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ORIGINAL ARTICLE

Extracorporeal cardiopulmonary resuscitation

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Cardiac arrest;
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Abstract ECPR is defined as the rapidly-deployed application of venoarterial extracorporeal membrane oxygenation, in patients with cardiac arrest, during cardiopulmonary resuscitation before the return of ROSC. ECPR is one of the most rapidly growing segments of ECLS, and is becoming more widespread. Consideration for institution of ECPR is given to patients with witnessed arrest, good quality CPR instituted within 5 min of arrest, in whom ROSC does not occur within 15 min, and who can complete cannulation within 30–60 min. Patients from both inpatient and out-of-hospital settings are candidates if they meet these criteria. Deep hypothermic cardiac arrest, such as cold-water drowning, should receive consideration for ECPR even after considerable duration of arrest. Available outcome data are based on retrospective observation studies, some with propensity matching, and suggests a higher chance for survival with ECPR. Published outcomes from ECPR, however, are difficult to interpret, since many centers classify their use of ECLS after ROSC, in addition to ECLS before ROSC, as ECPR. Both children and adults are candidates for ECPR, but the experience in children is weighted heavily toward those with a diagnosis of cardiac disease and arrest occurring within closely monitored units.

1. Introduction

Extracorporeal cardiopulmonary resuscitation (ECPR) refers to the use of rapid-deployment venoarterial extracorporeal membrane oxygenation to provide circulatory support during cardiac arrest, when conventional CPR has failed to provide return of spontaneous circulation (ROSC) [1,2], or when repetitive arrests occur without sustained ROSC. Venoarterial (VA) ECMO is the required mode of support since cardiac output is absent or at best inadequate and intermittent. ECPR has sometimes been used to refer to extracorporeal support of low cardiac output states following ROSC, but the Extracorporeal Life Support Organization (ELSO) does not include this scenario in its definition of ECPR [2].

ECPR is one of the most rapidly growing segments of ECLS as reported to the ELSO Registry. In the interval 2012 through 2015 there were 869 neonatal, 1106 pediatric, and 1337 adult cases reported. This number underrepresents

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the actual number, as a number of centers performing ECPR are not ELSO centers and are not reporting their data.

2. Rationale

Several factors have been associated with survival following cardiac arrest [3–10]. Included are the initial rhythm and whether it is shockable, and the presence of comorbidities, which may be related to initial rhythm. The time to initiation of external chest compressions, and the adequacy of those compressions are both important factors. The time to defibrillation in the presence of a shockable rhythm and the time to return of spontaneous circulation (ROSC) are also major determinants.

ECPR has the potential to modify some of these factors, although data are lacking to demonstrate any direct influence. The institution of support provides definitive and immediate return of circulation, albeit not spontaneous, thereby providing adequate organ perfusion not possible with CPR. Improved perfusion of the myocardium may allow success at defibrillation, or elimination of myocardial hypoxemia that may have led to non-shockable rhythms, thereby allowing return of myocardial function. External circulation can permit rapid institution of hypothermia during the resuscitation phase, greatly reducing exposure to higher temperatures at the time of reperfusion.

3. Patient selection

In the adult population, there is sufficient experience with ECPR to provide guidance for selecting patients who may benefit [11]. As new data accumulate, it is likely that criteria for consideration will change. One of the difficult decisions to make is when to consider conventional resuscitation measures inadequate and an indication to initiate ECPR. Too early implementation would lead to application in many patients who would have recovered conventionally, whereas too late implementation could lead to application beyond the period of reversibility. The rate of ROSC decreases with time, with half or more of patients recovering from in-hospital and out-of-hospital cardiac arrest within 10–15 min, and the great majority within 20 min [12,13]. The target to initiation of support would be ideally 30 min, but no more than 60 min, from onset of conventional resuscitation. Beginning the decision-making within 10 min and completing by 15 min would allow identification of patients with low chance of ROSC with conventional means and allow for ECPR within the allowable time limits [11].

The arrest should be witnessed, and the duration of no-flow prior to resuscitation efforts should be less than 5 min. Good-quality CPR should have been provided at all times, which may best be performed with properly adjusted mechanical compression devices. Additional considerations include the presence of comorbidities, especially cardiovascular, and the pre-arrest functional status. Patients sustaining cardiac arrest in both the inpatient and out-of-hospital setting should be considered.

ECPR is now the treatment of choice for deep hypothermic (<20 °C) cardiac arrest refractory to conventional resuscitation efforts. Variance on the times to conventional CPR and time to ECPR can be afforded these patients, since experience suggests good outcomes with therapy delayed to as long as 226 min [14].

4. Technical considerations

As a rapidly-deployed procedure, ECPR programs benefit from simplified pre-primed circuits positioned in a strategic location, trained individuals to perform percutaneous or surgical cannulation, and a cross-discipline organization structure supported by defined protocols.

5. Extracorporeal circuit

Centrifugal pump systems with hollow-fiber membrane oxygenators have numerous advantages that make them most suitable for ECPR. These components can be quickly primed and have reasonably small priming volumes. The centrifugal pump is afterload-dependent, and circuit rupture is non-existent when properly assembled and operated, eliminating the need for pre- and post-pump pressure monitoring. The pump provides a controlled inlet pressure, allowing augmented venous return without the need for gravity-facilitated hydrostatic pressure, allowing the pump to be positioned close to the patient. Hollow-fiber membrane oxygenators prime quickly without residual deadspace.

The size of the extracorporeal circuit depends on patient size. Circuits with ¼″ tubing size are used for pediatric circuits for body weights up to about 15 kg. Larger children and adults are managed with ⅜″ tubing size circuits. Centrifugal pumps currently are available in one size with ⅜″ inlet and outlet ports, and require downsizing for pediatric circuits. Membrane oxygenators are available in adult (⅜″ connector), and pediatric (¼″ connector) sizes, with some manufacturers providing a neonatal size. The membrane oxygenator should have a rated flow at least 1.5 times the expected maximum flow for the patient.

The use of pre-primed circuits eliminates any time lost to priming at the time of cardiac arrest. Circuits primed with crystalloid alone (free of glucose, protein and blood products) have been shown to be infection free for 14 days [15] and up to 30 days [16]. It is likely that longer durations of storage are safe, but data are lacking. A potential approach to prolonged storage is to sample the circuit for bacterial antigens or culture at intervals and discard the circuit if contamination is found. Although microporous hollow-fiber membrane oxygenators lose some function after pre-priming [17], modern nanoporous “plasma tight” hollow-fiber membrane oxygenators do not appear to lose any functional capacity when stored for 2 weeks [18], and there does not appear to be any leaching of plasticizers into the prime [19].

The introduction of small-footprint, portable, integrated ECLS systems has streamlined the initiation of ECLS, and has demonstrated functionality during transport [20] and in-hospital support [21].

6. Cannulation

The cannulation sites for arteriovenous support in the adult depend on the circumstances surrounding resuscitation. Patients in the emergency department or hospital ward who are not post-op cardiac patients will usually undergo