ECMO: Extra Corporeal Membrane Oxygenation

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ECMO
Temporary cardiopulmonary support for severe respiratory or cardiac failure refractory to conventional therapy.

- Provide \( O_2 \)
- Remove \( CO_2 \)
- Support perfusion

→ Bridge to recovery or to heart or lung Tx

1. History
- Developed in 1970s for acute respiratory failure
  - Adding \( O_2 \), removing \( CO_2 \)
  - Limited to 5 days
  - Cannulation of femoral artery and vein
    → 1979 first randomized trial: survival rate not higher than mechanical ventilation alone + very high complication rates
- Early 1980s
  - Switch to veno-venous
  - But technology largely abandoned (bleeding and poor outcomes)

History
- Children
  - Successful in newborns with acute respiratory failure and persistent pulmonary hypertension of the newborn
  - ARF relies on PPH and poor cardiac function → mechanical circulatory support for cardiac failure (balloon pumps difficult)
  - ECMO → ECLS
  - 1996 randomized controlled trial for severe neonatal respiratory failure
    - Improved survival
    - Better long-term neurodevelopmental outcomes

- Global pandemic of influenza H1N1 in 2009-2010
  - Several centers report survival benefits for ARDS secondary to influenza
  - Two retrospective case-control studies:
    - Lower mortality among younger patients who received ECMO
  - Cardiogenic shock
    - Single-center retrospective and observational studies
      - Better outcomes
        - Neurologic outcomes
        - Hemorrhagic complications
        - Sepsis-related complications
        - Extracorporeal cardiopulmonary resuscitation
2. WHAT IS ECMO?

The ECMO circuit

a. Blood pump
b. Membrane oxygenator
c. Gas mixer
d. Cannulas
e. Heater/cooler
f. Console
g. Tubing

From this…

To this…

3. TWO BASIC CONFIGURATIONS

• Veno-arterial
  - Complete or partial support heart and lungs
  - Isolated refractory cardiac failure
  - Deoxygenated blood from venous system, oxygenated blood to arterial circulation

• Veno-venous
  - Isolated respiratory failure
  - Deoxygenated blood from central venous system, oxygenated blood to RA

• (Hybrid configurations)
**Veno-arterial ECMO**

- **Central**
  - Intake cannula surgically in RA
  - Return cannula in proximal ascending aorta

- **Femoral**
  - Drainage cannula in femoral vein → RA
  - Return cannula in proximal ascending aorta
  - Retrograde flow → impaired oxygen delivery to upper body

- **Axillary**
  - Return cannula into axillary artery → antegrade flow
  - Pulmonary hypertension or RVF

**Veno-venous ECMO**

- **Past: femoral-atrial**
  - Drainage femoral vein, tip inferior vena cava
  - Return right internal jugular vein, tip SVC → RA
  - "Recirculation" 😱

- **Currently: double lumen**
  - Right internal jugular vein
  - Tip in IVC: drainage IVC and SVC
  - Returned jet over tricuspid valve
  - Advantages:
    - Reduces recirculation
    - Only a single cannula
    - Facilitates ambulation and rehabilitation

**Extracorporeal removal of CO2**

- **For hypercapnic respiratory failure**
- **Past: ECMO with very low blood flow**
  — smaller cannulae
- **Now: Pumpless extracorporeal lung-assist (Novalung®)**
  - Arteriovenous (femoral artery and vein)
  - Two small cannulae
  - Avoids pump complications (hemolysis, clotting, ...)
  - Reduces frequency and intensity of mechanical ventilation
  - Good CO2 prerequisite

4. **(CONTRA-)INDICATIONS**

- **Delay in referral ↓**
- **Irreversible ventilator-induced lung injury ↑**
Severe aortic incompetence and aortic dissection

- EDP ↓: Ventricular distention, compromised myocardial oxygenation, and worsening LVFP

Outcomes of ECMO in pregnancy and postpartum similar than nonpregnant patients!

Increasing use in posttrauma patients

Newer types cannulas: BMI > 60 kg/m²

5. HOW DO YOU DO IT?

Use Echocardiography!

5. HOW DO YOU DO IT?

Use leg perfusion!

ECMO: Cannulas

Echo is fundamental

- At the time of cannula insertion
  - To verify correct positioning of the venous cannula
- For daily surveillance
  - Heart recovery
  - Evolution of weaning success
  - Complications
    - Perivalvular effusion
    - Myocardial edema
Management of ECMO

Initial ECMO settings and monitoring

• VV cannulas: fluoroscopic/echocardiographic guidance

• Three main variables:
  – Blood flow
    • HFOV, protocol, afterload
    • Systemic hypertension, hypotension, cardiac tamponade, tension pneumothorax
  – preload: systemic blood pressure
  – afterload: cardiac output
  – Clots in oxygenator, kink in circuit

• Resistance directly proportional to cannula lengths and inversely proportional to the fourth power (Poiseuille's law)

• Fraction of oxygen in sweep gas
  – Increase fraction → increase PaO2
  – Increase flow rate → greater CO2 elimination

Mechanical ventilation on ECMO

• Aim: reducing ventilator-induced lung injury ("lung rest")
  – Low tidal volumes (6 mL/kg), even very low (3-6 mL/kg)
  – Safe extubation while on ECMO to prevent ventilator-induced lung injury is possible!
If hypoxemia persists

1. Inadequate blood flow to match metabolic demands
   - Mortal obesity or severe sepsis and fever
   - Ensure no recirculation
   - Maximize blood flow
   - Optimize hematocrit
   - Decrease oxygen consumption (sedation, paralysis, hypothermia)

If hypoxemia persists

2. Recirculation
   - Calculate by measuring $SaO_2$ before and after oxygenator + in central venous blood
   - Reduced by use of double-lumen cannulas
   - Reduce by manipulation of reinfusion cannula or increasing distance between drainage and reinfusion

3. Expert opinion?
   - $SaO_2 > 86\%$ and $PaO_2 > 55$mmHg on VV ECMO sufficient to prevent hypoxia-related end-organ injury
   - VA ECMO when refractory hypoxemia with VV ECMO

If hypoxemia persists

4. "Harlequin" syndrome
   - Peripheral VA ECMO
   - Flow competition in aorta → Upper body hypoxia (coronary and cerebral)
   - Impaired pulmonary function
     - "Blue head": deoxygenated blood directed to the upper part of the body
     - "Red legs": hyperoxygenated blood in the lower part of the body
   - $SaO_2$, probe, blood gases on right hand/ear lobe/radial artery
   - Correction by adjusting FiO2, PEEP
   - Switch arterial cannulation from femoral to axillary or carotid
   - Switch to VV ECMO if persistent lung failure

If hypoxemia persists

5. Mixed configuration
   - Venoarterial-venous ECMO
   - Portion of arterial outflow diverted via right internal jugular artery to right heart
   - Better oxygen delivery to coronary and cerebral circulations.

Anticoagulation

• Heparin
  - $aPTT$: 45-60 sec, 1.5 x control
• Aspirin
  - $AUC$: P2a / Rapamycin ≤ 40 G.L
  - Interval if $AUC$: 75-100 G.L
• Aspirin + Clopidogrel
  - When $AUC$: > 400 G.L
  - When early/massive fibrin deposition

Anticoagulation problems...

• Massive bleeding...
  - In cases of MOF
  - Massive hepatic failure
  - Consumptive
  - Stop aspirin, clopidogrel
  - Possible to stop heparin for a few hours... or days...
  - When early/massive fibrin deposition or heparin coated...

• Clotting...
  - Membrane/Cannulas
  - Check for clotting if
    - Increased blood flow /PaO2
    - Hemolysis
    - LA/PA/LV drainage
Hemolysis

- May occur due to
  - Membrane failure
  - Pump with highly turbulent flow
  - Clotting in the cannulae
  - High energy blood suction
  - Hyperviscosity
  - Microvascular injury due to shearing forces

- Bloody diarrhea
- Check regularly serum free hemoglobin

Transfusions

- Traditionally liberal use of blood products
- Recent data: outcomes similar with conservative use

Fluid management on ECMO

- ECMO-patient is fluid overloaded (inflammatory response and/or heart failure)
- Conservative fluid management improves lung functions and shortens duration of mechanical ventilation and ICU
  - Net fluid balance should be kept negative and renal and hemodynamic parameters kept stable
- High incidence of AKI. Fluid overload main indication for renal replacement therapy
  - In-line hemofilter
  - Incorporating machine in ECMO circuit

Tubing Surveillance

- Frequent surveillance
  - No kinking
  - No retraction
  - No precipitation
  - Maintain lines along leg axis
  - Kink in line
  - No reperfusion line inserted
- Special attention when moving the patient...

Patient’s Surveillance

- Maintain lines along leg axis for >40 cm
- Check frequently
  - Skin aspect at cannula insertion site
  - Tenderness
  - Numbness and pain sensation
- Special attention when moving the patient...

Patient’s Surveillance

- Watch for leg ischemia...
- Especially if no reperfusion line inserted
Reperfusion Line Surveillance

Bad installation vs Correct installation

Lines “kicking” hard…

- Check for hypovolemia
  - TTE/TEE
  - CVP
- Frequent in case of vasoplegia due to Multiple Organ Failure
- Fluid challenge if patent hypovolemia
  - Should be placed in the RA

Physical rehabilitation and ambulation

- Accelerate weaning process and shorten length of stay in hospital after ECMO
- Especially beneficial in patients awaiting LungTx and may improve post-transplant recovery and outcomes.

Weaning from ECMO

1. Weaning from VV ECMO
   - If lung compliance, tidal volumes, and oxygenation have improved
     - Reduce circuit flow rate < 3L/min
     - Adjust ventilator settings to standard lung-protective settings
     - Reduce flow rate sweep gas < 2L/min
   - If tidal volumes, respiratory rate, and gas exchange remain adequate after 2-4 hours of low rate of sweep gas → wean off

2. Weaning from VA ECMO
   - If myocardial recovery with improved pulse pressure and contractility on echo
     - Reduce flow rates in increments of 5L to 2L/min over 24 to 36 hours
     - Monitor MAP, CVP, and myocardial contractility
     - Usually weaned in surgical setting
     - Avoid prolonged periods of low flow rate to prevent thrombus

6. PRO’S AND CON’S
Advantages in cardiogenic shock

- Easy/rapid implantation if peripheral ECMO
  - No sternotomy, local anesthesia
  - Emergency situations
- Provides high flow:
  - Up to 7 L/min
- Bridge to: Recovery, Bridge, Transplantation
  - Or whatever seems reasonable
  - Triage if doubt about neurological status
- "Low cost", 2-40 times cheaper/other devices

Advantages in cardiogenic shock

- Mobile Cardiac Assistance Unit
  - For highly unstable patients

DISADVANTAGES

Mechanical complications (e.g., oxygenator failure, cannula malposition, pump-related, vascular cannula, problems with venous/arterial connection) [8];
- Bleeding, coagulopathy and hemolysis [2], [8], [9];
- Hemorrhages associated with anticoagulation requirements [2], [8], [9];
- Compartment syndrome and leg ischemia [2], [9];
- Air embolism, shunt occlusion and mechanical problems [2], [8], [9];

Outcomes and long-term quality-of-life of patients supported by extracorporeal membrane oxygenation for refractory cardiogenic shock

<table>
<thead>
<tr>
<th>Factor</th>
<th>OR (95% CI)</th>
<th>P</th>
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<tbody>
<tr>
<td>Regional setting</td>
<td>1.80 (1.06–3.32)</td>
<td>0.03</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>1.05 (0.92–1.20)</td>
<td>0.37</td>
</tr>
<tr>
<td>CHF with systolic LVEF &lt; 40%</td>
<td>2.00 (1.08–3.68)</td>
<td>0.03</td>
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Increased risk of ICU death
Cardiopulmonary resuscitation with assisted extracorporeal life support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis

- 3-year prospective observational study
- ECMO for 59 patients
  - Aged 18-75 years
  - With-witnessed in-hospital cardiac arrest of cardiac origin
  - Undergoing CPR of more than 10 min
- Compared with patients
  - Receiving conventional CPR
- Matching process based
  - On a propensity-score

1. Alternative ECMO strategies
   - Normal or high flow for septic shock?
   - Different types of peripheral or trans-thoracic cannulation
   - Initiating ECMO earlier

2. Different patient groups
   - Immune suppression or cancer
   - Pregnant women
   - Elderly

3. Extracorporeal support-assisted organ donation
   - Renal
   - Liver
   - Heart
   - Lung
   - Intestinal
   - Pancreas

NEW AND/OR FUTURE APPLICATIONS

8. NEW AND/OR FUTURE APPLICATIONS
3. Extracorporeal support-assisted organ donation

9. FACILITATING SAFE USE OF OTHER TREATMENTS

1. Complex surgery or interventional cardiology procedures
2. Hemodialysis in newborn infants
3. Support of vital organ function during rewarming from accidental hypothermia (avalanche victims)
4. Complex chemotherapy or immunotherapy that cause severe systemic inflammatory response
5. Long-term bridge for LungTx
6. Resuscitation from cardiogenic shock and transport to local cardiac surgical centres for long-term support with VADs and transplant programs

9. QUESTIONS?