Extracorporeal Lung Support (ECLS): A Technology Revolution and Improved Outcomes for Lung Transplant Patients

Marcelo Cypel MD, Matthew Hartwig MD and Shaf Keshavjee MD
1Toronto Lung Transplant Program, University of Toronto
2Duke University Medical Center, Duke University

Much has been learned in the last decade about ECLS management. The well-known term Extracorporeal Membrane Oxygenation (ECMO) has now become obsolete since artificial lung devices can now be used to treat other conditions associated with end-stage lung diseases such as hypercapnic respiratory failure or right ventricular (RV) dysfunction associated with pulmonary hypertension (PH). Thus ECLS seems to be a more inclusive and appropriate term. Progressive improvements in technology especially with new centrifugal pumps, polymethylpentene membranes, cannulas, and heparin-coated circuits have allowed safer and efficacious institution of this therapy for lung transplant patients.

ECLS can be applied in lung transplantation (LTx) in 3 situations: 1) Bridge to transplant in patients with severe refractory respiratory failure, 2) Intraoperative support, 3) Management of severe primary graft dysfunction (PGD) after transplantation.

**Bridge to transplant**

Significant advances have been made in this area. Tailoring of ECLS configuration and devices based on the patient’s physiology has been a significant improvement in practice in comparison with the past where veno-arterial (VA) ECLS was almost the sole mode of application. Most centers today would consider single cannula veno-venous (VV) ECLS for most patients with hypercapnic and/or hypoxemic respiratory failure. The advantage of this set-up is the provision of excellent lung support (in contrast to femoral VA set up where central hypoxia often develops) that allows a significant decrease in ventilator settings, extubation of the patient and even ambulation in some cases. In our experience in Toronto, more than 50% of patients on ECLS will be off the ventilator prior to LTx. The absence of groin cannulation facilitates patient mobilization and physiotherapy.

Thus, ECLS in 2013 represents an opportunity not only to “gain more time” to a life-saving transplant, but also the chance to improve physical condition prior to the transplantation procedure. A second subset of patients on lung transplant wait lists includes those with PAH and severe RV dysfunction. We have used the interventional lung assist device (Novalung) in a pumpless mode placed in parallel with the native lung (pulmonary artery to left atrium). In our experience in Toronto, the use of this setup completely decompressed the right ventricle and stabilized patients with cardiogenic shock secondary to PAH. A disadvantage of this set up is the need for a sternotomy and open chest procedure. Thus, less invasive techniques evaluating a similar approach are being investigated.
General outcomes in experienced ECLS and lung transplant centers have demonstrated that at least 80% of these patients will survive to transplantation\(^5\). Outcomes after transplantation are also quite acceptable, although incidence of PGD seems to be increased in this population\(^8\). With improved outcomes of ECLS bridge to transplant, a major challenge in the next few years will be to determine criteria for patient selection and organ allocation policies. Currently, most groups offer ECLS bridge to wait list patients with younger age and absence of significant comorbidities. To illustrate this, we would offer ECLS to a 30-year-old patient with Cystic Fibrosis without hesitation, but would be very concerned to consider a 65-year-old patient with pulmonary fibrosis, secondary PAH and some degree of coronary artery disease. A more liberal approach may be possible in the future with the rapid improvement in ECLS technology and outcomes.

**Intraoperative ECLS**

Many centers have now adopted ECLS when cardiopulmonary support is required during transplantation procedure instead of full cardio-pulmonary bypass (CPB). Some of the advantages of ECLS over CPB include a simpler set-up, significantly lower anticoagulation requirements (usual activated clotting times (ACT) of 180-220 sec), decreased transfusion requirements, and the possibility to continue ECLS into the post-operative period to protect the graft in patients with PAH for example\(^9\). One recent study compared ECLS with CPB in LTx and demonstrated significantly less complications and better survival for the ECLS group\(^10\).

**ECLS for Primary Graft Dysfunction (PGD)**

PGD remains the leading cause of early post-transplant morbidity and mortality. After excluding reversible causes, supportive treatment includes optimization of ventilator parameters, inotropic support, diuresis, and nitric oxide. A strategy of early institution of VV ECLS appears to be beneficial in patients severely affected by PGD\(^11\). At Duke University we often implement ECLS support when recipients demonstrate decreasing pulmonary compliance (e.g. plateau pressures > 34-36 cm H\(_2\)O) or hypoxia requiring high FiO\(_2\). Our preferred VV cannulation is via a dual-lumen right internal jugular venous cannula. This allows for maximal patient mobility and rehab potential while on ECLS\(^2\). An alternative VV strategy includes a venous catheter in the right femoral vein and an “arterial” cannula in an internal jugular vein. Cannulas are placed percutaneously using a modified Seldinger technique. Transesophageal echo or fluoroscopy guide the insertion of cannulae, while the level of recirculation in the system determines the optimal placement of circuit in-flow and out-flow ports. ECLS flows are typically 2-4 liters/minute with a sweep gas flow adjusted to maintain the pCO\(_2\) close to 30 mm Hg so as to minimize pulmonary vasoconstriction. During VV support, a protective ventilator strategy should be initiated that is similar to what has been described in the support of ARDS patients. Weaning from VV ECLS simply involves discontinuing membrane gas flow and increasing ventilator parameters as needed but still on protective settings. Patients are often weaned from ECLS within one week. Pulmonary vascular resistance decreases following institution of ECLS and pulmonary capillary leak appears to resolve more quickly. Using this strategy, the 30-day survival in patients requiring VV ECLS for PGD should be approximately 90%; a much improvement compared with the 50% described previously. However, long-term maximum allograft function may still be attenuated in patients severely affected by PGD\(^12\).

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