ECMO Strategies for Refractory Respiratory Failure: The Who, How and Why

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The Extracorporeal Life Support Organization
2013 Award for Excellence in Life Support

- Demonstrates
- High quality standards
- Specialized equipment and supplies
- Defined patient protocols
- Advanced education of all staff members

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NO DISCLOSURES

- No financial relationships to disclose
- Any reference to a specific brand or product is not intended as an endorsement, but rather a reflection of the device or product with which we are familiar.
OBJECTIVES

† Describe the clinical indications for ECMO support and discuss how ECMO supports oxygenation and ventilation
† Describe nursing actions required to prepare a patient for initiation of ECMO
† Identify the unique multisystem nursing considerations for adult patients on ECMO

The ECMO team

Clinical

- Nursing – Bedside
- Nursing – ECMO Specialist
- Perfusionist
- Respiratory Therapist
- Physician
  - Surgeon
  - Critical Care
- Interventional Radiology
- Palliative Care/Social Worker
- PT/OT/Speech Therapy
- Dietitian

Administration

- ECMO Manager
- ECMO Director
- ECMO Coordinator
- Registrar
- PI Coordinator
- ECMO Bedside Educator
- ECMO Specialist Educator

Extracorporeal Membrane Oxygenation (ECMO): What?

† Mechanical cardiopulmonary or pulmonary support
† May be configured Venoarterial (VA) or Venovenous (VV)
† Lungs no longer primary site of oxygenation and ventilation
The Cannulas

The Pump
Centrifugal pumps
- Most prevalently used
- Improved performance with less complications
- Preload and afterload dependent

The Oxygenator
- Hollow fibers (<0.5mm in diameter) coated with polymethylpentene
- Allow diffusion of gas but not liquid.
- As blood flows through the oxygenator, “sweep gas” (oxygen) is piped through the inside of the hollow fibers
- Oxygen and CO₂ diffuse across membrane
The Circuit

ECMO: How?
Physiology of Extracorporeal Support

It comes full circle...

Flow and Sweep
- Flow = quantity of blood delivered (L/min)
- Sweep = Flow rate of oxygen from blender to oxygenator

ECMO CIRCUITS
Rotoflow
Cardiohelp
Anatomy of an ECMO Circuit

- Essential Components:
  - Cannulas
  - Tubing
  - Pump
  - Oxygenator
  - Gas Blender
  - Heat exchanger
  - "Bridge"
  - O2 Sat measurement
  - Bubble detectors
  - Monitors and alarms

The artificial endothelium
aka – the ECMO circuit

ECMO and Heparin

Anticoagulation is essential to prevent clotting in the ECMO circuit

Oxygenator

Centrifugal pump

This makes bleeding the #1 risk factor related to ECMO
Extracorporeal Membrane Oxygenation (ECMO)

Does not “cure” anything

It takes over the work of the heart or lungs while they heal

ECMO: Why?

+ Improving efficacy and outcomes with advent of new technology
+ Increasing patient volumes = more experience = more informed practice

Conventional Ventilation of ECMO for Severe Adult Respiratory Failure (CESAR)

+ 180 patients randomized to either conventional management group or consideration for ECMO treatment.
+ Eligible patients had potentially reversible respiratory failure and met strict entry criteria.
+ Findings: 6 month survival rate 63% versus 47% for control group.

**EOLIA trial**
- ECMO to rescue lung injury in severe ARDS (EOLIA)
- Ongoing international randomized controlled trial
- Daniel Brodie

**ECMO: Where? Regional Referral Program**
- ECMO care requires a trained, multidisciplinary team
- ECMO patients have improved outcomes when cared for at experienced, high volume centers
  “... advanced critical care for profound ARDS, including ECMO, represents the type of time-dependent and high-reliability practice that might best be provided in a focused setting in which the provider and systems aspects of performance would benefit from a high density of experience.”
  - Michaels et al. (2013)

**Why Transfer?**
- **CESAR TRIAL**: “We recommend transferring of adult patients with severe but potentially reversible respiratory failure, ..., to a center with an ECMO-based management protocol to significantly improve survival without severe disability.” - Peek et al. 2009
- **JAMA**: “For patients with H1N1-related ARDS, referral and transfer to an ECMO center was associated with lower hospital mortality compared with matched non-ECMO-referred patients.” – Noah et al. 2011
Who Needs ECMO?

- Refractory ARDS
- Pneumonia
- Sepsis
- Severe respiratory failure
- Shock
- Near Drowning
- Bridge to transplant
- Trauma

ECMO Contraindications

** All Contraindications are relative **

- Related to patient’s premorbid condition:
  - Age and size
  - Contraindication to anticoagulation
  - Chronic condition associated with poor outcome
  - Underlying terminal condition not related to ARDS
  - Limitations to care (code status)

- Related to treatment of current illness:
  - Greater than 7 - 10 days on mechanical ventilator with peak airway pressure > 30 cmH2O and/or FiO2 > 0.8

** Must have an endpoint to care **
**VA vs VV ECMO**

**CARDIAC FAILURE**
- VenoArterial

**PULMONARY FAILURE**
- VenoVenous

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**VenoArterial ECMO**

**Cardiac**
- May be applied for management of cardiac and/or respiratory failure
- Blood access via central vein and central artery, primarily femoral
- Controls up to 80% of patient’s total cardiac output (CO)

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**VenoArterial ECMO**

**Indications**
- Patients who cannot wean from cardiac bypass
- Refractory cardiogenic shock
  - Bridge to VAD
  - Bridge to transplant
  - ECPR

Must have endpoint to care
**VenoVenous ECMO**

**Respiratory**

- Provides pulmonary support only
- Relies on the patient’s native heart function to circulate the newly oxygenated blood
- "IV Oxygen"
- Blood access via femoral and/or internal jugular vein

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**VenoVenous ECMO**

**Indications**

- Severe Refractory Respiratory Failure from potentially reversible cause.
- Type I (Hypoxemic) Respiratory Failure (severe) with P:F <80 on FiO2 >90% with a Murray lung injury score of ≥ 3.0.
- Type II (Hypercapnic) Respiratory Failure with a pH ≤ 7.2.

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**Acute Respiratory Distress Syndrome (ARDS)**

- No effective pharmacological treatment
- Cornerstone to therapy remains supportive care with mechanical ventilation
- ARDS Network recommendations for volume and pressure limited ventilation strategies associated with decreased mortality
- Despite ARDSnet strategy, some patients continue to decline
Current definition of ARDS aka, the "Berlin Definition":

- Mild ARDS (PaO₂ to FiO₂ ratio 200 – 300)
mortality: 27%
- Moderate ARDS (PaO₂ to FiO₂ ratio 100 – 200)
mortality: 32%
- Severe ARDS (PaO₂ to FiO₂ ratio < 100)
mortality: 45%

28% of all ARDS is “severe”


ECMO: When?
Hypoxia becomes refractory to conventional management

- Recruitment maneuvers
- Neuromuscular blockade
- Inhaled NO / EPO
- Prone Positioning
- APRV
- HFOV / HFPV
- ECMO

Hypoxia becomes refractory to conventional management

ECMO: When?
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KEY POINTS

- Increased ventilator days and high ventilator settings are associated with higher mortality.
- Preferred fewer than 7 intubated days
- The longer the patient has been sick, the longer they will be on ECMO.

Early referral saves lives!

Before going on ECMO

- Baseline labs
  - **Type and Crossmatch**
  - Hct and coag
- Anticipate fluid / blood volume resuscitation
- Place all lines and tubes prior to initiation of anticoagulation
  - Central Lines
  - Peripheral IV
  - Foley Catheter
  - Feeding tube

Transformation

Intensive Care to Operating Room
COMMUNICATION

- Blood bank
- Respiratory Therapy
- Pharmacist
- Operating Room staff
- X-Ray
- Family

Heparin Monitoring for effect:
- ACT (goal ~1.5x normal, 180-220 seconds)
- Heparin level (0.2-0.4)
- Optimize AT III (>80)

Direct Thrombin Inhibitors
- Argatroban
- Bivalirudin
- PTT (45-75)
Cannulation: Going on ECMO
- May be performed in ICU or OR
- Full sterile prep and OR team present
- Deep sedation / paralysis essential
- Heparin bolused (50-100 units / kg) prior to cannula placement
- Coordination between surgeon, perfusion and bedside RNs

This is a critical time. The room needs to be quiet for clear communication

And we’re on….
- ECMO flow slowly increased to maximum tolerated, then decreased to lowest level required for adequate support.
- Sit back and watch the red blood flow…

What could go wrong?
- Patient is bolused with approximately 1 liter of saline from ECMO circuit
- This essentially empties blood from the heart temporarily
Code situations

**Bedside Nurse Manages the Patient**

- Full ventilator support
- Titrate vasoactive drugs
- May need blood and products
- Prepare code cart and ACLS drugs
- May need to emergently switch to VA

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Complications

- **Vessel injury**
- **Lung injury**
- **Thrombus**
- **Air emboli**
- Equipment Malfunction

**Occurs less than 5%**

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Emergencies
Bleeding Emergencies

Massive transfusion

• Time to call the blood bank
• Know your institution’s resources and policies

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ECMO is initiated

Oxygenation improves immediately

+ Perfusion improved
+ Myocardial function improved
+ Pulmonary pressures decrease
+ Wean inotropes and vasoactive drips
+ Rest settings on ventilator

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Diagnostic Procedures

+ Labs
  ABG guides ECMO therapy
  PTT 45-75
+ Chest X-ray
  Cannula placement
+ Occasional tests
  Echocardiogram
  EKG
  Ultrasound
  CT
Multisystem care of the ECMO patient

- Cardiovascular / Hemodynamic
- Respiratory
- Hematologic Considerations
- Neurologic / Sedation
- Renal
- Metabolic / Gastrointestinal
- Skin
- Family
- Recovery vs. Futility
- Decannulation

Cardiovascular and Hemodynamic Considerations

- VV: Pt. dependent on native hemodynamic physiology
  - Support with inotropes, vasoactives, fluid, blood etc. as indicated
  - MAP >65
- VA: ECMO flow provides primary hemodynamic support
  - May require fluid / blood / vasopressors to augment
  - Maintain MAP 50-70

Additional Hemodynamic Considerations

- Trend markers of perfusion / native heart function
  - Lactate
  - ABGs
  - SvO₂
  - Continuous pulse contour analysis (PICCO™, FloTrac™)
    - VV only
  - Echocardiography
  - Urine output, skin color/temp, cap refill, etc.
- Pulmonary artery catheters?
- Pt. temp controlled by heat exchanger
Infection
Abx
Antiviral therapy (H1N1)

Inflammation
Plasmapheresis
IVIG

Trauma
Surgical repair

*Infectious Disease and Pharmacy input is crucial*

Treating the Underlying Problem

Respiratory Considerations

The lungs are no longer the primary site of oxygenation and ventilation!!!

3 R’s
Rest
Recover
Recruit

Rest

Reducing pressure and FiO2

ELSO Recs:
Mode: pressure control
FiO2: 0.3
PEEP: 10-15 cmH2O
PIP: ~20 (PEEP + 10)
F: 4-5

LEH:
Mode: Volume Diffusive Respirator (VDR)
FiO2: 0.4
PEEP: 12*
PIP: 24*
F: 15
Percussive Rate = 500

Other: CPAP, MMV, Extubation?

* VDR settings: PEEP = Oscillatory PEEP, PIP = Pulsatile PEEP
What is the VDR?
A pneumatically powered, pressure limited, time-cycled, high frequency flow interrupter.
Delivers smaller, percussive tidal volumes at rates that range between 300-700 oscillations per minute at lower pressures.
Enhances oxygenation, promotes CO₂ clearance and facilitates mobilization of secretions while minimizing barotrauma
Increased secretion clearance necessitates vigilant oral care and secretion maintenance by RN staff

Recruit

- Recruitment maneuvers
  - Positional Therapy
  - Bronchoscopy
  - Aggressive diuresis
  - Ventilator recruitment maneuvers
    - Initiated once lungs begin to show recovery

Additional Respiratory Considerations

- Pulmonary Hypertension Management
  - IV agents: Epoprostenol (Flolan), Nitroglycerin
  - Inhaled agents: Nitric Oxide, Epoprostenol
- Tracheostomy
- Pneumothorax (To drain or not to drain?)
**Hematologic Considerations**

- Systemic anticoagulation essential
- Bleeding is a major complication of ECMO
  - Visible versus occult
  - Common bleeding sites:

<table>
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<tr>
<th>Intracranial</th>
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<td>Cannulation Sites</td>
<td>Central lines and PIVs</td>
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<td>Surgical sites</td>
<td>GI Tract</td>
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- **ICH on ECMO usually extensive and fatal**
- Minimize Hemolysis
  - Monitor Plasma Free Hgb

**Bleeding Management**

(Focus on prevention)

- Vigilant monitoring
- Coagulation studies
  - Pts, PT/INR, Fibrinogen, Viscoelastography (TEG™ / Rotem™)
  - Cannula sites, IVs, mucous membranes, neuro exam
- Maintain Coagulation factors at acceptable levels
  - Platelets ≥ 50,000*
  - INR ≤ 2.2
  - Fibrinogen ≥ 100,000
- Minimize venipuncture, fingersticks, insertion of tubes/drains, etc.

**When Intervention is Required:**

(Bleeding Management continued)

- Return coagulation status to normal
- D/C anticoagulant infusion (if necessary)
- Thrombotic dressings
- OR as last resort
**Neurologic Considerations**
- Maintain sedation and analgesia with least amount required to provide effective support & maintain safety
- Daily awakening trials as soon as tolerated
- Neuromuscular blockade?

**Note:** Some medications shown to have increased adsorption to circuit and oxygenator

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**Neuro Assessment**
- Sedated and paralyzed?
- Hourly pupil response assessment
- Train of four
- Low threshold for Head CT with neuro change
- Pupilometry
- Near Infrared Spectroscopy (NIRS)
- Bispectral index monitor (BIS)

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**Renal Considerations**
- Euvolemia is the goal
- Diurese aggressively
- Hemofiltration
- CRRT if necessary
  - Directly into circuit
  - HD Catheter

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Gastrointestinal / Metabolic Considerations
- Place post-pyloric feeding tube pre-ECMO if possible
- Early consult from dietician
- Enteral nutrition as soon as tolerated
- TPN until tube feed tolerated at goal rate
- Probiotic supplements
- GI continuity
- Stress ulcer prevention
- Blood glucose management per hospital critical care insulin management protocol

Skin Care Considerations
- Eyes
- Mucous membranes
- Blisters
- Pressure points
- Q 2 hour turning and ROM essential
- Continence management

Family Care Considerations
- Include family as much as possible
- Allow family presence in rounds
- Include in plan of care
- Honest and direct communication
- Early palliative care consult
### Futility
- Possibility of stopping for futility should be discussed with family at outset of therapy
- Promptly discontinue ECLS when there is irreversible organ damage and no option for transplant
- Definition of irreversible damage depends on the institution and available resources
- Arbitrary timeframes for recovery are discouraged

### Signs of Recovery
- Hemodynamic stability
- Patient tolerates decreasing ECMO Flow and Sweep
- Evidence of clearing on CXR and bronchoscopy
- Pulmonary “step-up”

### Trial off
- **VV:**
  - Wean flow and sweep to minimal settings
  - Set ventilator to acceptable settings
  - “cap off” oxygenator
  - Maintain ECMO blood flow while monitoring SaO₂, PO₂ and CO₂
- **VA:**
  - Reduce flow
  - Clamp access and return lines
  - Monitor SaO₂, PO₂ and CO₂
  - If VA for cardiac support, ECHO very helpful
Decannulation

- May be performed at bedside if vascular repair not required
- Anticoagulant off for 30-60 minutes
- Get “comfortable”

Program Considerations

- Education and team maintenance
- Intra-hospital Transport
- Inter-hospital Transport

ECMO Education and Team Maintenance

- Formal ECMO education process
- ECMO handbook for bedside nurses
- Skills, drills, simulation, lecture, online SLMs
- Collaborate with Pt. care champions
- Additional mandatory CEUs

Roles
- Bedside RNs
- Transport RNs
- ECMO Specialists

Simulation Lab
Intra-hospital Transport

- Have a plan
- Bedside RN is the team leader
- Clear hallways
- Coordinate with receiving department

Inter-hospital Transport
References


ELSO Adult Respiratory Failure Supplement to the ELSO General Guidelines. Version 1.3 December 2013 Ann Arbor, MI, USA www.elsonet.org


Thank you!