Novel Uses of Extracorporeal Membrane Oxygenation in Adults

Darryl Abrams, MD, Daniel Brodie, MD*

KEYWORDS

• ECMO • $ECCO_2R$ • ARDS • Lung transplantation • ECPR • Cardiogenic shock
• Pulmonary hypertension

KEY POINTS

- Extracorporeal carbon dioxide removal ($ECCO_2R$) may play an emerging role in the management of respiratory failure.
- Novel upper-body configurations help facilitate patient mobilization and are particularly well-suited to maintain physical conditioning in the pretransplant population.
- Extracorporeal cardiopulmonary resuscitation has the potential to improve neurologically intact survival from cardiac arrest. However, appropriate patient selection is a key factor in optimizing outcomes.
- In decompensated pulmonary hypertension, extracorporeal membrane oxygenation may serve as a bridge to recovery in patients with reversible processes or to transplantation for irreversible disease.
- More data are needed to define the optimal patient populations for extracorporeal support. Cost–benefit analyses should be undertaken.

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) has been available for decades as a supportive therapy for severe cardiopulmonary disease; however, its early use was marred by high complication rates and poor outcomes.[1,2] Advances in technology have led to improved complication rates[3] and an increasing amount of evidence suggesting a potential benefit in select forms of cardiac and respiratory failure has resulted in a notable increase in the use of ECMO.[4] As both cannulation technique and extracorporeal circuits evolve, there are an increasing number of indications for which ECMO may provide a benefit.[5] This article reviews these emerging indications and discusses potential future applications.

CONFIGURATIONS OF EXTRACORPOREAL MEMBRANE OXYGENATION

ECMO refers to an extracorporeal device that directly oxygenates and removes carbon dioxide from the blood. Deoxygenated blood is withdrawn

Funding Sources: None.
Conflicts of Interest: Dr D. Brodie previously received research support from Maquet Cardiovascular, including travel expenses for research meetings and compensation paid to Columbia University for research consulting. He is a member of the Medical Advisory Boards for ALung Technologies and Kadence. All compensation for these activities is paid to Columbia University. Dr D. Abrams has no conflicts of interest to report.
Division of Pulmonary, Allergy and Critical Care, Columbia University College of Physicians and Surgeons, PH 8E 101, New York, NY 10032, USA
* Corresponding author.
E-mail address: hdb5@cumc.columbia.edu

Clin Chest Med 36 (2015) 373–384
http://dx.doi.org/10.1016/j.ccm.2015.05.014
0272-5231/15/$ – see front matter

from a central vein through a drainage cannula via an external pump. The blood passes through an oxygenator, where gas exchange occurs across a semipermeable membrane, and is then reinfused into a central vessel. Venovenous ECMO refers to a circuit in which blood is both drained from and returned to a central vein. A venovenous configuration only supports gas exchange.[6] Venoarterial ECMO refers to a circuit in which blood is drained from a vein and reinfused into an artery. Venoarterial configurations can support impairments in both gas exchange and hemodynamics. Two of the major determinants of systemic oxygenation with the use of ECMO are the rate of extracorporeal blood flow and the fraction of oxygen in the gas compartment of the oxygenator.[7,8] Blood flow is determined predominantly by the size of the cannulae used for drainage, and, to a lesser extent, reinfusion. Larger cannulae are generally able to achieve higher blood flow rates, which results in a greater proportion of the cardiac output oxygenated by the ECMO circuit. The major determinant of carbon dioxide removal, by contrast, is the rate of gas flow through the gas compartment of the oxygenator (known as sweep gas), with extracorporeal blood flow rate, among other factors, having a less significant impact.[8] The intrinsic diffusion properties of the extracorporeal membrane and the contribution of the native lungs will also have a direct impact on gas exchange. Because oxygenator membranes are highly efficient at carbon dioxide removal, lower blood flow rates and, therefore, smaller cannulae may be used when the primary intention in using the device is extracorporeal carbon dioxide removal (ECCO$_2$R).[9] An alternative to venovenous and venoarterial configurations is an arteriovenous strategy, in which the patient's native cardiac output, instead of an external pump, generates the extracorporeal blood flow.[10] The blood flow rates are generally lower than what can be achieved with a mechanical pump, and, therefore, its use is predominantly restricted to ECCO$_2$R.

Venovenous ECMO configurations may consist of either a 2-site or single-site cannulation strategy. In a 2-site setup, the drainage cannula is typically placed into the inferior vena cava via the femoral vein and the reinfusion cannula is placed into the internal jugular vein with its tip near the junction between the superior vena cava and the right atrium (**Fig. 1**).[7] More recent advances in cannula design have led to the development of a bicaval, dual-lumen cannula that allows for both drainage and reinfusion through 1 cannula placed in the internal jugular vein (**Fig. 2**).[11] When properly positioned, which usually requires transesophageal and fluoroscopic guidance, the reinfusion jet of oxygenated blood is directed toward the

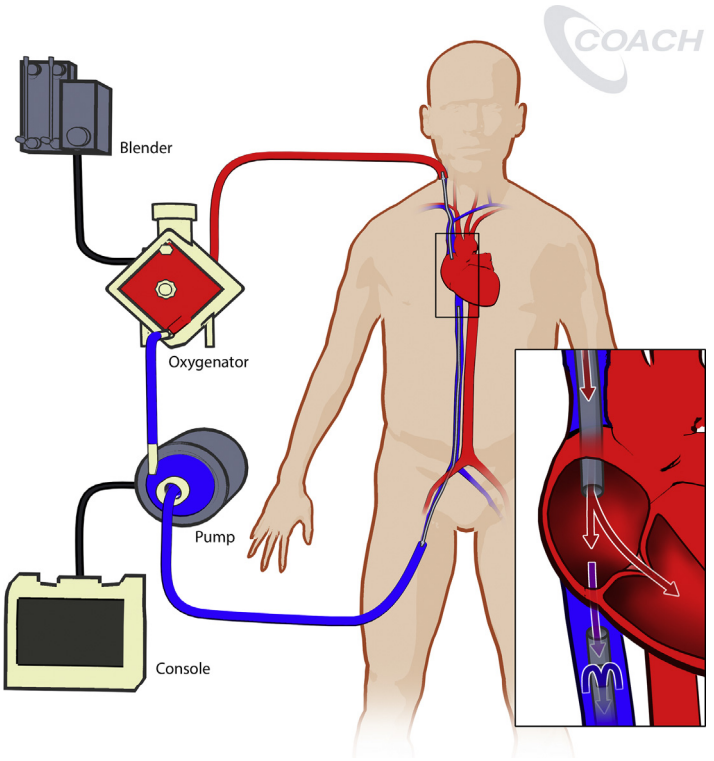

Fig. 1. Two-site venovenous extracorporeal membrane oxygenation. Venous blood is withdrawn from a central vein, pumped through an oxygenator, and reinfused into a central vein. *Inset*: When drainage and reinfusion ports are in close approximation, some portion of reinfused, oxygenated blood (*red arrow*) may be drawn back into the circuit without having entered the systemic circulation, known as recirculation (*purple arrow*). (*Reprinted from* CollectedMed.com; with permission.)