

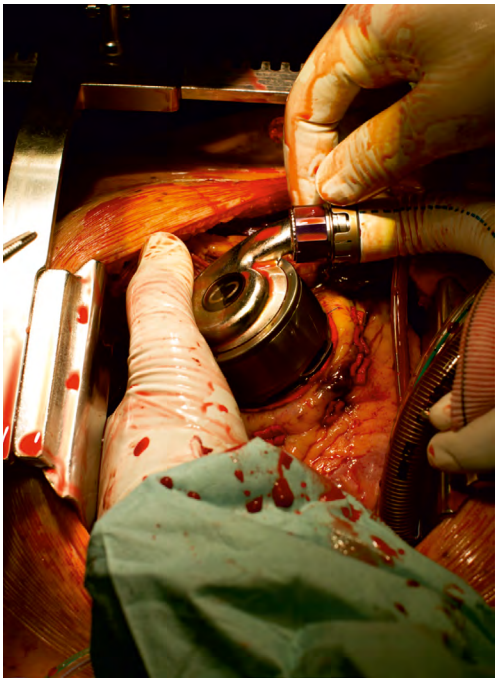

Figure 5. Left ventricular assist device (LVAD) pump *in situ*

According to ESC 2021 guidelines for the diagnosis and treatment of acute and chronic HF, LVAD may be used as [2]:

- Bridge to Candidacy — to improve organ function in a patient for whom transplantation has so far been impossible,
- Bridge to Transplantation — to enable the survival of a high-risk patient until an organ is available for heart transplantation,
- Bridge to Recovery — to ensure patient survival until heart function improves,
- Bridge to decision/Bridge to bridge — in patients with cardiogenic shock until haemodynamics and end-organ perfusion are stabilized,
- Destination Therapy — as an alternative to heart transplantation in a patient with end-stage heart failure, ineligible for transplantation (still not possible indication in Poland).

Based on the register of patients with mechanical cardiovascular support INTERMACS, it was determined that the best candidates for LVAD are patients who do not tolerate physical activity, with the presentation of congestion, recurrent fluid retention, or requiring inotropic support, but are hemodynamically stable. It has been estimated that the annual survival of patients with LVAD is 80%, and the biennial survival is 70% [7].

The largest study of LVAD patients is the MOMENTUM 3 clinical trial. In this trial, patients reported a significant improvement in their condition within 180 days after implantation. The total patient survival rate was 89%. These patients also reported a significant improvement

in the (QoL as measured by standard tests. In 77% of patients, the reduction of HF symptoms to NYHA I or II was achieved [8].

Medical contact with patients

Paramedics' interventions at patient's home are rare. Goebel et al. [6] emphasize that the most frequently reported complaint is weakness followed by chest pain. In a group of 15 patients, only one required LVAD-specific interventions (battery switch). Furthermore, Tainter indicates that the most common presentation of patients admitted to an emergency department are: bleeding (18% — gastrointestinal, epistaxis, other), chest pain (14%) and syncope (13%). The first visit at an emergency department (ED) occurred between 2 and 1279 days after discharge from the index admission (median 31, mean 100 days). LVAD patients must take anticoagulants every day. This is important in terms of bleeding and incidental thrombosis inside the pump clotting. Therefore, patients must be equipped with a home-care device for daily International Normalized Ratio (INR) monitoring. Although admission to hospital still remains common, some number ED patients may be managed successfully in the ED and then discharged home [9]. Readmissions among this group of patients are frequent [10]. Patients with a sudden cardiac arrest can be challenging especially in those regions where LVAD therapy remains uncommon [11]. This is related to difficulties in proper assessment function and efficiency of the cardiovascular system.

Complications related to the device itself are not frequent. However, its sudden dysfunction may be fatal. Cases of accidental or suicidal pump disconnection were described [12–14]. LVAD therapy may provide some side effects. The most common are gastrointestinal bleedings, other bleedings requiring surgical intervention, pump embolism (these complications are mainly associated with the use of anticoagulant therapy), technical defect of the pump, infections of the driveline [15–18]. Ventricular arrhythmias occur in about half of patients, usually within the first four weeks after implantation [19]. Moreover, cases of ventricular fibrillation, which were well tolerated by patients, have been described. The only worrying symptoms were numerous discharges of implantable cardioverter-defibrillator [20, 21]. Such situations may cause anxiety among healthcare providers and pose a significant therapeutic challenge.

It should be noted that in patients with LVAD, despite the improvement of some QoL elements, functional limitations and patients' lack of independence still exist. The problem of device-related distress is also highlighted. One study showed a significantly high level of depression and anxiety, which was revealed in 24% and 13% of patients respectively [22]. Local emergency providers must be informed that there is a patient with LVAD in their operation area. It is recommended that emergency personnel take part in training based on the medical simulation method [23].

Examination

The examination of a conscious patient with LVAD should be based on the ABCDE scheme, well-known in emergency medicine. However, interpretation may be difficult and may raise doubts. The device itself does not directly affect the airway patency, respiratory process, and neurological condition. However, the pulse oximeter reading may not be reliable. To maintain proper functioning, this device needs pulsatile blood flow which the LVAD does not deliver. LVAD radically changes the functioning of the cardiovascular system. Knowing the influence of this device on physiology will help to understand the modifications to be made during the examination.

The first difference concerns the assessment of cardiovascular function. In physiology, myocardial contraction causes a short but rapid increase in intravascular pressure. The radial expansion of the aorta provided through the blood injected into it causes a pressure wave that moves at a certain speed along its walls. A medic placing his or her fingers in the designated areas, feels the pulse, which is a reflection of the mechanical work of the heart muscle.

The LVAD system provides a continuous rather than physiological (pulsed) blood flow. This results in a lack of pressure gradient. Therefore, in such a patient, it is not possible to feel the pulse and to measure blood pressure using the classic method. It should be noted that depending on the level of own ejection fraction of the patient's heart, the pulse can be present in some cases. The method for measuring arterial blood pressure should be modified. A Doppler probe should be used instead of a stethoscope. This method is not available for paramedics in prehospital conditions. A classic sphygmomanometer should be placed on the patient's arm. Before the examination, the probe should be placed above the brachial artery to find the echo of blood flow. The cuff should be inflated to 160 mmHg, and then pressure should be gradually lower. The value at which the echo appears indicates the patient's mean blood pressure. The correct value is 70–90 mmHg. It is crucial to assess capillary refill time and proper skin color and moisture. These two parameters can be used as the fastest and most reliable to suspect cardiac arrest in an unconscious, non-breathing patient with LVAD. The LVAD system supports only the left ventricle. This means that the right ventricular function must be maintained. Therefore, the assessment of potentially right ventricular failure (jugular vein overload, liver enlargement, peripheral oedema) is still essential. Chest

auscultation also provides valuable information on the functioning of the pump. The dominant auscultatory feature of a properly functioning device is humming representing blood flow. Moreover, a three-component sound with a short pause afterwards can be heard. There are sounds that help to identify individual dysfunctions of the pump, but their detailed description exceeds the framework of this article. The tones of a patient's own heart are most often dominated by the noise of the device, so listening to them can be a problem. The technique of performing an electrocardiogram does not differ from that recommended by PSC. LVAD does not affect electrical function of a heart muscle. The device itself does not generate electrical effects that could interfere with those generated by a heart.

The second difference in the patient`s examination arises from the need to assess whether the device works properly. In conscious, spontaneously breathing patients, this element should be performed after the patient`s body exposure. A loud alarm coming from the controller probably indicates a stopped LVAD. This should be assumed unless the display shows another reason. Nevertheless, LVAD failure is still possible even without alarm sounds (for example alarm failure). In the stage "C" of examination, stethoscope should be placed over the apex of the heart to listen for a humming sound.

It should be determined whether both cables are connected to the device. LVAD regulates basic flow parameters such as speed and number of rotations to suit the patient's current needs. When resting, the flow should be between 2.5 and 10 l/min. The green light indicates the proper functioning of the pump. If a pump malfunction occurs, the display presents the appropriate warning. In Figure 6, the authors presented an

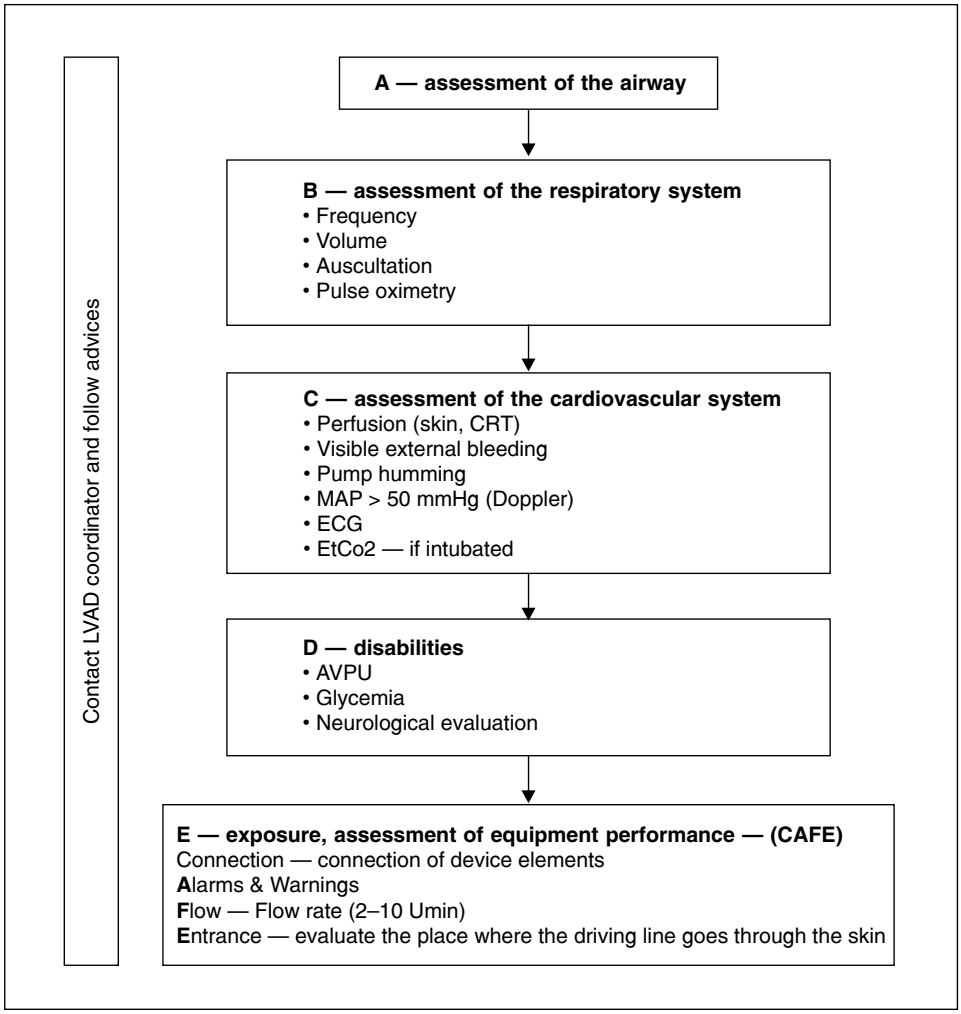

Figure 6. Proposal of modified ABCDE examination algorithm for a patient with left ventricular assist device (LVAD); AVPU — alert, voice, pain, unresponsive (simple scale to assess the level of consciousness in emergency medicine); CRT — capillary refill time; ECG — electrocardiogram; $EtCO_2$ — end-tidal CO_2; LVAD — left ventricular assist device; MAP — mean arterial pressure

ABCDE examination algorithm adjusted to the specifics of a patient with LVAD.

Dealing with LVAD patients can be challenging, even for experienced healthcare providers. Only a thorough examination creates a complete picture of the patient's current condition. Essential to this examination is basic knowledge and awareness of the different functioning of the LVAD patient. Training for healthcare professionals is essential as they have the potential to significantly affect patient outcomes in crisis situations. If possible, simulation training should be provided to present basic LVAD features [24, 25]. With simulation, skills that are rarely used, and therefore at risk of being forgotten, are exercised and retained [26]. It has been also found, that simulation training allows one not only to improve technical skills but also to build a good communication, complex procedural chain, eliminate errors at every stage of patient care [27, 28]. EveryLVAD patient is covered by the programme of 24/7 LVAD-coordinator care. This is a person responsible for monitoring a patient and a device as well. If any alarms occur, a patient should first contact the coordinator. Moreover, the coordinator may be helpful if a patient has any concerns regarding driveline care or problems with maintaining the INR at the proper level. After contacting a patient also receives suggestions as to whether to attend medical advice and how urgent it should be.

The role of the coordinator is indirectly supposed to prevent critical incidents. Probably that is the reason why critical incidents are rarely described in publications. Every patient should have the telephone number of the coordinator with them on the pump. In this way, the Coordinator can also be a link for other medical personnel including the Emergency Medical Service.

Conclusions

There is the need to inform healthcare professionals about LVAD patients and possible contact with this challenging therapy in emergencies. Implementation of the modified examination algorithm may help in safe diagnosis and correct treatment. Moreover, specially designed high-fidelity simulation-based trainings should be organized for medics to enable them to develop respective skills.

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