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/CO_2 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_2
- ECMO only likely to be helpful if "lung rest" begun when ECMO instituted: continuing toxic ventilator pressures and high FiO_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)

- Am J Respir Crit Care Med 1994
  - Randomized trial of PC inverse ratio ventilation versus VV ECMO for CO_2 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
  - Ann Surg 1997 226: 544-64
    - Michigan; 54% survival
  - JAMA 2009 302: 1888-95
    - Australia/New Zealand; at least 71% survival to ICU discharge

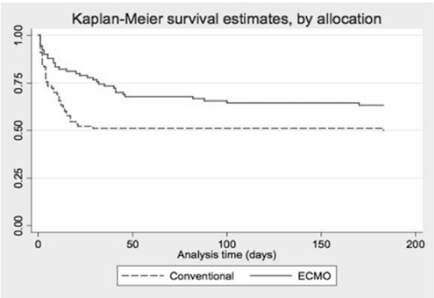
CESAR: Conventional Ventilatory Support versus ECMO for Severe Respiratory Failure

- 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, FiO_2 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
  - F_IO_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"

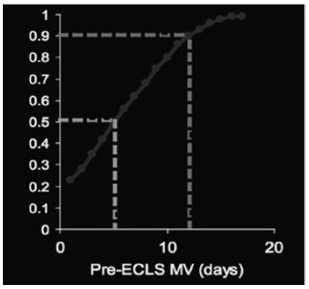
Veno-Venous Exclusion Criteria & Absolute Contraindications

- 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 (CO_2 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

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 IJ 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

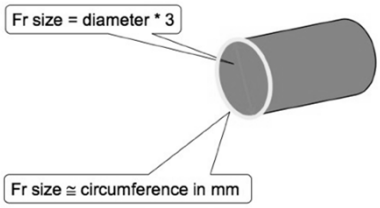
- Vascular ultrasound to size the right IJ and the femoral veins

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



ECMO: The Circuit in More Detail

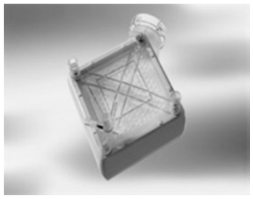
- Venous cannula for blood removal
- Pump (we use centrifugal)
- CRRT circuit if needed
- Membrane oxygenator (we use Quadrox-iD)
  - Pressure monitor before and after
- Heat exchanger (connects to the Quadrox-iD)
- Venous cannula for blood return

Other components: CDI, flow cut offs, bridge, bubble detector

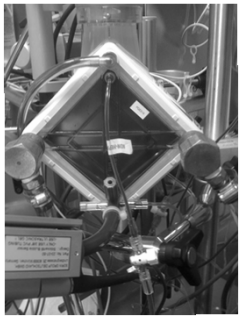
Picture of 1970's circuit

Quadrox D

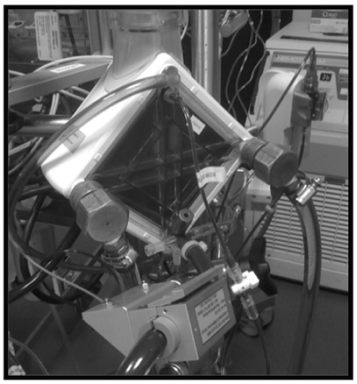
- Polymethylpentene hollow fiber membrane
- Low pressure drop
- Easy priming
- Ports for sweep gas, blood flow, and heat exchange fluid



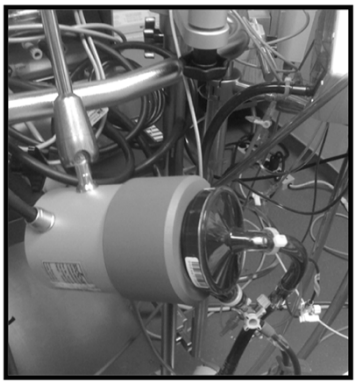
Quadrox D in use



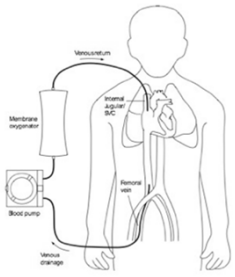
Quadrox D
Oxygenator



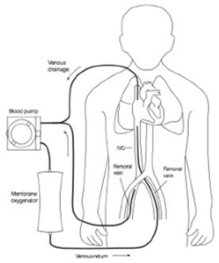
Sorin Revolution
Centrifugal Pump



2 cannula technique



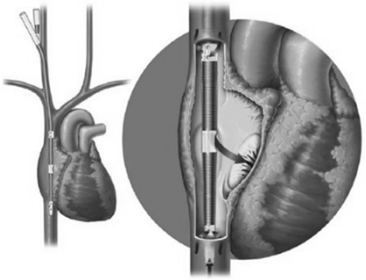
3 cannula technique



Avalon Dual Lumen

Courtesy R Firmin, Leicester, UK

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 FiO_2
- Adjust settings for comfort without compromising lung safety
- Adjust sweep gas: almost certainly will need to increase

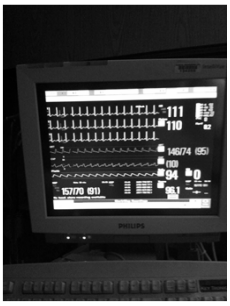
Patient pre ECMO

Patient on ECMO, lung white

Monitor Pre-ECMO

Ventilator Monitor on ECMO

Monitor on ECMO



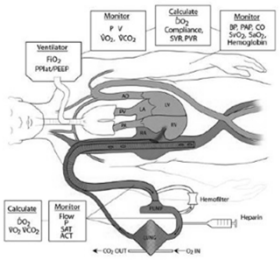
Nursing issues

- 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

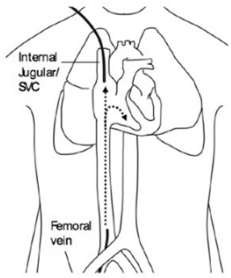
Why are the sats so low on ECMO ?

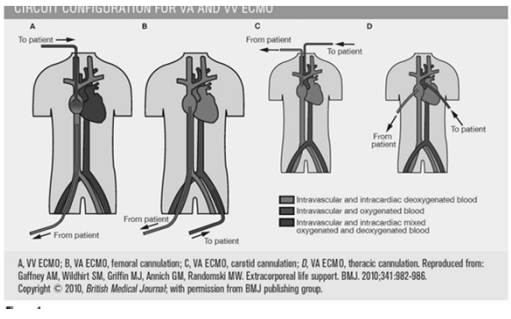
- The blood coming out of the oxygenator typically has saturation ~100%
- The arterial blood on ECMO may have a saturation <85%, and may even be in the 70's

Dual Lumen Avalon cannula



Two Cannula Recirculation





A, VV ECMO; B, VA ECMO, femoral cannulation; C, VA ECMO, carotid cannulation; *D*, VA ECMO, thoracic cannulation. Reproduced from: Gaffney AM, Wildhirt SM, Griffin MJ, Annich GM, Randomski MW. Extracorporeal life support. BMJ. 2010;341:982-986. Copyright © 2010, *British Medical Journal*; with permission from BMJ publishing group.

Recirculation and SaO_2

- 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 ml/kg IBW
  - 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 . . .

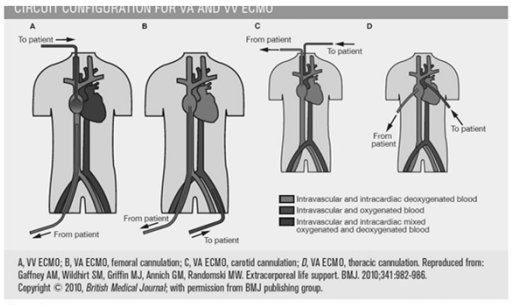
Indications for VA ECMO

- 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



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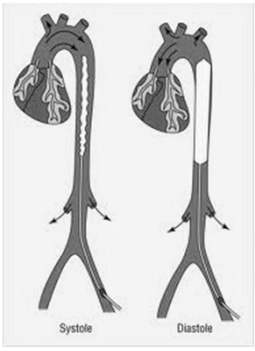


Management while on VA ECMO

- 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

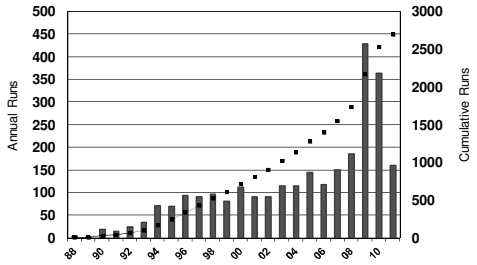
Weaning from VA ECMO

- 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



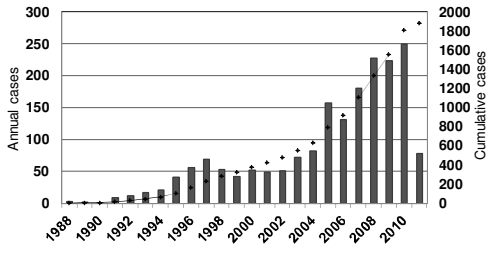
ELSO Registry July 2011

Adult Cases by Diagnosis

	Runs	% Surv
Viral Pneumonia	110	65
Bacterial Pneumonia	459	59
Aspiration	66	61
ARDS	612	50
Acute Resp Failure, Non-ARDS	149	56
Other	1,297	53

ELSO Registry July 2011

Cardiac Cases By Year
16 years old and over



ELSO Registry July 2011

Cardiac ECLS by Diagnosis
16 years old and over

	Runs	% Survived
Congenital Defect	147	35
Cardiac Arrest	95	29
Cardiogenic Shock	231	38
Myocardiopathy	236	45
Myocarditis	71	69
Other	1,105	38

ELSO Registry July 2011

The future of ECMO

- Improvement in cannulas
- Improvement in materials with reduced clot formation
- Better anticoagulation schemes
- More trials, more science

ECMO 1971