INTRODUCTION TO ECMO

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Objectives

- Definition of ECMO
- Description of VV versus VA ECMO
- Data supporting use and benefit of ECMO
- Indications for VV ECMO
  - Management of the patient on V-V ECMO
  - Weaning from VV ECMO
- Indications for VA ECMO
  - Management of the patient on VA ECMO
  - Weaning from VA ECMO
- Complications

ExtraCorporeal Membrane Oxygenation

- An extracorporeal technique where lung and/or heart function is supported by passing deoxygenated venous blood over a membrane oxygenator/CO₂ remover, and then returning the blood to the body
Normal physiology:
- Deoxygenated blood returns from the body to the central veins
- Venous blood (from SVC and IVC) enters right atrium (RA)
- Blood pumped from the RA to the right ventricle (RV)
- Blood is pumped from the RV through the pulmonary arteries (PA) and to the lungs
- Oxygenated blood exits the lungs via the pulmonary veins (PV) and enters the left atrium (LA)
- Blood is pumped from the LA to the left ventricle (LV)
- Blood is pumped out of the LV to the body via the aorta

ECMO Circuit Basics
- Deoxygenated blood is removed from a large central vein
- This deoxygenated blood is then pumped through a membrane oxygenator
  
  For Veno-Venous ECMO (VV ECMO)
  - Oxygenated blood is returned to a large central vein/RA
  - The patient’s own heart pumps the oxygenated blood through the damaged lungs and to the body

  For Veno-Arterial ECMO (VA ECMO)
  - Blood is returned to the aorta, thus supporting cardiac function as well, bypassing the lungs entirely

Indications: General

V-V ECMO
- Severe potentially reversible hypoxemic respiratory failure with intact cardiac function unresponsive to standard modalities

V-A ECMO
- Severe potentially reversible cardiac failure, with or without hypoxemic respiratory failure unresponsive to standard modalities
How might ECMO work?

• Helps keep the patient alive until the potentially reversible lung injury resolves
• May allow lung recovery without superimposed trauma from mechanical ventilation and high FiO\textsubscript{2}
• ECMO only likely to be helpful if “lung rest” begun when ECMO instituted: continuing toxic ventilator pressures and high FiO\textsubscript{2} counterproductive

Barotrauma

• Good data that ventilators can damage lung
• High ventilator pressures worsen inflammatory mediators
• Modern mechanical ventilation techniques for ARDS try to minimize ventilator associated lung damage
Insert slide of barotrauma CXR

Does ECMO work?
- MANY anecdotal reports, small series, historical controls, etc.
- FEW randomized studies

- JAMA 1979
  - Randomized NIH funded randomized study of VA ECMO vs. conventional ventilation in 90 patients with severe ARDS
  - 4 patients in each group survived
  - No benefit seen from VA ECMO as used in the study for ARDS

- OLD study
  - No lung protective strategy used
  - Different techniques, etc.
  - No applicability to present day VV ECMO (or to any other aspect of modern ICU care for that matter)
Randomized trial of PC inverse ratio ventilation versus VV ECMO for CO₂ removal in ARDS in 40 patients
- The study was NOT designed to provide oxygen via the extracorporeal circuit; that had to be done via the ventilator as usual
- No difference between the two groups
- 38% survival overall
- Poor study; did not provide oxygenation, so no lung rest possible
- No applicability to present day ECMO whatsoever

Occasional large non-randomized series:
- Chest 1997 112: 769-64
  - British study: 66% survival on ECMO
  - Michigan; 54% survival
- JAMA 2009 302: 1888-95
  - Australia/New Zealand; at least 71% survival to ICU discharge

CESAR: Conventional Ventilatory Support versus ECMO for Severe Respiratory Failure
- 180 patients with severe ARDS, less than 7 days on ventilator, no contraindication to anticoagulation, potentially reversible condition
- Patients randomized to either conventional modern ventilator management, or ECMO; patients transferred to an appropriate center for care

Lancet 2009; 374: 1351-1363
• Veno-venous ECMO

• “Lung rest”: Peak pressure 20, PEEP 10, vent rate 10, 
  FiO₂ 0.3
• Hgb kept at 14 (More on this later!)

• 180 patients randomized
• 68/90 randomized to ECMO received it
• Survival at 6 months without disability:
  • 63% vs. 47%
• They recommend referral to an ECMO center when 
  patients meet entry criteria into this study
Summary of Published Data

- One high quality RCT supports its use in selected patients with severe ARDS
- Anecdotal experience from experienced centers supports utility
- Definitely need more studies . . .

Identify the patient for VV ECMO

- In properly selected patients, 60-70% survival rates with VV ECMO
- Hence, patients with anticipated survival rates less than this without ECMO are possible candidates

Indications for VV ECMO

- Severe potentially reversible hypoxemic respiratory failure failing conventional therapy, with adequate cardiac function
  - $\text{FiO}_2 > 0.8$, high PEEP despite optimal Rx
  - PF (PaO$_2$/FiO$_2$) ratio $< 100$
  - pH $< 7.2$ (due to high PaCO$_2$)
  - Age $< 60$
  - Short duration of mechanical ventilation
  - High Murray Scale
  - “Worsening trajectory”
Veno-Venous Exclusion Criteria & Absolute Contraindications

- Contraindication to anticoagulation
- Acute ICH
- Uncorrectable thrombocytopenia
- Irreversible CNS damage
- Extremely poor prognosis due to underlying disease (e.g., terminal cancer)
- Irreversible acute lung failure or severe pre-existing pulmonary disease
- Chronic severe pulmonary hypertension
- Refusal to accept blood products

Veno-Venous ECMO relative contraindications

- Age > 70
- Trauma with multiple bleeding sites
- Weight over 120 kg
- Multiple organ failure
- Mechanical ventilation > 10 days

Probability of death vs Duration of Mechanical Ventilation
Which diseases are appropriate to consider for ECMO?

- ARDS
- Severe pneumonia
- Aspiration
- Pulmonary contusion
- Airway obstruction
- Smoke inhalation
- Alveolar proteinosis
- Alveolar hemorrhage syndromes
- Status asthmaticus (CO₂ removal)

“Ideal Patient”

- ARDS
- No concomitant extra-pulmonary failure
- Good cardiac function
- Age < 60
- PF ratio < 100
- Ventilator < 5 days
- Failing maximum standard modalities

Obtain Consent

- Specific form to facilitate
- Emphasizes:
  - Risk of cannula insertion
  - Risk of bleeding (cannula related, as well as systemic, including brain)
  - Frequent need for blood products with their associated risks
  - Risk of mechanical complications of the circuit
  - Risk of infection
  - High risk of death
  - Possibility of turning into futile care situation
  - "Off label" use of equipment

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VV ECMO circuit

- Note:
  - All of the equipment used in ECMO is FDA approved
  - Most of the devices are not specifically approved for ECMO or for prolonged duration of use

Mobilize the ECMO Team

- Pulmonary Intensivist
- ECMO Medical Director
- ECMO Surgical Director (CT surgeon for cannula insertion)
- Adult ECMO coordinator
- Perfusionist(s)
- Blood Bank
- ICU PPN; plan on two ICU RNs with ECMO familiarity
- ICU Pharmacist
- OR crew
- Respiratory Therapy
- Fluoroscopy tech with equipment
- Echo tech with equipment for TTE and TEE

Begin “Pre ECMO” orders

- Move patient to appropriate room at SMC-Austin ICU
- Draw baseline laboratory
- T&c; transfuse towards hematocrit 35-40, platelets >100k
- “Size” right LI and femoral veins ultrasonographically
- Insert arterial line if not already in (ideally right radial)
- Place central line(s), ideally PICC(s) if time allows
Decide on Circuit Setup
- Vascular ultrasound to size the right IJ and the femoral veins
  Decide on:
  - Single cannula, dual lumen
  - Two single lumen cannulas
  - Three single lumen cannulas
  Decisions based on patient size, vessel size, equipment available, expertise, anticipated flow

Vessel sizing
\[ \text{Fr size} = \text{diameter} \times 3 \]
\[ \text{Fr size} \approx \text{circumference in mm} \]

ECMO: The Circuit in More Detail
- Venous cannula for blood removal
- Pump (we use centrifugal)
- CRRT circuit if needed
- Membrane oxygenator (we use Quadrox-iD)
  - Pressure monitor before and after
- Heat exchanger (connects to the Quadrox-iD)
- Venous cannula for blood return

Other components: CDI, flow cut offs, bridge, bubble detector
Picture of 1970’s circuit

Quadrox D
- Polymethylpentene hollow fiber membrane
- Low pressure drop
- Easy priming
- Ports for sweep gas, blood flow, and heat exchange fluid

Quadrox D in use
3 cannula technique

Avalon Dual Lumen

Dual lumen Avalon cannula
Perfusionist sets up & primes circuit
- Fluoroscopy & ultrasound (including TTE) available
- Procedure cart with cannulas, dilators, etc.
- Drugs immediately available (heparin, sedation, etc.)

Cannula insertion
- Scrub and drape patient
- TIME OUT! Verify that:
  - Patient consented
  - All equipment available
  - Insertion sites, cannulas, flow direction agreed upon
  - Allergies understood
- Locate vein; guidewire inserted
- Anticoagulate with heparin
- Dilate vein, then insert and secure cannula(s)
- Connect to ECMO circuit: re-verify which are drain, which are return cannulas

Initiate flow
- TIME OUT!
  - Verify that everyone is ready—RN, RT, pharmacist, intensivist, perfusionist
  - Resuscitation equipment available
  - Go slow—over 5-10 minutes
  - Adjust sweep gas as needed to optimize patient gasses
Optimize circuit/patient layout

- All cannulas securely fastened to bed/mattress
- Warning signs posted
- Be sure that ALL visitors know what is going on, what to touch, what not to touch (family, friends, housekeeping, PT, doctors, etc.)

Turn down ventilator

- Decrease ventilator pressures/volumes
- Decrease FiO₂
- Adjust settings for comfort without compromising lung safety
- Adjust sweep gas: almost certainly will need to increase

Patient pre ECMO
Patient on ECMO, lung white

Monitor Pre-ECMO

Ventilator Monitor on ECMO
Monitor on ECMO

Nursing issues
- All basic “routine” ICU care continues
- Adequate sedation/restraint ESSENTIAL
- Meticulous catheter management
- Frequent lab draws
- High risk for bleeding and infection
- Providing safe environment: risk of line disruption, etc.
- Education of visitors and other workers

Why are the sats so low on ECMO?
- The blood coming out of the oxygenator typically has saturation ~100%
- The arterial blood on ECMO may have a saturation <85%, and may even be in the 70’s
Dual Lumen Avalon cannula

Two Cannula Recirculation

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Recirculation and SaO₂

- If all of the blood was recirculated, then NONE would be delivered to the patient; hence, severe arterial desaturation
- There always will be SOME recirculation
- In addition, not all blood will be sent to the oxygenator
- The less the recirculation, the higher the arterial saturation (all other things being equal . . .)
- The mixing of deoxygenated venous blood plus fully oxygenated post-membrane blood leads to arterial SATURATIONS often in the 70's to mid 80's

- As long as adequate oxygen DELIVERY is maintained, saturations in mid 70's are okay
- Keep CO adequate
- Keep Hgb high (CESAR study kept it at 14 . . .)
- Monitor end-organ function
  - Urine, normal/falling lactic acid, improving LFTs, good CNS function
- Maintain lung protective ventilator settings

What if renal failure also?

- Dialysis can be done as part of the circuit
- No need for separate dialysis lines
- Dialysis lines connect between the pump and the oxygenator
- Routinely would use CRRT (CVVH) if needed
Weaning from VV ECMO

- As patient’s lungs improve:
  - CXR looks a bit better
  - Volumes on ventilator improve
- Adjust ventilator to “conventional” settings:
  - $V_t = 6 \text{ ml/kg BW}$
  - $\text{FIO}_2 0.5$
  - PEEP 10
- Turn off sweep gas; watch a few hours
- If tolerated, decannulate and hold pressure 30 minutes

Weaning from ECMO (continued)

- If wean fails, resume “protective” ventilation strategies
- Assess for reversible processes
  - Infection
  - Bronchospasm
  - Airway obstruction (bronchoscopy)
  - Volume overload
- Try again the next day
- No role for “some ventilator” and “some ECMO”
CXR just before ECMO stopped

What could possibly go wrong?
- Circuit disconnections
- Air embolism
- Circuit thrombosis
- Infection
- Bleeding: at insertion sites, as well as remote sites (chest, GI, RP, brain)
- Failure of underlying lung disease to resolve
- Plus, any of the "usual" ICU issues . . .

Indications for VA ECMO
- Severe potentially reversible cardiac failure, with or without hypoxemic respiratory failure unresponsive to standard modalities
- Bridge to recovery
- Bridge to LVAD or BIVAD, with or without transplant
- Bridge to decision
VA ECMO circuit

- Venous drainage cannula, typically femoral insertion, advanced to RA/IVC
- Blood pumped through oxygenator
- Arterial return cannula, typically femoral

- Oxygenated blood pumped RETROGRADE up the aorta
Management while on VA ECMO
- Similar to VV in many respects
- Optimize oxygen delivery/tissue perfusion to maximize chance for end-organ recovery
- Early investigation into cardiac prognosis and options

What is the end game?
- VA ECMO is not a long term option: typically try for <1 week, usually no more than 5 days
- Is heart function recovering?
  - If so, wean and decannulate
  - If heart not recovering, is patient a candidate for VAD/transplant?
    - If so, place LVAD (or BiVAD)
      - Then, either bridge to recovery VAD, “destination” VAD, or bridge to transplant

Why not a candidate for VAD or transplant?
- Too old
- Other organ dysfunction/failure
- Psychosocial issues
- History of medical noncompliance
- Patient wishes (often as expressed through surrogates)
- Financial limitations
- Transplant program issues
What if not a candidate for VAD or transplant?
• TOUGH problem
• Ultimately, provide comfort and withdraw support

Weaning from VA ECMO
• Maximize cardiac support
  • IABP
  • Inotropic support
  • Adequate volume
• Turn down ECMO flow
• If tolerates, decannulate
• If fails:
  • Increase ECMO flow
  • Go to Plan B

VA ECMO complications
• Limb ischemia
• Embolism to any arterial supply
• Stroke, hemorrhagic or bland
• Plus, all of the usual VV ECMO complications
### Adult Respiratory Cases

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<th>Annual Runs</th>
<th>Cumulative Runs</th>
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### Adult Cases by Diagnosis

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<th>Diagnosis</th>
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<td>Bacterial Pneumonia</td>
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### Cardiac Cases By Year

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Cardiac ECLS by Diagnosis
16 years old and over

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<th>Diagnosis</th>
<th>Runs</th>
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<tr>
<td>Other</td>
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</table>

The future of ECMO
• Improvement in cannulas
• Improvement in materials with reduced clot formation
• Better anticoagulation schemes
• More trials, more science

ECMO 1971