Massive Pulmonary Embolism: The Role of Mechanical Circulatory Support

Use of mechanical circulatory support appears to be feasible in a subset of patients with pulmonary embolism, but expertise in placement and postprocedural management is critical.

By Catalin Toma, MD; Michael Jolly, MD; and Christopher Huff, MD

The contemporary risk stratification for pulmonary embolism (PE) is centered on the degree of right ventricular (RV) dysfunction rather than the anatomy of the thromboembolic event. High-risk (massive) PEs are relatively infrequent but have, by definition, acute RV failure with sustained hypotension with a systolic blood pressure < 90 mm Hg, vasopressor use, or evidence of distal organ hypoperfusion. Intermediate (or submassive) PEs represent approximately one-third of cases and have evidence of subclinical RV dysfunction (RV dilatation and positive biomarkers of myocardial injury) but no overt hemodynamic instability. The differentiation between these categories based on clinical criteria is not very robust, as submassive PEs may often have invasive hemodynamic characteristics consistent with cardiogenic shock despite apparent surface hemodynamic stability. Likewise, the massive PE category is relatively broad, including patients with hypotension and a minimal vasopressor requirement to cardiac arrest requiring CPR. Low-risk PE includes the majority of patients presenting with PE but have no evidence of RV strain.

PERT AND INITIATION OF MECHANICAL CIRCULATORY SUPPORT

Mortality related to massive PE remains high, approaching 40%. To address these higher-risk PE patients, an increasing number of institutions are establishing multidisciplinary pulmonary embolism response teams (PERTs) in an effort to standardize PE care and improve communication between specialists. Given the fact that PE is primarily a disease of RV failure, part of the PERT conversation and expertise has to include the use of mechanical circulatory support (MCS). Currently, there is very little guidance in this regard. The recently published European Society of Cardiology PE guidelines mention that extracorporeal membrane oxygenation (ECMO) may be used in patients with high-risk PE and circulatory collapse and cardiac arrest but underscore the lack of evidence. How to implement ECMO locally remains challenging and deserves the type of approach utilized for standardization of cardiogenic shock caused by myocardial infarction. At our institutions, the PERT includes local experts in the initiation and follow-up of MCS. In general, all massive (high-risk) PE patients who are candidates for advanced hemodynamic support are discussed on presentation and a decision on the candidacy for advanced support is made early in the care of the patient.

The decision to proceed with and the type of mechanical support is often done in conjunction with the PE treatment strategy. Although the latter is outside the scope of this review, in high-risk PE patients, this generally involves either anticoagulation alone or a reperfusion strategy, which consists of systemic thrombolysis, surgical thrombectomy, or a catheter-based procedure (lytic-based/catheter-directed thrombolysis [CDT] or aspiration thrombectomy). Only systemic lysis carries a class I indication for massive PE; however, this is based on limited evidence, and a large number of patients do not qualify for intravenous tissue plasminogen activator due to bleeding risk. The current PE interventional toolbox and the supporting evidence have been reviewed in a recent American Heart Association statement.
ECMO

ECMO is the most commonly used form of MCS in PE with circulatory collapse. Given the need for MCS over respiratory support, the venaarterial configuration is typically used. Peripheral ECMO involves placement of large venous (18–21 F) and arterial (14–16 F) cannulas via femoral access and can provide up to 5 L/min of flow, as well as oxygenation. ECMO is particularly suitable for the hemodynamic conditions occurring in massive PE because it is effectively unloading the dilated right ventricle, allowing for recovery. However, inadequate perfusion of the cerebral and coronary vasculature can occur because the oxygenating blood return will compete with the poorly oxygenated left ventricular (LV) outflow (north-south syndrome). Because the LV function generally is not affected in the PE setting, this is an important issue and should be carefully monitored by checking the right upper extremity oxygen saturation. Switching to central ECMO may provide a more effective, albeit more invasive, solution.

ECMO has a high complication rate, which traditionally tempers its use. Bleeding occurs in 30% of cases and can be related to access site bleeding or can be remote. Platelet dysfunction and acquired von Willebrand syndrome occur due to the interaction with the plastic tubing of the circuit and the oxygenator and should be monitored for carefully. Bleeding is particularly relevant for patients receiving thrombolytics (systemic or catheter-based). Distal limb ischemia is also another frequent complication related to the large size of the inflow cannulas and the concomitant use of vasoconstrictors.

Data supporting ECMO in PE are relatively scarce, consisting mainly of local case series with no randomized controlled trials available. Traditionally, ECMO is applied in the most extreme cases of circulatory impairment and used in conjunction with surgery, systemic thrombolysis, or anticoagulation alone. In recently published series, mortality remains high (near 50%). A systematic review by Yusuff et al looking at 78 cases over 20 years had a more favorable survival of 70%. As expected, initiation of ECMO during cardiopulmonary arrest was associated with higher mortality. Complications related to ECMO were frequent, occurring in 20% of cases, with some cases of fatal bleeding. Interestingly, the type of reperfusion therapy used did not impact survival in this small data set, but the data are numerically very limited.

A recent report from the Massachusetts General Hospital PERT team documented their experience with ECMO in 13 patients over 9 years. ECMO was used very selectively, but all patients had cardiac arrest prior to support initiation. Mortality at 30 days was 31%, but major bleeding was frequent at 54%, likely related to the fact that the majority of these patients also received systemic or catheter-directed thrombolytics.

Some centers have embraced a different strategy in which ECMO is used early in the protocol in all high-risk/massive PE patients. Pasrija et al evaluated 19 patients over 2 years; only five patients had cardiac arrest prior to support. Survival was very good at 95%, with ECMO-related complications in three patients. This result was achieved with routine ultrasound-based vascular access, as well as placement of femoral perfusion cannula to assist with distal limb circulation.

Current data show that ECMO with anticoagulation alone can eventually lead to sufficient RV recovery to allow for decannulation. However, these patients will likely require prolonged circulatory support, therefore exposing them to increased complications. In the authors’ opinion, in the current era in which several percutaneous reperfusion tools are now available, ECMO should be primarily used in conjunction with a reperfusion strategy. RV strain is markedly improved within 24 to 48 hours with percutaneous intervention, faster than with anticoagulation alone. As far as the choice of reperfusion strategy, thrombolysis utilization is problematic given the large-caliber arterial access and platelet dysfunction and increased probability of bleeding complications. Percutaneous mechanical aspiration thrombectomy (eg, FlowTriever system, Inari Medical) or surgical thrombectomy may be the preferred approach. The former is effective in very acute presentations, whereas surgery may be preferred in later presentations or patients suspected of having a significant chronic component as evidenced by RV hypertrophy or very high pulmonary artery (PA) pressures. Figure 1 describes a case example in which large-bore aspiration thrombectomy was feasible with a multistage venous ECMO cannula in place, and rapid wean of ECMO support was facilitated by the prompt reperfusion of the pulmonary circulation.

Conversely, consideration and initiation of ECMO semielectively provides the stability required for a successful percutaneous or surgical procedure. At our institutions, in hemodynamically tenuous patients who are taken to the cath lab, image-guided femoral arterial access is usually obtained upfront with the placement of a small-caliber placeholder sheath to facilitate rapid ECMO initiation in case of ensuing hemodynamic compromise.

ECMO is an effective means of supporting PE patients, but expertise in placement and postprocedural management is critical to obtaining good results. Patients with
massive PE and circulatory collapse/cardiac arrest with return of spontaneous circulation and reasonable neurologic recovery potential are the most common target patients. ECMO should also be considered in PE patients without cardiac arrest in preparation for reperfusion therapy (surgical or percutaneous), as well as patients with persistent circulatory collapse after reperfusion therapy.

**IMPELLA RP/PROTEKDUO**

Impella RP (Abiomed, Inc.) is approved for circulatory support for up to 14 days in patients who develop acute RV failure after LV assist device implantation, myocardial infarction, heart transplant, or open heart surgery. The device does not have a PE-specific indication. Impella RP is a 24-F axial flow pump placed via femoral venous access with an inflow inlet at the level of the right atrium and an outlet in the main PA.

The ProtekDuo device (LivaNova) is approved for temporary cardiopulmonary bypass for up to 6 hours. ProtekDuo has a dual-lumen cannula with an external pump and a similar inflow/outflow configuration to Impella RP. The main difference is that the pump is external in the ProtekDuo device. Notably, this device is placed via the right internal jugular vein, allowing for some patient mobility. An oxygenator can be placed in the circuit as well.

Theoretically, these devices can help support a failing right ventricle in the context of PE; however, their effectiveness is limited by the elevated afterload. There are also concerns of dislodging some of the proximal clot more distally. As such, right atrial–PA flow pumps
would be most beneficial after or concomitant with reperfusion therapy, either surgical or percutaneous, in the presence of persistent RV dysfunction. Similar to ECMO, in our opinion, this type of MCS should not be used as a stand-alone therapy. Because arterial access is not required, there is theoretically less likelihood of bleeding with thrombolytic-based therapies with these pumps than with ECMO.

Data supporting these devices in massive PE are scarce and limited to a few case series. Elder et al reported on a five-patient series of high-risk PE patients treated with Impella RP, placed at the same time as initiation of CDT with the EkoSonic endovascular system (Boston Scientific Corporation). There was significant improvement at 24 hours in cardiac output and PA pressures, although this has been shown to occur with CDT alone as well. All patients survived to discharge. Youssef et al reported on one patient with persistent RV dysfunction after systemic thrombolysis in whom the placement of Impella RP had an immediate effect on hemodynamics and helped bridge the patient to recovery. Importantly, in these case reports, the MCS was instituted in conjunction with or after reperfusion. Other than anecdotal information, there are no published data on the use of the ProtekDuo system in PE.

The role of these devices is more limited but may represent a reasonable alternative to ECMO in certain scenarios. In particular, persistent RV dysfunction after reperfusion could be supported with a right atrial–RV pump. The risk of bleeding is lower as compared with ECMO and utilization with thrombolytics may be feasible.

CONCLUSION
The field of interventional PE is rapidly expanding and an increasing number of tools are available, including CDT and aspiration thrombectomy. It is becoming increasingly important that interventional PE expertise is connected to local MCS expertise and evaluation of options and strategies are considered upstream rather than emergently. Understanding hemodynamic data during right heart catheterization is also critical in evaluating options and should be the standard of care.

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With a symbiotic interplay between reperfusion therapies and MCS, effective treatment of the highest-risk PE patients, who are most likely to derive a survival benefit, is increasingly possible. Implementation of an effective reperfusion therapy may shorten the time on MCS and potentially decrease the complications associated with these devices.


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