Improving Outcomes in Veno-Venous ECMO: What Is It, Who Benefits, and The Latest Research on Patient Management

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Disclosures

Terry – none

Paul - none

Course Outcomes

Identify	Identify the main components of the ECMO circuit
Identify	Identify appropriate candidates for VV ECMO
Describe	Describe oxygen content, O2 delivery, consumption, and shunting
Learn	Learn the latest research and guidelines for VV ECMO patient management

Case Study - Asthma

38-year-old male with history of mild intermittent asthma and active tobacco use

- Found on floor with empty albuterol container and unresponsive
- Initial ABG at OSH 6.8/120 - intubated
- Transferred to UVMMC
- Care escalated to include:
  - methylprednisolone 60 mg every 6 hours
  - Continuous albuterol nebulizer at 20 mg/hr
  - Propofol and vecuronium
  - Magnesium infusion
  - Anesthesia ventilator brought to bedside for use of isoflurane
  - Sodium bicarbonate infusion as patient had become hemodynamically unstable due to PcO_2 > 100
  - Norepinephrine 20 mcg/min

- What else can we offer him?????

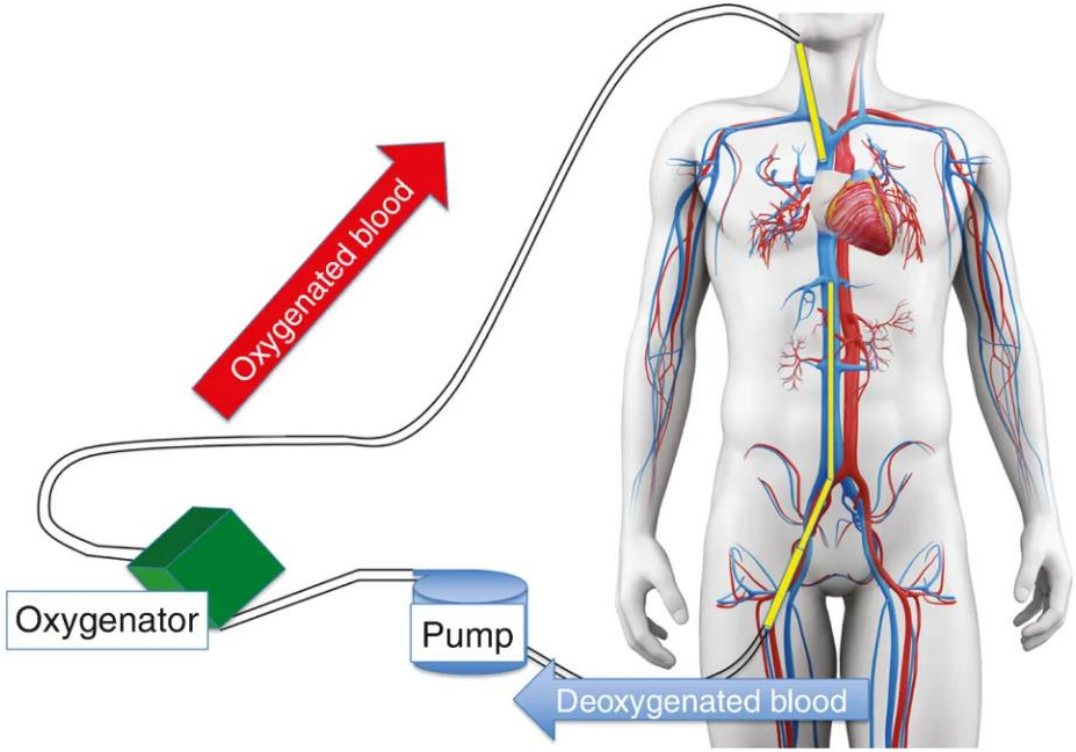
Severe Life-Threatening Asthma

- Conventional management includes:
  - Optimization of mechanical ventilation
  - Corticosteroids, bronchodilators
  - Sedation, neuromuscular blockade
- Mortality in severe asthma exacerbations requiring invasive mechanical ventilation- 6.5-10.3%
- VV-ECMO considered salvage or rescue therapy

Lozano-Espinoza, Respir Med, 2023

What is ECMO?

Extracorporeal Membrane Oxygenation (ECMO) is an advanced form of life support that functionally involves a blood pump and a membrane lung/oxygenator to support the heart and/or lungs.



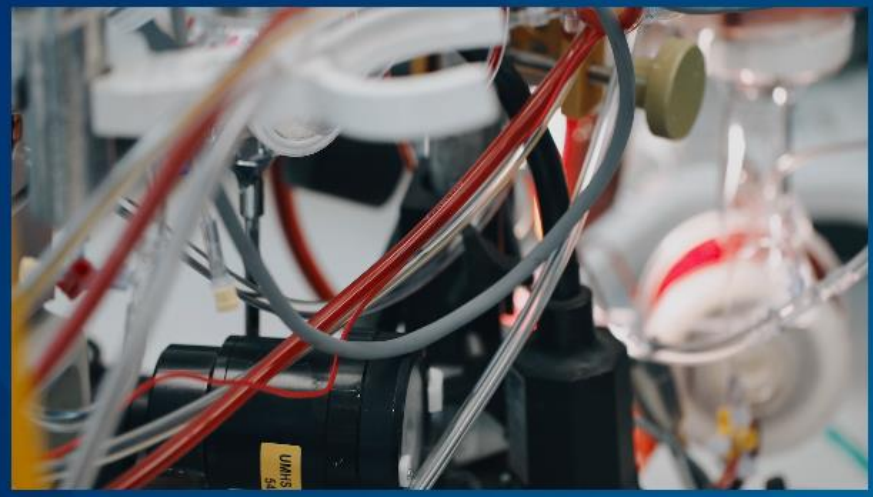
About Us Membership Registry Award Of Excellence ECMO Resources Publications Education

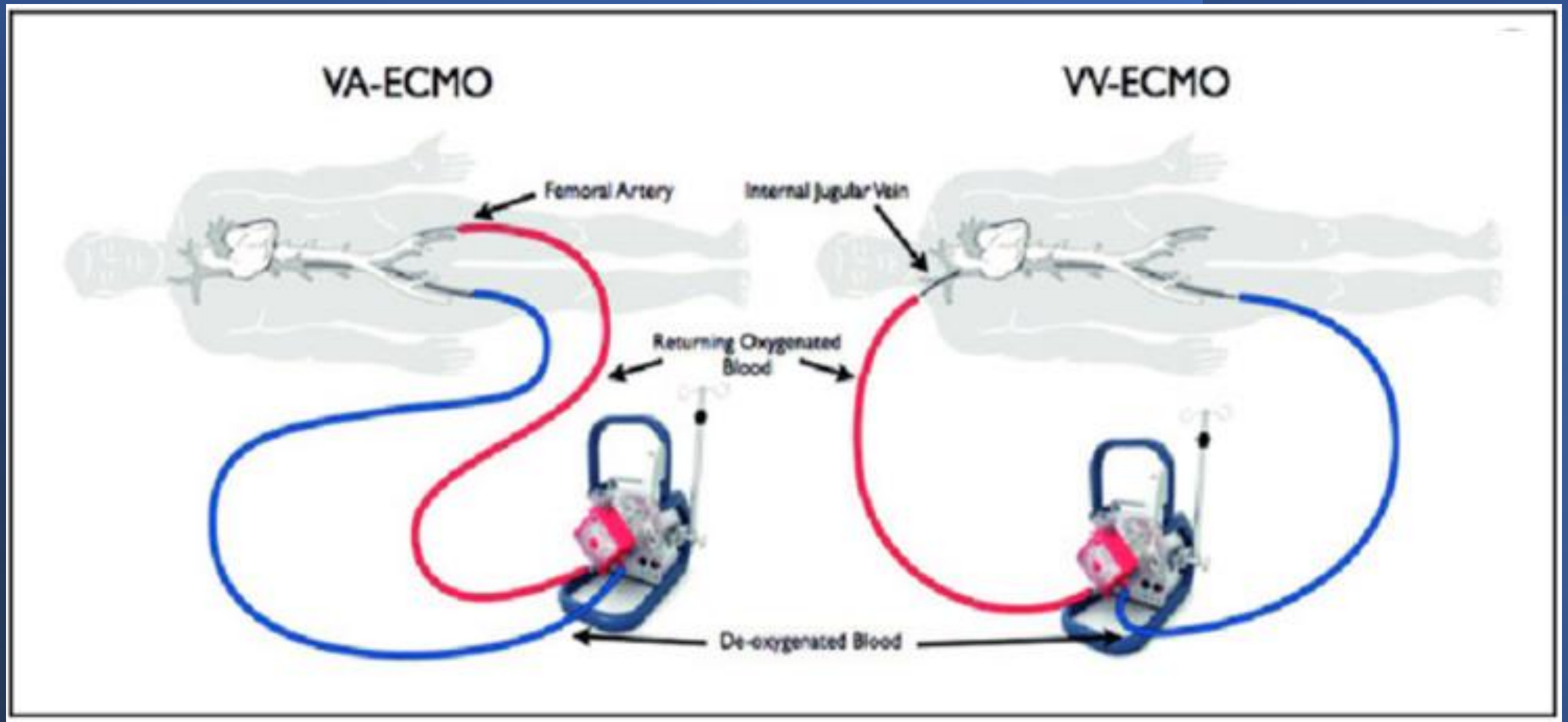
Extracorporeal Life Support Organization

ECMO's Global Community Since 1989

World's Largest ECMO Patient Registry and Community of ECMO Centers

ELSO is an international nonprofit consortium of health care institutions, researchers, and industry partners. We provide support to those delivering extracorporeal life support through continuing education, guidelines, original research, publications, and a comprehensive registry of extracorporeal membrane oxygenation (ECMO) patient data.





Modes of ECMO support. VV-ECMO provides only respiratory support while VA-ECMO provides full cardiovascular and respiratory support.

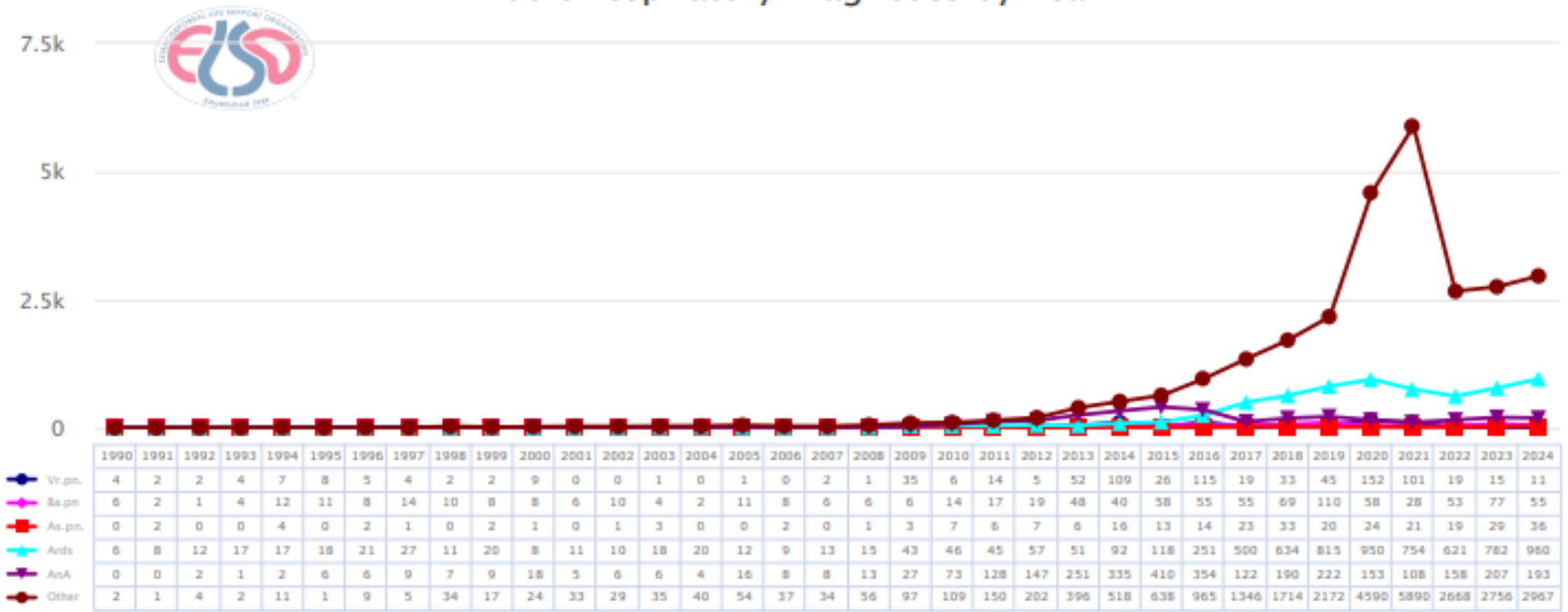
ECLS Registry Report

United States Regional Trend Summary
October, 2025.
Report data through 2024

Extracorporeal Life Support Organization
www.elso.org

Adult Respiratory (18 years and over)

Adult Respiratory Diagnoses by Year



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Vr.pn.	4	2	2	4	7	8	5	4	2	2	9	0	0	1	0	1	0	2	1	35	6	14	5	52	109	26	115	19	33	45	152	101	19	15	11
Ba.pn	6	2	1	4	12	11	8	14	10	8	8	6	10	4	2	11	8	6	6	6	14	17	19	48	40	58	55	55	69	110	58	28	53	77	55
As.pn.	0	2	0	0	4	0	2	1	0	2	1	0	1	3	0	0	2	0	1	3	7	6	7	6	16	13	14	23	33	20	24	21	19	29	36
Ards	6	8	12	17	17	18	21	27	11	20	8	11	10	18	20	12	9	13	15	43	46	45	57	51	92	118	251	500	634	815	950	754	621	782	960
AnA	0	0	2	1	2	6	6	9	7	9	18	5	6	6	4	16	8	8	13	27	73	128	147	251	335	410	354	122	190	222	153	108	158	207	193
Other	2	1	4	2	11	1	9	5	34	17	24	33	29	35	40	54	37	34	56	97	109	150	202	396	518	638	965	1346	1714	2172	4590	5890	2668	2756	2967

Vr.pn. - Viral pneumonia
Ba.pn. - Bacterial pneumonia
As.pn. - Aspiration pneumonia
AnA - Acute resp failure non ARDS

Blood flow through the ECMO circuit

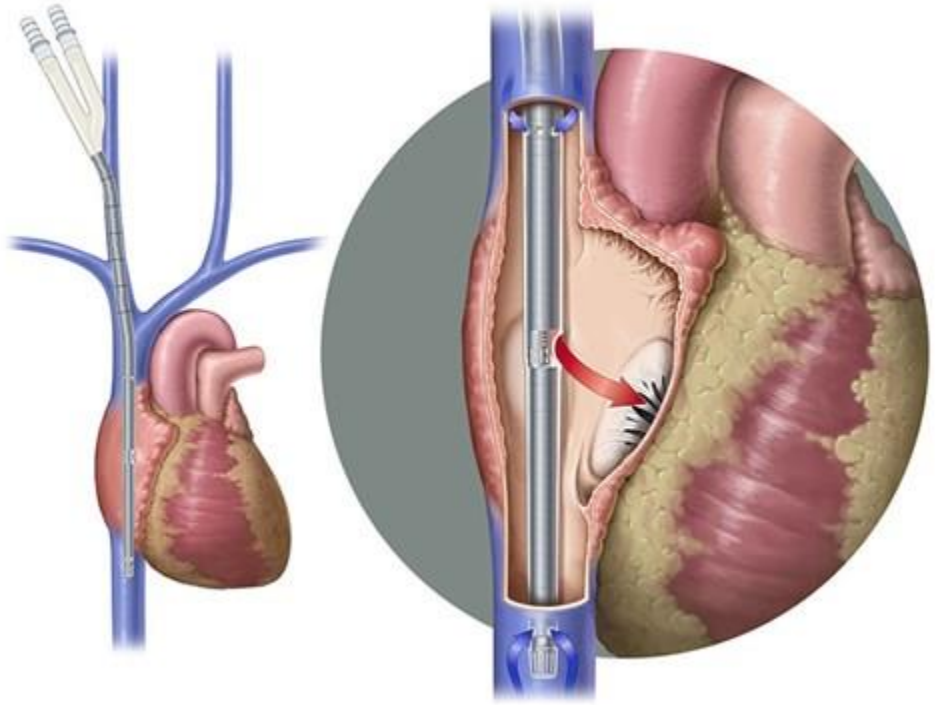
A ECMO circuit provides support by draining blood from the patient, using a pump to move blood through the circuit where it is artificially ventilated and oxygenated then returned to the patient.

Components (listed in order of blood flow) of the circuit that will be covered:

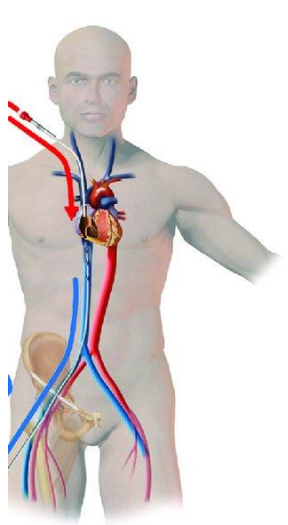
- Access (drainage) cannula
- Blood pump
- Pre-oxygenator pressure monitor
- Oxygenator
- Sweep gas and FiO2
- Heat exchanger
- Post-oxygenator pressure monitor
- Blood flow monitor
- Return cannula

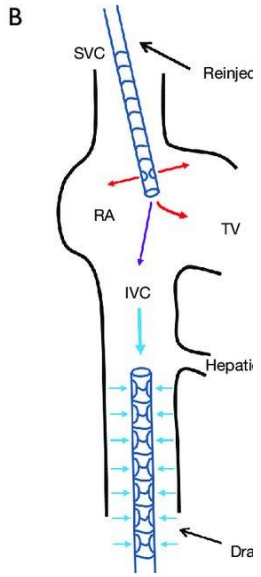
VV ECMO Cannulation Strategies

Avalon



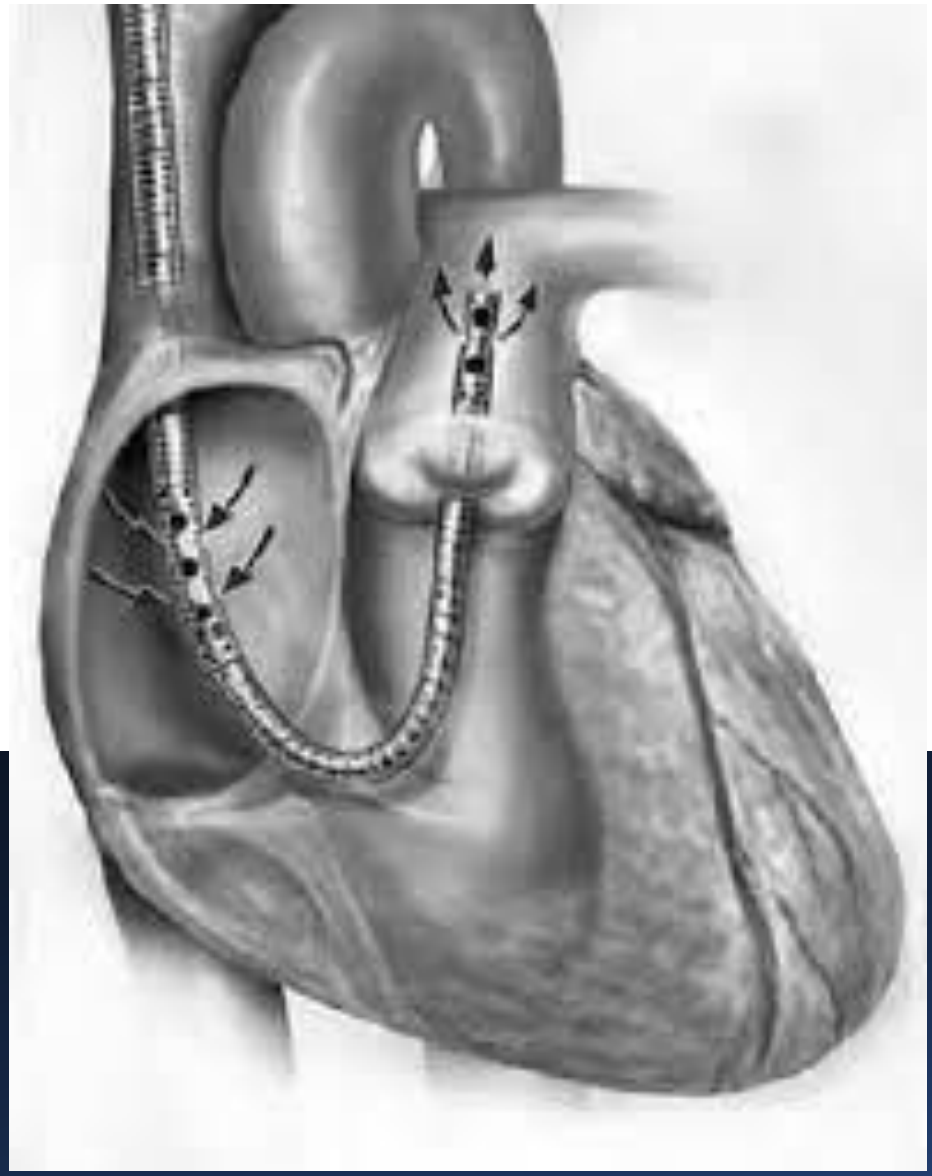
Dual site

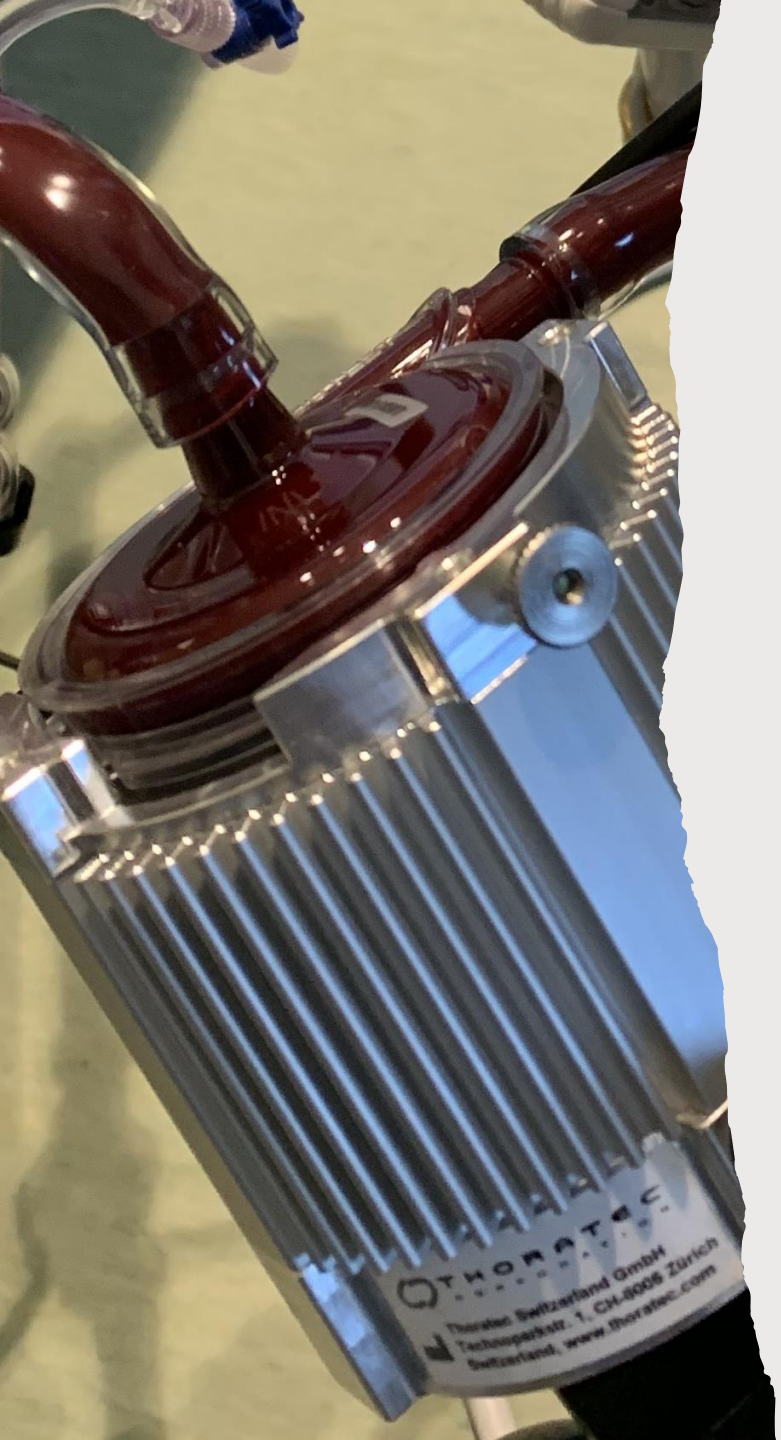




Cannulation Options for VV ECMO

RA to PA cannula. Can be used for VV ECMO and as a temporary right ventricular assist device.





Centrifugal Pump

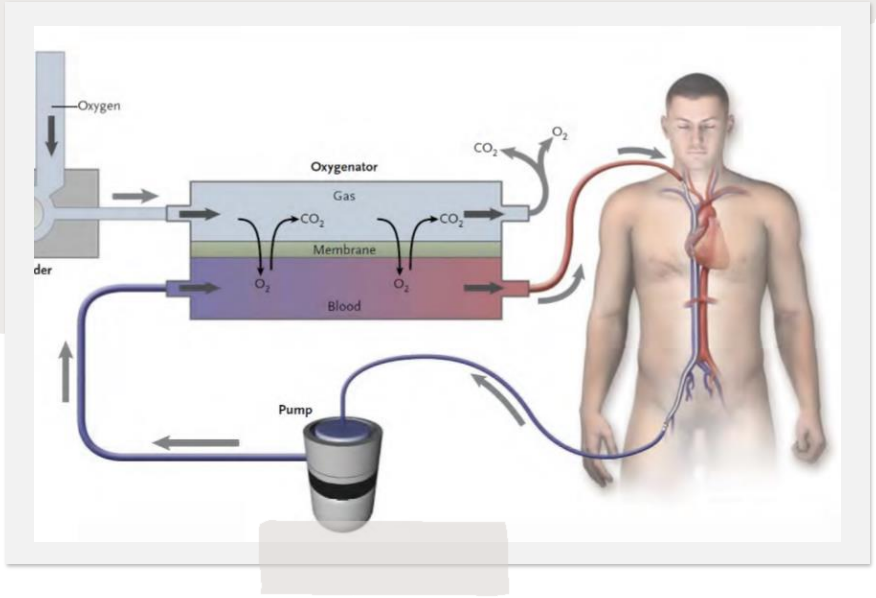
Preload dependent and after load sensitive

- Chatter - caused by insufficient blood flow to the pump. Causes range from hypovolemia, drainage cannula displacement, circuit tubing obstructed.
- Sensitive to resistance at the pump outlet which can be caused by HTN, clots distal to the pump. These will decrease flow regardless of pump RPMs.
- Non-occlusive - ALWAYS clamp lines when the pump is off.

Sweep Gas and FiO2

- Dual flowmeter
- FiO2 is set through the mixer. Responsible for oxygenating blood.
- The rate at which the gas flows through the oxygenator is set in liters/min (sweep gas). Responsible for CO2 removal of blood.

Oxygenator



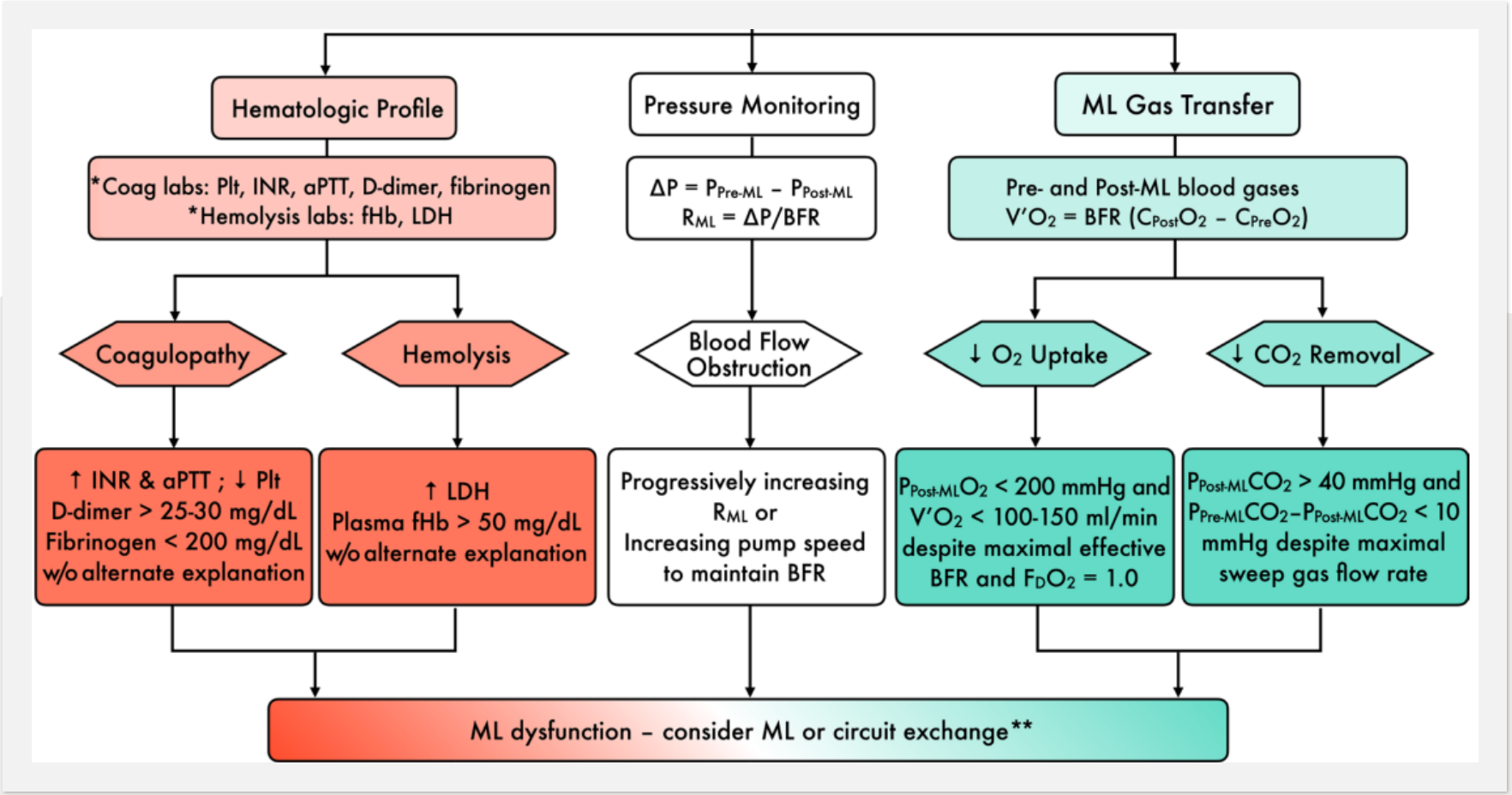
Oxygen transfer capacity depends on

- Properties of the oxygenator
- FdO2 set on blender
- Time that blood is in contact with the membrane.

Carbon dioxide transfer is determined by rate of gas flow through oxygenator (sweep gas)

Oxygenator complications

- Clots
- Membranes “wet” from condensation making membrane less permeable to CO2. Membranes dried by using sharply increasing sweep gas for several seconds (sighing)



Membrane Lung Failure Algorithm

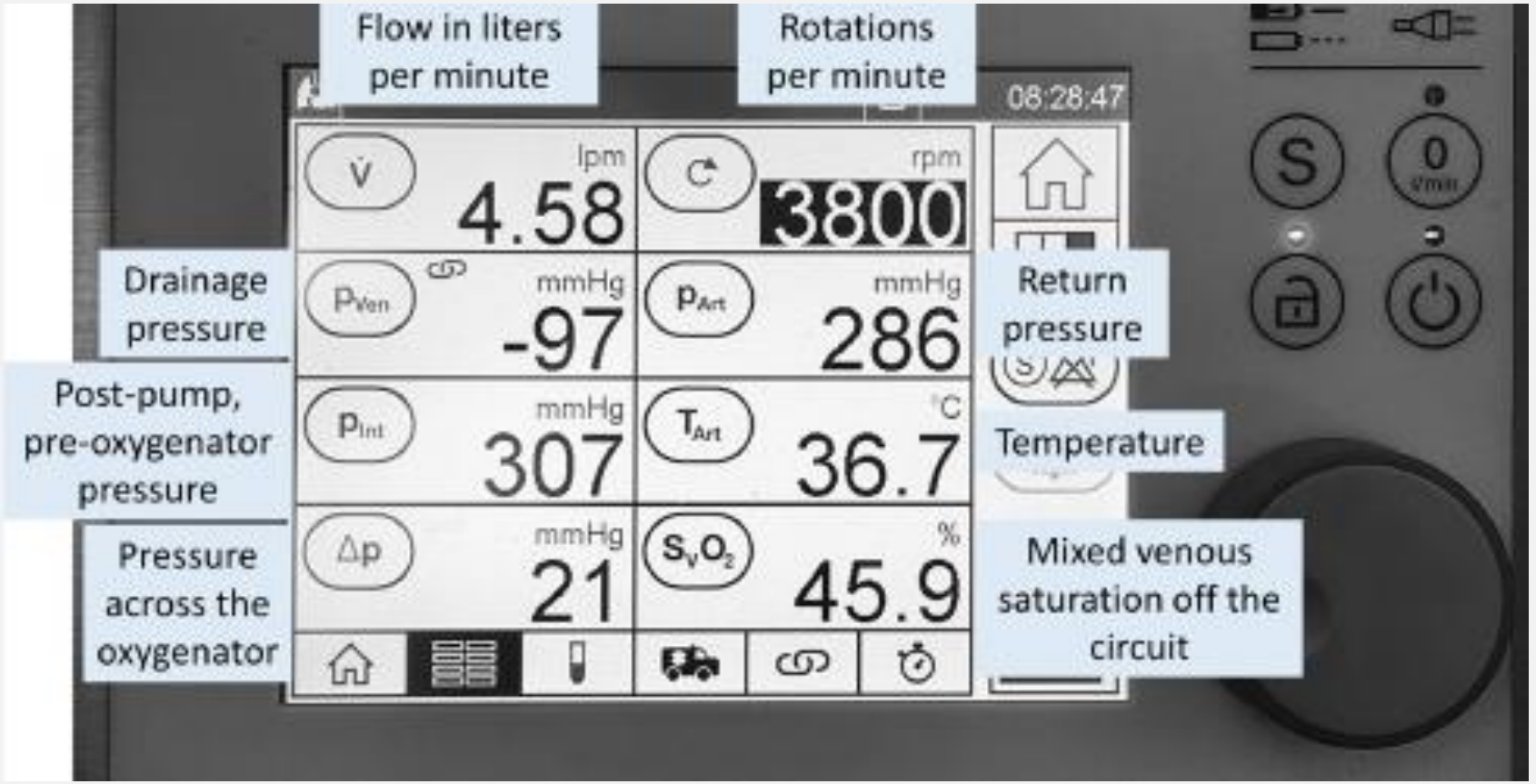
(Zakhary et al. Crit Care 2020)

Heat exchanger

- Integrated with the oxygenator via 2 couplings at bottom of oxygenator
- Help to keep patient normothermic
- Can be used for therapeutic cooling
- Ensure that it is connected and turned-on during circuit checks

Blood flow monitor

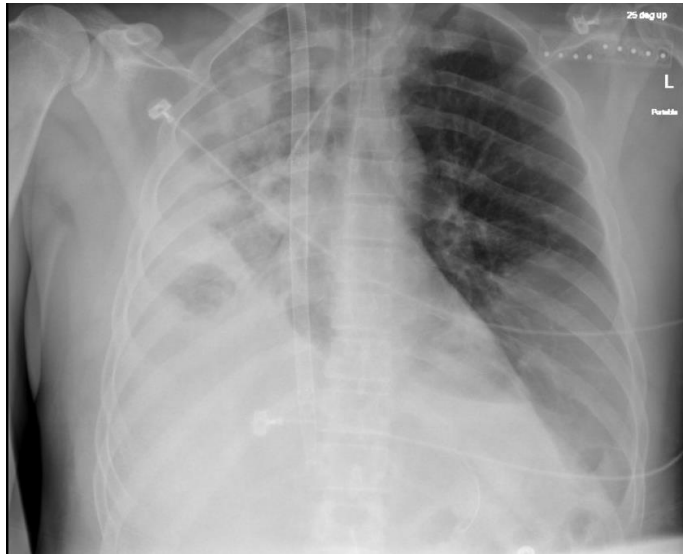
- Based on ultrasound technology
- Located on the return cannula
- Measures the actual rate of blood flow through circuit in liters/min
- On some consoles, also can detect air bubbles in the return circuit tubing



Pressure Monitoring and more!

Picture from Jennifer Vieira, Michael Frakes, Jason Cohen, Susan Wilcox, Extracorporeal Membrane Oxygenation in Transport Part 1: Extracorporeal Membrane Oxygenation Configurations and Physiology, Air Medical Journal, Volume 39, Issue 1, 2020, Pages 56-63

Back to our Asthma Case Study on HD # 3 – VV ECMO Initiated



- ABG pre-initiation:
- 7.22/128/124/>50 on PC/AC 100% RR 14 PC 35
- Lactic acid 3.3

A word about that ABG you just saw 7.22/128/124/>50

- Dr. Farkas had just published an article in PulmCrit- Extracorporeal CO2 removal: Putting the cart ahead of the horse?
- The premise was: So, we *can* remove CO2, but the question is: *should we*? ARDS patients don't need to have a pH of 7.40. We won't earn any gold stars for achieving euboxia. Ultra-protective ventilation could be achieved in a cheaper and easier fashion by accepting a lower pH target and slipping the patient a bit of bicarbonate. A less invasive strategy to ultra-protective ventilation would also be more accessible to thousands of hospitals which lack the technology to remove CO2 extracorporeally.
- This patient received A LOT of sodium bicarbonate before the decision was made to go on ECMO.

Case Study - Asthma

- Titrated BFR to 4.8 LPM. Sweep 5.2, FDO2 100%
- Over 12 hours ABG corrected to 7.5/53/199/43
- Patient was transferred to Montefiore Medical Center
  - Came off ECMO after 3 days
  - Extubates after 6 days
  - Transferred to the floor after 9 days
- Transferred to acute rehab after 14 days
- Discharge home after 18 days

Management of Adult Patients Supported with Venovenous Extracorporeal Membrane Oxygenation (VV ECMO): Guideline from the Extracorporeal Life Support Organization (ELSO)

Joseph E. Tonna, MD, MS,*† Darryl Abrams, MD,‡ Daniel Brodie, MD‡ John C. Greenwood, MD,§
Jose Alfonso Rubio Mateo-Sidron, MD,¶ Asad Usman, MD, MPH,‖ and Eddy Fan, MD, PhD#

Table 1. Indications/Contraindications for Adult VV ECMO

Common indications for venovenous extracorporeal membrane oxygenation
One or more of the following:

1) Hypoxemic respiratory failure (PaO_2/FiO_2 < 80 mm Hg)*, after optimal medical management, including, in the absence of contraindications, a trial of prone positioning.
2) Hypercapnic respiratory failure (pH < 7.25), despite optimal conventional mechanical ventilation (respiratory rate 35 bpm and plateau pressure [P_{plat}] ≤ 30 cm H_2O).
3) Ventilatory support as a bridge to lung transplantation or primary graft dysfunction following lung transplant.

Specific clinical conditions:

- Acute respiratory distress syndrome (*e.g.*, viral/bacterial pneumonia and aspiration)
- Acute eosinophilic pneumonia
- Diffuse alveolar hemorrhage or pulmonary hemorrhage
- Severe asthma
- Thoracic trauma (*e.g.*, traumatic lung injury and severe pulmonary contusion)
- Severe inhalational injury
- Large bronchopleural fistula
- Peri-lung transplant (*e.g.*, primary lung graft dysfunction and bridge to transplant)

Relative contraindications for venovenous extracorporeal membrane oxygenation

- Central nervous system hemorrhage
- Significant central nervous system injury
- Irreversible and incapacitating central nervous system pathology
- Systemic bleeding
- Contraindications to anticoagulation
- Immunosuppression
- Older age (increasing risk of death with increasing age, but no threshold is established)
- Mechanical ventilation for more than 7 days with P_{plat} > 30 cm H_2O and F_iO_2 > 90%

Tonna JE et al., ASAIO J 2021;67:601-610.

VV ECMO

VENOVENOUS ECMO FOR ACUTE RESPIRATORY FAILURE

INDICATIONS

Common Conditions

- ARDS
- Status asthmaticus
- Air-leak syndromes
- Thoracic trauma
- Inhalational injury

Acute Respiratory Failure

- $PaO_2:FiO_2 < 80$ and/or
- $pH < 7.25$ and $pCO_2 > 60$

*Despite optimal mechanical ventilation settings and conventional medical management including prone positioning

CONTRAINDICATIONS

Absolute Contraindication

- Irreversible lung injury in patients ineligible for transplant

Relative Contraindications

- >7 days of mechanical ventilation with injurious ventilator settings
- Age >75 or <16
- Significant CNS injury or unknown neuro status
- Severe acute MOSF
- Non-correctable coagulopathy/bleeding
- End-organ irreversible damage
- Advanced cancer

ECMO CONSULT

CALL EARLY!

UVMMC
Call PAS
@ 72700 for an
"ECMO Consult"

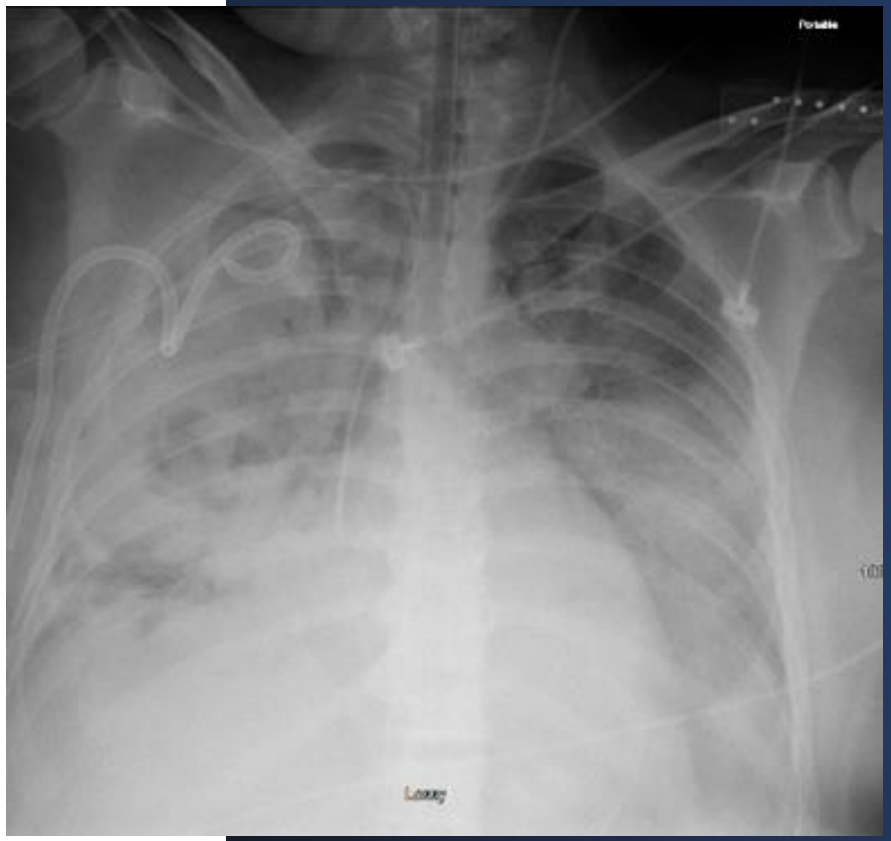
Outside Hospital
Call UVM Regional Transfer Center
@ 1-866-648-4866 for an
"ECMO Consult"

Case Study – ARDS

- 35-year-old female presented to OSH after “feeling ill” for 5 days. Room air oxygen saturation was in the 40’s. She was placed on Bipap initially and then intubated and sent to UVMMC MICU.
- Past Medical History:
  - Psoriatic arthritis – treated with Methotrexate and Infliximab
  - Chronic pain
  - HTN
  - Asthma
  - Idiopathic Intracranial Hypertension – s/p VP shunt
  - Depression
  - Current smoker – trying to quit using vaping

- **Hospital day 0 at UVMMC**
  - Patient neutropenic
  - Initial vent settings FiO2 100% PEEP 18 RR 15 TV 307
  - Inhaled flolan
  - Switched to APRV – Flolan weaned to off, FiO2 weaned to 50%
  - Patient weight 118 kg
  - Positive for Pneumococcal pneumonia – antibiotics changed to Zithromax and Ceftriaxone

- **Hospital day 3 at UVMMC**
  - Patient had decompensated overnight
  - Chest tube for right pneumothorax HD 1
  - Developed large right sided bronchopulmonary fistula
  - Started on muscle relaxants
  - Transitioned to PCV
  - Restarted Flolan
  - CXR with progression of R sided infiltrates
  - Due to her asymmetric lung disease and right sided apical pigtail, proning the patient was not a viable option
  - CT surgery consulted for ECMO



Prone Positioning

- Guerin et al published the PROSEVA RCT in 2013 showing that early, prolonged prone positioning (16 hours/day) in patients with severe ARDS significantly reduces 28-day mortality, 16% prone vs. 32.8% supine.
- Question: Prone positioning may improve the outcome of patients with severe acute respiratory distress syndrome, but is prone position superior to supine position among patients receiving VV ECMO for severe ARDS?

JAMA®

QUESTION Is prone positioning superior to supine positioning among patients receiving venovenous extracorporeal membrane oxygenation (ECMO) for severe acute respiratory distress syndrome (ARDS)?

CONCLUSION Among patients with severe ARDS supported by venovenous ECMO, prone positioning compared with supine positioning did not significantly reduce time to successful weaning of ECMO.

POPULATION

110 Men
60 Women

Patients with severe ARDS (94% COVID-19 related) undergoing venovenous ECMO for less than 48 hours

Median age: **51** years

LOCATION

14
ICUs in France

INTERVENTION

170 Patients randomized

86
Prone ECMO
Placement in a prone position during ECMO for at least 4 16-hour sessions during the first 4 days

84
Supine ECMO
Placement in a supine position for the duration of ECMO

PRIMARY OUTCOME

Successful ECMO weaning within 60 days of randomization

FINDINGS

Successful 60-day ECMO weaning

Prone ECMO
38 of 86 patients

Supine ECMO
37 of 84 patients

No significant difference in ECMO weaning was observed:

Risk difference, **0.1%** (95% CI, −14.9% to 15.2%)

Subdistribution hazard ratio, **1.11**
(95% CI, 0.71 to 1.75); *P* = .64

Schmidt M, Hajage D, Lebreton G, et al; PRONECMO Investigators; REVA Network; International ECMO Network (ECMONet). Prone positioning during extracorporeal membrane oxygenation in patients with severe ARDS: the PRONECMO randomized clinical trial. *JAMA*. Published online November 29, 2023. doi:10.1001/jama.2023.24491

15 minutes after ECMO initiated:

Ventilator settings reduced to
FiO2 50% PEEP 10 RR 10

ECMO settings:
FDO2 100% SGF 3.5 BFR 4.6

Pre-oxygenator gas:
PaO2 36 PCO2 85

Post-oxygenator gas:
PaO2 398 PCO2 52

ECMO Hour 4

Patient's SpO2 80-88%

ABG 7.36/51/43 SaO2 77% from radial arterial line

Ventilator FiO2 increased to 80%

No color change noted in flow lines

Delta p stable at 24

Concern for ECMO cannula positioning – echo repeated

Why is this happening if she is on VV ECMO??

ELSO says……

- In the absence of lung function, VV access can supply all metabolic oxygen requirements.
- The arterial saturation is usually 80-85%, but may be 75-80% (PaO2 45-55). This is ample oxyhemoglobin saturation for normal oxygen delivery if the cardiac output and hemoglobin concentration are adequate to maintain DO2 three times VO2.
- However, the ICU staff may be uncomfortable with arterial saturation under 90, and education regarding oxygen delivery is important. Avoid the temptation to turn up the ventilator settings or FiO2 above rest settings during VV support.

Blood oxygen content (CaO_2)

- Oxygen Content (CaO_2) = SpO_2 x Hgb g/dL x 1.36
- Normal CaO_2 = 20 mL O_2/100 mL blood
- Who has a better CaO_2?
  - Trauma patient with 99% SpO_2 and Hgb 9 g/dL
  - Asthma patient with 82% SpO_2 and Hgb 15 g/dL

Oxygen Delivery (DO_2)

- DO_2 = SpO_2 x Hgb x 1.36 x CO x 10
- Normal DO_2 = 1,000 mL O_2/min (adults)
- To accomplish adequate oxygenation, VV ECMO requires minimum blood flow rates which are determined by CO/ECMO flow, hemoglobin, and oxygen saturation.
  - Monitor for recirculation

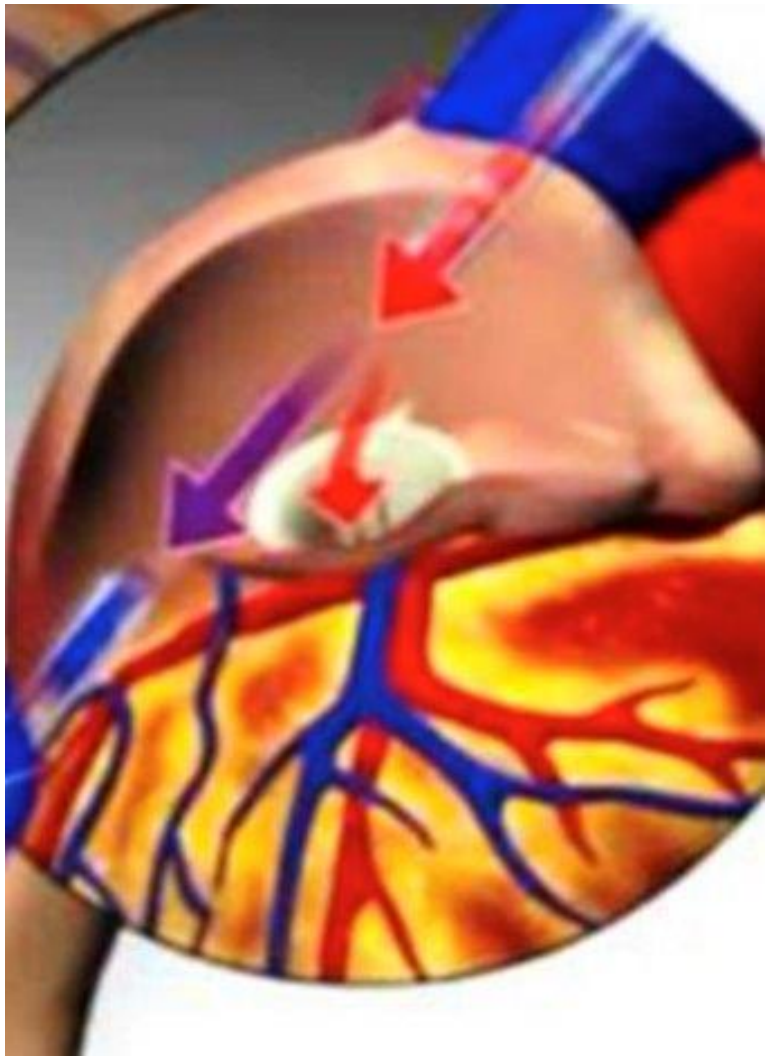
What is Recirculation?

Proportion of oxygenated blood returning to the ECMO circuit immediately after being infused to the patient from the ECMO circuit

Does not share in patient oxygenation

All patients on VV ECMO have some element of recirculation

- Decreased patient arterial SpO2 and PaO2
- Increasing pre membrane SvO2
- No color difference between drainage and return lines



VV ECMO Considerations

Oxygen Consumption (VO2)

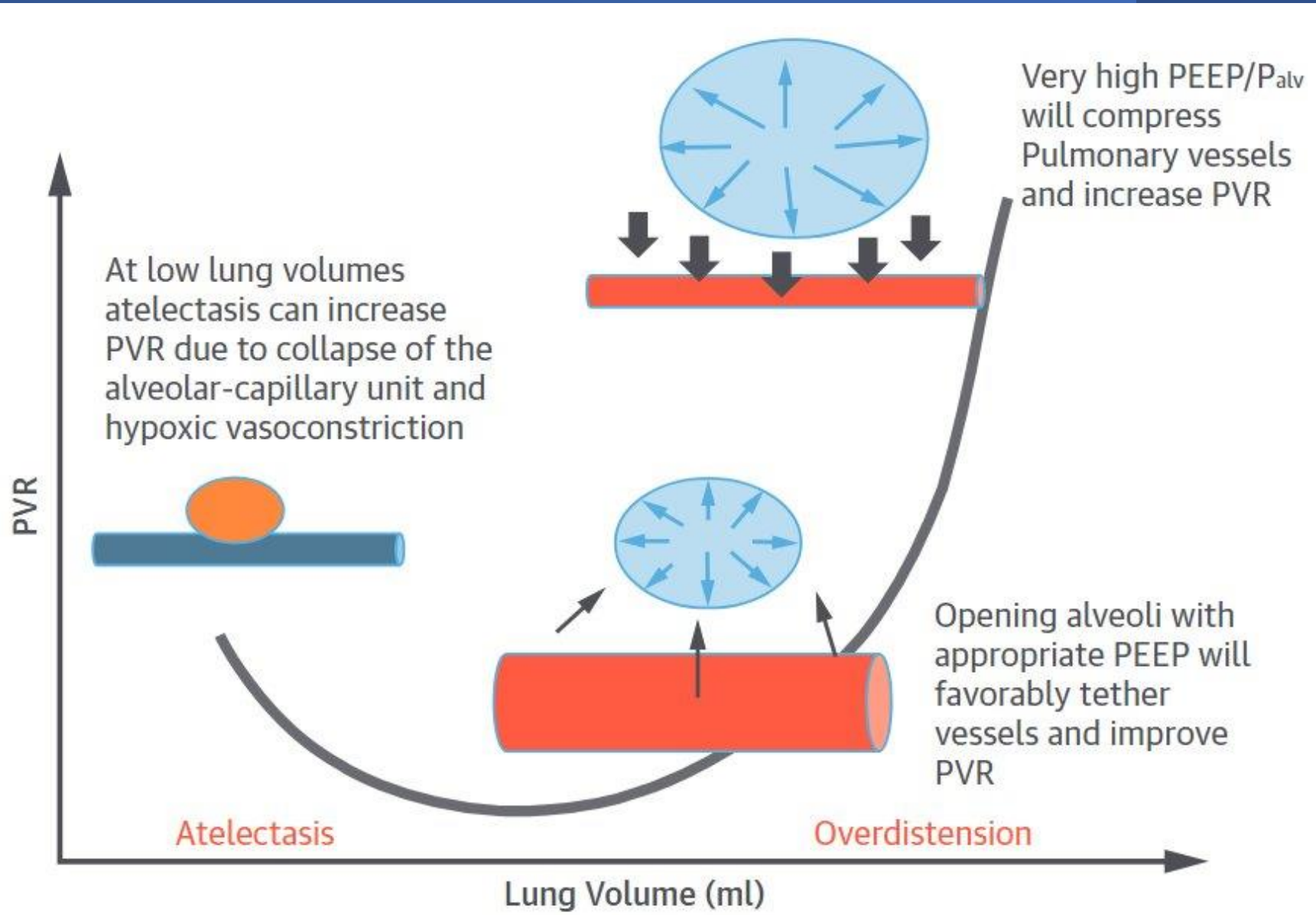
- VO2 = (SpO2 - SvO2) x Hgb x 1.36 x CO x 10
- Normal VO2 = 180-280 mL/min (adults)

Shunt fraction

- QECMO (ECMO BFR)/QCO (patient's CO) = shunt fraction
- Goal is to maintain shunt fraction > 60%
- In hypoxemic patients with adequate QECMO but increased QCO, the shunt fraction will fall resulting in inadequate oxygen delivery

Non-Circuit Interventions for shunt fraction less than 60%

- Consider insufficient analgesia or shivering
- Induce mild hypothermia using ECMO heat exchanger
- Lessen inotropy
- PEEP – can decrease QCO and help to prevent further atelectasis or help to recruit alveoli.


Very high PEEP/Palv will compress Pulmonary vessels and increase PVR
At low lung volumes atelectasis can increase PVR due to collapse of the alveolar-capillary unit and hypoxic vasoconstriction
Opening alveoli with appropriate PEEP will favorably tether vessels and improve PVR
PVR
Atelectasis
Overdistension
Lung Volume (ml)

By the time she left for Montefiore, her SpO2 was 88%.

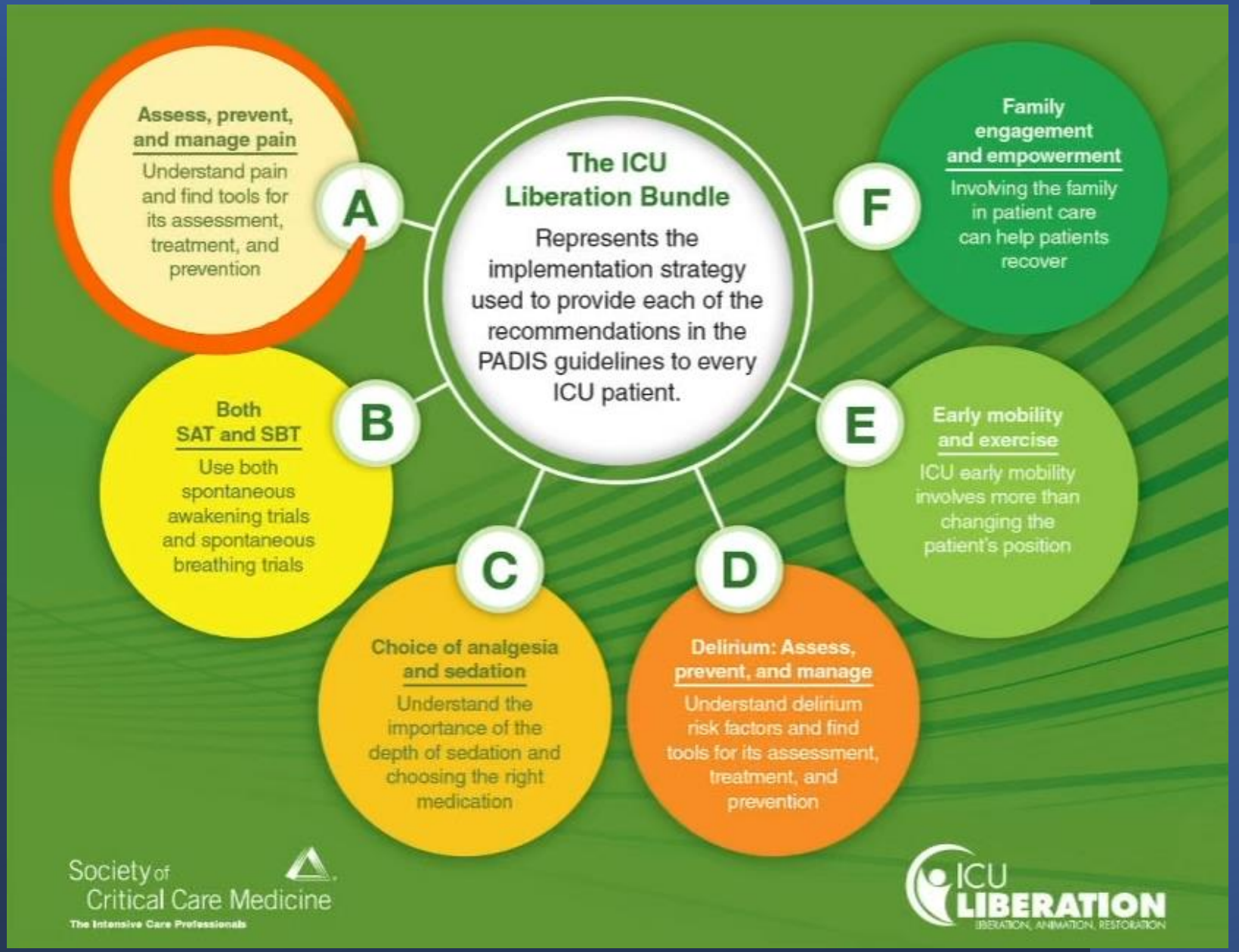
She was removed from ECMO on ECMO Day 8.

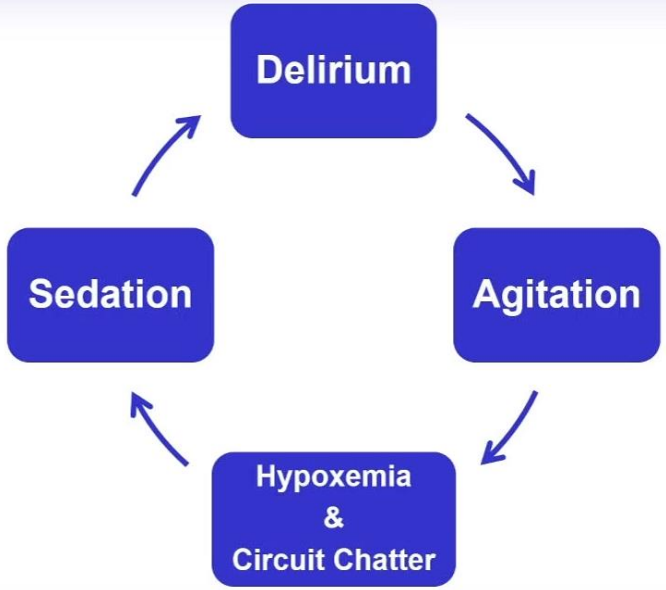
She was trached and a PEG was placed due to MRSA cavitary pneumonia.

Transferred back to UVMMC MICU after 36 days at Montefiore.

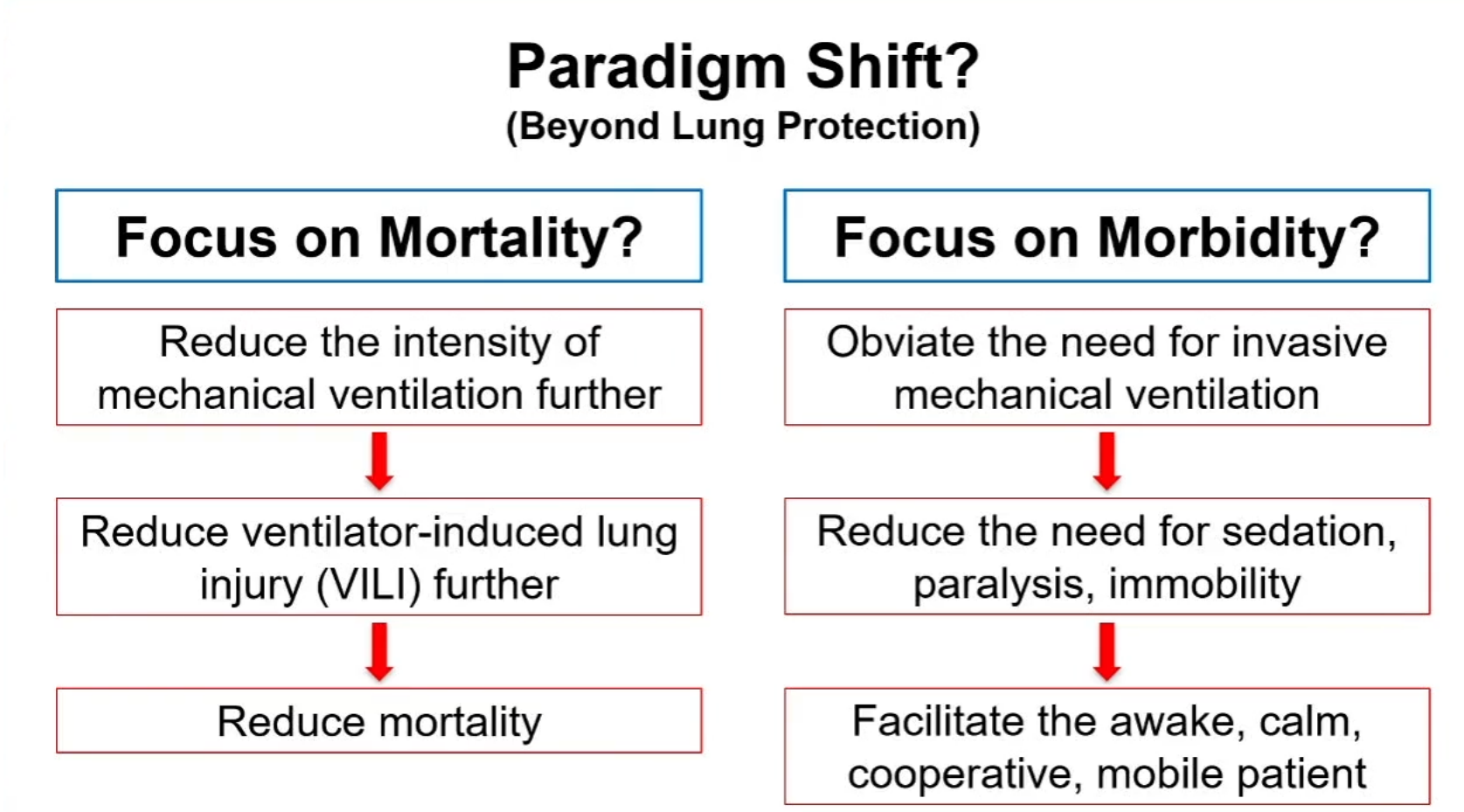
She was then discharged to acute rehab 58 days after being placed on ECMO.

Discharged home 69 days after being placed on ECMO.


The ICU Liberation Bundle
Represents the implementation strategy used to provide each of the recommendations in the PADIS guidelines to every ICU patient.
A
Assess, prevent, and manage pain
Understand pain and find tools for its assessment, treatment, and prevention
B
Both SAT and SBT
Use both spontaneous awakening trials and spontaneous breathing trials
C
Choice of analgesia and sedation
Understand the importance of the depth of sedation and choosing the right medication
D
Delirium: Assess, prevent, and manage
Understand delirium risk factors and find tools for its assessment, treatment, and prevention
E
Early mobility and exercise
ICU early mobility involves more than changing the patient's position
F
Family engagement and empowerment
Involving the family in patient care can help patients recover
Society of Critical Care Medicine
The Intensive Care Professionals
ICU LIBERATION
LIBERATION, ANIMATION, RESTORATION



- Dr. Phillip Mason (September 2025). *VV ECMO to De-Sedate and Mobilize in Hypoxic Respiratory Failure.* ELSO 2025 Annual Meeting, Oxon Hill, MD,



Eddy Fan Beyond EOLIA: New populations and personalized ventilation for VV ECMO

Targeting Patients with PF ratios 80-150

ULTIMATE Pilot Trial

Ultra-Low Tidal Volume Mechanical Ventilation in ARDS Through ECMO

Principal Investigators – Niall Ferguson and Eddy Fan

Sean Bagshaw
Laurent Brochard
Dan Brodie
Marcelo Cypel
Lorenzo Del Sorbo
Ewan Goligher
Terri Hough
Shaf Keshavjee
Arthur Slutsky

On behalf of ULTIMATE Trial Team

ClinicalTrials.gov NCT04832789

UHN ECLS PROGRAM

CIHR IRSC Canadian Institutes of Health Research / Instituts de recherche en santé du Canada

INTERNATIONAL ECMO NETWORK · ECMONet

PROACTIVE Pilot Trial

Prevent Reduced Outcomes in ARF by Transitioning from Invasive Ventilation to ECMO

Principal Investigators – Eddy Fan, Aidan Burrell, Niall Ferguson

Sean Bagshaw
Dan Brodie
Marcelo Cypel
Lorenzo Del Sorbo
Kai-Uwe Eckardt
Ewan Goligher
Carol Hodgson
Shaf Keshavjee
Laveena Munshi
Ken Parhar
Gurmeet Singh
Arthur Slutsky

On behalf of PROACTIVE Study Team

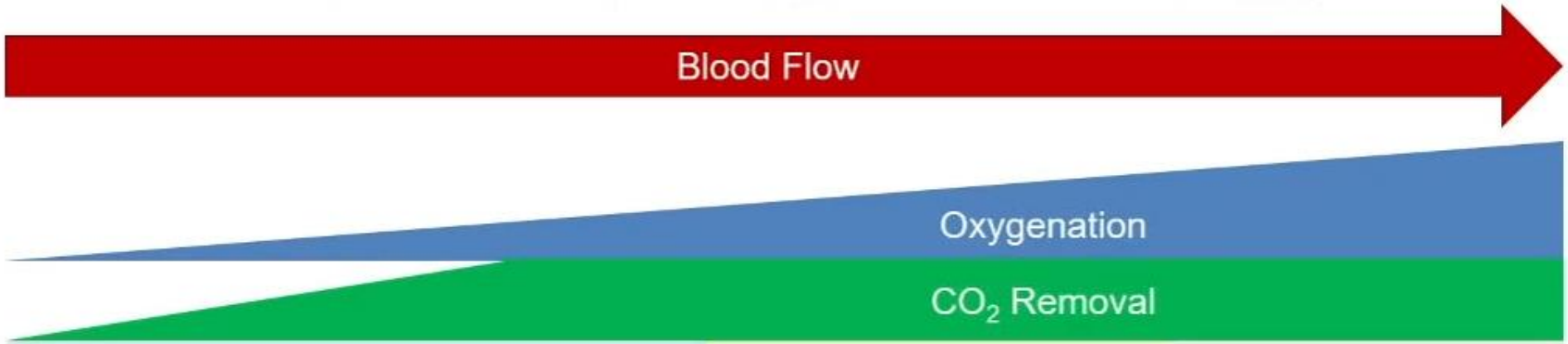
UHN ECLS PROGRAM

anzic research centre

CIHR IRSC Canadian Institutes of Health Research / Instituts de recherche en santé du Canada

INTERNATIONAL ECMO NETWORK • ECMONet

The Continuum of Extracorporeal Support for Acute Respiratory Failure



"Traditional" Labels	Low Flow $ECCO_2R$	High Flow $ECCO_2R$	Low Flow ECMO	Mid Flow ECMO	High Flow ECMO
Focus by Intent	Main Intent - CO_2 removal Reduce MV intensity		Main Intent - CO_2 removal and oxygenation Reduce MV intensity Facilitate awakening, MV liberation, rehabilitation (in select patients)		
Advances Needed Future Research	• Defining optimal patient population • Maximizing CO_2 clearance (e.g. acidification, respiratory electrodialysis) • Pumps and membranes designed for lower flows • Regional anticoagulation		• Defining optimal patient population (e.g., moderate ARDS?) • Optimizing MV settings	• Optimizing MV settings • Defining the role of prone positioning	

What if you completely removed someone's lungs?

[Doctors save Ontario woman's life by removing her lungs | Globalnews.ca]

Coming Soon…

ROMEO

Rest Or Moderate mechanical ventilation during ECMO support

PIs: Brij Patel, Luigi Camporota, Danny McAuley

+

JULIET

Judicious Use of Lung protection In ECMO Trial

PIs: Richard Greendyk and Eddy Fan

ROMEO

PRACTICAL
Platform Randomized Trial

Coming Soon…

PRESSURE

Positive Pressure to Maintain Lung Recruitment during ECMO

PIs: Richard Greendyk, Lorenzo Del Sorbo, and Ewan Goligher

PEEP 10 vs. PEEP 20 vs. PEEP AOP

Standardized

Individualized

PRACTICAL
Platform Randomized Trial


thank
you