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Editorial

Approach to Unresponsive Patient with LVAD

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Introduction

Unresponsive patient with left ventricular assist device (LVAD) is always a challenge. While LVAD by itself is a relatively novel technology, mere presence of which often puzzles providers not dealing with it on a daily basis, unresponsiveness in such patient adds another level of complexity. Two papers recently published in the Journal (1, 2) describe the course of the events in several patients with LVAD who coded, only one of which was discharged from the hospital alive (1).

Outcomes

The number of cases reported in the literature is very limited. We summarized them in Table 1. If such small amount of cases is of any representation of a general picture, survival of the patients with LVAD who become unresponsive and undergo some form of cardiopulmonary resuscitation (CPR) is overall less than 25%.

Table 1. Outcomes in patients with LVAD who required resuscitation

Outcomes	Total number	Survived arrest	Survived to discharge
Garg et al., 2014 (3)	16	10(63%)	5(31%)
Haglund et al., 2014 (4)	1	1(100%)	1(100%)
Shinar et al., 2014(5)	8	4 (50%)	
Yuzefpolskaya et al., 2016 (6)	1		0(0%)
Musa et al, 2018 (2)	3	3(100%)	0(0%)
Bhimaraj et al., 2017 (1)	1	1(100%)	1(100%)
Total	30		7(23.3%)

Scenarios

There are several possible scenarios of code in a patient on LVAD support.

1. *"LVAD is not working"*

LVAD stopped functioning appropriately and does not support sufficient blood flow. The patient's hemodynamic status depends on the remaining function of the left ventricle.

In this case, low flow alarm or no power alarm will is present, or recorded in the LVAD memory. The humming is not present or may sound abnormally. The flow indicator on the LVAD is low. Blood pressure (BP) is not measurable by Doppler.

The patient is in cardiogenic shock or cardiac arrest – usual CPR/advanced cardiac life support (ACLS) should be started, including chest compressions, pharmacologic support, electrical shock if appropriate, etc.

2. *"Low flow despite functioning LVAD"*

LVAD per se is functioning appropriately, but circulatory support is still insufficient because of depletion of intravascular volume ("nothing to circulate"), vasodilation, resulting from bleeding, vasoplegia, acidosis, sepsis or profound dehydration. The humming is present, but the flow is low.

LVAD hum is normal, low flow alarms may or may not be present, flow is below normal limits, BP is less than 50mmHg by Doppler.

Chest compressions may be appropriate but their value is questionable. The rest of ACLS protocol should be applied, including fluid resuscitation and pharmacological interventions/drips.

3. *"LVAD is fine, something else is wrong".*

LVAD is functioning appropriately and maintaining sufficient hemodynamics.

There are no alarms, flow is within normal limits, LVAD hum is normal, mean BP is above 50 mmHg.

Patient is unconscious due to respiratory, metabolic, or other non-circulatory problems such as stroke, acidosis, respiratory arrest, hypoglycemia, etc. No chest compressions are needed. Intubation and initiating a ventilator is indicated if appropriate, as well as neurology/neurosurgery consult, and correction of metabolic abnormalities.

We analyzed the cases reported in the literature (Table 1) from the standpoint of this classification and placed them in the Table 2.

Based on these three scenarios, we built an algorithm (Figure 1).

Table 2. Three scenarios of code in LVAD patient: characteristics and distribution of reported cases.

	LVAD is not working	Low flow despite functioning LVAD	LVAD is fine, hemodynamics is stable, something else is wrong
Normal hum	-	+	+
Low flow (<2.5L/min), with or without low flow or no power alarms	+	+	-
Mean BP<50mmHg by Doppler/ arterial line	+	+/-	-
Differential diagnosis	Power/cables/batteries/ contoller disconnected, batteries depleted LVAD mechanical failure Pump thrombosis Driveline fracture	Dehydration Bleeding Acidosis, respiratory or metabolic Cardiac tamponade Overdose of vasodilators/antihypertensives Infection Ventricular arrhythmia Right ventricular failure	Stroke, ischemic or hemorrhagic Trauma
Cases reported in the literature Number/source/cause	2 (3, 5) driveline fracture 6 (3-5) power disconnection 1(5) ventricular tachycardia/fibrillation 2 (5) unclear etiology and LV clot, but both had chest compressions	3 (3)bleeding 2 (3)sepsis 2 (1,3) right ventricular failure 2 (3) ventricular tachycardia/fibrillation 1(3) asystole 1(6) hypoxia 1(2) dehydration 1(2)stroke 1(2) respiratory acidosis	5(3)respiratory failure
Total	11	14	5

Algorithm

Based on these three scenarios, we built an algorithm suggesting the approach to unresponsive patient on LVAD (Figure 1).

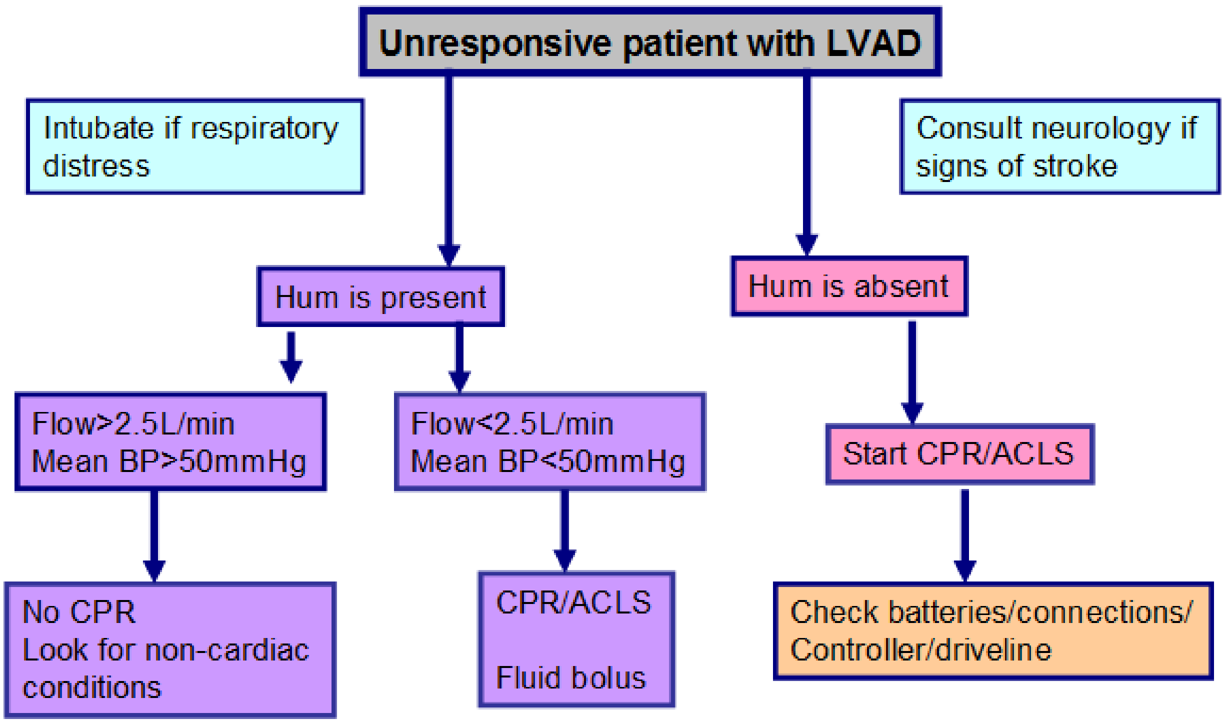

Figure 1. Proposed algorithm for unresponsive patient with LVAD

Several centers reported their own algorithms before.

Single Center Algorithms

Vanderbilt University

The algorithm is reproduced on Figure 2. While quite elaborate, this algorithm raises some questions.

First, after it is established that the patient with LVAD is unresponsive, or LVAD is alarming, there is supposed to be a call to LVAD specialist. It is unclear how many LVAD specialists are in the institution, and whether they are on call 24/7. If this is not the case, calling them may not be helpful. As a next step, the algorithm gives one of two options: yes or no. However, if there is no unresponsive patient with LVAD, further steps are not very meaningful.

The algorithm following the Yes option is excellent and has only three logical steps: verify the connections of LVAD components and reconnect if missing, listen to the hum, and if there is none, start CPR immediately, including chest compressions.

If there hum is present, the next step is to treat underlying conditions. Recommendation to listen to the hum in both arms of the algorithm is somewhat confusing. Also, suggestion to check for pulse and to Doppler the blood pressure is not followed by any instructions on what should be done differently based on the findings.

As a unique feature, the authors suggest to consider abdominal rather than chest compressions, to avoid cannulae dislodgement.

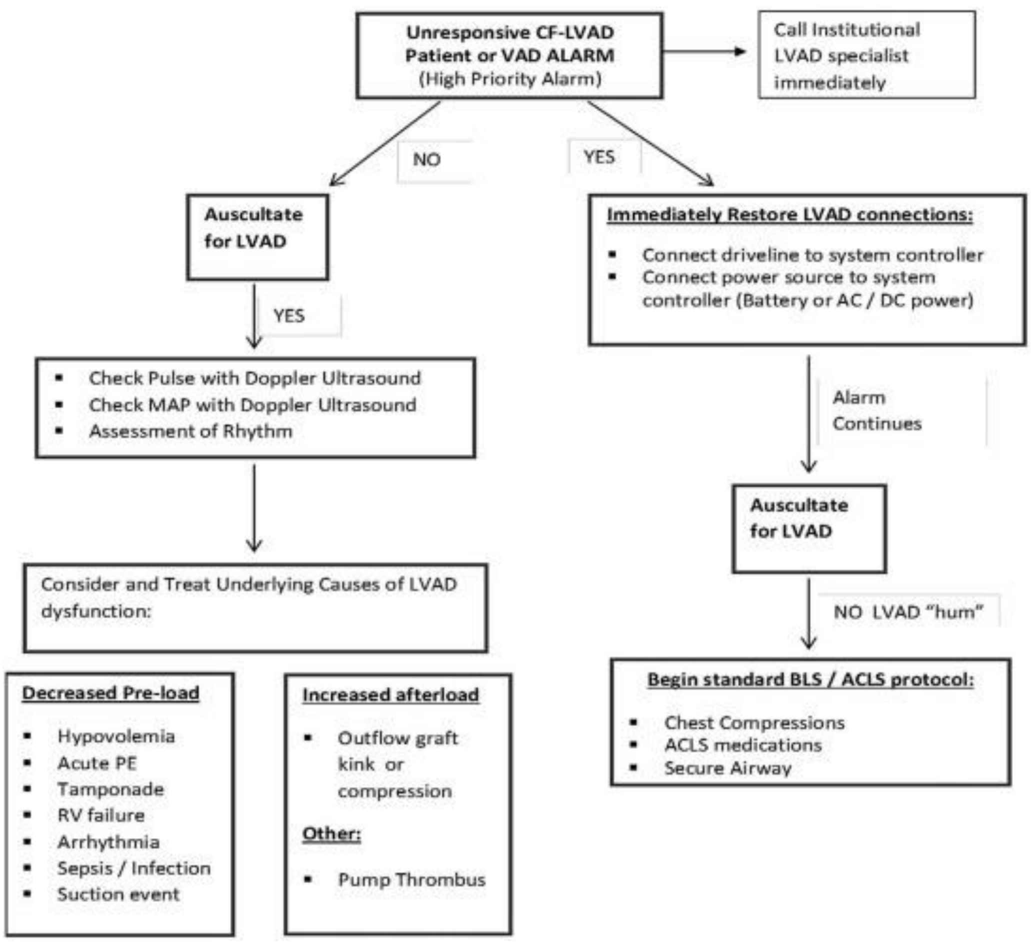

Figure 2. The Vanderbilt protocol. Reproduced from Haglund et al.(4), with permission

University of Texas Southwestern Medical Center

Garg et al. (3) reported 16 LVAD patients with arrest, with 5 (31%) surviving to hospital discharge. Specifically, both patients who eventually survived cardiac arrest, received CPR immediately, in <2 minutes, while none of the patients who received CPR after a delay of ≥2 minutes survived the arrest. The authors also reported that the time from the arrest to beginning of CPR was longer in patients with LVADs than is patients who coded not being on LVAD support, despite the fact that many arrests on LVAD occurred in the intensive care unit with most experienced, trained and prepared providers.

Two of their patients who survived the arrest after CPR with chest compressions had echocardiogram confirming the appropriate position of the LVAD cannulae after the resuscitation.

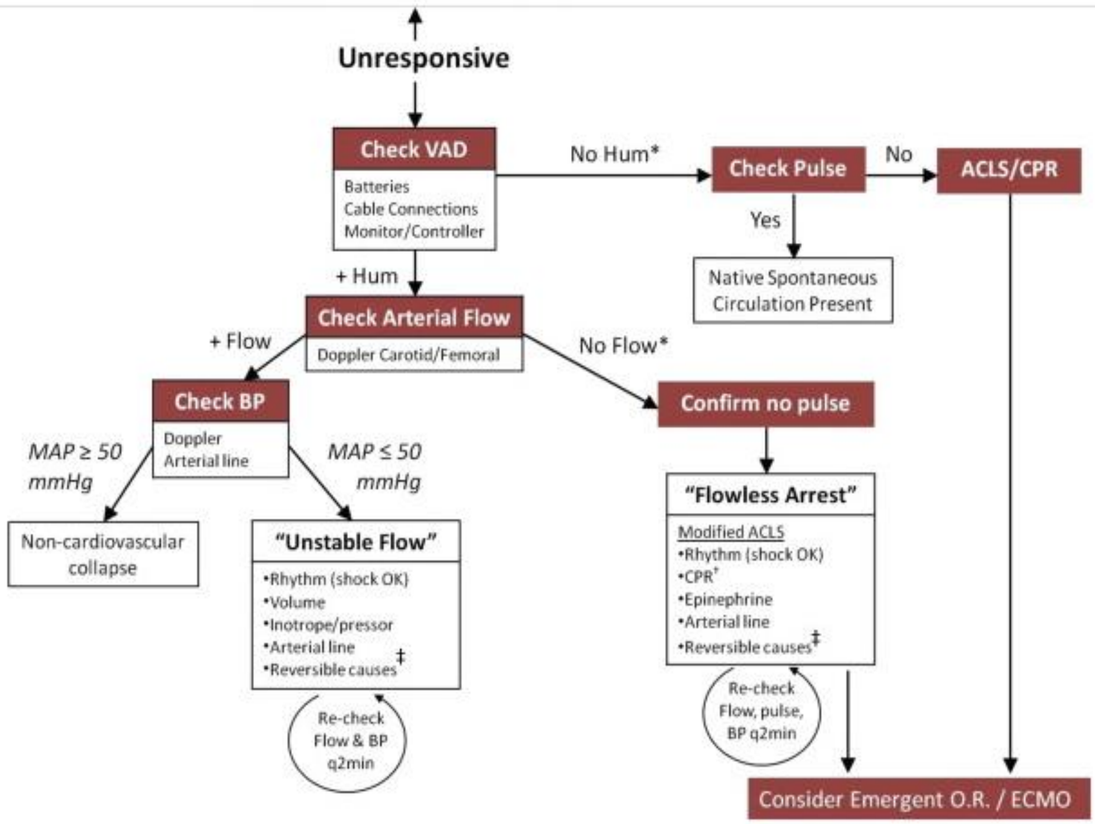

Figure 3. The UT Southwestern protocol. Reproduced from Garg et al.(3), with permission

The algorithm they developed is very straight forward (Figure 3) and is based on three major steps: check and restore the connection of the VAD components, listen to the hum, check pulse, and start ACLS/CPR if neither hum no pulse is present. If there is hum but no pulse, check flow and BP with Doppler, if neither is present, start CPR. IF BP is present but is less than 50mmHg (mean), check for reversible cardiovascular and non-cardiac causes, and if BP is greater than 50 mmHg, cardiac causes are ruled out, treat an underlying non-cardiac condition. The only confusing part of the algorithm is where it separates two conditions: 1) flow is present by Doppler but there is no blood pressure ("flowless arrest"), and 2) flow is present and blood pressure is less than 50mmHg ("unstable flow"). CPR is recommended in the first case scenario but not in the second. In practice, if the flow is present by Doppler, at some point BP would be measurable, and differentiation between these two conditions may be challenging.

Also, in the end of the algorithm, they suggest to consider an ECMO, which is a very logical step.

Columbia University

The algorithm from Columbia is shown on Figure 4

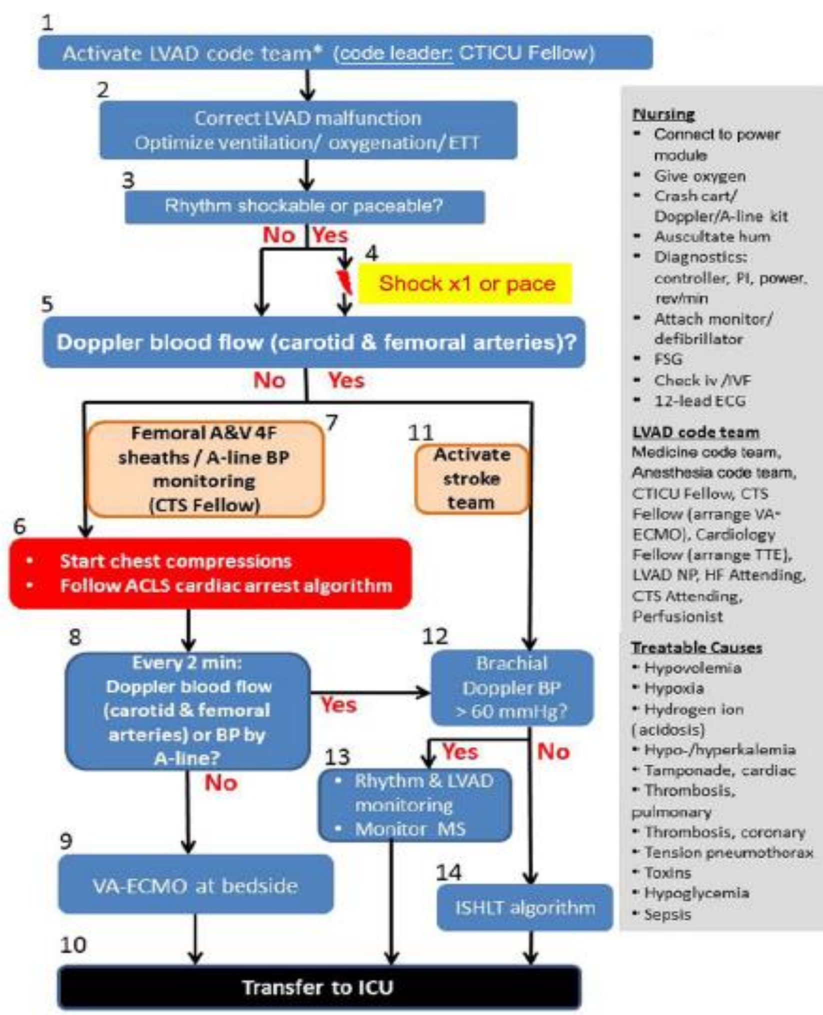

Figure 4. The Columbia protocol. Reproduced from Yuzefpolskaya et al.(6), with permission

This algorithm (Figure 4) requires an LVAD code team, consisting of several fellows (critical care and cardiology), a perfusionist, and, if in-house, an LVAD nurse practitioner, a surgeon and a heart failure cardiologist. This ensures that several people will be in house 24/7, ready to respond. They also introduce the VAD code pager, separate from general in-hospital code pager. They also require endotracheal intubation immediately and prioritize electrical shock or pacing if the patient is in shockable/paceable rhythm. If there is flow present by Doppler, they immediately activate stroke team. They also advocate ACLS/chest compressions if there is no flow by Doppler. The only step which is present in all other algorithms and absent from the Columbia one is listening to the hum and act differently based on its presence or absence.

University of Kentucky

The algorithm of University of Kentucky is described in details in this Journal (2). We are reproducing our algorithm on Figure 5.

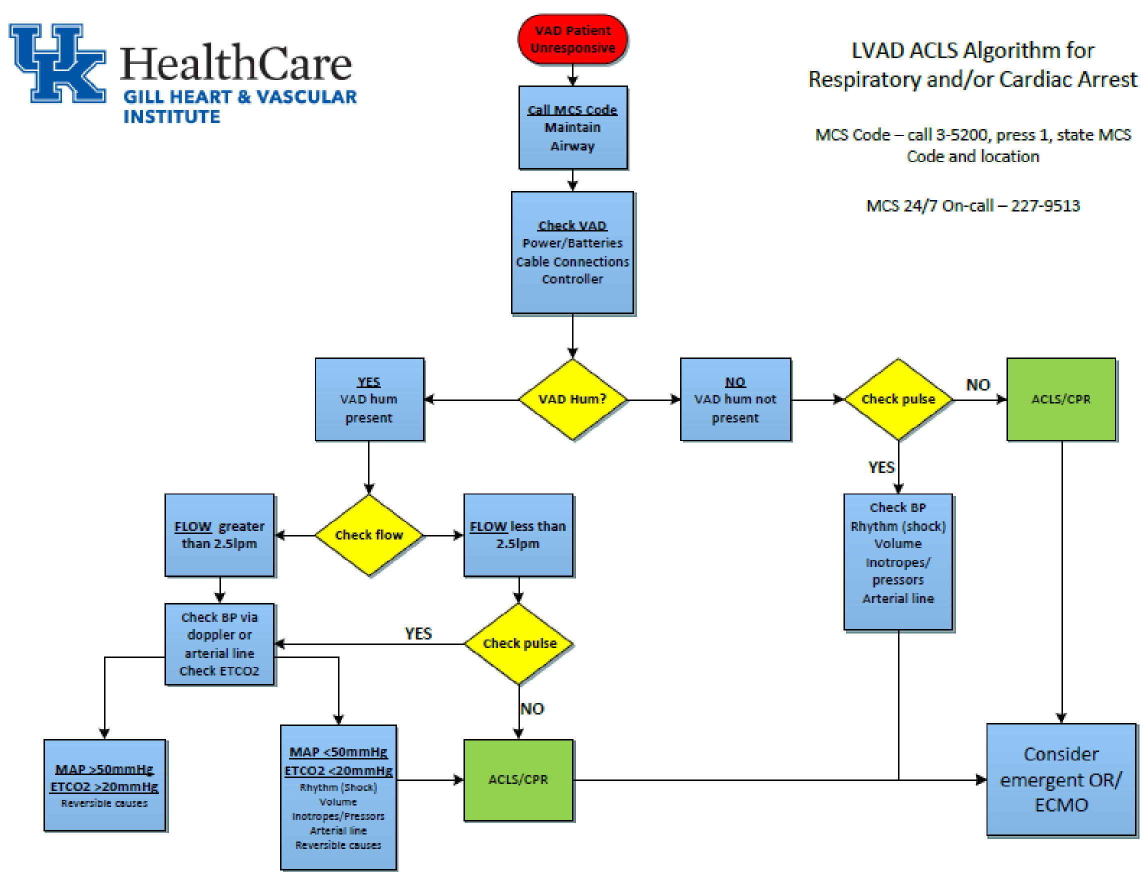

Figure 5. The University of Kentucky algorithm

The American Heart Association Algorithm

The newest development was provided by group of experts who wrote a scientific statement from the American Heart Association (AHA) on CPR in LVAD (7). Their algorithm consists of the following steps:

1. Assess ventilation and perfusion by skin color and temperature.

2. If perfusion is normal, look for non-LVAD related causes for altered mental status, such as stroke, blood glucose abnormalities, drug overdose, or hypoxia.

If perfusion is abnormal, check LVAD hum and alarms

3. If LVAD is functioning, check mean arterial pressure and end-tidal carbon dioxide (PETCO2).

If mean arterial pressure >50mmHg and PETCO2>20mmHg, do not perform chest compressions but follow BLS/ACLS protocol.

If mean arterial pressure <50mmHg and PETCO2<20mmHg, perform chest compressions

4. If the LVAD is not functioning, check driveline, controller, batteries, and try to restart LVAD. ill it is restarted, perform BLS/ASLS

The difference with the algorithm we proposed is in the initial step (Figure 1)– we suggest to start with listening to LVAD hum. The AHA algorithm begins with evaluating perfusion using skin color, skin temperature, and capillary refill. In our view, using these measures as the decision point for proceeding through the algorithm could lead to under or over treatment of the patient. Patients with poor peripheral perfusion may not have adequate capillary refill. Capillary refill is not a precise measurement in the setting of potential cardiopulmonary arrest. Skin color and temperature could be late or at least delayed sign of poor perfusion for in hospital arrests.

Conclusions

Despite many efforts put into the above algorithms, many questions still remain unanswered. What is the risk/benefit of using chest compressions in LVAD patients? If the LVAD is functioning but the patient is underperfused, should chest compressions be standard depth and frequency in line with ACLS guidelines or should modified chest compressions be used?

As cases of unresponsive patients with LVADs are accumulating, we hope that these and other questions will be answered.

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