Extracorporeal Life Support After Pulmonary Endarterectomy as a Bridge to Recovery or Transplantation: Lessons From 31 Consecutive Patients

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Background. **Extracorporeal life support (ECLS) can be used to sustain patients having cardiorespiratory failure after pulmonary endarterectomy (PEA). We aimed to assess outcomes and to identify factors associated with short-term survival among patients who required ECLS after PEA.**

Methods. **We reviewed the charts of consecutive patients who required ECLS after PEA between 2005 and 2013 at our institution. Patients with failed PEA were scheduled for heart-lung transplantation, and patients with potentially reversible hemodynamic or respiratory failure were given appropriate supportive care until recovery.**

Results. **Of the 829 patients who underwent PEA, 31 (3.7%) required postoperative ECLS. Of these, 23 continued to receive support, and 8 were listed for heart-lung transplantation during ECLS. Overall inhospital survival was 48.4% (15 of 31). Of patients listed for transplantation, 2 died while on support; 4 of the 6 patients undergoing transplantation lived to hospital discharge. Of the 23 supportive care patients, 11 (47.8%) were alive at hospital discharge. The factors associated with survival were younger age ($p = 0.02$), larger post-PEA decrease in mean pulmonary artery pressure ($p = 0.020$), lower post-PEA total pulmonary resistance ($p = 0.008$), and pure respiratory failure related to reperfusion edema or airway bleeding ($p = 0.003$).**

Conclusions. **Extracorporeal life support may be useful to support patients with complications after PEA either to recovery or to salvage transplantation.**

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The survival of patients with chronic thromboembolic pulmonary hypertension has improved with the advent of pulmonary endarterectomy (PEA). After PEA, 5-year survival rates range from 75% to 82% [1–3], a substantial improvement over the rates of 20% to 50% seen in the pre-PEA era [4]. Operative mortality has also decreased significantly, from 13% in the first case series study reported in 1983 [5] to 2.2% to 4.7% in recent studies [3, 6].

Despite these major advances, high-risk patients [7–9] may have life-threatening postoperative complications related to either pulmonary artery (PA) revascularization, such as airway bleeding and pulmonary edema, or to suboptimal or failed PEA with persistent pulmonary hypertension and right ventricular failure. These complications may require extracorporeal life support (ECLS) as a bridge to recovery (BTR) or bridge to transplantation (BTT). In a recent European multicenter registry study, ECLS was used in 3.1% of patients after PEA [6].

To date, only two studies have reported outcomes after ECLS as BTR in patients with complications of PEA. In the first study [10], venovenous (VV) extracorporeal membrane oxygenation (ECMO) was used in 20 patients with respiratory failure, 6 (30%) of whom survived. In the second study [11], 7 patients with cardiorespiratory failure were managed with venoarterial (VA) ECMO, and 4 (57%) survived. Although these studies established the feasibility and benefits of ECLS as BTR in patients with cardiorespiratory failure after PEA, they were not able to identify factors associated with short-term survival. Furthermore, no studies have assessed ECLS as BTT in

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Abbreviations and Acronyms

BTR	=	bridge to recovery
BTT	=	bridge to transplantation
ECLS	=	extracorporeal life support
ECMO	=	extracorporeal membrane oxygenation
IQR	=	interquartile range
LA	=	left atrium
MPAP	=	mean pulmonary artery pressure
PA	=	pulmonary artery
PEA	=	pulmonary endarterectomy
VA	=	venoarterial
VV	=	venovenous

patients with refractory right ventricular failure after failed PEA.

Here, we report our experience of patients managed with ECLS using a BTR or BTT strategy after complicated PEA.

Patients and Methods

Our Institutional Review Board approved the study and waived the requirement for written informed consent in compliance with French law on retrospective studies consisting of analyses of anonymous data.

Patients

We retrospectively identified all patients who underwent PEA at the Marie Lannelongue Hospital between January 2005 and July 2013. A multidisciplinary team specialized in chronic thromboembolic pulmonary hypertension management selected patients for PEA. We identified those who had received postoperative ECLS and reviewed their records for data on medical history and perioperative data.

Pulmonary Endarterectomy

Pulmonary endarterectomy was performed as described previously [9]. Briefly, cardiopulmonary bypass with bicaval and ascending aorta cannulations was established; body temperature was decreased to 20°C before cross-clamping of the aorta. Right, and then left PEA was performed with sequential circulatory arrests for distal PA recanalization. After PA closure, a Swan-Ganz catheter was introduced into the main PA trunk for postoperative hemodynamic assessments.

Classification of Cardiorespiratory Failure After PEA

We retrospectively classified cardiorespiratory failures requiring ECLS as follows: (1) pure respiratory failure defined as hypoxia with pulse oximetry oxygen saturation less than 90% despite mechanical ventilation with 100% fraction of inspired oxygen, without preexisting hemodynamic failure (ie, without inotropic support or systemic hypotension, defined as mean systemic pressure less than 60 mm Hg or cardiocirculatory arrest); (2) pure hemodynamic failure defined as circulatory failure precluding weaning off cardiopulmonary bypass or new-onset cardiogenic shock requiring inotropic support initiation or VA ECLS, without prior respiratory failure; and (3) mixed respiratory and hemodynamic failure defined as any combination of signs of both respiratory and hemodynamic failure.

Strategy and Timing of ECLS

When ECLS was started in the operating room immediately after PEA, preference was given to central cannulation and use of VA-ECMO or central PA-to-left atrium (LA) Novalung (Novalung GmbH, Heilbronn, Germany), the latter being preferred for BTT. The sternum was left open in patients with major postoperative ventricular enlargement and hemodynamic deterioration at attempted sternum closure. In patients whose sternum was already closed at the time of decision for ECLS implantation, peripheral VA-ECMO was generally used. When ECLS was started after postoperative intensive care unit admission, we generally used peripheral VA-ECMO. We used VV-ECMO in 2 patients with pure respiratory failure occurring at least 7 days after PEA. Additional embolization of the systemic vasculature to the lung was successfully performed in 4 patients with airway bleeding. In case of pulmonary edema occurring during VA-ECMO, an additional LA vent line was surgically implanted to decrease pulmonary vein pressures.

Excluding PA-LA Novalung, an ECLS weaning trial was performed after 48 hours of hemodynamic and respiratory stabilization, assessing the possibility of removing the ECLS by echocardiography, clinical monitoring, and laboratory tests. When weaning from ECLS proved impossible and complications such as refractory bleeding or multiorgan failure arose, a conference among staff members in charge of the patient was held and an ethical evaluation performed to determine the appropriateness of ECLS system removal. The ECLS was removed after informed consent was obtained from the family.

Patients considered for transplantation fell into two categories. For patients with preoperative hemodynamic compromise due to distal PA occlusions, the need for a BTT strategy was anticipated before the PEA procedure, leading to full pretransplantation workup, with the informing of the patient and the family. In the other category of patients, the need for a BTT strategy became obvious only when weaning from ECLS proved impossible after failed PEA with refractory hemodynamic failure, persistent pulmonary hypertension, and right ventricular failure. Heart-lung transplantation was usually preferred over double-lung transplantation in case of persistent right ventricular failure and because of proximal PA frailty related to the recent PEA. However, because of donor scarcity, we now try to perform double-lung transplantation as often as possible considering the good results of double-lung transplantation in pulmonary hypertension patients. Of interest, a large amount of PA should be harvested to overcome any problem at the level of the PA anastomosis.

We administered anticoagulation therapy to patients according to the institutional standard protocol for the