MedCrave
Step into the World of Research
Journal of Anesthesia and Critical Care: Open access

Research Article

Open Access

Protocol-based implementation of combined extracorporeal carbon dioxide removal and continuous renal replacement therapy using prismalung platform: a critical care innovation

Abstract

Introduction: The combination of Extracorporeal Carbon Dioxide Removal ($ECCO_2R$) with Continuous Renal Replacement Therapy (CRRT) represents an essential therapeutic approach for treating hypercapnic respiratory failure and multi-organ dysfunction in critically ill patients. This protocol-based study outlines the implementation of a standardized combined $ECCO_2R$-CRRT strategy in a critical care setting using the PrismaLung platform.

Methods: We established a comprehensive protocol addressing patient selection criteria, cannulation methods, device settings, and anticoagulation protocols and strategies for managing complications during $ECCO_2R$-CRRT therapy. The protocol was developed through evidence-based and expert consensus methods to treat patients who have concurrent respiratory and renal failure.

Results: The protocol defines specific inclusion criteria for ARDS patients (driving pressure >14 cmH_2O, plateau pressure >25 cmH_2O), COPD exacerbations (pH <7.25, $PaCO_2$ >70 mmHg), and concurrent renal failure requiring CRRT. The technical specifications include dual-lumen catheters (≥13F), blood flow rates of 350-450 mL/min, and sweep gas flow of 2-10 L/min. The anticoagulation strategy with systematic monitoring protocols.

Conclusion: The implementation of a structured $ECCO_2R$-CRRT protocol using PrismaLung in ICU settings proves safe for specific patient populations. This combined approach provides simultaneous lung and kidney protective support and may reduce ventilator dependence in hypercapnic respiratory failure with concurrent renal dysfunction. The safety concerns associated with standalone $ECCO_2R$ machines must be re-evaluated in integrated $ECCO_2R$-CRRT utilizing this novel protocol.

Keywords: $ECCO_2R$, CRRT, ARDS, hypercapnia, lung protective ventilation, PrismaLung, extracorporeal support

Volume 17 Issue 5 - 2025

Donia Elmasry, Khaled Sewify, Ragheb Elmessery, Ahmed Shaban, Wael Gomaa
Department of Critical Care Medicine, King Fahd Military Medical Complex, Saudi Arabia

Correspondence: Khaled Sewify, MD, Department of Critical Care Medicine, King Fahd Military Medical Complex, Saudi Arabia, Tel 966-544802229

Received: October 10, 2025 | **Published:** October 31, 2025

Introduction

The low-flow extracorporeal therapy known as Extracorporeal Carbon Dioxide Removal ($ECCO_2R$) functions to selectively remove CO2 while minimizing mechanical ventilation (MV) induced lung injury. The two large randomized controlled trials (RCTs), the SUPERNOVA and REST trials, identified the feasibility of $ECCO_2R$ in removing CO_2 and allowing ultra-protective lung ventilation strategies in ARDS patients.[1,2] The high risk of bleeding occurred mostly because of using high doses of anticoagulation, which led to numerous safety concerns about major bleeding. However, this might not be the case when combined CRRT with $ECCO_2R$-CRRT through a low-flow system minimal anticoagulation that allows simultaneous management of respiratory and renal dysfunction, which frequently occur together in critically ill patients through a low-flow circuit with minimal anticoagulation. $ECCO_2R$-CRRT strategies implement PrismaLung shared platforms to achieve better efficiency and reduce invasiveness.[3,4]

Materials & methods

Protocol development

We established a comprehensive protocol for $ECCO_2R$-CRRT implementation through evidence-based systematic review and expert consensus guidelines, and institutional experience. The protocol contains essential information about clinical and technical aspects of therapy implementation.

Patient selection

Inclusion criteria

Our protocol identifies several clinical scenarios where the combined approach may be beneficial:[5]

CRRT indication

a. Persistent acute kidney injury (AKI) KDIGO stage 2-3 requiring renal replacement therapy for >72 hours and/or

b. Life-threatening indications for CRRT.

In addition to one of the following:

ARDS patients not responding to the prone position (to allow protective lung strategy):

a. Age 18-75 years with moderately severe ARDS (PaO_2/FiO_2<150 mmHg).

b. Driving pressure >14 cmH_2O (primary criterion).

c. Plateau pressure >25 cmH_2O despite lung-protective ventilation.

d. pH <7.30 with $PaCO_2$ >50 mmHg.

COPD exacerbation not responding (to prevent intubation and mechanical ventilation):

a. Persistent severe respiratory acidosis (pH <7.25, $PaCO_2$ >70 mmHg).

b. Non-invasive ventilation (NIV) failure with persistent hypercapnia.

Other recommendations (bridging therapy):

a. Early weaning from mechanical ventilation in difficult-to-wean patients.

b. Early weaning from ECMO support.

c. Bridge to lung transplant.

Exclusion criteria

a. Severe hypoxemia (PaO_2/FiO_2 <100 mmHg).

b. Active bleeding or recent hemorrhage (<48 hours).

c. Recent intracranial hemorrhage (<7 days).

d. Hemodynamic instability requiring high-dose vasopressors.

e. Life expectancy <48 hours.

Technical specifications

The integrated $ECCO_2R$-CRRT system utilizes the following technical components (Figure 1 illustrates the complete circuit integration):

a. Cannulas: ≥13F dual-lumen catheter preferred.

b. Membrane gas exchanger: CO_2 removal via diffusion across 0.8 m^2 membrane surface[6] (illustrated in Figure 1).

c. Pump: Maintains blood flow between 350-450 mL/min.

d. Sweep gas: Delivers 2-10 L/min of gas to promote CO_2 diffusion.

e. CRRT filter and lines: Integrates renal support seamlessly with $ECCO_2R$ using the same extracorporeal circuit.

f. CRRT parameters: Customized based on renal indication, integrated in the Prismax-2 platform.

g. Circuit duration: Up to 72 hours.

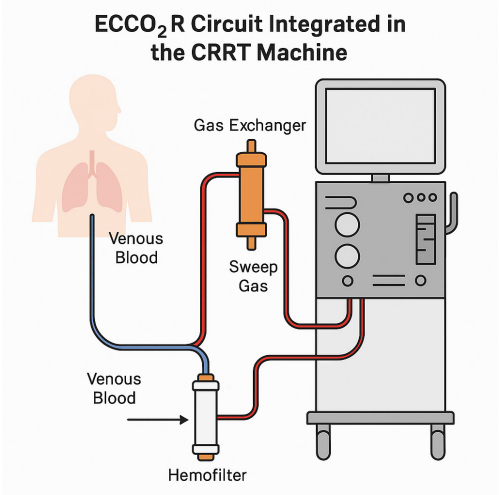

Figure 1 3D Schematic of $ECCO_2R$ Circuit Integrated with CRRT Machine.

Figure 2 illustrates the PrismaLung+ membrane cross-section showing the gas exchange surface. Figure 3 shows the detailed PrismaLung $ECCO_2R$-CRRT cardex used in protocol initiation.

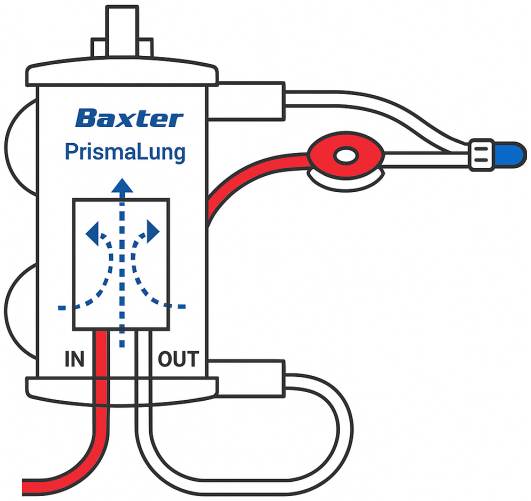

Figure 2 Prisma Lung+ Membrane Cross-Section.

PRISMA LUNG
LUNG-PROTECTIVE STRATEGY

Prisma Lung ECCO2R Initiation	
Access	≥ 13.5 FR
Ecco2r Membrane Surface	0.8 m^2
Priming Volume	310 mL (Artificial Lung (94 mL) + (216 mL Oxiris kit or M150 Kit)
Blood Flow	350 - 450 mL/min
Sweep Gas Flow	8 -10 L/min
Duration of The Circuit	72 hrs

Prepared by Dr. Khaled Sewify

Figure 3 Prisma Lung $ECCO_2R$-CRRT Cardex used in protocol initiation.

Anticoagulation strategy

Primary anticoagulation - unfractionated heparin protocol:

a. Loading dose: 50-100 units/kg (reduce by 50% if bleeding risk).

b. Initial infusion: 10-20 units/kg/hour.

c. Target aPTT: 45-60 seconds (1.5-2.0 times normal).

d. Monitoring: aPTT every 4 hours for the first 24 hours, then every 6-12 hours.

e. Adjustment: ±2-5 units/kg/hour based on aPTT results.

Alternative anticoagulation strategies

Regional citrate anticoagulation:

- Indication: Patients with heparin contraindications or high bleeding risk.[7]
- Protocol: Target circuit ionized calcium 0.25-0.35 mmol/L.
- Monitoring: Systemic ionized calcium every 2-4 hours.
- Safety consideration: Requires experienced staff and protocol adherence.

Citation: Elmasry D, Sewify K, Elmessery R, et al. Protocol-based implementation of combined extracorporeal carbon dioxide removal and continuous renal replacement therapy using prismalung platform: a critical care innovation. *J Anesth Crit Care Open Acces.* 2025;17(5):140–144.
DOI: 10.15406/jaccoa.2025.17.00636

Monitoring Protocol

Table 1 outlines the key monitoring parameters and target ranges for safe $ECCO_2R$-CRRT implementation.

Table 1 Monitoring Parameters and Target Ranges

Parameter	Target Range	Monitoring Frequency	Action Threshold
pH	>7.30	Every 4-6 hours	<7.25 or >7.50
$PaCO_2$	10-20% reduction from baseline	Every 4-6 hours	>20% increase
Driving Pressure	<14-15 cmH_2O	Continuous	≥18 cmH_2O
Blood Flow	350-450 mL/min	Continuous	<300 or >450 mL/min
aPTT	45-60 seconds	Every 4-6 hours	<35 or >80 seconds
Hemoglobin	>7 g/dL	Every 6-12 hours	<6 g/dL or >2g/dL drop

Weaning and discontinuation protocol

Weaning criteria assessment

Respiratory improvement:

a. Achievement of acceptable gas exchange (pH >7.35, $PaCO_2$ <50 mmHg) with conventional protective ventilation.

b. Stable oxygenation without deterioration.

c. Reduced ventilatory requirements.

Renal recovery:

a. Adequate urine output (>0.5 mL/kg/hour) with stable creatinine.

b. Resolution of fluid overload.

c. Stable electrolyte balance without continuous intervention.

Systematic weaning process

Phase 1: Gas exchange weaning (6-12 hours)

a. Reduce sweep gas flow by 2-3 L/min every 2-4 hours.

b. Simultaneously adjust the ventilator toward conventional protective settings.

c. Monitor arterial blood gas 2 hours after each adjustment.

d. Proceed if pH remains >7.30 and $PaCO_2$ increases <10%.

Phase 2: Trial off $ECCO_2R$ (4-6 hours)

a. Complete cessation of sweep gas flow.

b. Maintain blood flow for CRRT if indicated.

c. Arterial blood gas at 2 and 4 hours post-cessation.

d. Proceed to discontinuation if gas exchange remains acceptable.

Phase 3: System discontinuation

a. CRRT weaning per standard protocols if renal function recovered.

b. Anticoagulation cessation 2-4 hours before discontinuation.

c. Circuit removal following standard central line removal protocols.

d. Post-removal monitoring for bleeding or access complications.

Results

$ECCO_2R$ performance

The systematic review data show that 1,672 patients experienced substantial physiological advantages.[8]

a) $PaCO_2$ reduction: Mean decrease of 15-25% from baseline values.

b) pH improvement: Significant increase across all patient groups ($p<0.001$).

c) Plateau pressure reduction: Mean decrease of 3-5 cmH_2O.

d) Tidal volume reduction: Achievement of ultra-protective ventilation (4-6 mL/kg) in 78-82% of patients.

Technology-Specific Performance

PrismaLung+ device studies demonstrate:[9]

a) CO_2 removal efficiency: 90+ mL/min at 400-450 mL/min blood flow.

b) Performance comparison: 50% greater CO_2 removal than previous generation devices.

c) Pressure characteristics: Lower resistance compared to larger membrane systems.

d) Temperature stability: Effective blood warming with automatic adjustment.

Clinical outcomes by indication

ARDS outcomes

Ultra-protective ventilation achievement:

a. SUPERNOVA study: Target tidal volumes achieved in 78% within 8 hours, 82% within 24 hours.[10]

b. Driving pressure reduction: Mean decrease of 4-6 cmH_2O.

c. PaO_2/FiO_2 ratio: Significant improvement in ARDS patients ($p=0.038$).

Clinical outcomes:

a. Ventilator-free days: No significant difference in recent RCTs.

b. Mortality: No demonstrated benefit; 73% probability of increased mortality,[11] possibly due to high-dose anticoagulation in high-flow circuits used in clinical studies, e.g., NOVA-Lung and A-Lung rather than $ECCO_2R$ integrated with CRRT.

COPD exacerbation outcomes

Physiological improvements:

a. Work of breathing: Significant reduction in respiratory effort.

b. NIV failure prevention: Success rate >50% in selected studies.

c. Weaning facilitation: Earlier extubation in mechanically ventilated patients.

Center clinical experience

We successfully used this protocol without any safety concerns in the following cases:

a. Status asthmaticus series: prevented the patient from intubation.

Citation: Elmasry D, Sewify K, Elmessery R, et al. Protocol-based implementation of combined extracorporeal carbon dioxide removal and continuous renal replacement therapy using prismalung platform: a critical care innovation. *J Anesth Crit Care Open Acces.* 2025;17(5):140–144.
DOI: 10.15406/jaccoa.2025.17.00636

b. COPD exacerbation: prevented the patient from undergoing intubation.

c. ARDS: successful application of protective lung strategy and weaning from mechanical ventilation.

d. Multiple organ dysfunction syndrome (MODS): as a part of the combo therapy with the oXiris filter and CRRT, with survival benefits.

Complications and safety

Table 2 summarizes the complication management protocols developed for our integrated approach.

Table 2 Complication Management Protocols

Complication	Incidence	Immediate Actions	Escalation Criteria
Bleeding (Minor)	2-3%	Reduce anticoagulation by 25-50%	Hemodynamic instability
Bleeding (Major)	1-2%	Stop anticoagulation, transfuse	Hgb drop >2g/dL
Circuit Clotting	Variable	Increase anticoagulation, assess flow	Recurrent clotting
ICH	<1% (↑ risk)	Immediate discontinuation	Any neurological change
Hemolysis	Rare	Reduce blood flow, check the circuit	LDH >1000 U/L

Key safety considerations:

a. **Patient-related challenges:** Bleeding related to vascular access and anticoagulation, hemolysis, and heparin-induced thrombocytopenia.

b. **Circuit and catheter-related challenges:** Vascular injury, vascular occlusion, thrombosis, hematoma, aneurysm, bleeding from the cannula site, kinking or displacement of the cannulas, and infections.

c. **Mechanical challenges:** Air embolism, clot formation, malfunctioning or failure of the pump, oxygenator, or heat exchange malfunction.

Discussion

The PrismaLung+ platform demonstrates significant technological progress through its ability to remove CO_2 more efficiently at low blood flow rates that match standard CRRT procedures. This evolution allows for true integration of respiratory and renal support through single platforms, which could decrease treatment invasiveness and enhance patient tolerance. The first implementation of the $ECCO_2R$-CRRT protocol proved its practicality by integrating into ARDS and acute kidney injury care bundles. The approach enabled CO_2 reduction within hours, while supporting a protective lung strategy, and providing renal support. This approach matches previous research findings from SUPERNOVA and REST trials, which showed physiologic improvements and ventilation benefits.[12,13]

The isolated $ECCO_2R$ machines, e.g., HemoLung RAS and Novalung, presented safety concerns because of bleeding complications and increased mortality, which might result from using high-dose anticoagulation for maintaining high blood flow in the circuits. The only Italian study done on integrated $ECCO_2R$ and CRRT did not show any safety concerns.[14] However, larger trials are required to validate outcomes and to address any safety concerns related to integrated $ECCO_2R$ with CRRT, where low flow and low-dose anticoagulation are used.

The selection of patients stands as the essential factor for implementing $ECCO_2R$ safely according to expert consensus.[15] Our protocol uses driving pressure ≥14-15 cmH_2O as the main selection criterion because the 2022 European roundtable recommendations show this parameter identifies patients who need ultra-protective ventilation strategies.[16] The exclusion of patients with severe hypoxemia (PaO_2/FiO_2 <100 mmHg) reflects recognition that these patients require comprehensive ECMO support rather than selective CO_2 removal. Similarly, the emphasis on hemodynamic stability acknowledges that $ECCO_2R$ should not be viewed as rescue therapy for multi-organ failure.

The recent safety data requires more than traditional monitoring protocols used for ECMO or CRRT individually. The increased risk of intracranial hemorrhage requires regular neurological assessment, while the overall bleeding risk demands careful anticoagulation management with lower targets than historically used. Our protocol requires immediate discontinuation of treatment when safety signals appear instead of trying to handle complications during ongoing therapy. This approach demonstrates the understanding that $ECCO_2R$ represents an adjunctive rather than life-saving intervention in most clinical scenarios.

Future research directions and protocol evolution

The current evidence base highlights several critical research needs:

Prospective safety studies: Long-term follow-up data from existing cohorts to better characterize delayed complications and outcomes.

Biomarker development: Identification of patients most likely to benefit from $ECCO_2R$ intervention through predictive modeling and biomarker analysis.

Technology optimization: Continued membrane and circuit development to maximize CO_2 removal while minimizing complications.

Comparative effectiveness research: Direct comparison of $ECCO_2R$-enabled ultra-protective ventilation versus alternative lung-protective strategies.

Implementation considerations and institutional requirements

Successful implementation of combined $ECCO_2R$-CRRT programs requires substantial institutional commitment:

Expertise requirements: Multidisciplinary teams with experience in both $ECCO_2R$ and CRRT technologies.

Infrastructure needs: Dedicated ICU space with enhanced monitoring capabilities and immediate access to emergency interventions.

Quality assurance: Systematic data collection for ongoing safety monitoring and outcome assessment.

Ethical framework: Institutional review and ethics committee oversight are given for the experimental nature and safety concerns.

Limitations and protocol constraints

This protocol has several important limitations:

Citation: Elmasry D, Sewify K, Elmessery R, et al. Protocol-based implementation of combined extracorporeal carbon dioxide removal and continuous renal replacement therapy using prismalung platform: a critical care innovation. *J Anesth Crit Care Open Acces.* 2025;17(5):140–144.
DOI: 10.15406/jaccoa.2025.17.00636

Evidence quality: Limited high-quality RCT data and a highly selected group of patients with concerning safety signals requiring conservative recommendations.

Technology specificity: Focusing on the PrismaLung+ platform may limit generalizability to other $ECCO_2R$ systems.

Patient population: Recommendations based primarily on ARDS and COPD populations with limited data for other indications.

Long-term outcomes: Insufficient data on long-term neurological and functional outcomes following $ECCO_2R$ exposure.

Conclusion

A structured $ECCO_2R$-CRRT protocol using PrismaLung can be safely implemented in ICU settings for selected patients. This integrated strategy enables simultaneous lung- and kidney-protective support in moderately severe ARDS and may reduce ventilator dependence in hypercapnic respiratory failure with concurrent renal dysfunction. The safety concerns related to isolated $ECCO_2R$ machines with high blood flow circuits must be re-evaluated in integrated $ECCO_2R$-CRRT low flow circuits utilizing this novel protocol. Further prospective studies are needed to validate clinical outcomes and establish optimal patient selection criteria.

Data availability

All protocol materials, monitoring forms, and implementation tools will be made freely available upon publication to facilitate widespread adoption and standardization of combined $ECCO_2R$-CRRT therapy.

References

1. Bein T, Weber-Carstens S, Goldmann A, et al. Lower tidal volume strategy (≈3 mL/kg) combined with extracorporeal CO_2 removal versus "conventional" protective ventilation (6 mL/kg) in severe ARDS: the prospective randomized Xtravent study. *Intensive Care Med.* 2013;39(5):847-856.
2. Karagiannidis C, Kampe KA, Weinmann-Menke J, et al. Veno-venous extracorporeal CO_2 removal for the treatment of severe respiratory acidosis: pathophysiological and technical considerations. *Crit Care.* 2014;18(3):R124.
3. Fanelli V, Ranieri MV, Mancebo J, et al. Feasibility and safety of low-flow extracorporeal carbon dioxide removal to facilitate ultra-protective ventilation in patients with moderate acute respiratory distress syndrome. *Crit Care.* 2016;20(1):36.
4. Morelli A, Del Sorbo L, Pesenti A, et al. Extracorporeal carbon dioxide removal ($ECCO_2R$) in patients with acute respiratory failure. *Intensive Care Med.* 2017;43(4):519-530.
5. Schmidt M, Jaber S, Zogheib E, et al. Feasibility and safety of low-flow extracorporeal CO_2 removal managed with a renal replacement platform to enhance lung-protective ventilation of patients with mild-to-moderate ARDS. *Crit Care.* 2018;22(1):122.
6. Combes A, Fanelli V, Pham T, et al. Feasibility and safety of extracorporeal CO_2 removal to enhance protective ventilation in acute respiratory distress syndrome: the SUPERNOVA study. *Intensive Care Med.* 2019;45(5):592-600.
7. Goligher EC, Combes A, Brodie D, et al. Determinants of the effect of extracorporeal carbon dioxide removal in the SUPERNOVA trial: implications for trial design. *Intensive Care Med.* 2019;45(9):1219-1230.
8. Combes A, Auzinger G, Capellier G, et al. $ECCO_2R$ therapy in the ICU: consensus of a European round table meeting. *Crit Care.* 2020;24(1):490.
9. McNamee JJ, Gillies MA, Barrett NA, et al. Effect of lower tidal volume ventilation facilitated by extracorporeal carbon dioxide removal vs standard care ventilation on 90-day mortality in patients with acute hypoxemic respiratory failure: the REST randomized clinical trial. *JAMA.* 2021;326(11):1013-1023.
10. Giraud R, Banfi C, Assouline B, et al. The use of extracorporeal CO_2 removal in acute respiratory failure. *Ann Intensive Care.* 2021;11(1):43.
11. Millar JE, Boyle AJ, Drake TM, et al. Extracorporeal carbon dioxide removal in acute hypoxaemic respiratory failure: a systematic review, Bayesian meta-analysis and trial sequential analysis. *Eur Respir Rev.* 2022;31(166):220030.
12. Gattinoni L, Coppola S, Camporota L. Physiology of extracorporeal CO_2 removal. *Intensive Care Med.* 2022;48(10):1322-1325.
13. Tiruvoipati R, Ludski J, Gupta S, et al. Evaluation of the safety and efficacy of extracorporeal carbon dioxide removal in the critically ill using the PrismaLung+ device. *Eur J Med Res.* 2023;28(1):291.
14. Combes A, Auzinger G, Camporota L, et al. Expert perspectives on EC-CO_2R for acute hypoxemic respiratory failure: consensus of a 2022 European roundtable meeting. *Ann Intensive Care.* 2024;14(1):132.
15. Stommel AM, Herkner H, Kienbacher CL, et al. Effects of extracorporeal CO_2 removal on gas exchange and ventilator settings: a systematic review and meta-analysis. *Crit Care.* 2024;28(1):146.
16. Lamas T, Fernandes SM, Vasques F, et al. Recent advances and future directions in extracorporeal carbon dioxide removal. *J Clin Med.* 2025;14(1):12.

Citation: Elmasry D, Sewify K, Elmessery R, et al. Protocol-based implementation of combined extracorporeal carbon dioxide removal and continuous renal replacement therapy using prismalung platform: a critical care innovation. *J Anesth Crit Care Open Acces.* 2025;17(5):140–144.
DOI: 10.15406/jaccoa.2025.17.00636