ECLS as Bridge to Transplant

Marcelo Cypel MD, MSc
Assistant Professor of Surgery
Division of Thoracic Surgery
Toronto General Hospital
University of Toronto
MARCELO.CYPEL@UHN.CA
Application of ECLS

• Bridge to lung recovery in ARDS/ALI

• Bridge to lung transplantation

• Bridge to recovery from primary graft dysfunction

• Cardiogenic Shock
Indications for ECLS in adults with respiratory failure (n=75)

Number of cases

Year


PGD
ARDS
Bridge to LTx
<table>
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<tr>
<th>Diagnosis</th>
<th>Age</th>
<th>Mode</th>
<th>Site</th>
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## Table 2
Experience with ECLS as a bridge to lung transplant (series with more than 4 cases)

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<th>Author</th>
<th>Number of Cases</th>
<th>Days on Device (Mean)</th>
<th>Mode ECLS</th>
<th>Bridged to LTx (%)</th>
<th>30-d Survival After LTx (%)</th>
<th>1-y Survival (%)</th>
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</table>

Extracorporeal life support as a bridge to lung transplantation.
Figure 1

- **All LTx**: Blue line
- **ECLS**: Red line

Survival Over Days After Transplantation

Percent survival vs. Days after transplantation with a p-value of 0.13.
Advancements in ECLS Technology

ECLS

- Membrane Gas Exchanger
- Pumps
- Cannulas
- Tubing Circuits
Membranes

Quadrox

Novalung

- gas inlet
- membrane ventilator
- NovaPort low resistance cannula
- Blood in / out (symmetrical)
- gas outlet
PUMPS

Rotaflow (Maquet)

Centrimag (Thoratec)
Cannulas (Avalon®)

• One canula inserted through right internal jugular vein

• Drainage from IVC and SVC → oxygenated blood returned to right atrium

• Allows mobilisation of extubated patients
Successful ECLS bridge to LTx

1) Avoid pre-ECLS prolonged mechanical ventilation!

2) Provide adequate mechanical support

3) Avoid groin cannulation if possible

4) Have an engaged AND persistent multidisciplinary team

5) Consider early tracheostomy and nutritional support
Successful ECLS bridge to LTx

1) Avoid pre-ECMO prolonged mechanical ventilation!

2) Provide adequate mechanical support

3) Avoid groin cannulation if possible

4) Have an engaged AND persistent multidisciplinary team

5) Consider early tracheostomy and nutritional support
“There is nothing more helpless than to sit at the bedside of a patient, adjusting ventilator settings while the severity of respiratory failure continues to worsen”.

Hubmayr and Farmer, Chest 2010;137:745
• Injurious mechanical ventilation should be avoided!

• Typical comment: “who cares if the lungs will be replaced”
Injurious Mechanical Ventilation and End-Organ Epithelial Cell Apoptosis and Organ Dysfunction in an Experimental Model of Acute Respiratory Distress Syndrome

Figure 3. Apoptotic Index Percentages in the Lung, Kidney, and Small Intestine

Imai/Sltusky, JAMA 2003
• Historical Reports have demonstrated dismal outcomes in patients on prolonged high pressure mechanical ventilation prior to or during ECMO.

• > 7 days on mechanical ventilation precludes ECMO candidacy (CESAR trial and EOLIA trial)
Successful ECLS bridge to LTx

1) Avoid pre-ECMO prolonged mechanical ventilation!

2) Provide adequate mechanical support

3) Avoid groin cannulation if possible

4) Have an engaged AND persistent multidisciplinary team

5) Consider early tracheostomy and nutritional support
ECLS Modes

- **Pump (supported)**
  - Veno - venous (V-V)
  - Veno - arterial (V-A)
  - Hybrid Veno - venoarterial (V-VA)

- **Pumpless (pump is patient’s heart)**
  - Arterio-venous (A-V)
  - Pulmonary artery to left atrium (PA-LA)
Selection of iLA Support Level/Configuration

Hypercapnic failure

Hemodynamic stable

Support level A
Arterio-Venous (pumpless)

PAH (severe RV dysfunction)

PA-LA (pumpless)

Hemodynamic instability

Support level C
Veno-Arterial (pump-driven)

Support level B
Veno-Venous (pump-driven)

Hypoxic failure

Hemodynamic stable
Hypercapnic Respiratory Failure
Novalung
Pumpless Mode – Femoral Artery to Femoral Vein (extra-corporeal ventilation)
AV pumpless

- Excellent mode for **hypercapnic** respiratory failure and acidosis
- Blood flow through the device: 15-20% CO
- Prompt CO$_2$ clearance **but does not improve** oxygenation
- Maintenance less demanding than pump ECLS modes
- Contra-indicated in severe hypoxia or unstable hemodynamics
**Initial Experience with Novalung as a Bridge to Lung Transplantation – Hannover Medical School**

**TABLE 1. Changes in blood gases, hemodynamics, and the ventilatory regimen**

<table>
<thead>
<tr>
<th></th>
<th>Before iLA (n = 12)</th>
<th>After iLA implantation</th>
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<tbody>
<tr>
<td></td>
<td>BL (n = 12)</td>
<td>6 ± 0 h (n = 12)</td>
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<tr>
<td>MAP (mm Hg)</td>
<td>72 ± 8</td>
<td>74 ± 7</td>
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<tr>
<td>Pao₂ (mm Hg)</td>
<td>71 ± 27</td>
<td>83 ± 17</td>
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<tr>
<td>Paco₂ (mm Hg)</td>
<td>128 ± 42</td>
<td>52 ± 5</td>
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<tr>
<td>pH</td>
<td>7.121 ± 0.1</td>
<td>7.344 ± 0.1</td>
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<tr>
<td>Po₂/Fio₂ ratio</td>
<td>135 ± 33</td>
<td>150 ± 24</td>
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<tr>
<td>Peak VP (mm Hg)</td>
<td>45 ± 5</td>
<td>45 ± 5</td>
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<tr>
<td>PEEP (mm Hg)</td>
<td>13 ± 1</td>
<td>13 ± 1</td>
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</table>

*iLA, Interventional lung assist device; BL, baseline before interventional lung assist device implantation; MAP, mean arterial blood pressure; Fio₂, fraction of inspired oxygen; VP, ventilatory pressure; PEEP, positive end-expiratory pressure.*

Limitations of AV Novalung

1) Need of arterial cannulation (increased risk of bleeding and ischemic complications compared to VV)

2) Groin cannulation prevents ambulation

3) Limited support – respiratory failure usually progress to hypoxia requiring switching of ECLS configuration.
Novalung iLAactive
Hypoxemic Respiratory Failure
VV ECMO
VV ECLS

- Hypercapnia and hypoxemia with stable hemodynamics
- The most common mode of ECLS used for lung failure
- Femoral vein (drain) and Jugular vein (return) or dual lumen Jugular vein
- Ratio of mixed blood ecmo/patient blood is 3/1. Central sats 80-95% (depending on lung contribution)
- Significantly less complications compared to VA ECLS
Avalon Elite™ Bi-Caval Dual Lumen
Clinical Case

- 46 y female
- LAM
- Admitted to hospital – deterioration – BiPAP
- Mechanical Ventilation – Cardiac Arrest due to tension pneumothorax
- CPR + chest tube insertion
- VV ECMO inserted
25 days after LTx
Another case……

• 34 F
• Pulmonary Fibrosis
• Assessed for LTx but not listed
• Acute Deterioration
• Intubated – 100% FiO2 – Sats 70 - 75% for 2 hours
• Underwent urgent VV ECLS
• 25 days on support extubated prior to LTx
24hs later...

Rule 1. I'm not an idiot

Rule 2. I'm better
writing on my own

Rule 3. Let me finish interpreting

Rule 4. I wrote!
18 days on ECMO….
60 days post transplant
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<td>In hospital</td>
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VA ECMO
VA ECMO

• Severe hypoxemia AND hemodynamic compromise

• Mode of choice for cardiogenic shock

• Excellent central oxygenation is provided if central cannulation is performed (axillary/carotid artery)

• Central hypoxia often occurs if femoral artery is used – NOT a good support for lung failure

• V-VA (infusing blood also to RA) can correct this
Pulmonary Hypertension and RV Failure
Pulmonary Hypertension

• High wait list mortality
• Death: Severe Right Heart failure / arrhythmia
• Bridging options – limited efficacy
  • PG /vasodilators etc.
  • Atrial septostomy → trade-off pressure decompression with systemic hypoxia
PAH – Support Options

1) PA-LA Novalung (pumpless)
2) VA ECMO
3) VV ECMO if ASD or septostomy
Novalung PA to LA
Bridge to Lung Transplant for PAH Patients
“The Oxygenating Septostomy”

1. Pumpless
2. Effectively: an oxygenating shunt → provides pressure decompression AND gas exchange

Insertion of PA-LA Novalung

- Patient brought to the operating room
- VA ECMO inserted under local anesthesia through femoral vessels to stabilize the patient
- Induction of anesthesia
- Sternotomy and insertion of LA and PA cannulas
- VA ECMO weaned
- Drainage and sternotomy closure
Novalung PA to LA
Bridge to Lung Transplant
Novalung PA-LA: Bridge to lung transplant
ECLS decreases wait list mortality in iPAH patients: Toronto experience

Wait list mortality: 22% → 0%

Number of patients

1998-2005 2006-2010

Patients listed
Patients transplanted
Died on waiting list

p=0.03

de Perrot et al J Heart Lung Transplant 2011
VA ECMO for PAH
Extracorporeal Membrane Oxygenation in Nonintubated Patients as Bridge to Lung Transplantation

Olsson, AJT 2010
VA ECMO “Sport Mode”
Jugular Vein - Subclavian Artery

Veno-venous extracorporeal membrane oxygenation with interatrial shunting: A novel approach to lung transplantation for patients in right ventricular failure

Daniele Camboni, MD, Begum Akay, MD, Joshua R. Pohlmann, MS, Kelly L. Koch, MS, Jonathan W. Haft, MD, Robert H. Bartlett, MD, and Keith E. Cook, PhD
Ambulatory ECMO

1) Avoid pre-ECMO prolonged mechanical ventilation!

2) Provide adequate mechanical support

3) Avoid groin cannulation if possible

4) Have an engaged AND persistent multidisciplinary team

5) Consider early tracheostomy and nutritional support
Active rehabilitation and physical therapy during extracorporeal membrane oxygenation while awaiting lung transplantation: A practical approach

David A. Turner, MD; Ira M. Cheifetz, MD, FCCM; Kyle J. Rehder, MD; W. Lee Williford, RRT; Desiree Bonadonna, BSE, CCP, LP; Scott J. Banuelos, MD; Stacey Peterson-Carmichael, MD; Shu S. Lin, MD, PhD; R. Duane Davis, MD; David Zaas, MD

Figure 1. Sixteen-year-old patient ambulating while being managed with venovenous extracorporeal membrane oxygenation.

Figure 2. Twenty-four-year-old patient ambulating while being managed with venovenous extracorporeal membrane oxygenation.
Success depends on ECLS team effort

(1) ECLS/Transplant surgeon
(2) Critical care physician
(3) Perfusionist
(4) Transplant respirologist
(5) ECMO dedicated and trained nurses, pharmacists, respiratory therapist, nutritionists, physical therapist
Summary

- Artificial lung technology has significantly improved in the last years.

- Better understanding of ECLS physiology have improved patient outcomes.

- Single cannula VV ECMO is the ideal mode for lung failure – decreased complications and allow patient mobilization. It might be the mode of choice for almost all BTT patients in near future.

- Consider ECLS early in the course of respiratory failure.
Thank you

Marcelo.cypel@uhn.ca