




PART 5
PVAD PATIENT
MANAGEMENT IN THE
ICU, WEANING AND
ESCALATION

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Key messages

- ✓ The patients should be cared in an ICU with adequately trained personnel.
- ✓ Hemodynamic monitoring with PAC is mandatory.
- ✓ After stabilisation a thorough evaluation of patient's comorbidities, current medications and, eventually, end of life wishes should be performed.
- ✓ Imaging with echocardiography is mandatory.
- ✓ Persistence of shock could be driven by insufficient LV support or by RV dysfunction: each require different management, with an escalation strategy.
- ✓ Management of medications is crucial and is different according to the timing of primary insult, hemodynamic status, residual myocardial function and pVAD flow.

- ✓ Evaluation of the vascular access and limb for bleeding/ischemia should be performed at least at every shift.
- ✓ If the patient is managed with a multidevice strategy (ECPella), descalation should proceed with ECMO removal first.
- ✓ Upper body strategies, with transaxillary access, should be exploited to facilitate mobilization and ambulation if the patient is MCS dependent.
- ✓ Weaning from pVAD should not be performed until inotropes have been weaned and the patient has received low doses heart failure medications (ACE-inhibitors, Angiotensin Receptor Blockers, aldosterone antagonists).

Executive summary

Management of patients with pVAD in the ICU requires the availability of an adequately trained personnel in critical care medicine.

Patients must receive advanced hemodynamic monitoring with pulmonary artery catheter and evaluation of pump parameters.

Hemodynamic monitoring dictates pharmacologic manipulation of afterload and fluid management.

Echocardiography is essential to identify complications secondary to the underlying disease (mechanical complications of myocardial infarction), correct positioning of the pump, evaluation of concomitant or emerging valvular disease, myocardial viability and recovery.

The pump interferes with doppler and can make challenging the diagnosis and grading of mitral regurgitation, due to the unloading provided by the pump.

Antiplatelet and anticoagulant therapy should be administered according to guidelines, preferably with short acting and reversible agents, as these patients are at high risk of bleeding.

The risk of limb ischemia is high, and the diagnosis can be delayed: the limb must be evaluated at least at every shift for access bleeding and ischemia. The management could require interventional procedures or vascular surgeon consultation.

The level of support should be tailored on the resolution of shock markers and the attainment of hemodynamic stability.

Lack of clearance of shock parameters, pulmonary oedema, refractory end-organs dysfunction warrant evaluation for escalation.

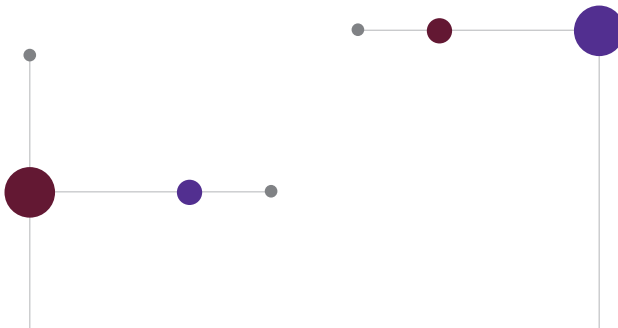
The escalation strategy with ECPella, BiPella, Impella 5.0/5.5, intrathoracic VAD is based on the mechanism of cardiac dysfunction and the occurrence of right ventricular failure.

The transition to an upper body approach allows patients' mobilization and full clinical evaluation for LVAD implantation or heart transplantation.

The ideal candidate to weaning is a patient cooperative, spontaneously breathing, hemodynamically stable without inotropic support, with recovered end-organ function; in case of multivessel coronary disease, the patient should receive complete revascularization after myocardial viability tests and major valvular dysfunctions should be addressed.

Oral heart failure medications with ACE inhibitors/ARB should be started.

The amount of pump flow at low speed is not negligible, as this is rarely <1 L/min: the hemodynamic impact of the final phase of weaning can be strong.



1 - STANDARD CRITICAL CARE

Patients should be cared in an ICU with adequate nurse-to-patient ratio and availability of comprehensive hemodynamic invasive and non-invasive monitoring, invasive and non-invasive ventilation and renal replacement therapy. Physicians should be trained in critical care medicine and attend the ward 24 hours/7days.

Continuous monitoring should focus on pump performance, cardiac output, blood pressure, cardiac filling pressures and residual ejection of the LV; these, together with shock parameters (lactates, metabolic acidosis, mixed venous oxygen saturation) should drive pump speed setting in order to generate adequate pump flow (**See chapter 9**). The use of pulmonary artery catheter is mandatory. Fluid management is to be tailored according to filling pressures, pulmonary oedema, and dimension of the LV, with inherent issues of mechanical interaction with the pump.

Pharmacological manipulation of cardiac afterload with vasodilators is beneficial to improve pVAD performance, reduce ventricular wall tension and myocardial oxygen consumption (see chapter concomitant inotropic support). Institutional transfusion guidelines of the non-bleeding patient will be followed.

Once the patient is stabilized, a comprehensive past medical history focused on comorbidities, age and end-of-life wishes should be obtained.

Anticoagulant/antiplatelet drugs should be administered as indicated (**See chapter 28**); however, these patients are often prone to bleeding (not necessarily from the access site) and, therefore, judicious balance of the antithrombotic regimen can be maintained with short acting/reversible intravenous agents.

These patients often show a Systemic Inflammatory Response Syndrome, due to AMI, shock, haemolysis: this can be a driver of hemodynamic instability and end-organ dysfunction and deserves adjunctive therapies, such as hemadsorption with specific cartridges.

2 - IMAGING







Echocardiography is essential in identifying pump mal-positioning, in guiding pump repositioning, but mostly to monitor AMI-related complications (tamponade, heart rupture, ventricular septal defect) and biventricular function (see chapter: imaging and weaning).

Over time, it is mostly focused on the assessment of myocardial recovery, remote ischaemia and residual myocardial viability in multivessel disease. Evaluation of the mitral valvular apparatus and mitral valve regurgitation is challenging, as the device interferes with the colour Doppler signal and the loading conditions of the LV are artifactually changed by the pump, possibly leading to underestimation. Moreover, multiple mechanisms (ischemic, functional, organic) can affect the mitral valve in this clinical scenario.

Imaging is warranted with daily chest X-rays to assess pulmonary congestion and respiratory complications, with computed tomography of the brain for neurological evaluation and with ultrasound to assess the access site for complications or the axillary artery for escalation of support.

3 - LIMB ISCHEMIA

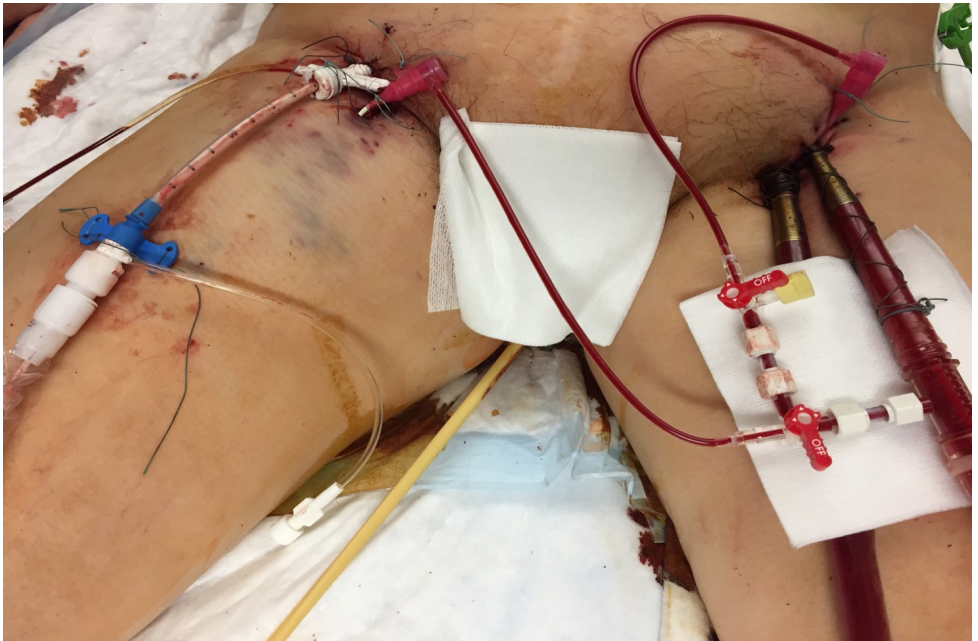
Identification and management of limb ischemia is challenging due to multiple factors affecting common practice in this setting:

-  Pulselessness → unreliable (pulse pressure may be reduced or even absent)
-  Pallor → subjective
-  Pain → absent in sedated patients: unreliable
-  Poikilothermy → contralateral limb cold in shock: subjective
-  Paresthesia → absent in sedated patients: unreliable
-  Paralysis → late and masked by sedation: delayed

In case of concomitant ECPella configuration, reperfusion of the limb with an introducer flowing blood from the ECMO circuit should be considered (**Figure 1**). Surgical consultation should be readily available and change of access site is most often required if surgery is needed. Device removal should also carefully evaluate from the technical standpoint: multiple options are available (manual/mechanical compression, use of pre-post closure devices, surgery, interventional procedures with balloon-stent haemostasis in the catheterisation laboratory). We recommend that the approach should be dictated by institutional and operator experience/availability in uncomplicated cases; whereas vascular surgical evaluation and planning is mandatory in complex scenarios, such as ischemic limb and/or need for an alternative access.

Figure 1 - Contralateral reperfusion of the limb with Impella via the port of the V-A ECMO arterial cannula

Note the different site for access of the sheath according to preemptive vs bailout puncture.



4 - ESCALATION/DE-ESCALATION

As the dynamics of myocardial dysfunction is extremely complex in cardiogenic shock due to the interplay between primary and secondary myocardial dysfunction, and eventually the occurrence of right ventricular failure, clinical sensitivity should trigger the need for escalation of mechanical circulatory support and selection of the most appropriate configuration (ECPella, BiPella, Impella 5.0/5.5, intrathoracic VAD).

Inotropes should be progressively weaned before any reduction of pump flow; cut off values are extremely valuable for clinical purposes (inotropic score >20 should warrant evaluation for escalation). Similarly, the requirement of inotropes after 48 hrs should trigger full hemodynamic re-evaluation.

Transition to an upper body approach with a more powerful pump (5.0/5.5) has multiple advantages: allows prolonged myocardial recovery, a thorough medical and full neurological evaluation, optimization in the perspective of heart transplantation (HTx)-LVAD, fixing possible complications. Furthermore, the implantation of a full support mid-term LVAD (Impella 5.0/5.5) allows the evaluation of the right ventricular function and pulmonary vascular resistances; this is particularly valuable in light of the unsatisfactory results of direct INTERMACS 1 implantation of LVAD or HTx.

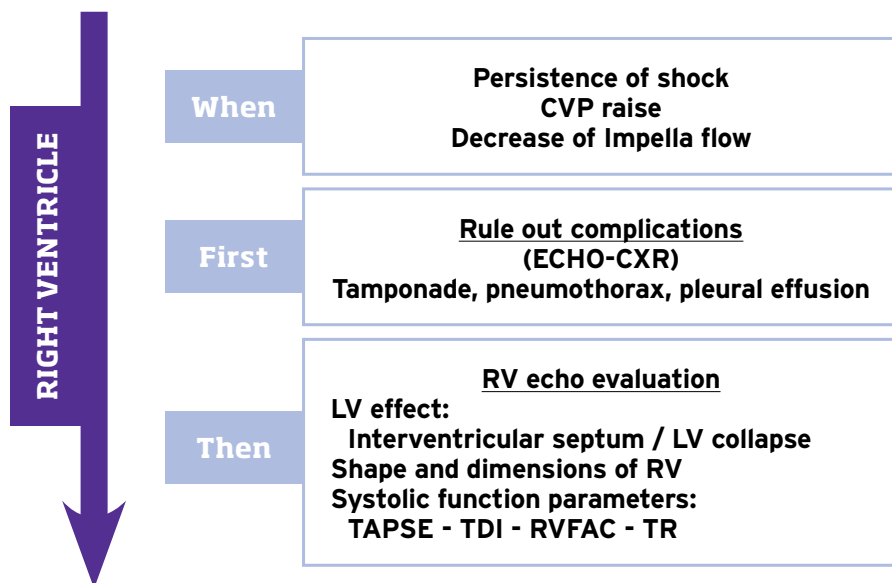
Moreover, the patient can be safely mobilized out of bed, favouring the recovery of his general physical status. Mobilization is extremely helpful in the clinical evaluation of patients who have limited native heart recovery: it shows haemodynamic response to physical activity, tolerability of heart failure medications and avoidance of unsuccessful device removal.

5 - RIGHT VENTRICULAR FAILURE

The selection between V-A ECMO and BiPella (with Impella) as right ventricular mechanical support device is dictated by the global haemodynamic status of the patient: in case of persistent cardiogenic shock, V-A ECMO could be the first option due to ease of insertion and management, whereas BiPella can effectively fix the rest of the patients. Adequate venous cannulation for V-A ECMO in this scenario is fundamental: large bore venous drainage with cannulation up to the superior vena cava is recommended (*See chapters 10 & 19*).

Figure 2 - Timeline and modalities of RVF evaluation

TAPSE: > 1.6 cm; TDI: tissue Doppler imaging of the tricuspid annulus (> 10 cm/s); RVFAC: $> 30\%$.



6 - WEANING

The process of weaning is complex and should follow a strict stepwise procedure: first of all, the patient should be hemodynamically stable without inotropic support, with low cardiac filling pressures and with recovered end-organ function; in case of multivessel coronary disease the patient should be evaluated for complete revascularization. (*Figure 3* shows a proposed algorithm) which will be performed under device support. Heart failure medications with ACE inhibitors/ARB should be started and major valvular dysfunction should be ruled out (transcatheter therapies are an option).

During the weaning phase, consideration to the amount of pump flow at low speed should not be neglected, as this is rarely < 1 L/min with CP and < 1.5 L/min with 5.0. In this regard, right heart catheterization during this phase is strongly advised.

As LVEF does not usually return to normal, the administration of levosimendan over the weaning phase could be considered to facilitate the procedure. The gradual introduction of low dose ACE inhibitors or ARB should be attempted when pump support is reduced and ejection with adequate pulse pressure is present. Beta blockers should not be started during this phase and control of heart rate should be obtained with ivabradine/digoxin.

The weaning process should also consider pump durability as each Impella device is certified for a specific duration and pump failure would eventually jeopardize the patient; therefore, clinicians should take into account duration of support, pump performance parameters and intensity of anticoagulation in order to capture the 'timely window' for shifting to pump exchange or removal, avoiding critical complications.

The evaluation of the aortic valve is also important: transvalvular pumps can produce some amount of aortic regurgitation. This turns into a lower net antegrade flow and LV unloading. As this situation is solved by removal of the pump, we have to expect a more consistent hemodynamic stability after weaning as compared to patients who maintain normal aortic valve competence during support.

Figure 3 - Descalation and weaning

