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SEOUL NATIONAL UNIVERSITY BUNDANG HOSPITAL

ECMO Basic Concepts and Hybrid mode ECMO

Sung Yoon Lim, MD, PhD

Division of Pulmonary and Critical Care Medicine,
Department of Internal Medicine, Seoul National University College of Medicine
Seoul National University Bundang Hospital

No conflicts of interest or financial disclosures

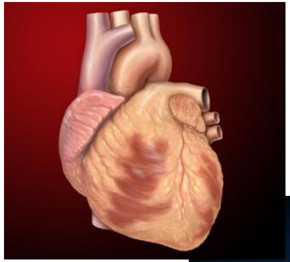
Contents

- Components of Extracorporeal membrane oxygenator (ECMO)
- Reasons for Hypoxemia during VV-ECMO
- Hybrid mode ECMO particularly V-VA ECMO

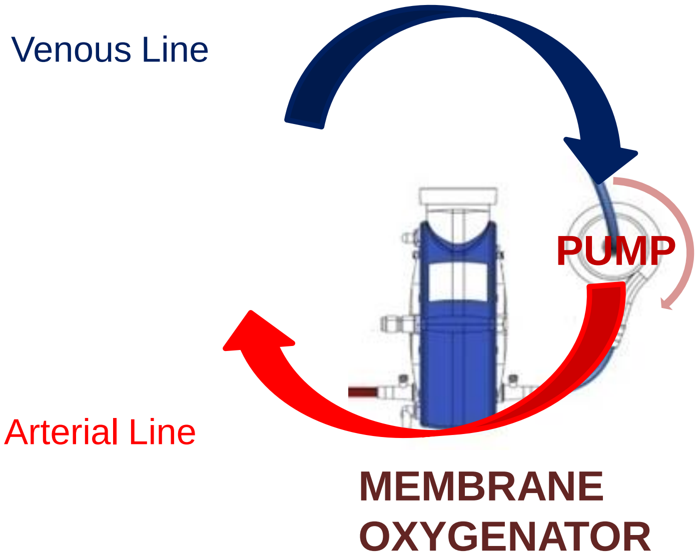
Purpose of the cardiorespiratory system

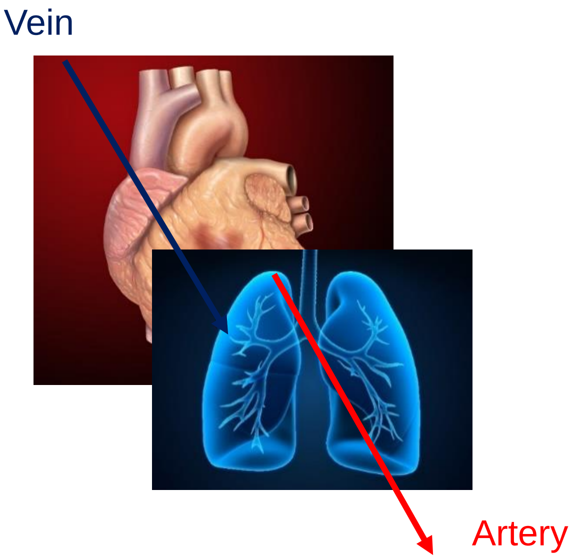
- Brings oxygen into our cells (oxygenation)

- Remove carbon dioxide



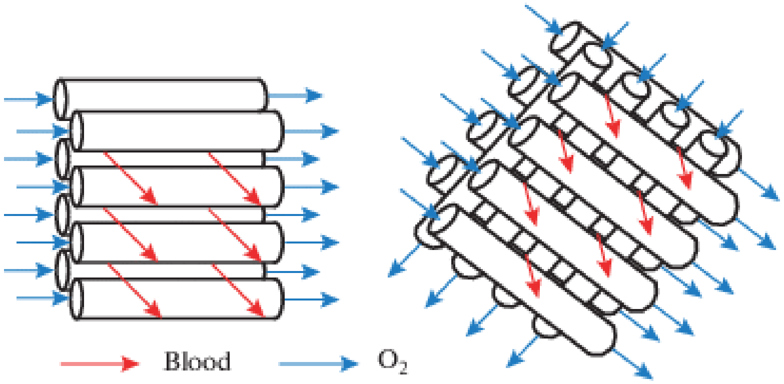
ExtraCorporeal Membrane Oxygenator





ExtraCorporeal **Membrane Oxygenator**

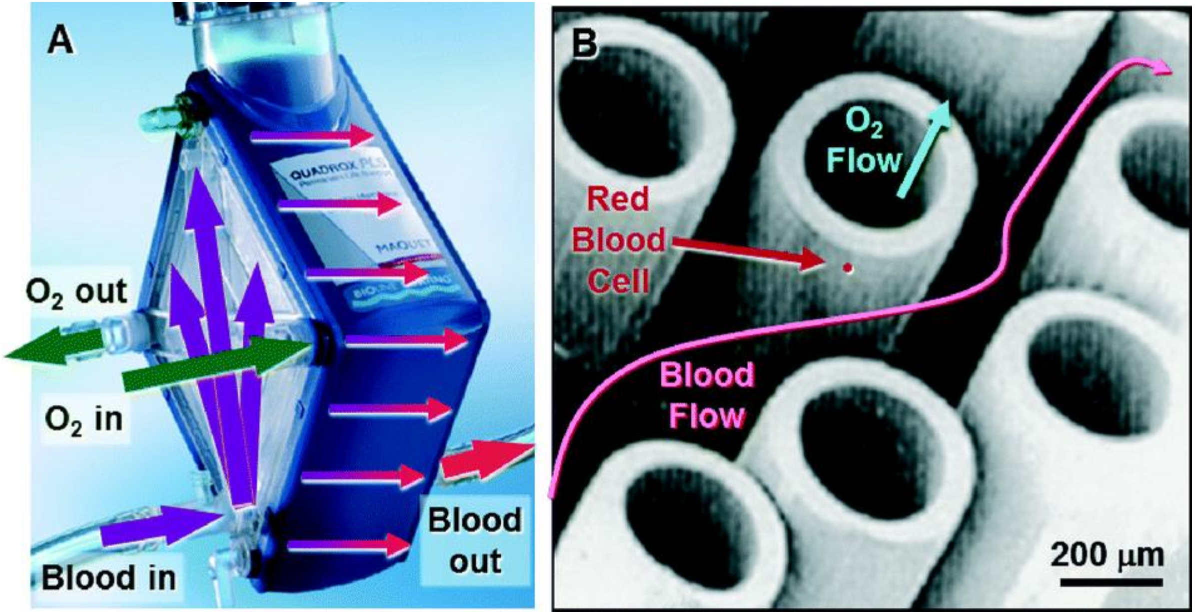
- **thin gas-permeable membrane** separating the blood and gas flows

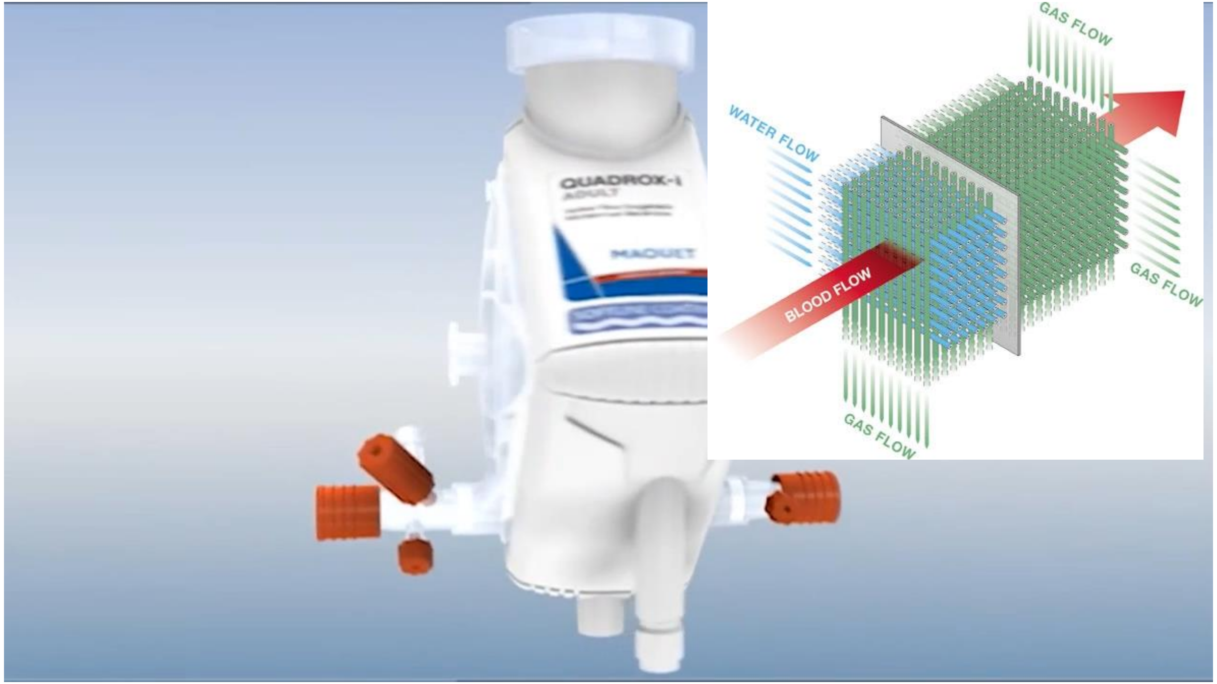


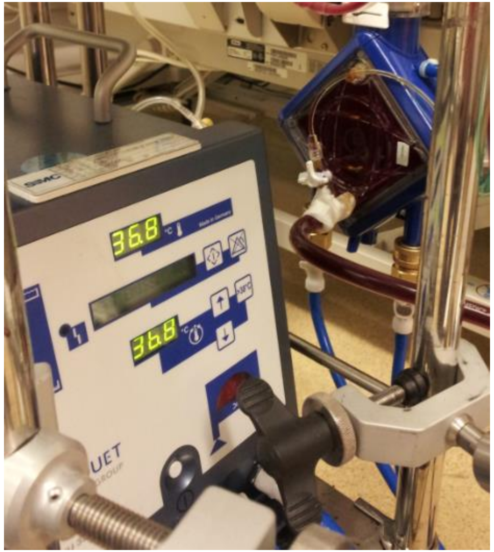
- CO_2 is removed and Oxygen is added

Membranes and Membrane Technologies volume 1, pages201–211(2019)

PMP oxygenator




QUADROX-i
ADULT
MAQUET
WATER FLOW
GAS FLOW
BLOOD FLOW
GAS FLOW
GAS FLOW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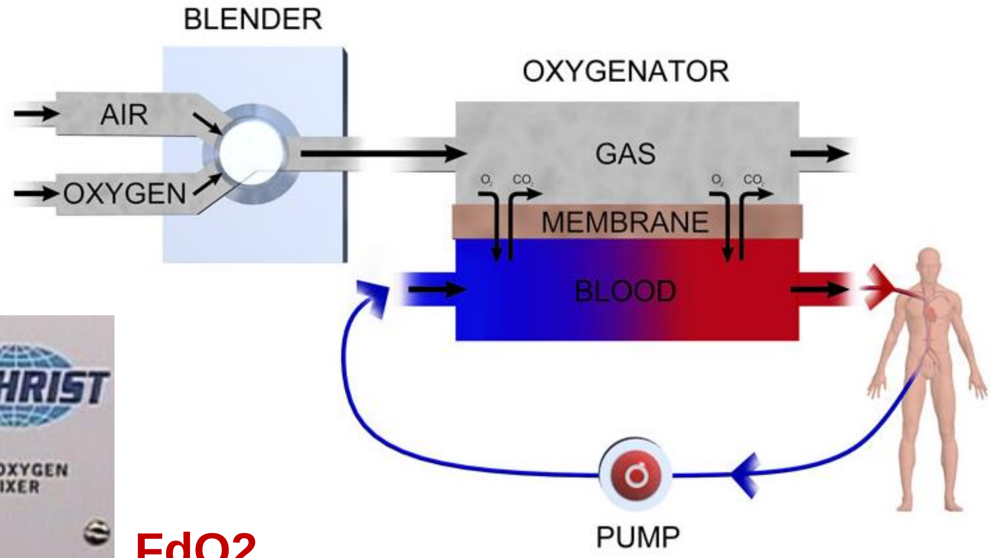
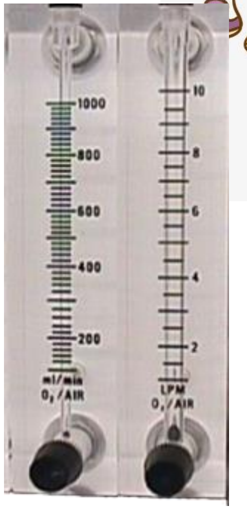
FdO2 and Sweep Gas Flow



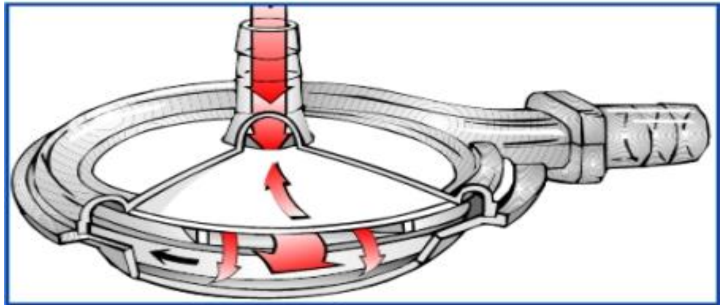
FdO2

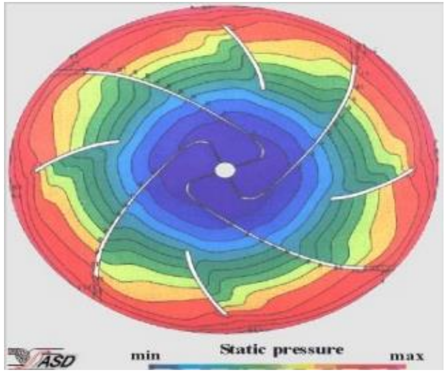


Sweep

gas flow

Centrifugal Pump





Rotation per minute (RPM)

Liter per minute (LPM)

Factors affecting Oxygenation and Decarboxylation

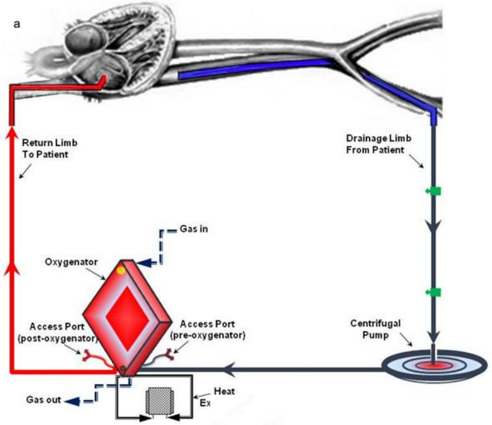
- **Oxygenation: FdO2 and Blood flow**

- **Decarboxylation: Sweep gas flow** and (Blood flow)

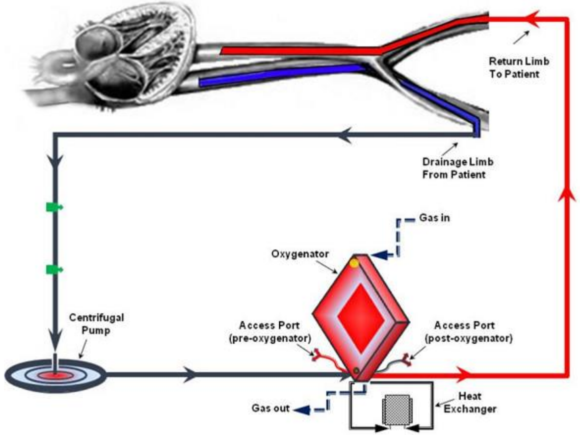
- **Blood flow rates of 1–3 L/min** may be sufficient to fully remove the entire CO2 production of most patients, but insufficient to provide the patient's full O2 consumption

VV vs VA ECMO

- Desaturated blood is **drained via venous cannula**
- Saturated blood is **returned via another vein (VV-ECMO)** or **artery (VA-ECMO)**



VV ECMO



VA ECMO

Ther Apher Dial, Vol. 18, No. 6, 2014

Indications

- acute severe cardiac or pulmonary failure that is **potentially reversible** and **unresponsive to conventional management**

  ***severe neurologic injury, end stage malignancy**

- **VV ECMO**
  - **ARDS**
  - Air leak syndrome
  - Severe Asthma Exacerbation

- **VA ECMO**
  - **Cardiogenic shock**
  - **Cardiac arrest (ECPR)**
  - **Massive Pulmonary Embolism**
  - **Decompensated pulmonary hypertension**

- **bridge to either cardiac or lung transplantation**

ECMO survival rate

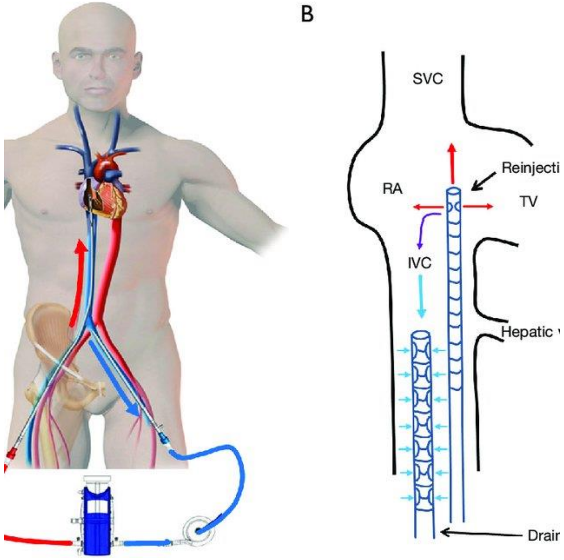
Table 1. ECLS Cases and Survival to Discharge

	No. Cases	Survived ECLS, N (%)	Discharged, N (%)
Neonatal			
Respiratory	29,153	24,488 (84)	21, 545 (74)
Cardiac	6,475	4,028 (62)	2,695 (42)
ECPR	1,336	859 (64)	547 (41)
Pediatric			
Respiratory	7,552	5,036 (67)	4,371 (58)
Cardiac	8,374	5,594 (67)	4,265 (51)
ECPR	2,996	1,645 (55)	1,232 (41)
Adult			
Respiratory	10,601	6,997 (66)	6,121 (58)
Cardiac	9.025	5,082 (56)	3,721 (41)
ECPR	2,885	1,137 (39)	848 (29)
Total	78,397	54,866 (70)	45,345 (58)

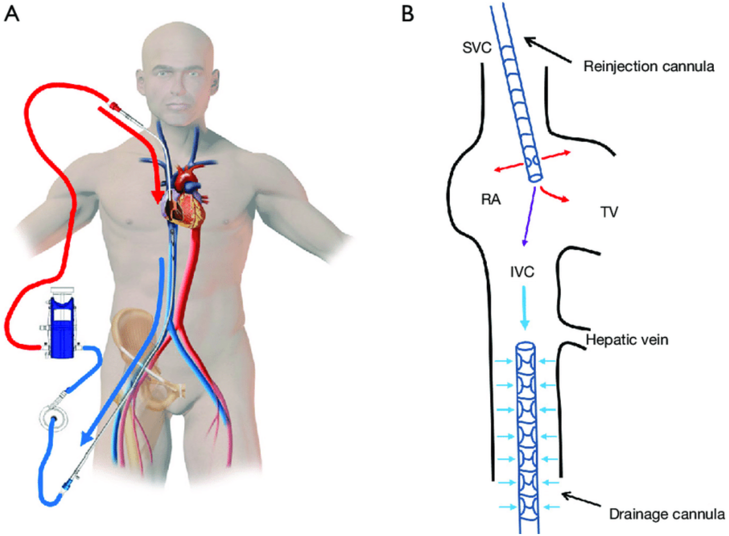
ECLS, extracorporeal life support; ECPR, ECLS to support cardiopulmonary resuscitation.

ASAIO Journal 2017; 63:60–67.

Configurations of VV-ECMO



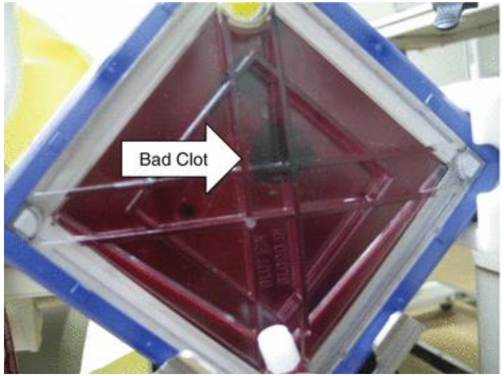
Femoral-**Femoral**



Femoral-**Jugular**

Reason for Hypoxemia during VV-ECMO

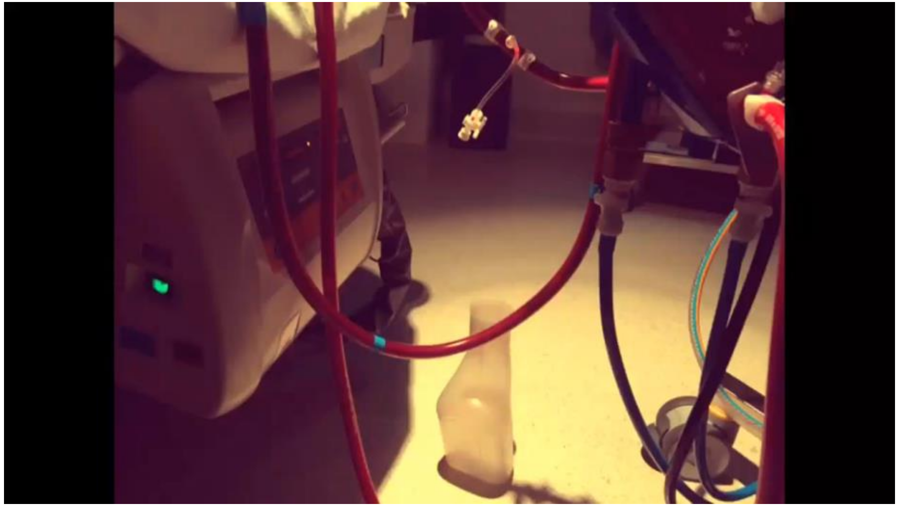
- Oxygenator Dysfunction: Plasma Hb, LDH, **Post membrane(oxygenator) blood gas analysis**



- Insufficient ECMO flow (including Drainage insufficiency)
- Recirculation
- Increased cardiac output and Poor native lung function
- Right Ventricle Failure

Drainage Insufficiency

- Fluctuating Flow rate and Limes Chattering (or Kicking or shaking)



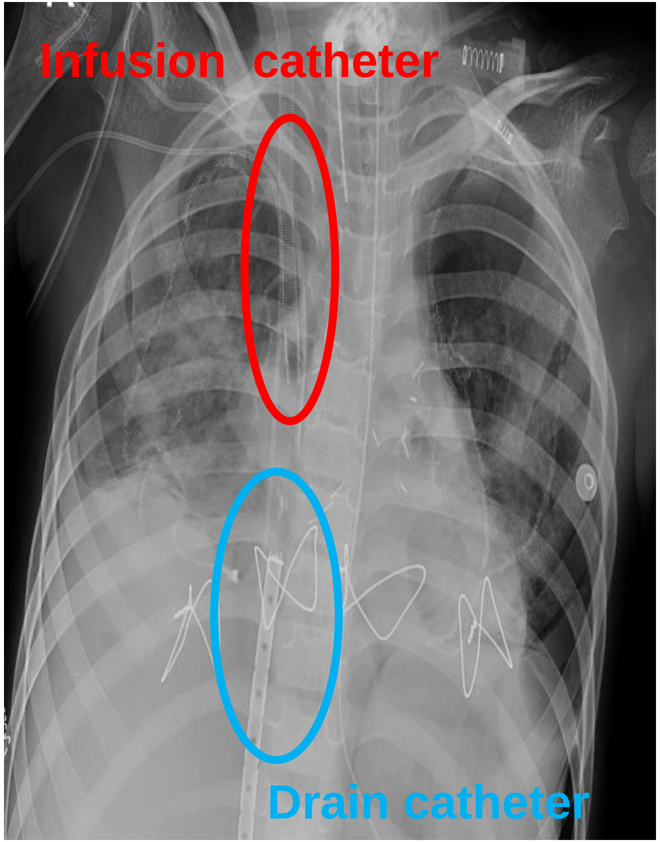
Poiseuille's Law

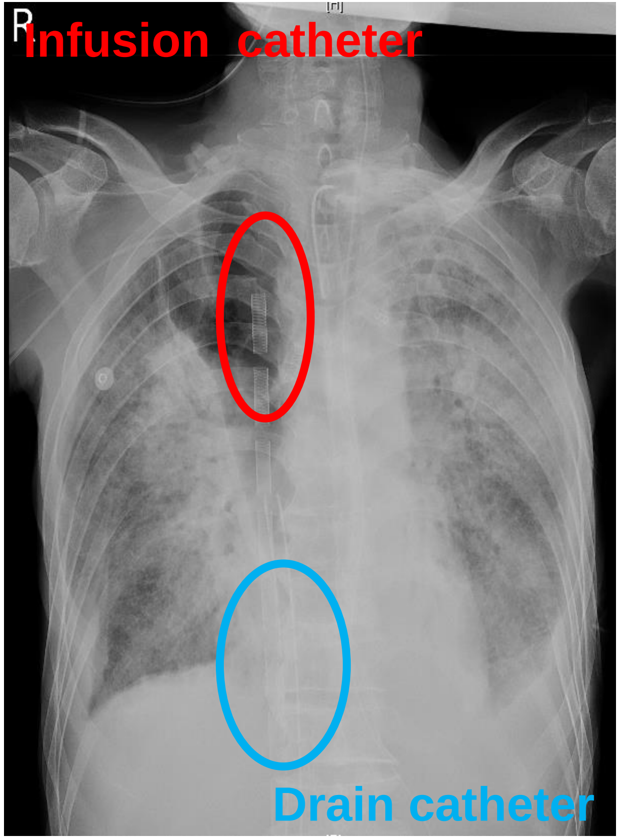
$$Q = \frac{\pi (P_1 - P_2) r^4}{8 \eta L}$$

Flow (litres per second) → Q; Pi → π; Pressure gradient → $(P_1 - P_2)$; Radius → r^4; Viscosity → η; Length → L

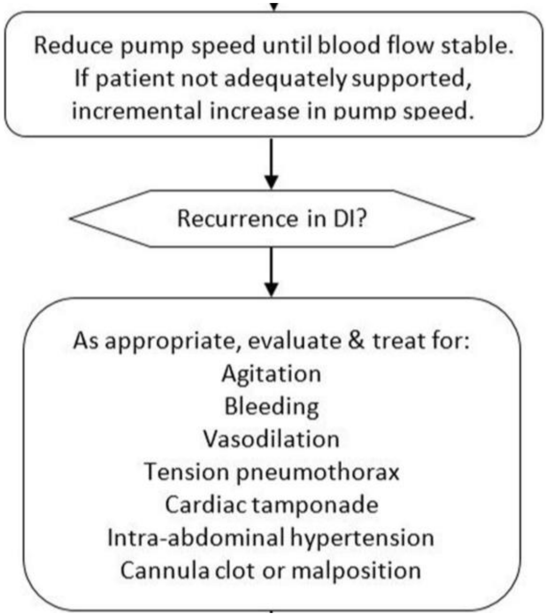
- Flow **increase with** **lumen diameter** and decrease with length

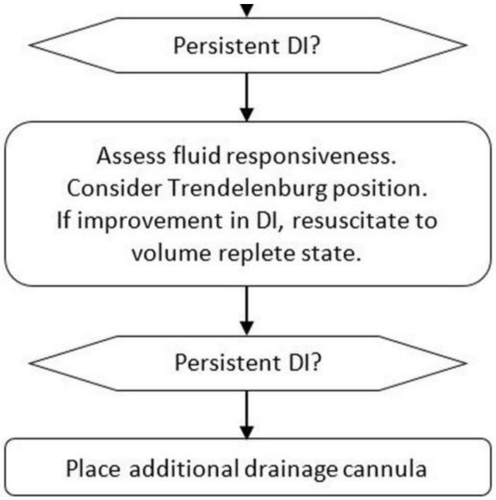
Location of Catheter Tip





Drainage insufficiency management

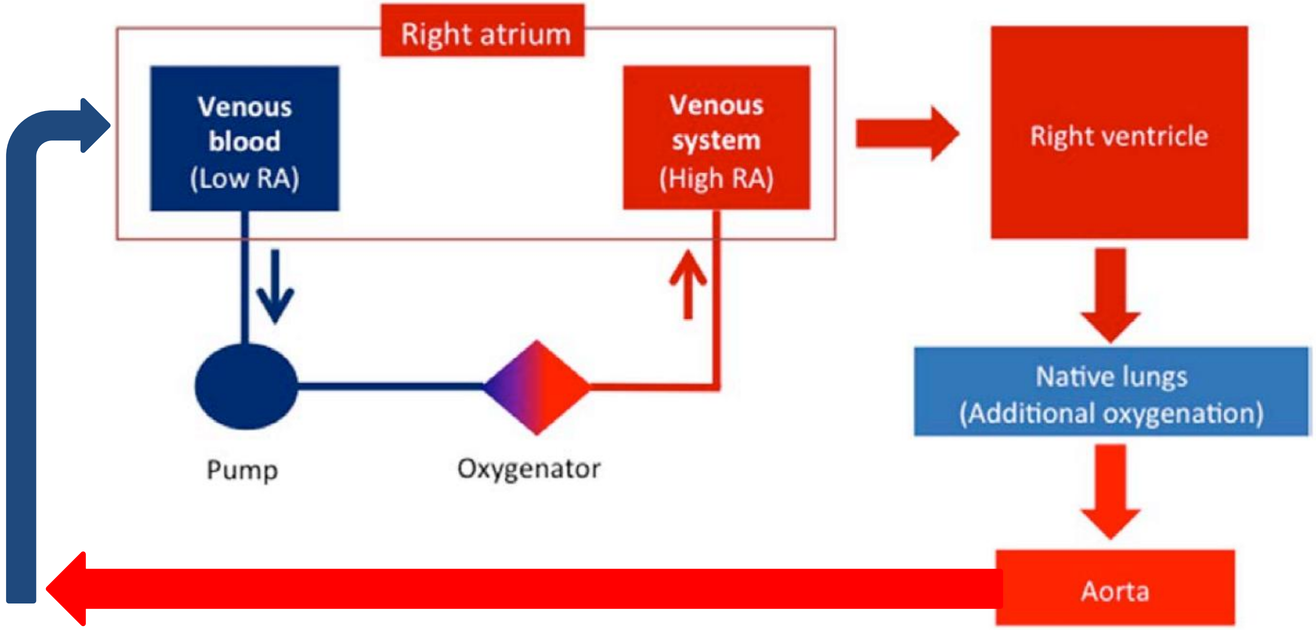




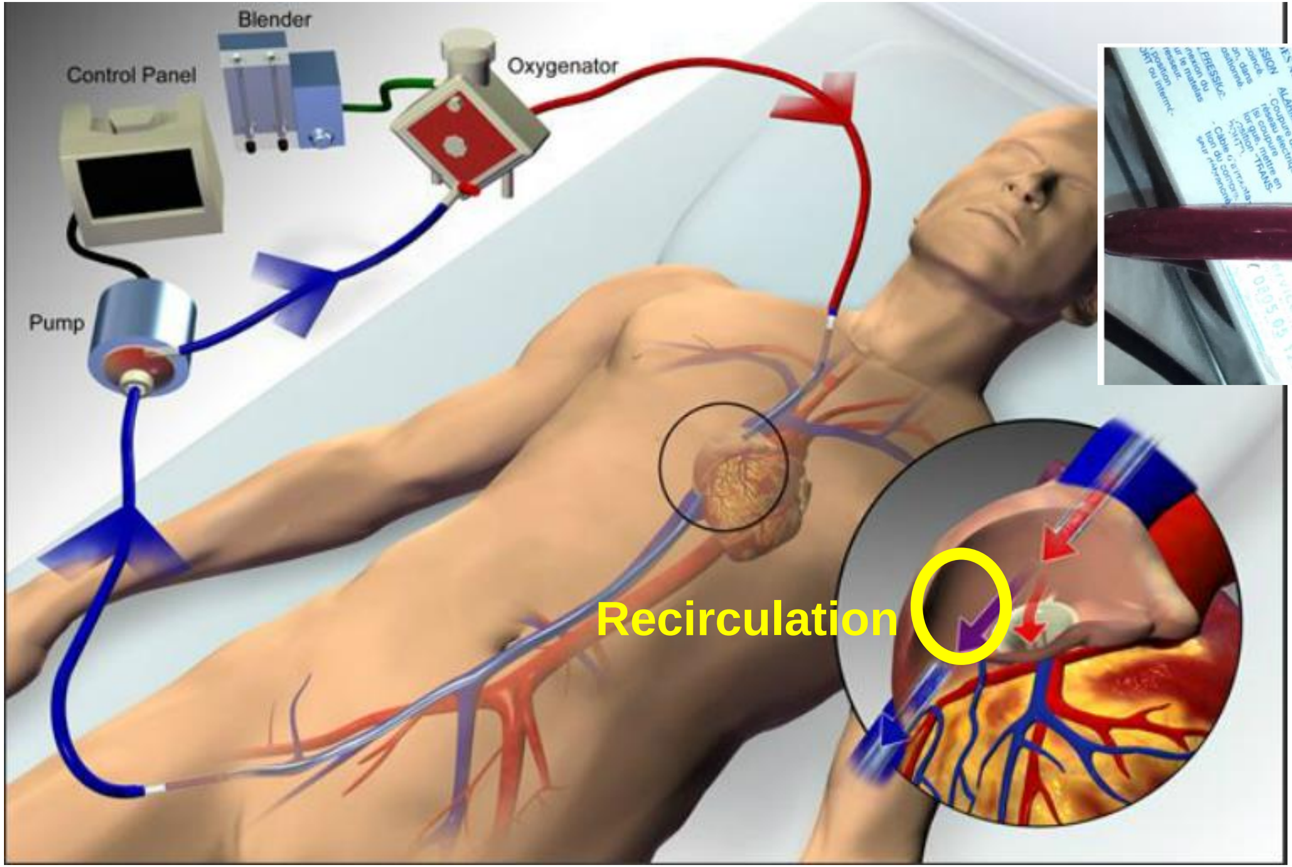
VV-V configuration

Crit Care . 2020 Apr 15;24(1):151.

Recirculation in VV ECMO



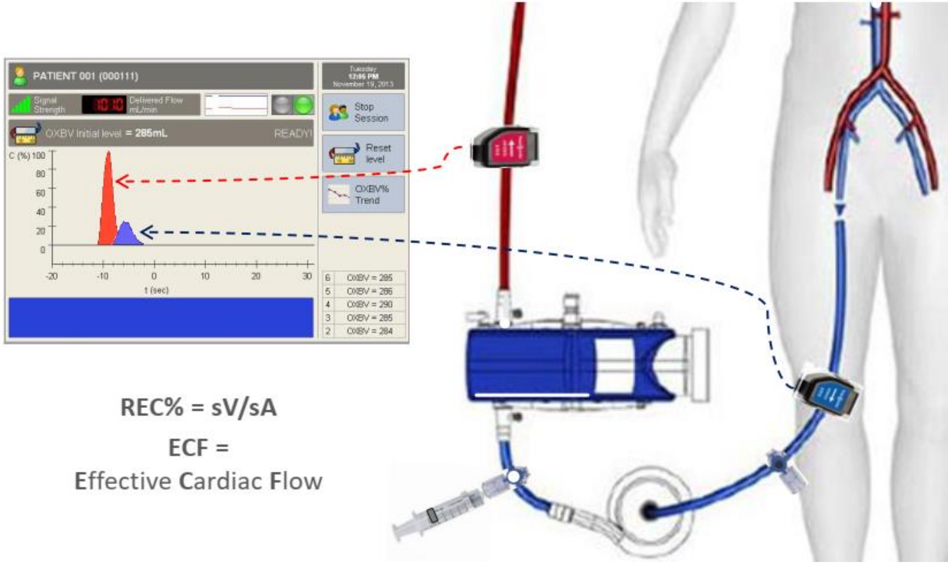
Korean Circ J. 2019 Aug;49(8):657-677.



A.J. Bastin, Heart 2011;97:1701-3

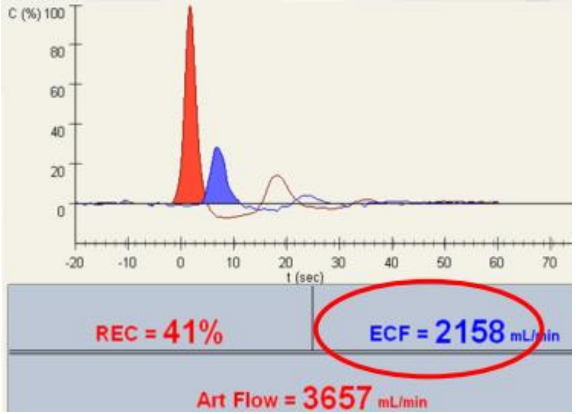
Measurement of Recirculation

- A high Recirculation will raise the Pre-oxygenator Oxygen saturation (SpreO2)
- Recirculation (%) = [(**SpreO2** – SvO2) / (SpostO2 – SvO2)]× 100



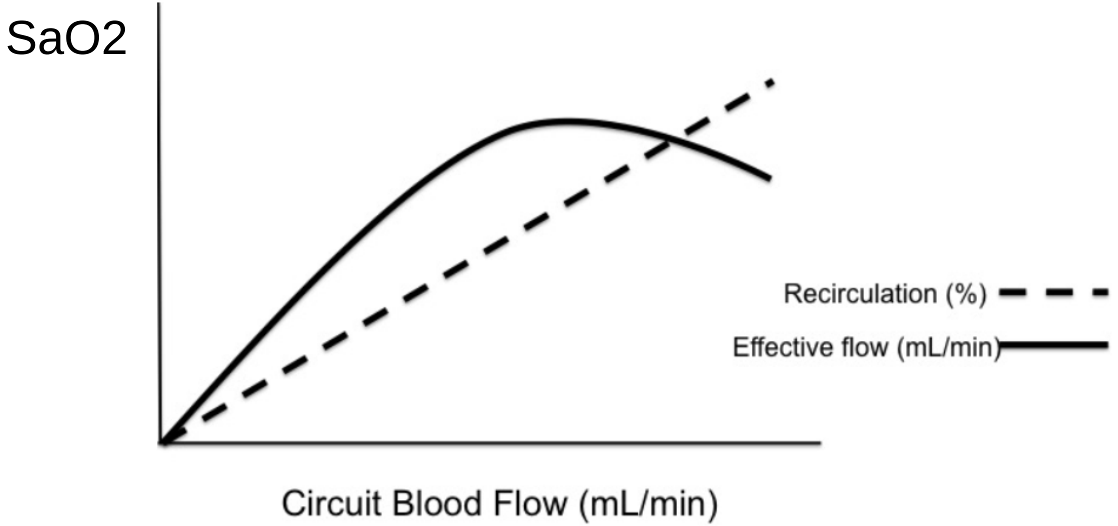
REC% = sV/sA

ECF = Effective Cardiac Flow



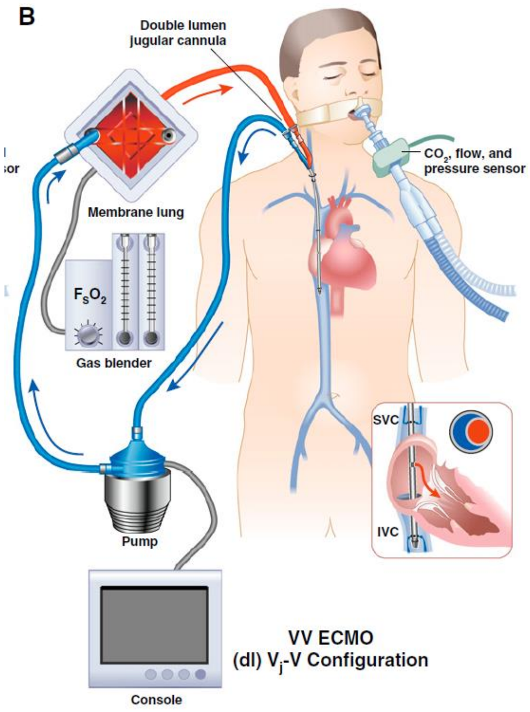
ECMO blood flow and Recirculation

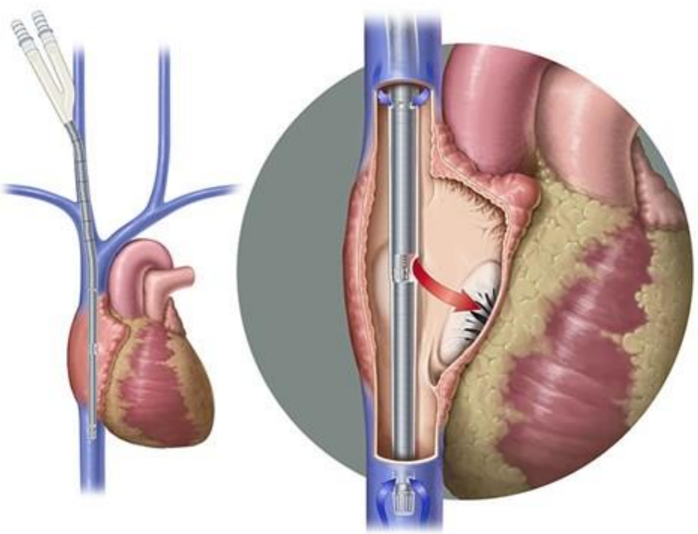
- Recirculation should also be suspected with a paradoxical decrease in systemic saturation with increasing VV ECMO flow



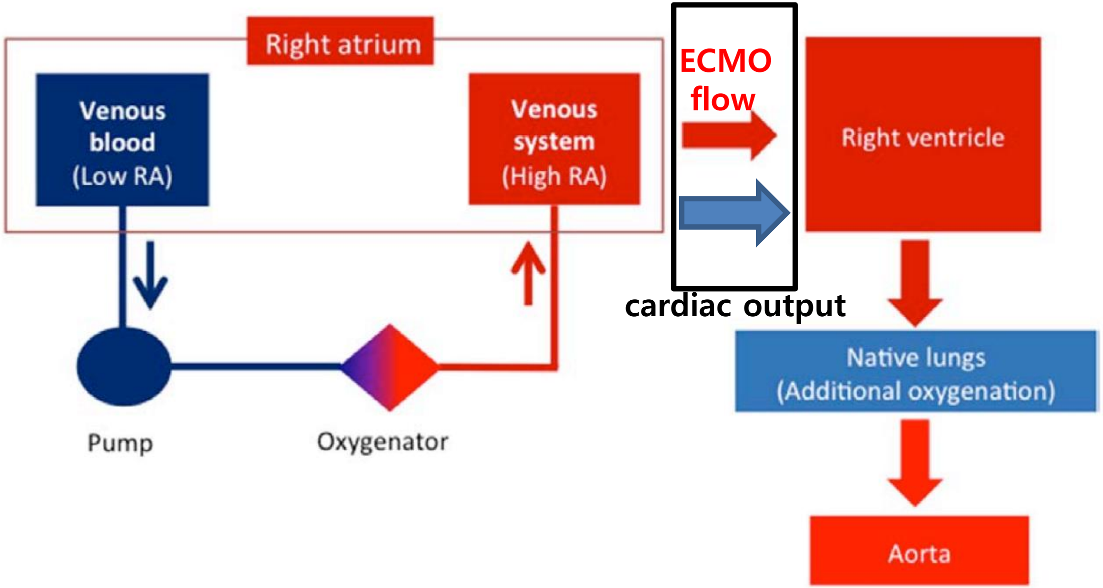
ASAIO J . Mar-Apr 2015;61(2):115-21.

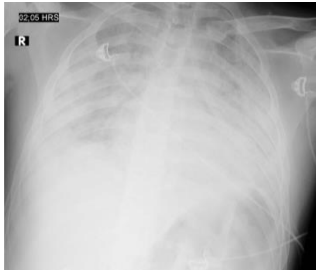
Bi-caval dual-lumen single catheter (DLSC)



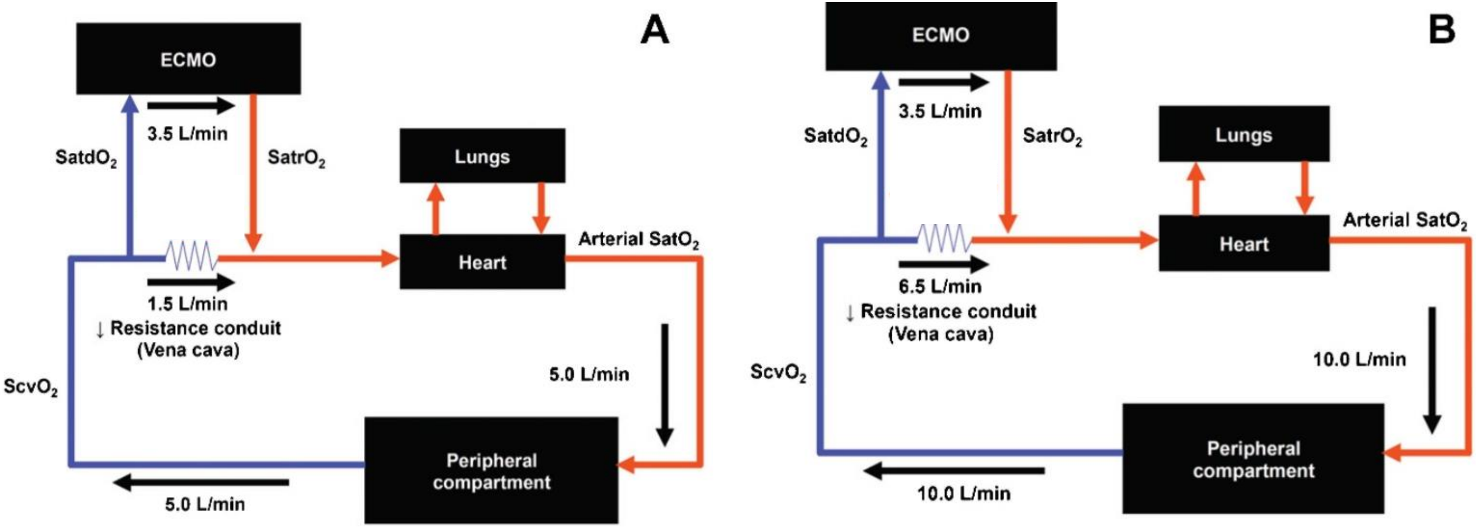


Increased Cardiac output with poor lung function





Korean Circ J. 2019 Aug;49(8):657-677.



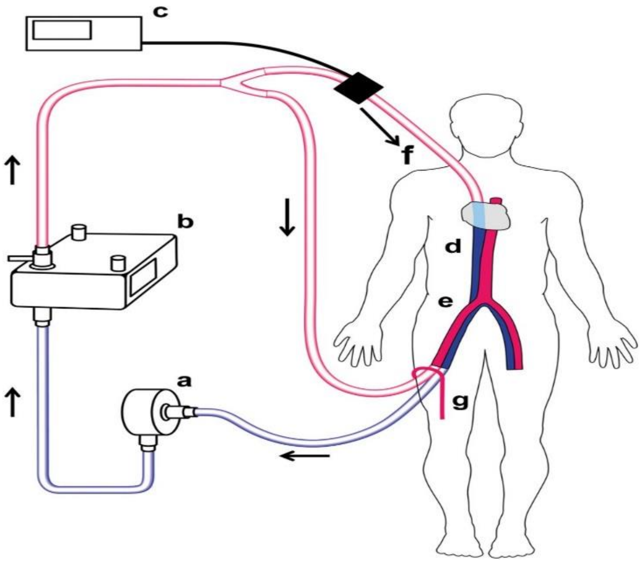
- ECMO flow/cardiac output > 0.6 associated with adequate blood oxygenation
- moderate hypothermia, neuromuscular blockade; pain control and sedation; Short-acting beta-blockers

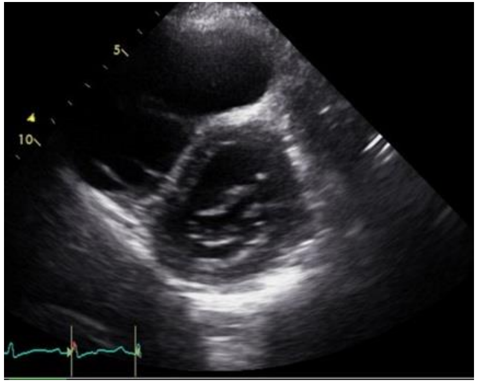
Clinics (Sao Paulo). 2014 Mar;69(3):173-8.

Right Ventricle Failure

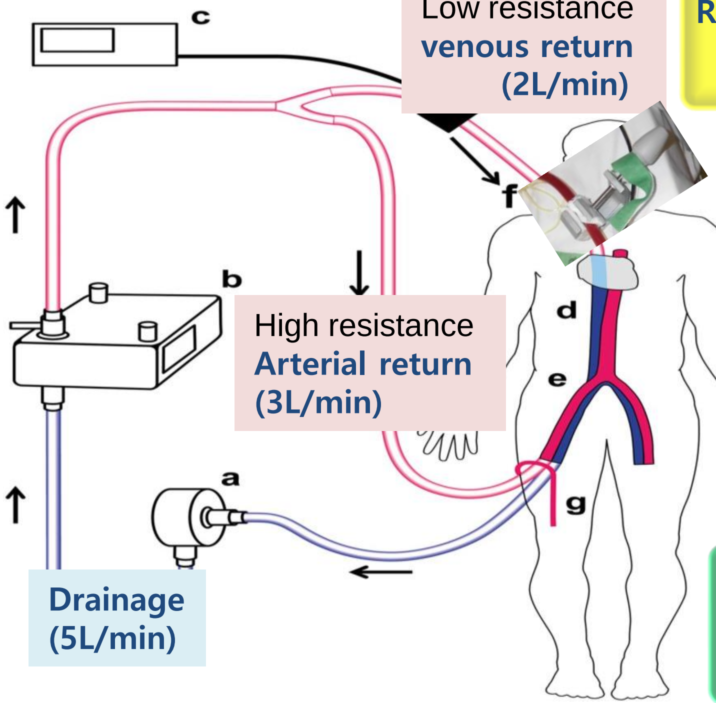
- Associated with underlying lung disease

- Conversion to **V-VA (or V-AV) ECMO**





V-VA ECMO flow management



Low resolution **venous return (2L/min)**

RV decompression and support

Partial clamp : increase resistance
Exact blood flow monitoring

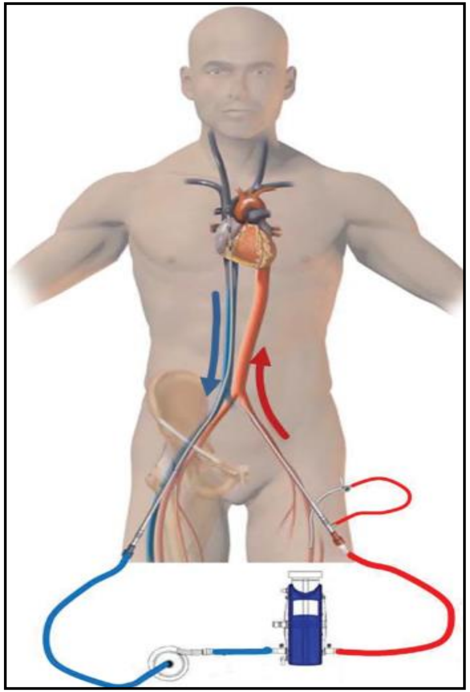
High resistance **Arterial return (3L/min)**

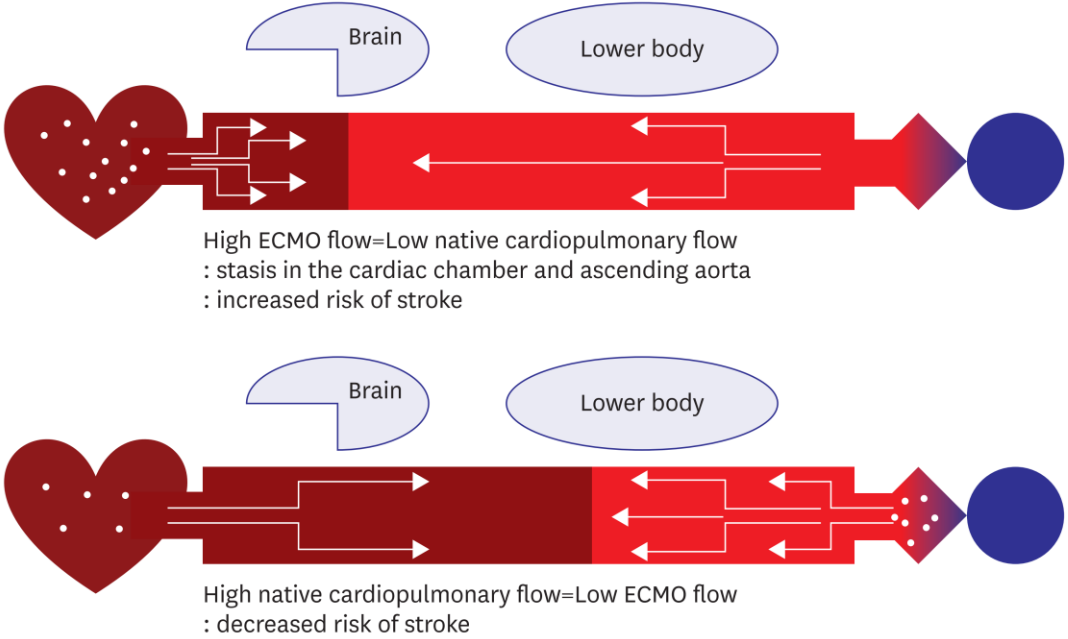
Drainage (5L/min)

Maintain Systemic Oxygenation

Courtesy by Prof. JS Jung

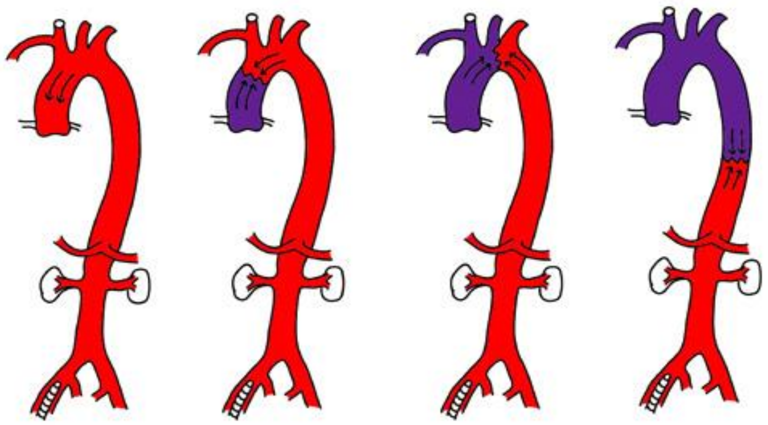
Worsened lung function during VA ECMO

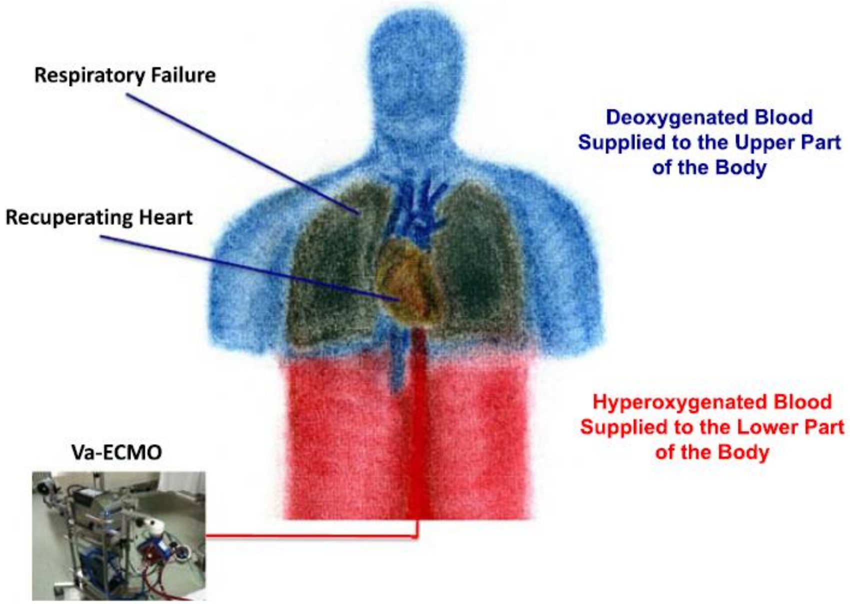




Korean Circ J. 2019 Aug;49(8):657-677.

Harlequin syndrome



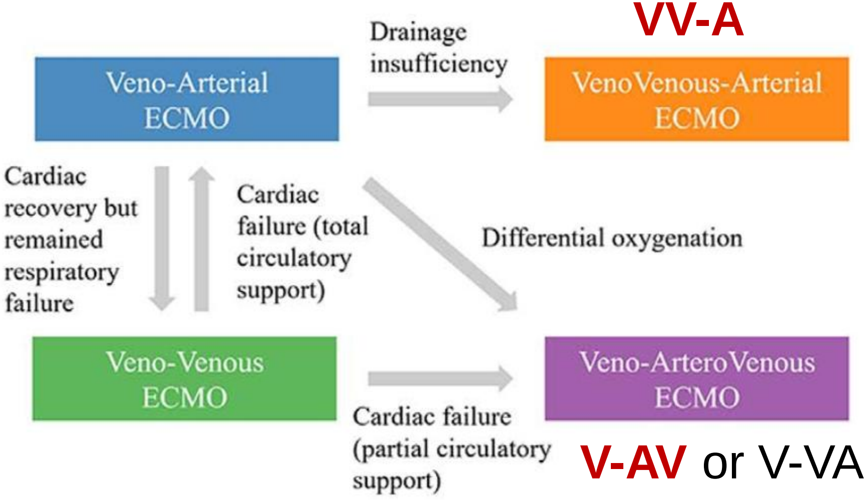


- Conversion to V-AV ECMO

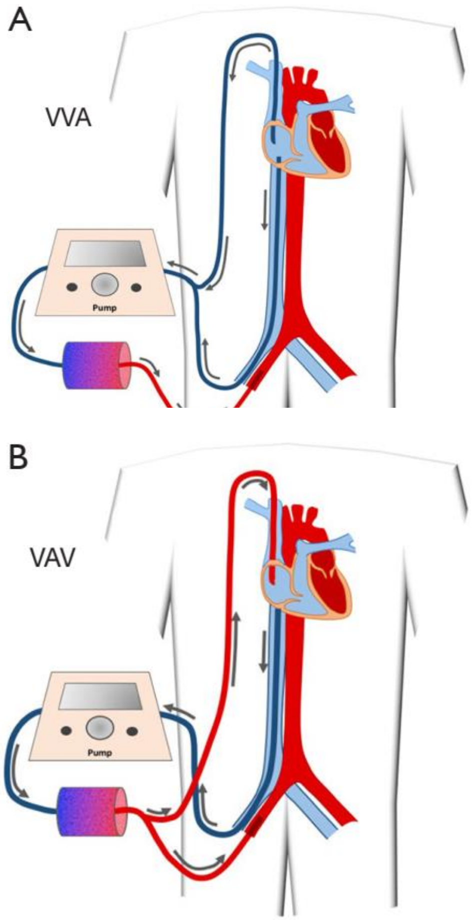
A.J. Bastin, Heart 2011;97:1701-3

Hybrid mode ECMO

VV-A



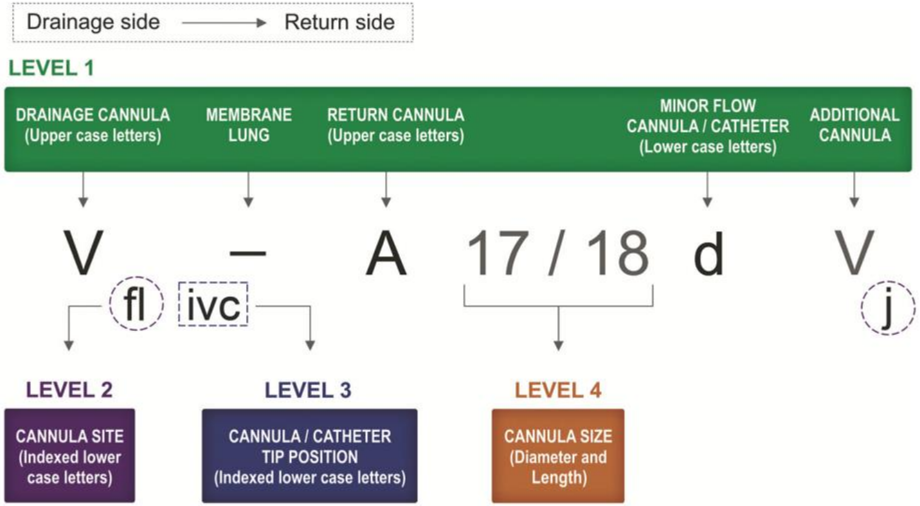
V-AV or V-VA



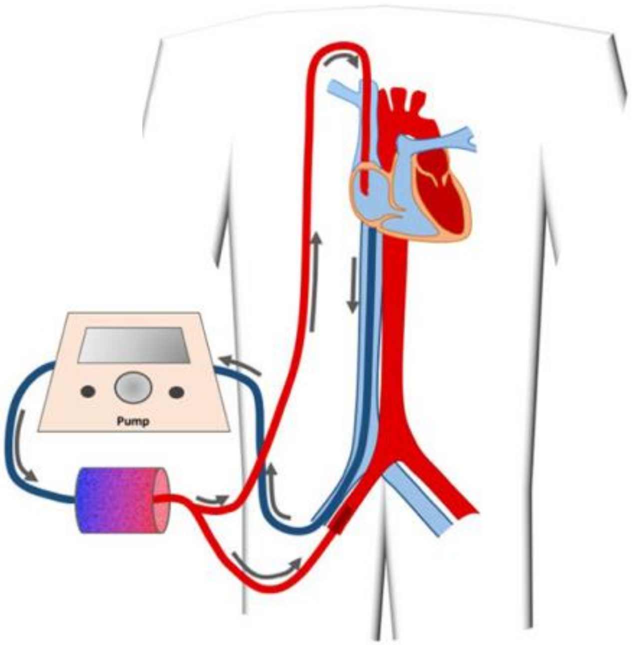
ASAIO Journal: August 3, 2021

RESEARCH Open Access

The ELSO Maastricht Treaty for ECLS Nomenclature: abbreviations for cannulation configuration in extracorporeal life support - a position paper of the Extracorporeal Life Support Organization



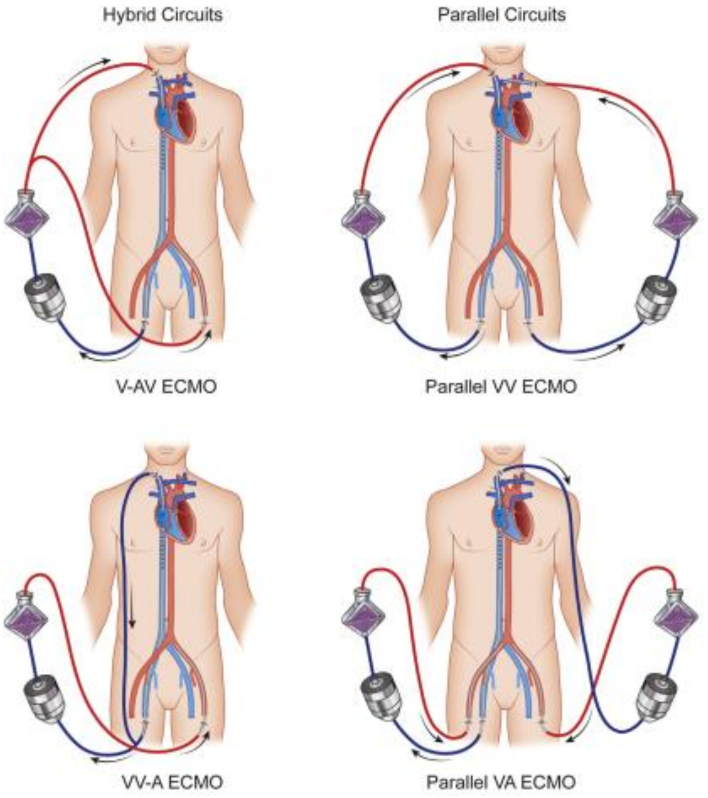
Crit Care, 2019 Feb 8;23(1):36



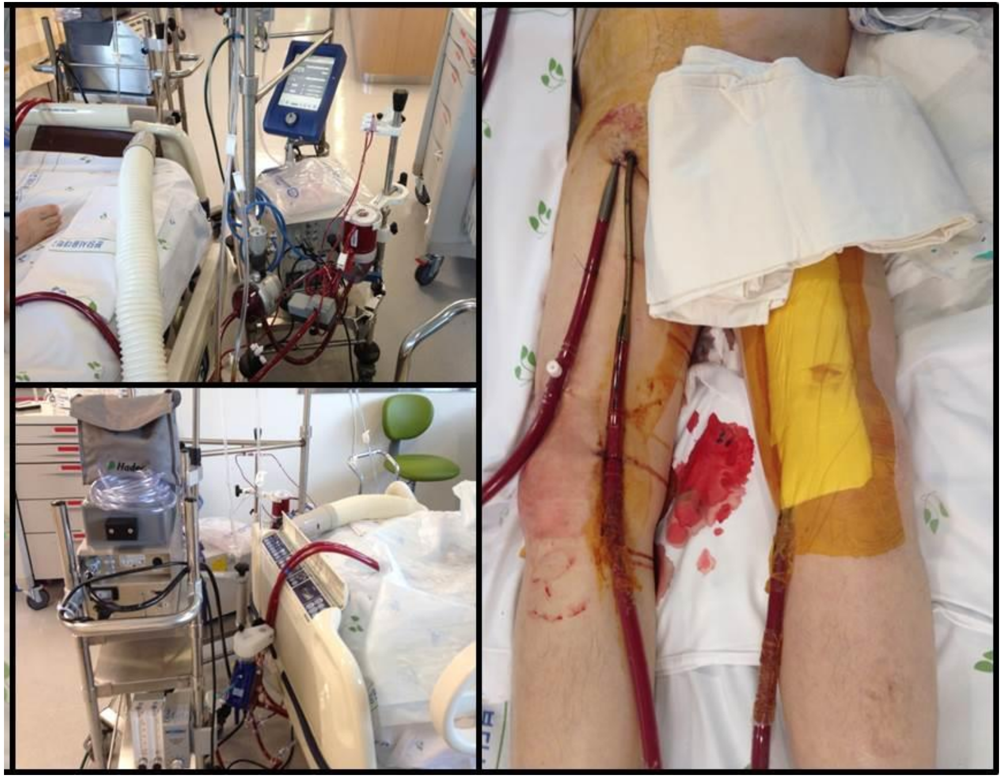
$V23/55_{fr\ IVC}\text{-}V15/15_{ja}A15/23_{fl}d_t$

J Thorac Dis 2018;10(Suppl 5):S707-S715

Hybrid vs Parallel



JCTVS Tech. 2021 Feb 24;8:77-85



The Korean Journal of Critical Care Medicine 2014; 29(3): 207-211.

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Outcomes of Hybrid mode

Study variables	Stöhr et al, 2011[14]	Biscotti et al, 2014[11]	Ius et al, 2015[15]	Werner et al, 2016[16]	Cakici et al, 2017[12]
	Study, y				
No. of adult patients on V-AV	11	21	10	23	12
Initial cannulation strategy: VA/VV/V-AV	3/5/3	2/8/11	1/9/0	7/6/10	9/3/0
Reason for conversion to hybrid ECMO, n	11	21	10	13	12
VV with cardiac failure	1 (9%)	16 (76.1%)	9 (90%)	6 (46%)	3 (25%)
VA with harlequin syndrome	0	1 (4.7%)	1 (10%)	5 (38%)	9 (75%)
Refractory hypoxia	10 (91%)	2 (10%)	0	2 (15%)	0
Other	0	2 (10%)	0	0	0
Outcomes					
Time with hybrid, d	N/A	N/A	N/A	4.58 (IQR, 2.63, 7.46)	6.4 ± 1.8
Time on ECMO, d	7.53 ± 7.21	6.5 ± 5.5	10 ± 4	5.88 (IQR, 4.04, 10.5)	N/A
Mortality	27%	38.1%	50%	61%	33%

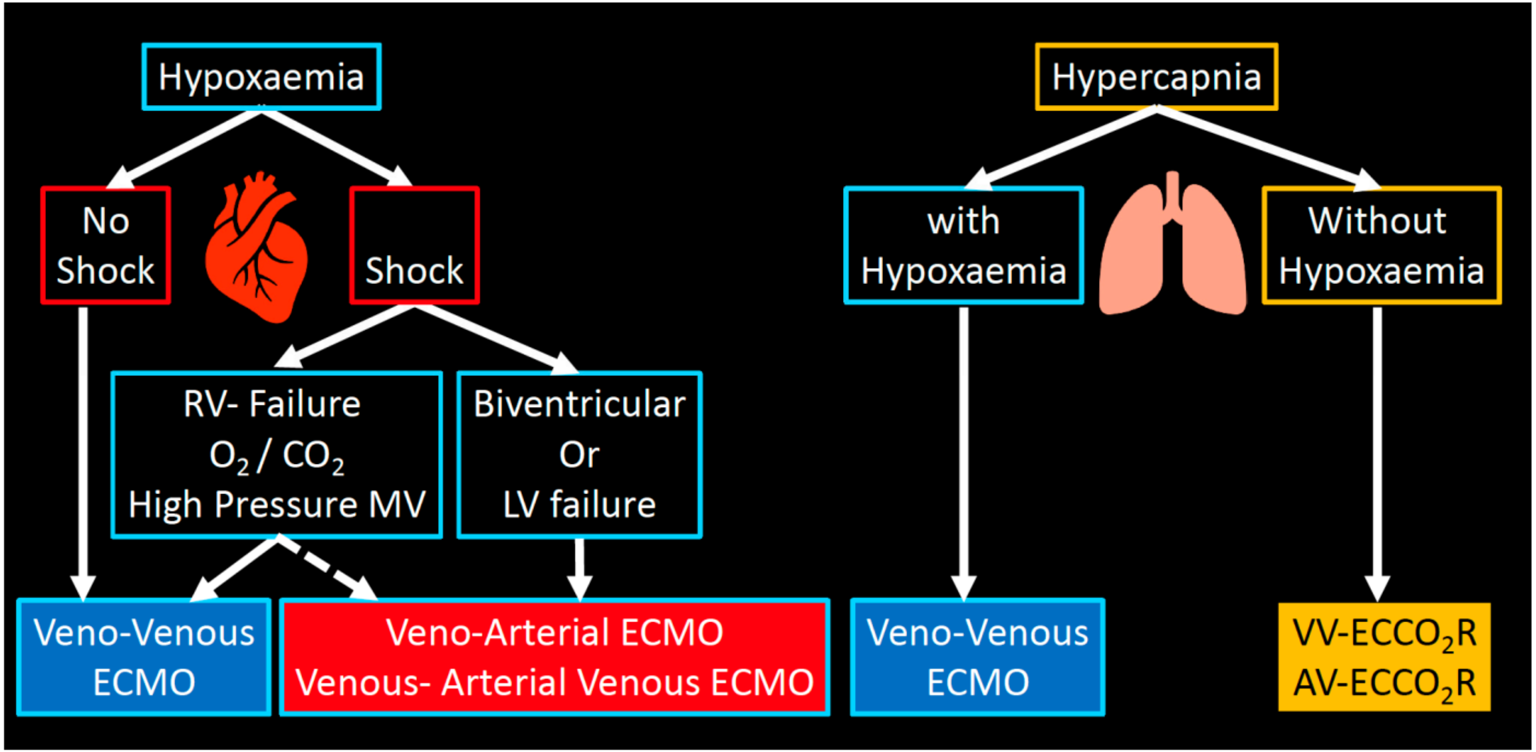
JCTVS Tech. 2021 Feb 24;8:77-85

Summary

- **VV ECMO can support gas exchange in patients with the ARDS**. Venous blood is drained from a central vein via a cannula, pumped through a semipermeable membrane that permits **diffusion of oxygen and carbon dioxide**, and returned via a cannula to a central vein

- Patients with **severe combined cardiopulmonary failure** may require both respiratory and hemodynamic mechanical support. **The VAV or VVA ECMO** may provide sufficient physiological support when traditional VV or VA configurations are inadequate

Summary



Membranes (Basel) . 2021 Mar 22;11(3):225.

Further Readings

Intensive Care Med (2020) 46:2464–2476
https://doi.org/10.1007/s00134-020-06290-1

REVIEW

Extracorporeal life support for adults with acute respiratory distress syndrome

Alain Combes[1,2*], Matthieu Schmidt[1,2], Carol L. Hodgson[3], Eddy Fan[4,5], Niall D. Ferguson[6,7], John F. Fraser[8], Samir Jaber[9,10], Antonio Pesenti[11], Marco Ranieri[12], Kathryn Rowan[13], Kiran Shekar[14,15], Arthur S. Slutsky[16,17] and Daniel Brodie[18,19]

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Abstract
Extracorporeal life support (ECLS) can support gas exchange in patients with the acute respiratory distress syndrome (ARDS). During ECLS, venous blood is drained from a central vein via a cannula, pumped through a semipermeable membrane that permits diffusion of oxygen and carbon dioxide, and returned via a cannula to a central vein. Two related forms of ECLS are used. Venovenous extracorporeal membrane oxygenation (ECMO), which uses high blood flow rates to both oxygenate the blood and remove carbon dioxide, may be considered in patients with severe ARDS whose oxygenation or ventilation cannot be maintained adequately with best practice conventional mechanical ventilation and adjunctive therapies, including prone positioning. Extracorporeal carbon dioxide removal ($ECCO_2R$) uses lower blood flow rates through smaller cannulae and provides substantial CO_2 elimination (~ 20–70% of total CO_2 production), albeit with marginal improvement in oxygenation. The rationale for using $ECCO_2R$ in ARDS is to facilitate lung-protective ventilation by allowing a reduction of tidal volume, respiratory rate, plateau pressure, driving pressure and mechanical power delivered by the mechanical ventilator. This narrative review summarizes physiological concepts related to ECLS, as well as the rationale and evidence supporting ECMO and $ECCO_2R$ for the treatment of ARDS. It also reviews complications, limitations, and the ethical dilemmas that can arise in treating patients with ECLS. Finally, it discusses future key research questions and challenges for this technology.

Keywords: Acute respiratory failure, Extracorporeal membrane oxygenation, Mechanical ventilation, Outcome

Introduction

In a prospective international study conducted in 459 ICUs across 50 countries, acute respiratory distress syndrome (ARDS) represented 10.4% of total intensive care unit (ICU) admissions [1]. Over the past two decades, in-hospital mortality from ARDS has remained very high at approximately 40% [1]. Despite strong experimental and clinical evidence [2] that lung protection improves outcomes in ARDS, it remains underutilized [1].

With the ultimate goal of protecting the injured lung, and improving oxygenation, there has been increasing adoption of extracorporeal life support (ECLS) in adult patients with very severe ARDS. Advances in supportive care, innovations in technologies and insights from

*Correspondence: alain.combes@aphp.fr
[1] Sorbonne Université, INSERM, UMRS_1166-ICAN, Institute of Cardiometabolism and Nutrition, 75013 Paris, France
Full author information is available at the end of the article
Alain Combes, Matthieu Schmidt, and Daniel Brodie equally contributed to the work.
Alain Combes, Arthur Slutsky, and Daniel Brodie are co-senior authors.

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ASAIO Journal 2021 Guidelines

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#

Reviewers: Nicholas Barrett, MBBS,** Matthieu Schmidt,†† Thomas Mueller, MD,‡‡ Alain Combes, MD, PhD††
Kiran Shekar, MBBS, PhD§§

***Disclaimer:* The use of venovenous extracorporeal membrane oxygenation (VV ECMO) in adults has rapidly increased worldwide. This ELSO guideline is intended to be a practical guide to patient selection, initiation, cannulation, management, and weaning of VV ECMO for adult respiratory failure. This is a consensus document which has been updated from the previous version to provide guidance to the clinician.**

Key Words: venovenous ECMO, extracorporeal life support, ventilatory management, mechanical ventilation, circuit management, fluid management, cannulation/decannulation

INTRODUCTION

The use of venovenous extracorporeal membrane oxygenation (VV ECMO) among adults is rapidly increasing worldwide. By 2020, the Extracorporeal Life Support Organization (ELSO) Registry had recorded >24,000 cases of adult respiratory ECMO use among 282 centers internationally. Venovenous extracorporeal membrane oxygenation is a therapy in the management of respiratory failure in multiple guidelines. Extracorporeal Life Support Organization provides guidelines to inform and guide the initiation, use, management, and weaning of VV ECMO for adult patients with respiratory failure.

In this statement, we provide recommendations for the clinical management of adult patients supported with VV ECMO. Although these recommendations were not developed using a formal, reproducible methodology, we have reviewed English-language publications in PubMed, where available, in developing the guidance provided herein. As this is the fifth revision of these adult respiratory VV ECMO guidelines, we expect that it will be revised at regular intervals as new information, devices, treatments, and techniques become available. As with all guidelines, this statement should not replace the medical judgment and the multidisciplinary decision to establish and manage a patient's ECMO support strategy. A number of important management principles and recommendations are made in other ELSO guidelines, including: circuit components, patient selection, patient and circuit management, patient sedation, and nutrition. This document contains numerous additional literature references, organized by topic, found in Supplemental Digital Content 1, http://links.lww.com/ASAIO/A626.

From the *Division of Cardiothoracic Surgery, Department of Surgery, University of Utah Health, Salt Lake City, Utah; †Division of Emergency Medicine, Department of Surgery, University of Utah Health, Salt Lake City, Utah; ‡Division of Pulmonary, Allergy and Critical Care Medicine, Department of Medicine, Columbia College of Physicians and Surgeons/New York-Presbyterian Hospital, New York, New York; §Department of Anesthesiology and Critical Care, Department of Emergency Medicine, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania; ¶Critical Care Department, Hospital Universitario 12 de Octubre, Madrid, Spain; ||Department of Anesthesiology and Critical Care, University of Pennsylvania, Philadelphia, Pennsylvania; #Interdepartmental Division of Critical Care Medicine, University of Toronto, University Health Network and Sinai Health System, Toronto, Canada; **St. Thomas Hospital London; ††University of Paris, Paris, France; ‡‡St. Joseph Hospital, Berlin, Germany and ;§§Adult Intensive Care Services, The Prince Charles Hospital, Brisbane, Queensland, Australia.

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J.E.T. had full access to all the sections in the guideline and takes responsibility for the integrity of the submission as a whole, from inception to published article. J.E.T., D.A., and E.F. conceived guideline design; all authors drafted the work; all authors revised the article for important intellectual content, had final approval of the work to be published, and agree to be accountable to for all aspects of the work.

This version replaces ELSO Guidelines for Adult Respiratory Failure Version 1.4 from August 2017.

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Correspondence: Joseph E. Tonna, MD, MS, Division of Cardiothoracic Surgery, Division of Emergency Medicine, Department of Surgery, University of Utah Health, Salt Lake City, Utah. Email: joseph.tonna@hsc.utah.edu. Twitter: @JoeTonnaMD

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