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Clinical Paper

Extracorporeal life support as rescue strategy for out-of-hospital and emergency department cardiac arrest

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ABSTRACT

Background: Extracorporeal life support (ECLS) has been utilized as a rescue strategy for patients with cardiac arrest unresponsive to conventional cardiopulmonary resuscitation.
Objective: We sought to describe our institution's experience with implementation of ECLS for out-of-hospital and emergency department (ED) cardiac arrests. Our primary outcome was survival to hospital discharge.
Methods: Consecutive patients placed on ECLS in the ED or within one hour of admission after out-of-hospital or ED cardiac arrest were enrolled at two urban academic medical centers in the United States from July 2007–April 2014.
Results: During the study period, 26 patients were included. Average age was 40 ± 15 years, 54% were male, and 42% were white. Initial cardiac rhythms were ventricular fibrillation or pulseless ventricular tachycardia in 42%. The average time from initial cardiac arrest to initiation of ECLS was 77 ± 51 min (range 12–180 min). ECLS cannulation was unsuccessful in two patients. Eighteen (69%) had complications related to ECLS, most commonly bleeding and ischemic events. Four patients (15%) survived to discharge, three of whom were neurologically intact at 6 months.
Conclusion: ECLS shows promise as a rescue strategy for refractory out-of-hospital or ED cardiac arrest but is not without challenges. Further investigations are necessary to refine the technique, patient selection, and ancillary therapeutics.

1. Introduction

Extracorporeal life support (ECLS) has been used in cardiac surgery since the 1950s and has subsequently been applied to patients outside of the operating room with cardiopulmonary failure. A number of ECLS case series have demonstrated successful treatment of refractory respiratory failure, poisoning, cardiac arrest, and cardiogenic shock [1–7].

Japanese case reports of application of ECLS to patients with refractory cardiac arrest have appeared in journals since the mid-1980s. These cases were recently reviewed and summarized in *Resuscitation* [8]. The first English language reports of ECLS for refractory cardiac arrest were published in the late 1990s [4,9]. In 2000, physicians at the University of Michigan documented their experience with 1000 consecutive patients treated with ECLS for a variety of indications including cardiac arrest and cardiogenic shock as well as the scientific and logistical evolution of their program [1]. Since this time, a handful of centers both in the United States and internationally have documented success with using ECLS for cardiogenic shock or cardiac arrest refractory to traditional therapies [2,10–14]. Data from pediatrics and neonatology are most promising, with

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one study documenting 40% neurologically-intact survival among children who suffered in-hospital cardiac arrest [15].

A large randomized trial of ECLS for cardiac arrest has not yet been completed. Several analyses comparing cardiac arrest patients treated with ECLS and matched cohorts have demonstrated benefit [12,16,17]. A small but growing body of literature supports deployment of ECLS in the emergency department (ED) for selected cases of refractory out-of-hospital cardiac arrest [10–12]. The experiences from a few selected centers appear promising, but controversy still exists about the wide-spread adoption of ECLS as well as its cost-effectiveness, feasibility, and efficacy for cardiac arrest [18].

We aim to describe our institution's experience implementing ECLS as a rescue strategy in adult patients with out-of-hospital cardiac arrests and in the ED. Our primary outcome was survival to hospital discharge.

2. Methods

2.1. Study design

This is an analysis of consecutively enrolled patients in a prospective registry from July 1, 2007 to April 1, 2014. This study was approved by the Institutional Review Board of the University of Pennsylvania.

2.2. Setting

This investigation was conducted at the Hospital of the University of Pennsylvania (HUP) and Penn Presbyterian Medical Center (PPMC). HUP is an urban, academic, adult, quaternary referral center with 70,000 annual ED visits, 772 beds, 39,000 annual admissions, and a Level 1 trauma center. PPMC is an urban academic and community hospital with 40,000 annual ED visits, 331 beds, and 17,000 annual admissions. During the study period, 914 patients who suffered cardiac arrest were cared for in the study EDs.

2.3. Outcomes

Our primary outcome was survival to hospital discharge. Secondary outcomes include neurologically-intact survival at six months, ECLS processes, and ECLS complications.

2.4. Historical context and protocol

Patients in cardiac arrest or profound shock have been placed on veno-arterial (VA) ECLS at HUP since the late 1990s on a case by case basis at the discretion of the cardiothoracic (CT) surgery attending on call. During 2000–2005, the program was codified by CT surgery for in-patients and applied on an ad hoc basis for select ED patients. In 2006, the physicians, nurses, and perfusionists from Emergency Medicine and CT surgery met multiple times to develop a protocol for activation of ECLS in the ED. This protocol was implemented in July of 2007 for ED patients. (Figs. 1 and 2) Additional meetings between CT surgery and ED physicians occurred multiple times to refine processes and troubleshoot challenges that arose.

ED residents and faculty attended several educational sessions on ECLS including "Grand Rounds" lectures and simulation sessions during which ECLS was incorporated. In-service training sessions for ED nurses discussing equipment and procedures also occurred.

2.5. Subject selection

All patients who underwent ECLS cannulation for cardiac arrest in the ED or within one hour of transfer from the ED to an inpatient unit, operating room, or cardiac catheterization laboratory were included. These included ED patients who suffered out-of-hospital cardiac arrest, patients who suffered cardiac arrest in the ED, and patients who suffered cardiac arrest during transport or shortly after arriving to an inpatient unit or the cardiac catheterization lab. Inclusion and exclusion criteria (both in-hospital and out-of-hospital) are shown in Table 1. Patients were enrolled at the discretion of the treating ED team in collaboration with the CT surgery attending physician or on-call fellow.

Table 1
Inclusion and exclusion criteria for ECLS patients.

Inclusion criteria
Age 18–70
Witnessed arrest
Bystander CPR
Ventricular fibrillation or ventricular tachycardia as initial rhythm or obvious cardiac or other reversible etiology with non-shockable rhythm
Collapse to EMS arrival <15 min
Exclusion criteria
DNR or DNI status
Pre-arrest cognitive status severely impaired
Multiorgan dysfunction
Severe sepsis
Major preexisting medical comorbidities
Prolonged arrest time (>60 min)

2.6. ECLS procedures and techniques

For all patients, the treating emergency medicine team contacted the on-call cardiac surgery fellow, who is in-house around-the-clock at our institution. ED staff were encouraged to activate the ECLS protocol as rapidly as possible for all patients meeting inclusion criteria (Table 1). The fellow responded to rapidly gather clinical data and, in collaboration with the CT surgery attending and treating ED team, determined whether or not the patient was a suitable ECLS candidate. A perfusionist (also in-house around-the-clock) responded with a ECLS cart (stored in the cardiothoracic intensive care unit) that included a pre-primed cardiopulmonary bypass circuit and cannulae and cannulation supplies.

The ECLS cannulation technique was at the discretion of the treating physician. Because these patients were hemodynamically unstable, a peripheral cannulation approach was preferred. This involved cannulation of either the femoral or internal jugular vessels using a percutaneous Seldinger technique or, less commonly, surgical exposure via open cutdown. Typically, initial central venous access (and often arterial access) was obtained by an emergency medicine resident. (Fig. 2) A cardiothoracic surgery fellow or attending then performed ECLS cannulation. Central cannulation of the heart or great vessels was not performed. When femoral arterial cannulation is performed, the current practice is to place an additional catheter in the ipsilateral distal femoral or superficial femoral artery for leg perfusion. A continuous heparin infusion was initiated to maintain an activated clotting time (ACT) of 180–220 s. The ECLS circuit was managed and maintained by a perfusionist at all times.

Patients were subsequently cared for by cardiothoracic anesthesiologists, intensivists, and surgeons as well as pefusionists, critical care nurses, and ancillary staff in a dedicated cardiothoracic intensive care unit. Decisions to withdraw support were made at the discretion of the treating team.

2.7. Devices

The ECLS circuit consisted of a centrifugal pump (Maquet Rotaflo; Maquet Cardiovascular; Wayne, NJ), a polymethylpentene gas exchanger (Maquet Quadrox iD Adult; Maquet Cardiovascular;