Extracorporeal Gas Exchange

The Expanding Role of Extracorporeal Support in Respiratory Failure

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KEYWORDS

• Extracorporeal membrane oxygenation (ECMO) • Extracorporeal gas exchange
• Extracorporeal life support • Respiratory failure • Mechanical ventilation
• Extracorporeal carbon dioxide removal

KEY POINTS

- Extracorporeal support for respiratory failure is growing rapidly; critical care physicians will be required to make informed decisions about the application of extracorporeal gas exchange.
- Venovenous extracorporeal gas exchange for severe respiratory failure may be used to rescue patients with severe acute respiratory distress syndrome (ARDS) who are not responding to lung protective ventilation and optimal critical care therapies.
- Extracorporeal carbon dioxide removal is a promising emerging therapy that may be used as a preventive and even preemptive strategy in patients with non-ARDS respiratory failure.

INTRODUCTION

Mechanical ventilation defines the modern intensive care unit, yet it is clear that positive pressure ventilation injures the lungs.[1] Normal human inspiration is a negative pressure process, but positive pressure ventilation is necessary when gas exchanged is deranged due to lung injury.[2] When positive pressure ventilation does not achieve adequate gas exchange, the application of more positive pressure in many different ways has been used over the last 50 years. Despite extensive and well-done clinical trials, the optimal method of supporting severely injured lungs remains unclear.

Solid evidence exists that lung protective ventilation improves outcomes in patients with respiratory failure, yet for the patients who fail lung protective ventilation, any evidence for an alternative supportive therapy that improves survival remains in equipoise.[3] Most ventilator support modes used after the failure of protective ventilation involve the use of higher pressures and/or volumes, which directly challenge the principles of lung protection.

Over the last decade, extracorporeal support has emerged as a promising supportive therapy for adults with respiratory failure. Similar to the microprocessor technology that informs mechanical ventilators, extracorporeal technology has evolved faster than the ability to examine it in randomized controlled trials (RCTs). This paucity of evidence has understandably engendered caution in the pulmonary critical care community regarding

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extracorporeal support. The use of extracorporeal support, however, is expanding rapidly for adults with respiratory failure worldwide. Intensive care physicians will need to make prudent decisions about the application of extracorporeal support as they confront a significant paradigm shift in the care of patients with respiratory failure.

EXTRACORPOREAL SUPPORT TERMINOLOGY

Extracorporeal membrane oxygenation (ECMO) is a temporary extracorporeal life support system (ECLS) to support a failing cardiopulmonary system in the setting of severe critical illness requiring mechanical ventilator support. ECMO may be implemented via venoarterial (VA-ECMO) or venovenous (VV-ECMO) approaches to exchange carbon dioxide (CO_2) and oxygen under high blood flow conditions (up to 7 L/min) requiring large cannulas (20–31 Fr)[4] (**Table 1**). Extracorporeal CO_2 removal ($ECCO_2R$) incorporates a device that removes CO_2 at lower blood flow rates (<1.5 L/min) through smaller cannulas (14–23 Fr).[5] Respiratory dialysis (RD) refers to the use of a hemofiltration system often in series with a gas exchange membrane and can decarboxylate blood at lower flow rates using smaller catheters. The term *extracorporeal gas exchange* refers to VV-ECMO, $ECCO_2R$, and RD techniques that facilitate ventilation. Although VA-ECMO can provide full cardiopulmonary support in patients with both severe cardiac and pulmonary failure, extracorporeal gas exchange supports intolerable hypoxia and/or hypercapnia and may facilitate lung protection strategies in severe cases of acute respiratory distress syndrome (ARDS).[6] The acronym ECMO is linguistically incomplete, because ECMO regulates both oxygen and CO_2, but the term has persisted despite some attempts in the ECMO community to use the more inclusive term ECLS. As the technology of the pump, oxygenator, circuit, and cannulas evolves, the indications for ECLS have expanded to include non-ARDS respiratory failure, hypercapnic failure, bridge-to-lung transplantation, pulmonary hypertension, and donor lung resuscitation (**Box 1**).[7,8] ECMO and ECLS in

Table 1
Terms

Terms	Key Features	Support	Blood Flow (L/min)	Cannula Size	Priming Volume (mL)
VA-ECMO	Drains blood from the venous system and pumps it through a membrane oxygenator. Oxygenated blood is returned to the arterial system	Full cardiac-pulmonary support	High 2–6	Large (17–31 Fr)	500
VV-ECMO	Drains blood from the venous system, pumps it through a membrane oxygenator, and returns it back to the venous system	Respiratory support	High 2–5	Large (20–30 Fr)	500
$ECCO_2R$	Uses a venovenous (typically) or arteriovenous device to remove CO_2	Respiratory support	Low 0.25–2	Smaller (14–20 Fr)	300
RD	Venovenous device based on modified hemofiltration system with a membrane in series	Respiratory support	Low 0.25–0.55	Smaller (13–17 Fr)	280
Extra-corporeal gas exchange	Refers to VV-ECMO, $ECCO_2R$, and RD techniques	Respiratory support	High-low	Large-small	—