Extracorporeal Membrane Oxygenation for Resuscitation and Cardiac Arrest Management

Massimo Massetti, MD[a], Mario Gaudino, MD[a,*], Stefano De Paulis, MD[b], Andrea Scapigliati, MD[b], Franco Cavaliere, MD[b]

KEYWORDS

• ECMO • Cardiac arrest • Cardiopulmonary resuscitation • ECMO network

KEY POINTS

- The integration of extracorporeal membrane oxygenation (ECMO) technology into current strategies for cardiopulmonary resuscitation seems promising.
- Even in the absence of randomized trials and with a limited level of scientific evidence, several investigators have reported sound clinical benefits with the application of extracorporeal circulatory support in patients after cardiac arrest, both in and out of the hospital.
- ECMO support should be accompanied by a strategy of end-organ protection and (ideally) treatment.
- The recently developed concept of ECMO network extends the potential benefits of ECMO therapy to primary care centers and remote locations and is likely to grow considerably in the near future.

EXTRACORPOREAL CARDIOPULMONARY RESUSCITATION

Cardiac arrest (CA) can be defined as the complete interruption of oxygen delivery (D_{O_2}) leading to general cellular anoxia. Whatever the cause and the primary or secondary cardiac involvement, D_{O_2} interruption starts the process of cellular death within minutes, with regional discrepancies caused by specific tissue metabolism. Recommended treatment of CA consists of immediate procedures designed to generate blood flow and oxygenation in order to provide more time (ie, cardiopulmonary resuscitation [CPR], including chest compressions, rescue ventilations and early defibrillation, if appropriate) while searching and treating the precipitating cause (eg, myocardial infarction/reperfusion, cardiac tamponade/pericardiocentesis).[1] However, even the best-performed standard CPR results in only 25% of adequate cardiac output.[2] Furthermore, quality of CPR during both out-of-hospital CA (OHCA) and in-hospital (IHCA) CA in adults has been shown to be suboptimal compared with guideline recommendations in terms of compression rate, depth, and minimal interruption.[3,4] During CA, and once return of spontaneous circulation (ROSC) has been obtained, targeted temperature management for comatose survivors and avoidance of

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[a] Division of Cardiac Surgery, Department of Cardiovascular Sciences, Catholic University, L.go Gemelli 1, 00168 Rome, Italy; [b] Division of Cardiac Anesthesiology, Department of Cardiac Anesthesiology, Catholic University, L.go Gemelli 1, 00168 Rome, Italy
* Corresponding author.
E-mail address: mgaudino@tiscali.it

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hyperventilation and hyperoxia are other important, but often missing, steps able to improve survival to discharge.[5,6]

All these limitations in standard CPR and postresuscitation care could have played a role in the poorly improved survival rates over the last 30 years. Despite commendable efforts in research, evidence evaluation, and guideline implementation on a worldwide basis, survival to hospital discharge (StHD) rates are still discouraging for both OHCA and IHCA, being about 10% and 20% respectively.[7,8]

Definitions: Extracorporeal Cardiopulmonary Resuscitation and Extracorporeal Life Support

As with mechanical ventilation in acute respiratory failure or dialysis in renal failure, the ability to establish a bedside artificial circuit able to substitute the missing vital function has led to extracorporeal membrane oxygenation (ECMO) being considered as a possible artificial means to provide D_{O_2} in case of unresponsive CA. Together with blood flow, ECMO can provide both temperature and blood gas control to the appropriate level.

According to the definition of the Extracorporeal Life Support Organization (ELSO), extracorporeal life support (ECLS) is a "modified form of cardiopulmonary bypass used to provide prolonged delivery of oxygen to tissues" and extracorporeal cardiopulmonary resuscitation (ECPR) is "the use of ECLS for patients in CA when conventional resuscitative measures have failed."[9] For strict adherence to the concept of resuscitation, ECPR should be referred to when ECLS is initiated only "during conventional resuscitation, or when repetitive arrest events occur without ROSC for more than 20 minutes." Therefore this definition excludes patients undergoing ECLS for low cardiac output states as the result of or following CA, in which ROSC has been obtained before institution of ECLS.

ECPR can potentially be initiated for IHCA in specialized environments (such as intensive care units [ICUs] or operating theaters) or at the bedside (including in the emergency department); in case of OHCA, in the emergency department after patient arrival or, more rarely, outside the hospital.

ECPR has been applied in neonatal, pediatric, and adult patients in cases of both IHCA and OHCA.[10,11] This article reviews the use of ECPR for IHCA in adult patients.

Current Recommendations

In resuscitation guidelines from 2010, ECPR use is explicitly considered only in the pediatric life support section.[12] ECLS is recommended in cases of refractory CA occurred in a highly supervised environment and with expertise and equipment rapidly available. Most of the evidence supporting this recommendation was based on studies including children with cardiac disease who had CA as a complication of cardiac surgery. Evidence was insufficient to recommend ECLS outside the ICU or in patients with OHCA except for those with environmentally induced severe hypothermia.

ECPR is not cited in the adult life support section of 2010 guidelines, because evidence was considered insufficient to support its routine use in refractory CA. However, some forms of extracorporeal support are mentioned in the treatment of CA associated with special circumstances: temperature management (hypothermia/hyperthermia), removal of abnormal electrolytes or poisons, untreatable asthma, CA following cardiac surgery.[13]

Nevertheless, to support clinical decisions with consistent indication criteria in the absence of clear evidence and to limit inappropriate implementation of ECLS with possible disappointing results, local guidelines have been published. In 2009, a panel of French experts on behalf of the National Ministry of Health published the "Guidelines for Indications for the Use of Extracorporeal Life Support in Refractory Cardiac Arrest," providing an algorithm for ECLS use to define situations in which ECPR can be indicated, uncertain, or not indicated.[14]

Looking for Evidence

Reliable evidence is needed for wider ECLS implementation because establishment and management of this procedure are expensive and resource consuming. ECMO deployment has been estimated to have a cost of about US$100,000 per patient and requires a start-up phase with proper staff training and allocation to be available 24 hours a day, 7 days a week.[15] A statement of the ECLS Working Group of the European Association for Cardio-Thoracic Surgery has recently provided technical prerequisites for ECLS deployment.[16]

However, clinical research in resuscitation is generally difficult because of emergent and ethical characteristics of CA. Complexity and team expertise related to ECPR make these difficulties even greater. Studies providing the strongest evidence on treatment efficacy need large sample size, randomization with proper blinding, and homogeneous implementation of treatment: so far no study has achieved these targets. Therefore considerations on ECPR are based on observational studies or alternative design studies such as those using propensity-score analysis.