

## When NOT to use short-term mechanical circulatory support



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The use of short-term mechanical circulatory support (MCS) is increasingly being offered to patients with acute cardiogenic shock.<sup>1</sup> The results of therapy have been improving consistently, with survival to hospital discharge exceeding 60% for selected cohorts.<sup>2,3</sup> One-year survival after hospital discharge is also encouraging, suggesting that those patients who survive short-term MCS have reasonable mid-term outcomes.<sup>4</sup> In contrast to durable devices, patients who present with acute decompensated heart failure do not always have the luxury of time to determine their transplant candidacy, social supports, or important comorbidities. Usually, the clinical history is brief and pertains to the events leading up to the acute presentation (acute infarct, pulmonary embolus, viral prodrome, etc). Thus, clinicians are faced with assessing the prognosis of the patient in front of them. Common questions include the following: Has there been a significant period of low cardiac output? How long were resuscitative efforts in place before return of spontaneous circulation (ROSC)? Most experts agree that failure to achieve ROSC within 30 minutes is a poor prognostic indicator of survival.<sup>5</sup>

In addition, assessments of end-organ function are critical. While renal failure is common, it is helpful to distinguish acute kidney injury from an acute-on-chronic process. In patients with known chronic kidney disease who are not dialysis dependent, acute cardiogenic shock usually results in a permanent loss of renal function. Hepatic function is also critical to assess and while severe elevations in transaminase levels are frequently reversible, the onset of auto-anticoagulation with elevations in international normalized ratio is a poor prognostic marker. Likewise, the concept of metabolic shock compounding circulatory shock is gaining favor as a prognostic indicator. Patients who are profoundly acidotic (pH < 7.0) or with high



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### CENTRAL MESSAGE

The use of short-term mechanical circulatory support has emerged as an increasingly popular therapy for a wide variety of cardiac pathologies. While the alternative to providing support is usually imminent death, this should not force clinicians into providing therapy if the outcome is deemed to be futile.

See Commentaries on pages 111 and 112.

lactate levels (>15 mmol/L) have poor prognosis and likely should not be offered support.

When medical history is available, the presence of comorbid conditions will influence our decision to offer mechanical support. Patients with pre-existing neurologic deficits or those with a known degenerative neurologic disorder are poor candidates for MCS. Similarly, patients with previous vascular surgical interventions and/or known carotid or aorto-iliac disease are at high risk for complications during MCS. Patients with known metastatic malignancies should not be offered support. Other chronic disease states such as end-stage pulmonary disease or heart failure may also preclude support. In the case of known heart failure, we will offer short-term support as a bridge to decision in a patient who is potentially a transplant candidate. However, in a patient previously declined for transplant, we will not offer emergency short-term support as a bridge to destination therapy-ventricular assist device. **Table 1** illustrates the common predictors of poor outcome in patients being considered for short-term MCS.

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**TABLE 1. Predictors of poor outcome following short-term mechanical circulatory support**

Predictor	Comments
Advanced age	Variable based upon institutional guidelines. Generally, survival falls after age 60 y.
Prolonged resuscitation	Influenced by quality of resuscitation (ie, monitored blood pressure, external compression device). Failure to achieve spontaneous circulation within 30 min predicts poor outcome.
Renal failure	Acute kidney injury is common; however, underlying chronic kidney disease is worrisome.
Metabolic shock	Absolute cut-offs may vary by institution. The following are considered contraindications to initiating support at our institution: pH <7.0, bicarbonate <15, lactate >15 mmol/L, INR >5 in the absence of anticoagulation.
Neurologic deficit	Pre-existing neurologic deficit or degenerative neurologic disorder.
Peripheral vascular disease	Previous surgical intervention or known history of carotid or aortoiliac disease.
Comorbid disease	Known malignant disease with poor prognosis. Chronic obstructive pulmonary disease. Pre-existing heart failure in a nontransplant candidate.

INR, International normalized ratio.

An acute septic process is also associated with poor prognosis and while this remains a controversial topic, extracorporeal life support (ECLS) for primary sepsis, in the absence of a reversible cause, is associated with poor outcome. Venovenous extracorporeal membrane oxygenation (ECMO) is commonly offered for acute respiratory failure due to overwhelming pneumonia, but this is primarily to provide oxygenation and not circulatory support. Patients with sepsis usually have a high cardiac output, so the development of cardiac dysfunction likely predicts an irrecoverable situation.

Postcardiotomy shock remains a common indication for ECLS. Table 2 is a summary of the 2016 ELSO (Extracorporeal Life Support Organization) registry report.<sup>3</sup> In this report, acute fulminant myocarditis portends the best survival (65%). While the adult cardiogenic shock population is not otherwise specified, the vast majority of these patients represent either acute ischemic shock or postcardiotomy shock. In our own unpublished observations, we see very poor survival in these subgroups, particularly if the patient is older than 60 years. While it is often difficult to decline therapy for an otherwise-healthy-appearing 65-year-old patient with acute cardiogenic shock secondary to an infarct, one must recognize that advanced age is associated with comorbidities such as renal dysfunction, diabetes, and peripheral vascular disease, all of which may have been unrecognized before presentation.

An important observation is that the average duration of support for cardiac ECLS is approximately 5 to 7 days,

which is in stark contrast to respiratory (particularly venovenous) ECLS, which commonly provides therapy for weeks. This is likely due to the fact that cardiac ECLS is usually used as a bridge to decision. In our experience, 48 to 72 hours of support is usually sufficient to establish adequate end-organ perfusion to assess reversibility of organ failure and importantly, to assess neurologic status. While native myocardial recovery may not be evident at 48 hours, one usually has had an opportunity to assess candidacy for transplant or long-term mechanical support. Therefore, by 7 days, a decision has been made to withdraw support, explant for recovery, or upgrade to a durable device as either a bridge to transplant or long-term therapy. Depending upon jurisdiction, donor organ availability may favor the prolonged use of ECLS as a direct bridge to transplant.

### RISK SCORES TO PREDICT SURVIVAL FOLLOWING ECLS

Several predictive models have been developed to help clinicians in their decision-making process with this challenging patient population. Perhaps the most quoted score is the Survival After Venovenous-Arterial ECMO (SAVE) score.<sup>6</sup> Using 12 pre-ECMO variables, the authors developed 5 risk categories: SAVE score risk categories I ( $\geq 5$ ), II (1–5), III (–4 to 0), IV (–9 to –5), and V ( $\leq -10$ ). Mortality increases as the SAVE score drops from category I to V. Similarly, the ENCOURAGE (prEdiction of Cardiogenic shock OUtcome for Ami patients salvaGed by VA-

**TABLE 2. Indications and survival for adult cardiac extracorporeal life support**

Indication	Number of patients	Mean support time, h	Survival
Shock	2083	144	42%
Myocarditis	227	188	65%
Cardiomyopathy	704	162	51%
Congenital	420	129	37%

Modified from the 2016 Extracorporeal Life Support Organization Registry.

ECMO) score used 7 pre-ECMO variables to derive a predictive model.<sup>7</sup> Compared with SAVE, this model had better predictive capability, albeit in a homogeneous population of patients suffering refractory cardiogenic shock secondary to acute myocardial infarction. The 5 ENCOURAGE risk categories showed progressively greater mortality out to 30 days.

### ALTERNATIVE SHORT-TERM MCS DEVICES

While the focus thus far has been on cardiac ECLS as the primary therapy for acute cardiogenic shock, there are other options available depending on institutional preference and experience.<sup>8</sup> The Impella line of devices (ABIOMED Corp, Danvers, Mass) consist of small axial flow devices that are usually inserted percutaneously via either the femoral or axillary artery. The smaller devices are capable of providing greater than 3 L/min of support and are increasingly being used to support high-risk percutaneous coronary artery interventions. There is a larger Impella 5.0 device that usually requires surgical cut-down to insert and can provide in excess of 5 L/min of flow. Unfortunately, a randomized trial comparing Impella with intra-aortic balloon pump support in acute cardiogenic shock failed to demonstrate any survival benefit, and use of Impella was associated with greater adverse events.<sup>9</sup> An interesting concept is to use the Impella device to prevent subsequent left ventricular (LV) dysfunction by unloading the acutely ischemic ventricle before revascularization. The door to unloading STEMI (ST Elevation Myocardial Infarction) trial randomized patients to immediate versus delayed (30-minute) Impella support before percutaneous revascularization. This small, 50-patient trial demonstrated that there were no safety or feasibility issues with delayed reperfusion, and there was a nonsignificant trend to a reduction in infarct size (15% to 13%).<sup>10</sup> A larger pivotal trial to determine the efficacy of such a strategy has been recommended. We have employed the Impella device in selected clinical situations for the treatment of acute cardiogenic shock. Patients must have adequate right ventricular (RV) function, no evidence of pulmonary edema, and no evidence of apical thrombus. In addition, they need adequate femoral access for either percutaneous or surgical insertion. Once in place, the Impella can act as an effective LV decompression device should ECLS subsequently be required. Several centers routinely employ the Impella after the initiation of ECLS; however, in our experience, this is cost-prohibitive and associated with a greater incidence of limb ischemia, hemolysis, and aortic insufficiency. Our preferred venting strategy is a percutaneous left atrial vent inserted via the femoral vein.<sup>11</sup>

For patients with an open chest suffering from post-cardiotomy shock, we prefer to use central cannulation supported by a CentriMag device (Abbot Laboratories, Abbot Park, Ill). This device allows for isolated left, right, or biventricular assistance and can be connected

to an oxygenator to provide full cardiopulmonary support.

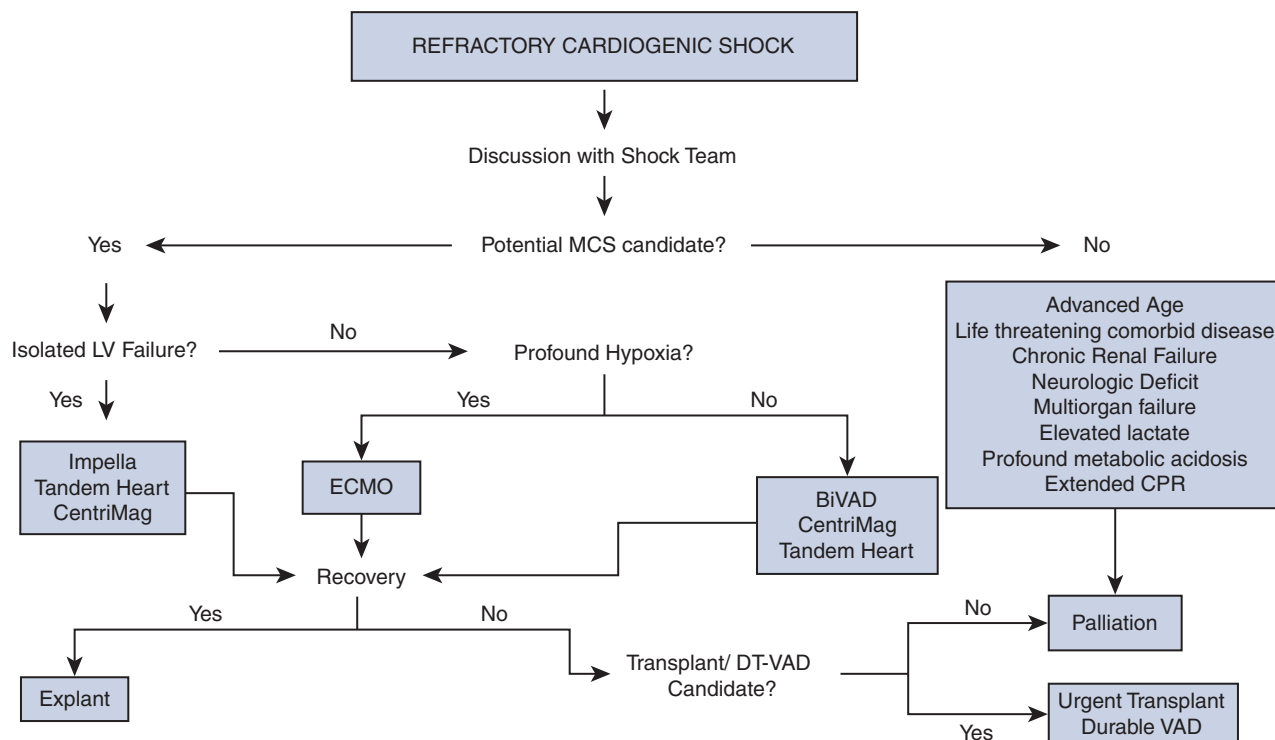
There are other percutaneous mechanical support devices in development. The TandemHeart (LivaNova; Pittsburgh, Pa) is approved by the Food and Drug Administration and uses a trans-septal cannula to provide left-sided support and has a unique dual lumen catheter (Protect-Duo) to provide isolated RV support. Again, this device can be connected to an oxygenator to provide full cardiopulmonary support if required.

The decision to use percutaneous or central cannulation is dependent on a lot of patient-specific factors, including body habitus, the mode of presentation (de novo vs postcardiotomy), and the presence of antiplatelet agents that may complicate sternotomy or thoracotomy. A unique approach to provide acute support has been proposed by the Columbia group.<sup>12</sup> The authors employ standard peripheral cannulation for ECLS consisting of femoral venous to axillary artery flow. A small left thoracotomy incision is made to facilitate the insertion of an LV apical vent which is then connected to the venous inflow line. An oxygenator (if needed) can be spliced into the femoral venous circuit and removed if pulmonary function recovers. If RV function also recovers, the femoral venous line is removed rendering the patient dependent on isolated LV support. This may be a useful strategy as a bridge to transplant, but in the event a durable device is required, the LV apical cannulation site can be employed for LVAD inflow. [Figure 1](#) illustrates our institutional algorithm for consideration of short-term mechanical support and the decision tree for device selection.

### CLINICAL VIGNETTE

To further illustrate the issues surrounding the decision to provide short-term MCS, we will frame the decision-making process around a clinical case. A 55-year-old male patient with no previous cardiac history presented to an outside hospital with evidence of an acute anterior ST elevation myocardial infarction complicated by cardiogenic shock. Successful percutaneous coronary intervention was performed to the culprit left anterior descending artery lesion, but there was residual 3-vessel coronary artery disease. Percutaneous coronary intervention was complicated by recurrent ventricular tachycardia with hemodynamic compromise. We were consulted and advised the local center to proceed with peripheral ECLS. They decided to stabilize the patient with an intra-aortic balloon pump and an intravenous lidocaine and amiodarone infusion.

Overnight, the patient displayed progressive oliguria and increasing pressor requirements. The following morning, we were re-consulted and agreed to accept the patient in transfer for re-consideration of advanced heart failure therapies. On admission to our unit, the patient was not intubated and supported with oxygen at 4 L/min by nasal prongs. He had evidence of shock liver with transaminases 2 to 3



**FIGURE 1.** Proposed algorithm for the management of patients with refractory cardiogenic shock. *MCS*, Mechanical circulatory support; *LV*, left ventricular; *ECMO*, extracorporeal membrane oxygenation; *BiVAD*, biventricular assist device; *CPR*, cardiopulmonary resuscitation; *DT-VAD*, destination therapy-ventricular assist device.

times above normal but a normal bilirubin and preserved coagulation. He was oliguric but not anuric and responded to a diuretic challenge. His creatinine was elevated at 200 μmol/L and appeared to have plateaued.

He was hemodynamically stable on dobutamine and norepinephrine. He received ticagrelor 24 hours before admission, and thus the decision was made to manage him conservatively with a plan to offer peripheral ECLS if he deteriorated. In the following 48 hours, a rudimentary transplant screen was performed, and no obvious contraindications to cardiac transplantation were present. The patient had excellent social supports and both the family and the patient consented to advanced therapies, realizing that long-term MCS was a possible outcome. He underwent surgical revascularization supported by cardiopulmonary bypass and weaned with the aid of a CentriMag LV assist device. He was extubated the following morning and displayed recovery of LV function by postoperative day 3. After aggressive diuresis, he was returned to the operating room on postoperative day 5 for decannulation of the LV assist device. His subsequent postoperative course was uneventful, and he was discharged on postoperative day 9.

Reviewing the preceding course of events, there are multiple decision points that may have resulted in us declining therapy. First, if his ventricular tachycardia deteriorated into ventricular fibrillation and ROSC was not obtained

within 30 minutes, we would have advised against ECLS cannulation. Second, if he deteriorated precipitously overnight such that on transfer he had evidence of irreversible end-organ injury (elevated bilirubin and international normalized ratio >3) and/or metabolic compromise (lactate >15 μmol/L or pH <7.0), we would not have offered MCS. Conversely, if he displayed a slow progressive deterioration several days after presentation but had similar biochemical/metabolic derangements and/or sepsis, we would conclude that the likelihood of recovery was poor and not offer support.

During transplant screening if we found that he had evidence of underlying chronic kidney disease and presented with anuric renal failure, it would be unlikely that we would have offered him advanced therapies. Lastly, if the family and/or patient was unwilling to accept the possibility of long-term mechanical support and thus raise the potential for withdrawal of care in the event of non-recoverable LV function, we would not proceed to intervention.

### PREDICTING FUTILITY AND WITHDRAWAL OF SUPPORT

As described, there are several risk indices that can be employed to determine whether provision of short-term MCS can yield a successful outcome or if it is a futile exercise. Sadly, it is an emotional decision to decline support in

a young patient with a very dismal prognosis, and often the patient is given the opportunity to benefit from MCS. A less-emotional decision process can be employed to determine when withdrawal of support is appropriate. Clearly, failure to demonstrate neurologic recovery is an indication to withdraw support. Often, these patients may present as suitable organ donors, particularly if hepatic, renal and respiratory function has recovered.<sup>13</sup>

Once circulatory support has been established, a more detailed medical and psychosocial assessment can be performed. An expedited transplant evaluation along with consideration of candidacy for durable mechanical support should be completed. Evidence of progressive end-organ failure, onset of sepsis refractory to pressor support and lack of an “exit” strategy (ie, transplant or durable ventricular assist device), should prompt consideration of withdrawal after 5 to 7 days of support.

As clinicians dealing with acute cardiogenic shock, it is a reflex to offer MCS as a bridge to decision. Often, this results in the tragic need to withdraw support in a neurologically competent patient who is either septic or displays multiorgan failure despite adequate circulatory support. When such an outcome is predictable, it behooves us to NOT offer circulatory support. The desire to prolong life can easily transform into an unintentional prolongation of death.

#### Conflict of Interest Statement

Dr Rao is a consultant to Abbott Labs and Medtronic Inc, a member of the North American Surgical Advisory Board to Medtronic Inc, and has a minor equity stake (<\$25,000) in Medtronic Inc. Dr Billia reported no conflicts of interest.

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#### References

1. Rao V. Resurgence of extracorporeal support for the primary management of cardiogenic shock. *J Thorac Cardiovasc Surg.* 2015;150:341-2.
2. Takayama H, Truby L, Koekort M, Uriel N, Colombo P, Mancini DM, et al. Clinical outcome of mechanical circulatory support for refractory cardiogenic shock in the current era. *J Heart Lung Transplant.* 2013;32:106-11.
3. Thiagarajan RR, Barbaro RP, Rycus PT, Memullan DM, Conrad SA, Fortenberry JD, et al. Extracorporeal life support organizing registry international report 2016. *ASAIO J.* 2017;63:60-7.
4. Cheng YT, Garan AR, Sanchez J, Kurlansky P, Ando M, Cevasco M, et al. Midterm outcomes of bridge to recovery patients after short-term mechanical circulatory support. *Ann Thorac Surg.* 2019;108:524-30.
5. Singal RK, Singal D, Bednarczyk J, Lamarche Y, Singh G, Rao V, et al. Current and future status of extracorporeal cardiopulmonary resuscitation for in-hospital cardiac arrest. *Can J Cardiol.* 2017;33:51-60.
6. Schmidt M, Burrell A, Roberts L, Bailey M, Sheldrake J, Rycus PT, et al. Predicting survival after ECMO for refractory cardiogenic shock: the survival after veno-arterial ecmo score. *Eur Heart J.* 2015;36:2246-56.
7. Muller G, Flecher E, Lebreton G, Luyt C-E, Trouillet J-L, Bréchet N, et al. The ENCOURAGE mortality risk score and analysis of long-term outcomes after VA-ECMO for acute myocardial infarction with cardiogenic shock. *Intensive Care Med.* 2016;42:370-8.
8. Tsuneyoshi H, Rao V. The role of extracorporeal membrane oxygenation (ECMO) therapy in acute heart failure. *Int Anesthesiol Clin.* 2012;50:114-22.
9. Ouweneel DM, Erikson E, Sjaauw KD, van Dongen IM, Hirsch A, Packer EJS, et al. Percutaneous mechanical support versus intra-aortic balloon pump in cardiogenic shock after acute myocardial infarction. *J Am Coll Cardiol.* 2017;69:278-87.
10. Kapur NK, Alkhouli MA, DeMartini TJ, Faraz H, George ZH, Goodwin MJ, et al. Unloading the left ventricle before reperfusion in patients with anterior ST-segment elevation myocardial infarction. *Circulation.* 2019;139:337-46.
11. Alhussain M, Osten M, Horlick E, Ross HJ, Fan E, Rao V, et al. Percutaneous left atrial decompression in adults with refractory cardiogenic shock supported with veno-arterial extracorporeal membrane oxygenation. *J Card Surg.* 2017;32:396-401.
12. Takeda K, Garan AR, Ando M, Han J, Topkara VK, Kurlansky P, et al. Minimally invasive CentriMag ventricular assist device support integrated with extracorporeal membrane oxygenation in cardiogenic shock patients: a comparison with conventional CentriMag biventricular support configuration. *Eur J Cardiothorac Surg.* 2017;52:1055-61.
13. Rao V, Dhanani S, Maclean J, Payne C, Paltser E, Humar A, et al. Effect of organ donation after circulatory determination of death on number of organ transplants from donors with neurologic determination of death. *CMAJ.* 2017;189:e1206-11.

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