Applications of Extracorporeal Carbon Dioxide Removal ($ECCO_2R$) Devices: A Brief Review

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ABSTRACT

Artificial lung technologies, particularly Extracorporeal Carbon Dioxide Removal ($ECCO_2R$) devices, have gained significant attention as a treatment for respiratory failure. This review explores the history, functionality, and practical applications of $ECCO_2R$ systems, detailing their components, configurations, and challenges. $ECCO_2R$, unlike Extracorporeal Membrane Oxygenation (ECMO), primarily focuses on CO_2 removal while maintaining lung-protective ventilation strategies. Various $ECCO_2R$ devices, including Maquet PALP® CardioHelp®, ALung Hemolung®, Estor ProLUNG®, and Novalung iLA, are discussed in terms of design, efficiency, and clinical applications. Despite the advantages of these systems, challenges such as blood clotting, vascular complications, and high costs remain. The development of $ECCO_2R$ continues to improve patient outcomes, particularly for those with conditions like COPD, ARDS, and hypercapnia.

INTRODUCTION

Technological innovation in biomedical engineering drives advanced solutions to treat chronic diseases and improve quality of life. Respiratory diseases such as Chronic Obstructive Pulmonary Disease (COPD), Acute Respiratory Distress Syndrome (ARDS), and hypercapnia pose significant health risks and can lead to severe complications if untreated. Mechanical ventilation has long been the standard for respiratory support, but it can introduce complications such as ventilator-induced lung injury (VILI) and high airway pressures. To address these concerns, extracorporeal support systems like Extracorporeal Membrane Oxygenation (ECMO) and Extracorporeal Carbon Dioxide Removal ($ECCO_2R$) have emerged as alternatives. While ECMO provides both oxygenation and CO_2 removal, $ECCO_2R$ is specifically designed to assist with CO_2 clearance, allowing for protective lung ventilation strategies. This review examines the historical development, technical components, and real-world applications of $ECCO_2R$ systems. By comparing various $ECCO_2R$ devices and their configurations, this review aims to highlight the effectiveness and challenges of the applications in managing respiratory failure.

OBJECTIVES

- Analyze the applications of $ECCO_2R$ devices in clinical settings.
- Compare $ECCO_2R$ with ECMO and traditional ventilation methods.
- Evaluate the performance of commercially available $ECCO_2R$ devices.
- Identify key challenges in the implementation of $ECCO_2R$.

METHODOLOGY

Research and Data Compilation:

- **Gather Information: from Databases:** National Institute of Health (PubMed), Mayo Clinic, Equipment Catalogs, etc.
- **Use research criteria based on keywords:** $ECCO_2R$, ECMO, ventilator, COPD, ARDS,

Selection & Refinement of Information:

- **Filter** atricles, books and papers published between 2005-2025.
- **Prioritize** sources based on relevance and **organize** references using a bibliographic review.

Selection of Topics:

- **Structure** the research by identifying key relations and relevance of the keywords.
- **Refine** the objective and scope of the study to ensure alignment with the main topic**.**

DATA

Device	Image	Configuration (VV/AV)	Pump Type	Membrane Polymer	Other
Maquet PALP® CardioHelp®		VV	Centrifugal	Polymethylpentene (PMP)	Portable, used for ARDS and PAP
Alung Hemolung®		VV	Centrifugal	Polymeric laminated polymer (PLP)	Integrated membrane-pump unit, prevents gas embolism
Estor ProLUNG®		VV	Peristaltic	Polymethylpentene (PMP) with phosphorylcholine	Minimally invasive, protective ventilation
DECAPsmart® Plus		VV	Roller	Polymethylpentene (PMP)	Includes hemodialysis filter for enhanced CO_2 removal
Novalung iLA®		AV	No pump (arterial pressure-driven)	Polymethylpentene (PMP)	Requires stable hemodynamics, long-term use
Novalung iLA Activve®		VV	Rotary (diagonal flow)	Polymethylpentene (PMP)	Modular system, supports both $ECCO_2R$ and ECMO
CO_2 RESET® Eurosets		VV	Roller	Polymethylpentene (PMP) with phosphorylcholine	Medium-flow system with hemofiltration capabilities

Table 1. Configuration and Components of $ECCO_2R$ devices (Colón & Vargas, 2025).

ANALYSIS AND RESULTS

- **Components:** $ECCO_2R$ systems consist of a membrane lung, a pump (if venovenous), and cannulas for blood extraction and return.
- **Configurations:** Arteriovenous (AV) $ECCO_2R$ operates without a pump, relying on the patient's blood pressure, while venovenous (VV) $ECCO_2R$ requires an external pump for circulation.
- **Device Comparison:** Commercial $ECCO_2R$ devices include the Maquet PALP® CardioHelp®, Alung Hemolung®, Estor ProLUNG®, DECAPsmart® Plus, Novalung iLA®, Novalung iLA® Activve, and CO_2 RESET® Eurosets, each with varying capabilities in CO_2 removal and patient support.
- **Clinical Outcomes:** $ECCO_2R$ reduces respiratory distress and enables ultra-protective ventilation in patients with COPD, ARDS, and hypercapnia.
- **Challenges:** Issues such as anticoagulation-related bleeding, hemolysis, and technical limitations in gas exchange efficiency remain barriers to widespread adoption.

CONCLUSION

The applications of $ECCO_2R$ devices have significantly expanded, offering critical support in managing conditions such as ARDS, COPD, and hypercapnia. These devices provide tailored solutions for different clinical needs. Despite their benefits, $ECCO_2R$ devices present challenges depending on device configuration. However, continuous advancements in membrane design, biocompatible coatings, and pump technologies have enhanced their safety and performance. As research and clinical trials continue to refine these systems, $ECCO_2R$ is becoming an increasingly viable option for a broader patient population. Future developments aim to improve device efficiency, accessibility, and integration into standard critical care protocols, further solidifying its role in respiratory support and lung-protective ventilation strategies.

FUTURE WORK

- Expansion of clinical trials to standardize $ECCO_2R$ guidelines.
- Integration with other supportive therapies for broader applications in critical care.
- Further research on improving biocompatibility and anticoagulation strategies.
- Optimization of device design to enhance CO_2 removal efficiency.

REFERENCES

Cove, M. E., MacLaren, G., Federspiel, W. J., & Kellum, J. A. (2012). Bench to bedside review: Extracorporeal carbon dioxide removal, past present and future. Critical Care (London, England), 16(5), 232. https://doi.org/10.1186/cc11356

Eurosets Artimedica. (2021). Medium flow device for $ECCO_2R$ treatments (MM3C02BE01). Strada Statale, 41036 Medolla (MO), Italy: Eurosets Artimedica.

Romay, E., & Ferrer, R. (2016). Extracorporeal CO_2 removal: Technical and physiological fundaments and principal indications. Medicina Intensiva, 40(1), 33–38.

Rondón, J., Muñiz, C., Lugo, C., Farinas-Coronado, W., & Gonzalez-Lizardo, A. (2024). Bioethics in Biomedical Engineering Bioética en Ingeniería Biomédica. Revista Ciencia e Ingeniería. Vol, 45(2).