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Darryl Abrams
Alain Combes
Daniel Brodie

What's new in extracorporeal membrane oxygenation for cardiac failure and cardiac arrest in adults?

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D. Abrams · D. Brodie (✉)
Division of Pulmonary, Allergy, and Critical Care, Columbia University College of Physicians and Surgeons, 622 W. 168th St, PH 8E 101, New York, NY 10032, USA
e-mail: hdb5@columbia.edu
Tel.: +1-212-3059817
Fax: +1-212-3058464

D. Abrams
e-mail: da2256@columbia.edu

A. Combes
Service de Réanimation Médicale, Groupe Hospitalier Pitié-Salpêtrière, Institute of Cardiometabolism and Nutrition (iCAN), Assistance Publique-Hôpitaux de Paris, Université Pierre et Marie Curie, Paris 6, France

Introduction

Extracorporeal membrane oxygenation (ECMO) is one of several mechanical circulatory support devices used for patients with cardiac failure (Fig. 1). Advances in both extracorporeal technology and cannulation techniques, which have led to an improved risk–benefit profile, have increased the use and broadened the potential applications for ECMO in these circumstances. Additional data is ultimately needed to select the most appropriate patients and circumstances for extracorporeal support [1].

Myocardial infarction-associated cardiogenic shock

Recent non-randomized studies suggest a survival advantage from the early use of ECMO in cardiogenic shock complicating acute myocardial infarction (Table 1). An observational study comparing patients with ST-segment elevation myocardial infarction-related cardiogenic shock undergoing percutaneous coronary intervention (PCI), before and after the availability of ECMO, revealed a significantly lower 30-day mortality among the ECMO recipients (39.1 vs. 72 %, $p = 0.008$) [2]. Interpretation of this data is limited by the comparison of groups over two consecutive time periods, with discrepancies in both medical and interventional management over time.

Fulminant myocarditis

Patients with cardiogenic shock from non-ischemic etiologies, including fulminant myocarditis, may likewise benefit from ECMO support. In a cohort of patients who received either a biventricular assist device ($n = 6$) or ECMO ($n = 35$) for fulminant myocarditis with refractory cardiogenic shock, intensive care unit (ICU) survival was 68 % [3]. Among a subset with long-term follow-up, health-related quality of life scores were lower than matched controls but comparable to other subjects who had received ventricular assist devices (VADs) as bridge to heart transplantation. ECMO may be as effective in supporting fulminant myocarditis as a VAD. In a cohort of 11 patients supported with either ECMO or a biventricular assist device, there was no significant difference in survival to discharge without transplantation (83 vs. 80 %). Those receiving ECMO had more rapid renal and hepatic recovery, despite a higher severity of illness prior to device implantation [4].

Sepsis-associated cardiomyopathy

Profound myocardial depression is a well-recognized consequence of severe septic shock. Emerging data

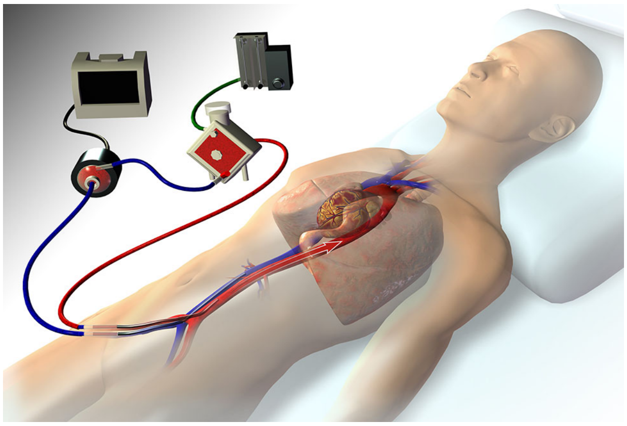

Fig. 1 Femoral venoarterial extracorporeal membrane oxygenation. Venoarterial ECMO involves draining venous blood from a central vein, pumping it through a gas exchange membrane, and reinfusing the oxygenated blood into a central artery. In contrast to venovenous ECMO, which reinfuses oxygenated blood into a central vein and provides only respiratory support, venoarterial ECMO provides both respiratory and hemodynamic support

suggests that ECMO may have a role in supporting patients who develop sepsis-associated refractory cardiac failure [5]. Additional studies are needed to better define the role of ECMO in these circumstances.

Pulmonary hypertension

In decompensated pulmonary hypertension with right ventricular failure, ECMO may be considered as either a bridge to recovery when there is a reversible process or as a bridge to transplantation for end-stage disease [6]. Novel configurations that avoid femoral cannulation have recently been developed, including the combination of internal jugular venous drainage and subclavian arterial return (via an end-to-side graft). For those with an atrial septal defect or patent foramen ovale, a bicaval dual-lumen cannula may be inserted in the internal jugular vein with the reinfusion jet directed across the defect, thereby creating an oxygenated right-to-left shunt with right heart decompression [6].

Bridging to VAD or transplantation and post-operative support

The use of ECMO has been reported as a bridge to VAD or heart transplantation, although its success depends in large part on pre-ECMO patient characteristics and organ availability in cases where transplantation is the goal [7]. In patients with biventricular dysfunction undergoing left ventricular assist device (LVAD) implantation, ECMO may be used to provide peri- and postoperative right ventricular support to avoid right ventricular distention and failure and poor LVAD filling [8]. In post-cardiotomy cardiogenic shock, ECMO may be considered as temporary support, particularly in those who cannot be weaned from cardiopulmonary bypass, although mortality remains high in this patient population [9]. Primary graft failure (PGF) after heart transplantation is likewise associated with a high mortality. However, those with PGF supported with ECMO who survive beyond the early post-transplant period have comparable long-term survival to non-PGF transplant recipients [10].

Pulmonary embolism and refractory shock

Patients with massive pulmonary embolism, including those in active cardiac arrest, may benefit from the use of ECMO for hemodynamic and respiratory support. ECMO combined with anticoagulation, thrombolysis, surgical embolectomy, or catheter-directed thrombectomy has been reported with variable success.

Table 1 Indications for ECMO in cardiac failure

Indication for ECMO	Highest quality studies available
Myocardial infarction-associated cardiogenic shock	Cohort studies
Fulminant myocarditis	Cohort studies
Sepsis-associated cardiomyopathy	Case series
Decompensated pulmonary hypertension with right ventricular failure	Case series
Bridge to VAD or heart transplantation	Cohort studies
Right ventricular support during LVAD implantation in biventricular failure	Cohort studies
Pulmonary embolism with refractory shock	Case series
Post-cardiotomy cardiogenic shock	Cohort studies
Primary graft failure post-heart transplantation	Cohort studies
Cardiac arrest (ECPR)	Cohort studies with propensity analyses

VAD ventricular assist device, *LVAD* left ventricular assist device, *ECPR* extracorporeal cardiopulmonary resuscitation

The role of ECMO in cardiopulmonary resuscitation

The most controversial and potentially expansive use of cardiac ECMO is as a means of restoring circulation during cardiac arrest, referred to as extracorporeal cardiopulmonary resuscitation (ECPR). A prospective matched propensity analysis demonstrated higher survival to discharge and 1-year survival among witnessed, in-hospital cardiac arrest patients who received ECPR as compared to conventional cardiopulmonary resuscitation (CPR) [11]. A more recent analysis confirmed these findings with a significantly higher rate of 2-year survival with minimal neurological impairment for ECPR recipients [12]. Younger age, shorter duration of CPR, and subsequent cardiac intervention all independently predicted good neurological outcome. ECPR has also been associated with higher neurologically intact survival at 3 months in out-of-hospital cardiac arrest.

The greatest potential for ECPR may come from its ability to increase coronary perfusion pressure while intra-arrest PCI is performed in patients with an acute coronary syndrome. The feasibility of such multimodal therapy has been demonstrated in a study combining ECMO with coronary angiography, with or without PCI [13]. Those receiving ECMO and PCI had higher rates of 30-day survival and favorable neurological outcome than those receiving ECMO and coronary angiography alone.

Ethical implications of ECPR

ECPR is an area with profound ethical implications. If not approached with measured consideration, our technical abilities could easily overrun our ethical obligations. First, the emerging role for ECMO in the setting of cardiac arrest must be carefully weighed against the potential for inappropriate use of this resource-intense technology. Second, the indiscriminate use of ECPR may result in patients dependent on ECMO without hope for recovery or the ability to bridge to destination therapy, the so-called "bridge to nowhere." Third, we must acknowledge the inevitability of cardiac arrest at the end of life, and offer ECPR only to those who may potentially benefit, not indiscriminately during every cardiac arrest. In centers performing ECPR, there should be strict criteria for initiating and withholding such therapy. These criteria should incorporate factors most likely to predict favorable outcomes, an area we hope will be further clarified as more data emerges.

Transporting on ECMO for refractory cardiogenic shock

Many patients with refractory cardiogenic shock, who are too unstable for transfer, do not have access to ECMO and other advanced cardiac therapies that are available only at specialized centers. Mobile ECMO transport teams offer the potential to stabilize patients for transport on ECMO to such centers and may result in improved survival [14].

Conclusion

The role of ECMO is rapidly expanding in cardiac failure. Additional data, including the development of outcomes prediction models, are needed to identify the patients most likely to benefit from this therapy [15].

Conflicts of interest Dr. Brodie reports receiving research support from Maquet Cardiovascular including travel expenses for research meetings and compensation paid to Columbia University for research consulting. He receives no direct compensation from Maquet. Dr. Brodie is a member of the Medical Advisory Board for ALung Technologies. Compensation is paid to Columbia University. Dr. Brodie receives no direct compensation from ALung Technologies.

Dr. Combes is the primary investigator of the EOLIA trial, NCT01470703, a randomized trial of VV-ECMO supported in part by Maquet Cardiovascular. Dr. Combes has received honoraria for lectures by Maquet Cardiovascular.

Dr. Abrams has no conflicts of interest to report.

References

1. Abrams D, Brodie D, Combes A (2013) What is new in extracorporeal membrane oxygenation for ARDS in adults? Intensive Care Med 39:2028–2030
2. Sheu JJ, Tsai TH, Lee FY et al (2010) Early extracorporeal membrane oxygenator-assisted primary percutaneous coronary intervention improved 30-day clinical outcomes in patients with ST-segment elevation myocardial infarction complicated with profound cardiogenic shock. Crit Care Med 38:1810–1817
3. Mirabel M, Luyt CE, Leprince P et al (2011) Outcomes, long-term quality of life, and psychologic assessment of fulminant myocarditis patients rescued by mechanical circulatory support. Crit Care Med 39:1029–1035

4. Pages ON, Aubert S, Combes A et al (2009) Paracorporeal pulsatile biventricular assist device versus extracorporal membrane oxygenation-extracorporal life support in adult fulminant myocarditis. J Thorac Cardiovasc Surg 137:194–197
5. Brechot N, Luyt CE, Schmidt M et al (2013) Venoarterial extracorporeal membrane oxygenation support for refractory cardiovascular dysfunction during severe bacterial septic shock. Crit Care Med 41:1616–1626
6. Abrams DC, Brodie D, Rosenzweig EB, Burkart KM, Agerstrand CL, Bacchetta MD (2013) Upper-body extracorporeal membrane oxygenation as a strategy in decompensated pulmonary arterial hypertension. Pulm Circ 3:432–435
7. Takayama H, Truby L, Koekort M et al (2013) Clinical outcome of mechanical circulatory support for refractory cardiogenic shock in the current era. J Heart Lung Transpl 32:106–111
8. Takayama H, Naka Y, Kodali SK et al (2012) A novel approach to percutaneous right-ventricular mechanical support. Eur J Cardiothorac Surg 41:423–426
9. Rastan AJ, Dege A, Mohr M et al (2010) Early and late outcomes of 517 consecutive adult patients treated with extracorporeal membrane oxygenation for refractory postcardiotomy cardiogenic shock. J Thorac Cardiovasc Surg 139:302–311
10. Marasco SF, Vale M, Pellegrino V et al (2010) Extracorporeal membrane oxygenation in primary graft failure after heart transplantation. Ann Thorac Surg 90:1541–1546
11. Chen YS, Lin JW, Yu HY et al (2008) Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. Lancet 372:554–561
12. Shin TG, Jo IJ, Sim MS et al (2013) Two-year survival and neurological outcome of in-hospital cardiac arrest patients rescued by extracorporeal cardiopulmonary resuscitation. Int J Cardiol 168:3424–3430
13. Kagawa E, Dote K, Kato M et al (2012) Should we emergently revascularize occluded coronaries for cardiac arrest?: rapid-response extracorporeal membrane oxygenation and intra-arrest percutaneous coronary intervention. Circulation 126:1605–1613
14. Beurtheret S, Mordant P, Paoletti X et al (2013) Emergency circulatory support in refractory cardiogenic shock patients in remote institutions: a pilot study (the cardiac-RESCUE program). Eur Heart J 34:112–120
15. Schmidt M, Zogheib E, Roze H et al (2013) The PRESERVE mortality risk score and analysis of long-term outcomes after extracorporeal membrane oxygenation for severe acute respiratory distress syndrome. Intensive Care Med 39:1704–1713