ExtraCorporeal Carbon Dioxide Removal ($ECCO_2R$)

An overview

Presented by: Dr Atiyeh Ghassemi

(MD, Pediatric Critical Care Medicine Fellow)

5th Pediatric Critical Care Congress

(Shiraz, Iran)

Date: 2024/10/25

What is ECCO2R?

- Definition: A form of ECLS that removes CO_2 across a gas exchange membrane without influencing oxygenation.
- Indications :
  - ARDS
  - AECOPD
  - LTx bridging
  - Status Asthma
  - Any condition with hypercapnic respiratory failure.

Giraud et al. Ann. Intensive Care (2021) 11:43
https://doi.org/10.1186/s13613-021-00824-6

Annals of Intensive Care

REVIEW

Open Access

The use of extracorporeal CO_2 removal in acute respiratory failure

Raphaël Giraud[1,6,7*], Carlo Banfi[2,3,6,7], Benjamin Assouline[1,6,7], Amandine De Charrière[1,6,7], Maurizio Cecconi[4,5] and Karim Bendjelid[1,6,7]

Abstract

Background: Chronic obstructive pulmonary disease (COPD) exacerbation and protective mechanical ventilation of acute respiratory distress syndrome (ARDS) patients induce hypercapnic respiratory acidosis.

Main text: Extracorporeal carbon dioxide removal ($ECCO_2R$) aims to eliminate blood CO_2 to fight against the adverse effects of hypercapnia and related acidosis. Hypercapnia has deleterious extrapulmonary consequences, particularly for the brain. In addition, in the lung, hypercapnia leads to: lower pH, pulmonary vasoconstriction, increases in right ventricular afterload, acute cor pulmonale. Moreover, hypercapnic acidosis may further damage the lungs by increasing both nitric oxide production and inflammation and altering alveolar epithelial cells. During an exacerbation of COPD, relieving the native lungs of at least a portion of the CO_2 could potentially reduce the patient's respiratory

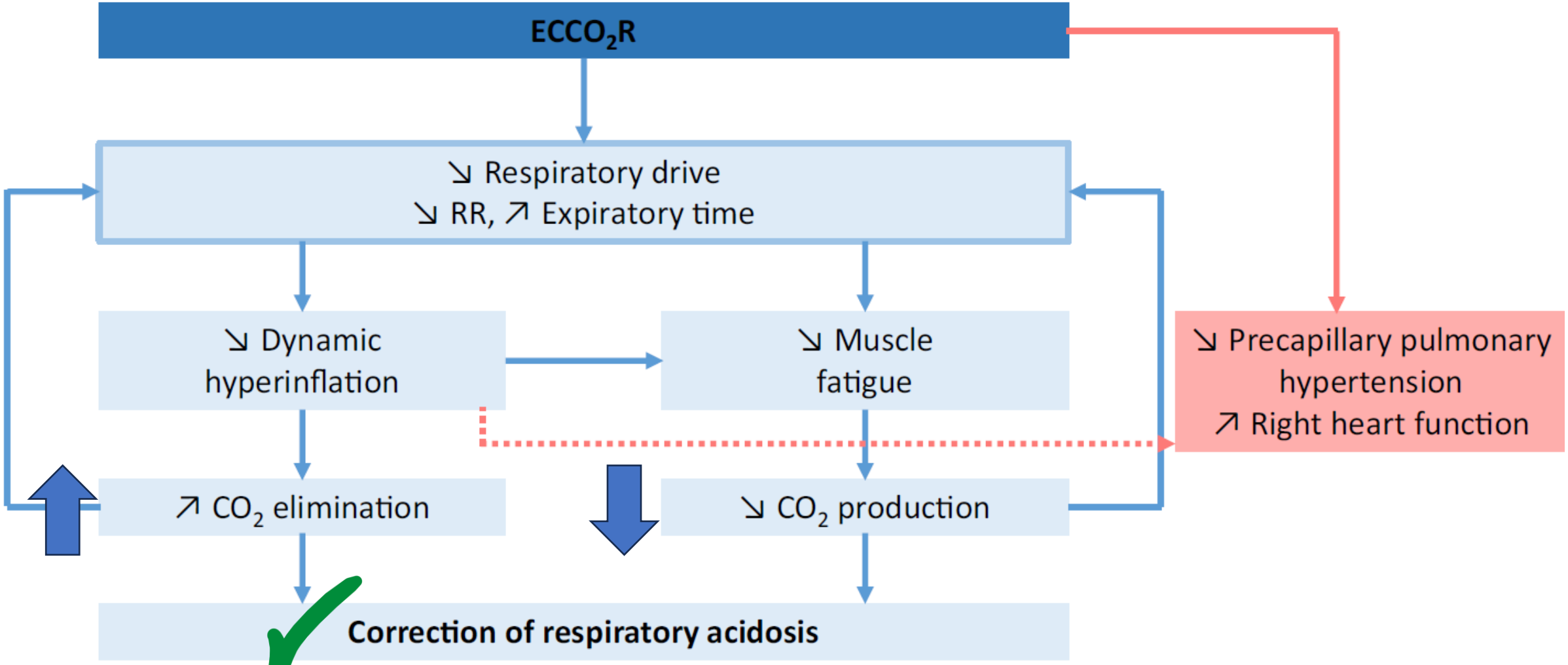
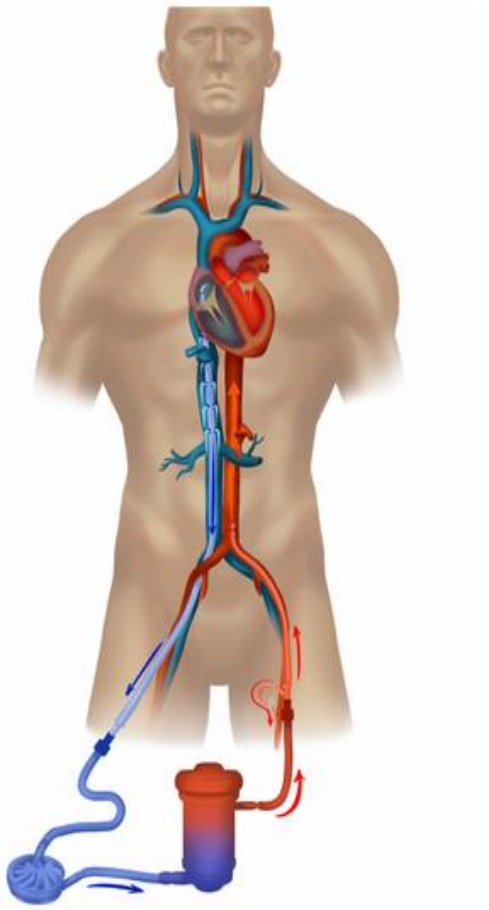
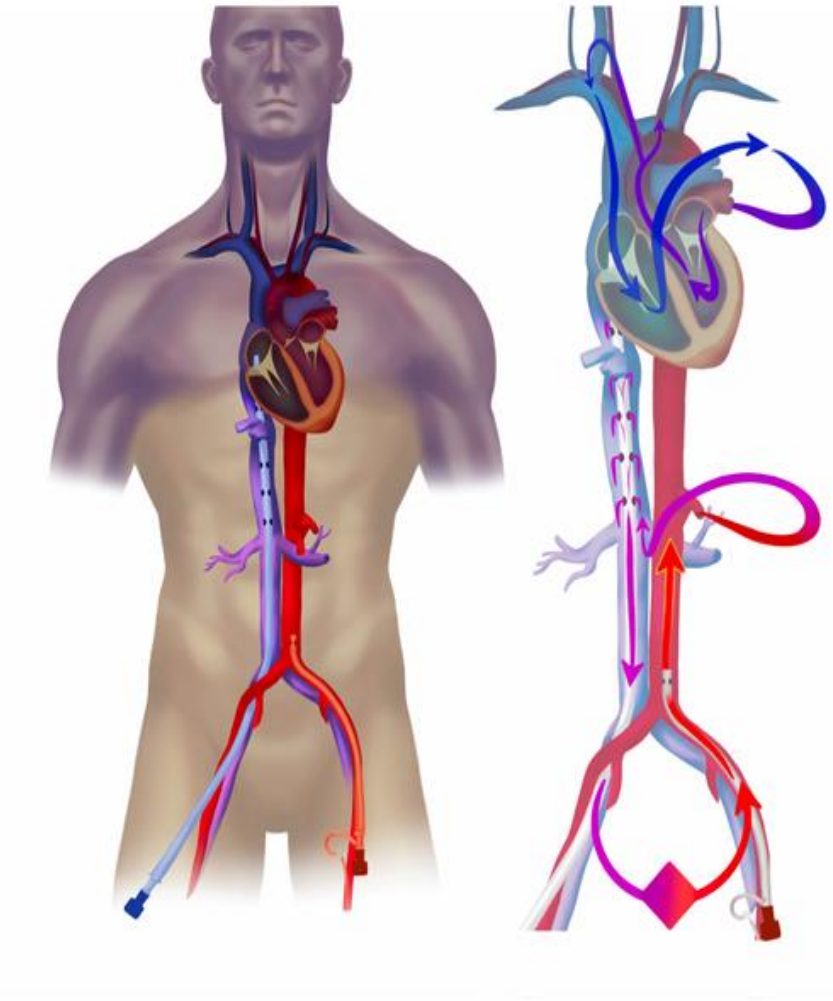


Fig. 1 Pathophysiological rationale for the use of $ECCO_2R$ in COPD exacerbations

Technical principles



(a)

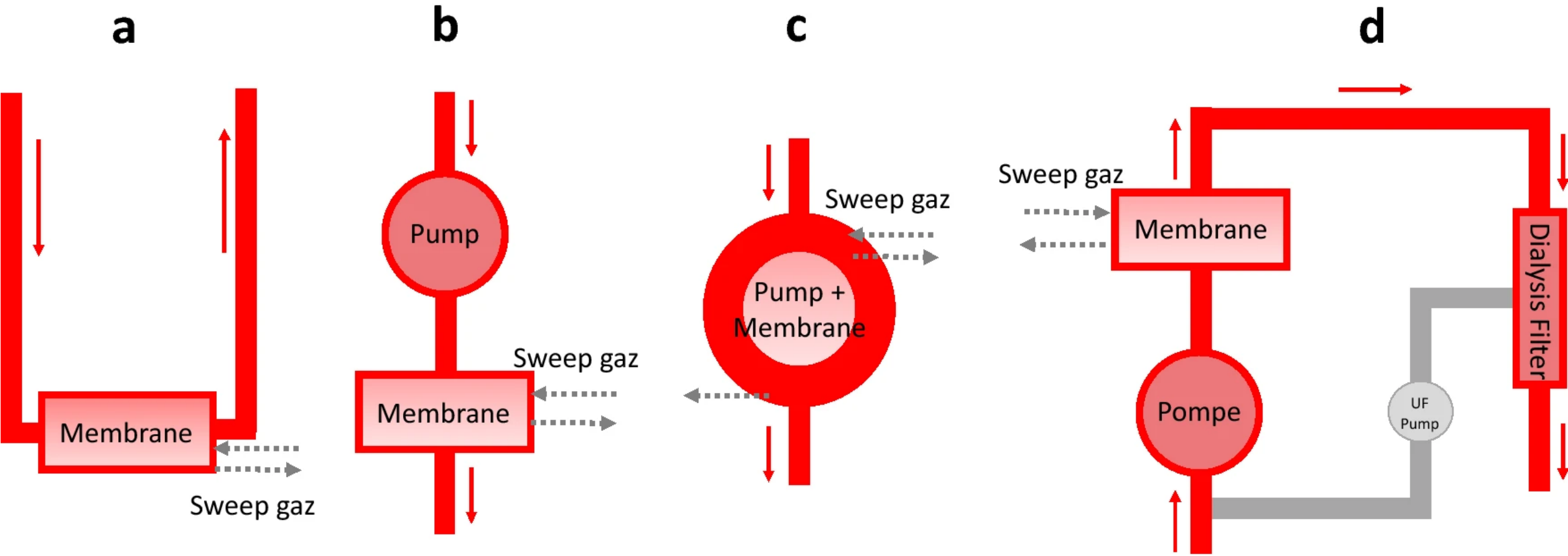


(b)

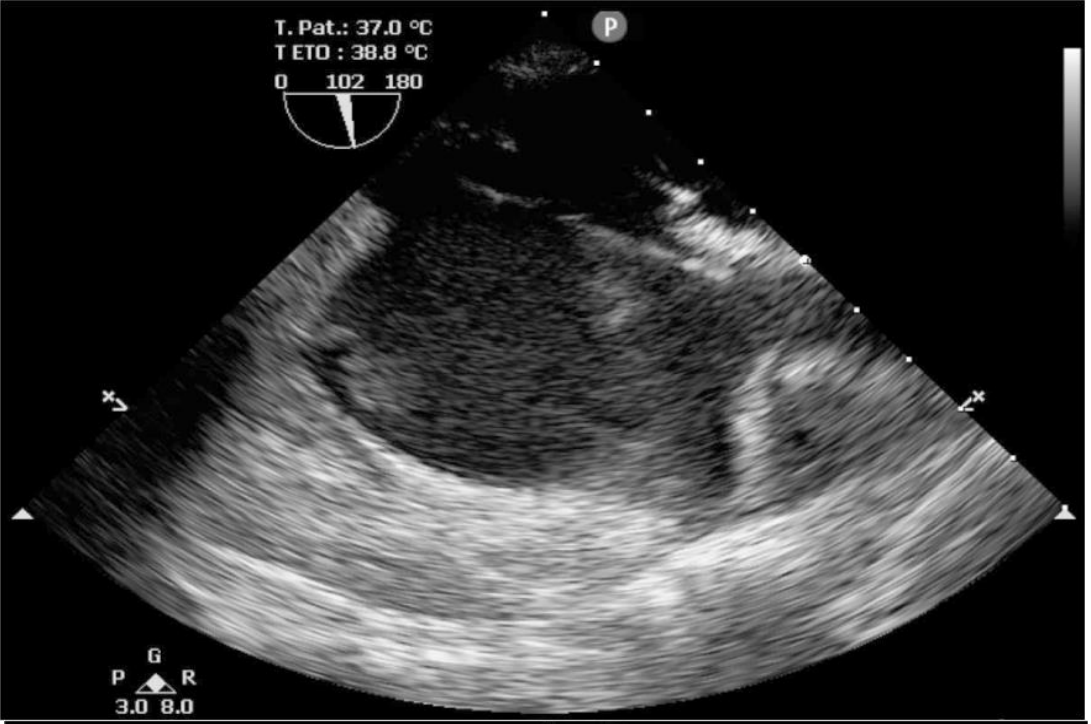
- Catheters or cannulas
- ARTERIOVENOUS technique:
  - Without a pump.
  - Femoro-femoral approach
  - Arterial and venous cannulation with 15 French cannulas.
  - The blood flow depends on the cardiac output.
  - Membrane surface of 1.3 m^2

Technical principles

- VENOVENOUS technique
  - Pump is necessary.
  - Uses low or very low blood flow.
  - Exchange membrane based on hollow fibers.
  - Poly-4-Methyl-1-Pentene (PMP).
  - Exchange surfaces size 0.32-0.65 m^2



A: Pumpless arterio-venous system
B: Veno-venous system. Pump and membrane are in series
C: Veno-venous system. Pump is integrated into the membrane
D: Veno-venous system. The membrane is integrated into an extra-renal purification system that has its own pump.



- Current systems: **VENOVENOUS**
- Double-lumen venous catheters/cannulas.
- Right internal jugular or femoral vein
- performed under ultrasound guidance.
- transesophageal or subxiphoid transthoracic echocardiography.
- Heparin
- Sweeping gas

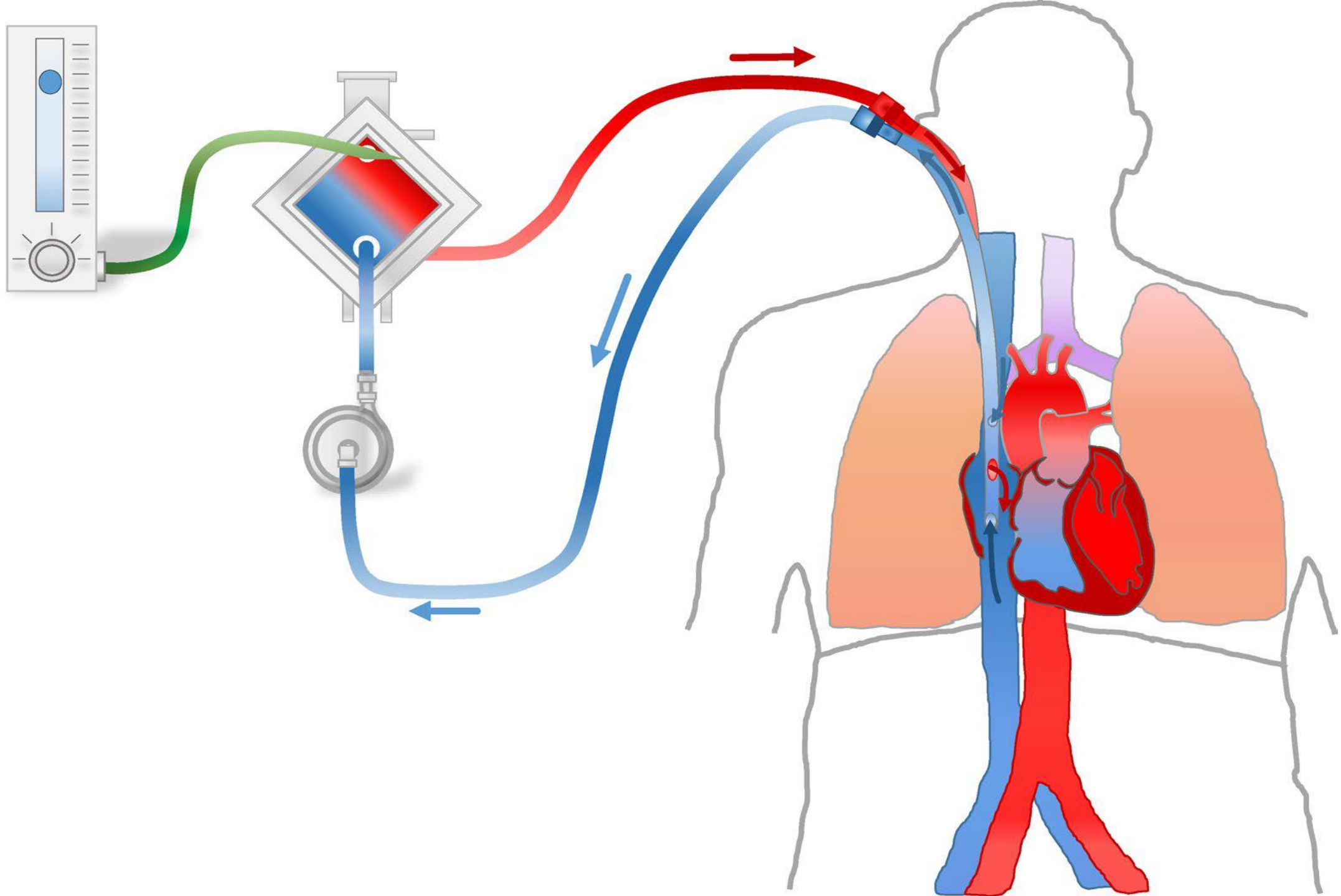


Table 1 Characteristics of the different $ECCO_2R$ and VV-ECMO systems

	Partial extracorporeal support ($ECCO_2R$)				Total extracorporeal support (ECMO)	
	Very low flow	Low flow	Intermediate flow	Intermediate flow	High flow	High flow
Blood flow (L/min)	200–400	400–500	500–1000	500–4500	2500–5000	2500–7000
Vascular access	Venovenous	Venovenous	Venovenous	Arteriovenous	Venovenous	Venovenous
Cannula size	13 Fr	15.5 Fr	18–19 Fr	15 Fr	27–31 Fr	Drainage: 25–29 Fr
Cannula configuration	Dialysis catheter	Double-lumen cannula	Double-lumen cannula	Arterial and venous cannulae	Double-lumen cannula	Reinjection: 17–21 Fr
Priming volume (mL)	140–160	200–300	250–350	175	300–500	300–500
Anti-Xa activity (UI/L)	0.3–0.4	0.3–0.4	0.3–0.4	0.3–0.4	0.2–0.3	0.2–0.3
Membrane surface (m^2)	0.32	0.59	0.65	1.3	1.8	1.8
CO_2 extraction (% of initial value)	< 25	25	50	50–60	> 50	> 50
O_2 transfer (mL/min)	Ø	10	20	20–50	150–300	150–350

$ECCO_2R$ extracorporeal carbon dioxide removal, *VV-ECMO* venovenous extracorporeal membrane oxygenation

Complications and Technical Limitations

- Hypoxemia and need for an increase in Fio_2
  - Atelectasis
  - IMV + Prone Position
- Venous and/or Arterial Cannulation
  - Transient ischemia of lower limb, False aneurysm of the Femoral artery, Fatal perforation, and Retroperitoneal bleeding
- Transient thrombocytopenia
  - Use of Heparin
- Clot formation in the Circuit
  - Life-threatening
  - Change the circuit

Table 4 Types of complications that can occur during treatment with $ECCO_2R$

Types of complications	
Complications related to cannulation	Bleeding at vascular access
	Thrombosis
	Infection of the insertion site
	Accidental arterial insertion (venovenous system)
	Pneumothorax
	Hematoma
	Distal ischemia of the cannulated limb (arteriovenous system)
	Aneurysm (arteriovenous system)
	Pseudoaneurysm (arteriovenous systems)
Mechanical complications	Malfunction or failure of the pump
	Malfunction or failure of the membrane
	Malfunction or heater failure
	Thrombosis in the circuit/membrane
	Gas embolism
Complications related to patients	Aggravation of hypoxemia during the establishment of ultraprotective ventilation
	Bleeding in relation to anticoagulation
	Hemolysis
	Infection
	Heparin-induced thrombopenia

$ECCO_2R$ extracorporeal carbon dioxide removal

Combes et al. Annals of Intensive Care (2024) 14:132
https://doi.org/10.1186/s13613-024-01353-8

Annals of Intensive Care

RESEARCH

Open Access

Expert perspectives on $ECCO_2R$ for acute hypoxemic respiratory failure: consensus of a 2022 European roundtable meeting

Alain Combes[1,2*], Georg Auzinger[3,4†], Luigi Camporota[5,6†], Gilles Capellier[7,8†], Guglielmo Consales[9†], Antonio Gomis Couto[10†], Wojciech Dabrowski[11†], Roger Davies[12,13†], Oktay Demirkiran[14†], Carolina Ferrer Gómez[15†], Jutta Franz[16†], Matthias Peter Hilty[17†], David Pestaña[18,19†], Nikoletta Rovina[20†], Redmond Tully[21†], Franco Turani[22,23†], Joerg Kurz[24] and Kai Harenski[24]

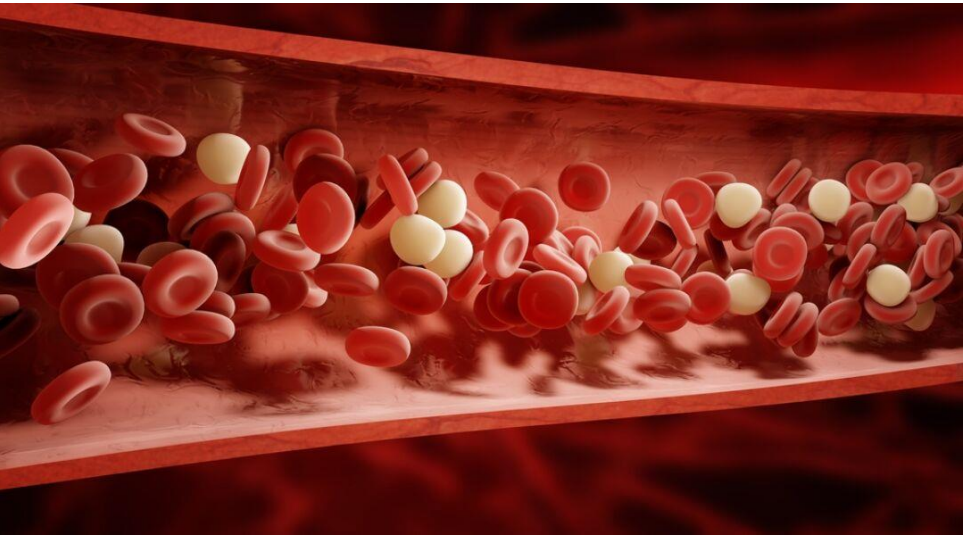
Abstract

Background By controlling hypercapnia, respiratory acidosis, and associated consequences, extracorporeal CO_2 removal ($ECCO_2R$) has the potential to facilitate ultra-protective lung ventilation (UPLV) strategies and to decrease injury from mechanical ventilation. We convened a meeting of European intensivists and nephrologists and used a modified Delphi process to provide updated insights into the role of $ECCO_2R$ in acute respiratory distress syndrome

Initiation and Discontinuation of ECCO2R

- PaCO2, pH, DP (Driving Pressure), and RR
  - (Driving Pressure: Ventilator-measured Pplat – applied PEEP)
- Sedated and ventilated patients with mild-to-moderate ARDS.
  - PaCO2> 60 mmHg and pH < 7.25
  - *No agreement* was reached on DP threshold; however, 10 participants selected either > 14 or > 15 cmH2O.
  - *No agreement* was reached on a threshold for RR.

Anticoagulation strategy for ECCO2R



- Unfractionated heparin (UFH)
- Citrate-based
- Partial thromboplastin time (PTT) 1.5–2.0 × control
- Anti-Xa testing of 0.3–0.5 IU/mL
- *No agreement* was reached on bolus or infusion dosage for UFH.

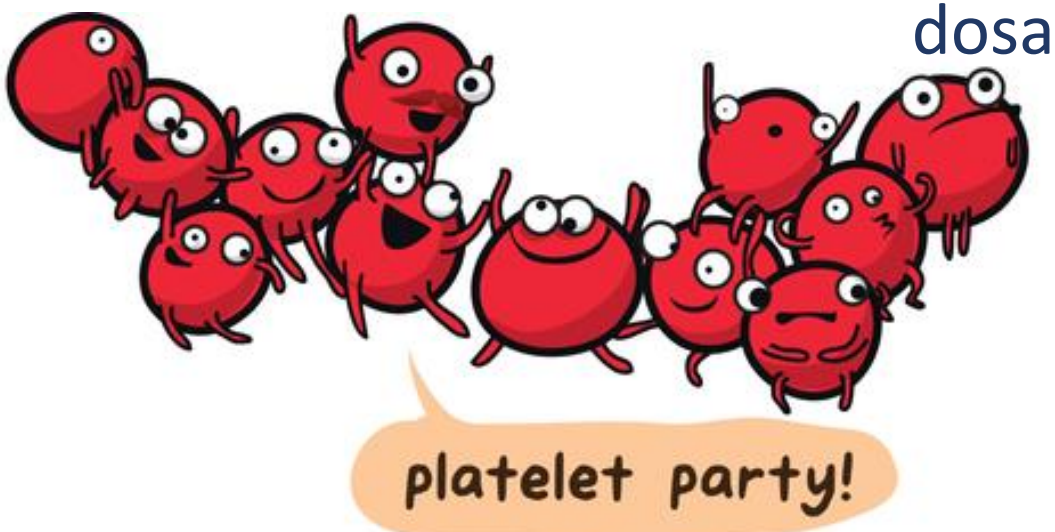


Table 2 Initiation and discontinuation thresholds for respiratory parameters when implementing $ECCO_2R$ in a sedated patient with mild-to-moderate ARDS

Criteria for initiation	Threshold value	Level of agreement
pH	< 7.25	7/13, majority[b]
$PaCO_2$	> 60 mmHg	8/14, majority[c]
ΔP	–	No agreement
RR	–	No agreement
Criteria for discontinuation[a]		
pH	> 7.3	7/14, majority[c]
ΔP	–	No agreement
RR	–	No agreement
P_{plat}	–	No agreement

Need for and design of another randomized trial of ECCO2R for patients with acute hypoxemic respiratory failure

Table 5 Preliminary suggestions for the design of a future randomized trial of $ECCO_2R$ for patients with acute hypoxemic respiratory failure

Criteria	Threshold value	Level of agreement
Inclusion criteria		
ΔP	≥ 14 or 15 cm H_2O	Consensus
Minimum PaO_2:FiO_2	50–100	No agreement
Maximum PaO_2:FiO_2	150–300	No agreement
Minimum PEEP	5–15	No agreement
pH	< 7.20–7.25	No agreement
$PaCO_2$	> 60 mmHg	No agreement
RR	> 25	No agreement
Mechanical power	–	No agreement
Exclusion criteria		
Contraindication to heparin	–	No agreement
High risk of bleeding	–	No agreement
Hemodynamic instability	–	No agreement
Major comorbidity	–	No agreement
Primary endpoint		
Mortality		No agreement
Time on invasive ventilation		No agreement
Improvement of physiological parameters (PaO_2, ΔP, mechanical power)		No agreement
Secondary endpoints		
Time on invasive ventilation		No agreement
Mortality		No agreement
Improvement in right ventricular function		No agreement
Safety endpoints		
Major bleeding (including CNS hemorrhage)		Majority
Catheter-associated complication (infection, vascular injury)		No agreement
Hemolysis		No agreement

ΔP driving pressure, CNS central nervous system, $ECCO_2R$ extracorporeal carbon dioxide removal, FiO_2 fraction of inspired oxygen, $PaCO_2$ partial pressure of carbon dioxide, PEEP positive end-expiratory pressure, pH potential of hydrogen, RR respiratory rate

ANNALS OF MEDICINE
2023, VOL. 55, NO. 1, 746–759
https://doi.org/10.1080/07853890.2023.2172606

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Extracorporeal carbon dioxide removal for patients with acute respiratory failure: a systematic review and meta-analysis

Zhifeng Zhou[a,b]*, Zhengyan Li[c]*, Chen Liu[a,b], Fang Wang[a,b], Ling Zhang[a,b] and Ping Fu[a,b]

[a]Division of Nephrology, Kidney Research Institute, West China Hospital of Sichuan University, Chengdu, China; [b]State Key Laboratory of Kidney Diseases, National Clinical Research Center for Kidney Diseases, First Medical Center of Chinese, PLA General Hospital, Beijing, China; [c]Division of Radiology, West China Hospital of Sichuan University, Chengdu, China

ABSTRACT

Background: Acute respiratory failure (ARF) is a common clinical critical syndrome with substantial mortality. Extracorporeal carbon dioxide removal ($ECCO_2R$) has been proposed for the treatment of ARF. However, whether $ECCO_2R$ could provide a survival advantage for patients with ARF is still controversial.

Methods: Electronic databases (PubMed, Embase, Web of Science, and the Cochrane database) were searched from inception to 30 April 2022. Randomized controlled trials (RCTs) and observational studies that examined the following outcomes were included: mortality, length of hospital and ICU stay, intubation and tracheotomy rate, mechanical ventilation days, ventilator-free days (VFDs), respiratory parameters, and reported adverse events.

Results: Four RCTs and five observational studies including 1173 participants with ARF due to

ARTICLE HISTORY

Received 13 September 2022
Revised 28 December 2022
Accepted 20 January 2023

KEYWORDS

Extracorporeal carbon dioxide removal; acute respiratory failure; mortality; meta-analysis

Results

- Mortality
  - No significant difference in 28-day mortality, 90-day mortality, ICU mortality or hospital mortality.
- Length of ICU and hospital stay
  - Within RCTs: similar duration of ICU stay
  - Within observational studies: significantly reduced length of ICU stay
- Intubation rate and tracheotomy rate
  - A total of 97 patients used ECCO2R during NIV and 77 patients had avoided intubation after the treatment of ECCO2R.

Results

- Mechanical ventilation support and ventilator-free days
  - The duration was shorter in the ECCO2R group in ARF patients with AECOPD
- Respiratory parameters
  - PH, PaCO2, PaO2, and RR
  - Treatment with ECCO2R could improve pH in ARF patients secondary to COPD, but not in ARDS or acute hypoxic respiratory failure patients.
  - An improvement of PaO2, RR and PaCO2 was also observed in patients with ARF secondary to COPD by ECCO2R therapy.


Thank You
Atiyeh.Ghassemi90@gmail.Com