Resuscitation 88 (2015) 126–131

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical Paper

Extracorporeal life support (ECLS) for refractory cardiac arrest after drowning: An 11-year experience

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ARTICLE INFO

Article history:
Received 29 August 2014
Received in revised form
19 November 2014
Accepted 21 November 2014

Keywords:
Hypothermia
Drowning
Cardiac arrest
Extracorporeal rewarming

ABSTRACT

Aim: Neuroprotective effects of hypothermia may explain surprisingly high survival rates reported after drowning in cold water despite prolonged submersion. We described a cohort of refractory hypothermic cardiac arrests (CA) due to drowning treated by extracorporeal life support (ECLS) and aimed to identify criteria associated with 24-h survival.

Methods: Eleven-year period (2002–2012) retrospective study in the surgical intensive care unit (ICU) of a tertiary hospital (European Hospital Georges Pompidou, Paris, France). All consecutive hypothermic patients admitted for refractory CA after drowning in the Seine River were included. Patients with core temperature below 30 °C and submersion duration of less than 1 h were potentially eligible for ECLS resuscitation.

Results: Forty-three patients were admitted directly to the ICU during the study period. ECLS was initiated in 20 patients (47%). Among these 20 patients, only four (9%) survived more than 24 h. A first hospital core temperature ≤26 °C and a potassium serum level between 4.2 and 6 mM at hospital admission have a sensitivity of 100% [95%CI: 28–100%] and a specificity of 100% [95%CI: 71–100%] to discriminate patients who survived more than 24 h. Overall survival at ICU discharge and at 6-months was 5% [95%CI: 1–16%] (two patients).

Conclusions: Despite patient hypothermia and aggressive resuscitation with ECLS, the observed survival rate is low in the present cohort. Like existing algorithms for ECLS management in avalanche victims, we recommend to use first core temperature and potassium serum level to indicate ECLS for refractory CA due to drowning.

1. Introduction

Although drowning causes many deaths each year worldwide,[1,2] there is very little evidence from clinical or experimental studies. Research is needed on this topic.[3,4] Survival following cardiac arrest (CA) due to drowning is limited and neurological prognosis is poor among the survivors.[5–9] This is likely to be due to asphyxia and to delayed cardiopulmonary resuscitation (CPR) because of the time needed to localize and remove the victim from water.[4,9] Patients with prolonged submersion have the worst prognosis. Survival is highly unlikely if submersion duration is longer than 30 min in temperate water.[1,10] A better prognosis may be encountered for patients drowning in cold water.[10–12] Under these circumstances, hypothermia may have neuroprotective effects, thereby explaining exceptional survivals reported for drowning in cold water despite prolonged submersion.[13–15] Hence, in hypothermic patients, CPR is often based on the classical principle "no one is dead until warm and dead." For these patients, cardiopulmonary bypass is the reference method for body rewarming as it allows for concomitant circulatory support.[16,17] Over the past decade, substantial technical progress allowed the use of simplified extracorporeal pumps that can easily be used outside the operating room. This technique is often referred to as extracorporeal life support (ECLS). Some observational studies have reported successful resuscitation of hypothermic CA patients using ECLS.[18–27] Out of these studies, only three included exclusively hypothermic CA patients after drowning.[25–27]

In 2002, a standardized protocol for CA due to drowning in the Seine River in Paris was initiated. This protocol encompasses rapid transport to a single intensive care unit (ICU) under chest

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http://dx.doi.org/10.1016/j.resuscitation.2014.11.023
0300-9572/

compression (automatic or manual) and immediate use of ECLS at hospital admission. The goals of the present study are to describe the characteristics of these patients and to identify criteria that discriminate patients who survived more than 24 h from those who died within the first 24 h.

2. Methods

2.1. Type of study and population

This retrospective study was undertaken in a surgical and trauma ICU between January 2002 and December 2012. The European Hospital Georges Pompidou is a teaching hospital located close to the Seine River in Paris, France. During the study period, all consecutive patients referred to our center for refractory CA due to drowning in the Seine River, were included in the study. Victims of drowning without CA and patients who returned to spontaneous circulation (ROSC) before hospital arrival were not included in the study. The ethics committee of the French Society of Intensive Care (SRLF) approved the design of the study.

2.2. Protocol for patient management

Our protocol concerns every step of the patient management from prehospital setting to ICU discharge.

2.3. Prehospital management

In the case of drowning in the Seine River, rescue divers from the Fire or the River Police Department team (first-tier response) remove the victim from water and start basic life support (BLS). Then, a second-tier response team with an emergency physician, is dispatched to the scene and starts advanced life support (ALS) according to international guidelines.[28] Immediately after tracheal intubation, all patients are transported by boat or ambulance to the single participating hospital under manual or automatic chest compression (LUCAS® device, Jolife AB, Lund, Sweden or AutoPulse® device, Chelmsford, MA, USA).

2.4. Hospital initial management

Upon hospital arrival, all patients in refractory CA are screened for eligibility for ECLS. Our criteria for initiating ECLS are severe hypothermia (i.e. core temperature between 18 and 30 °C measured with an esophageal probe) associated with an estimated submersion duration less than 60 min or a shockable initial cardiac rhythm. For patients with prolonged transportation duration, unknown submersion duration or very profound hypothermia (<18 °C), the cannulation procedure is initiated but the decision to start ECLS is moderated by the initial serum potassium concentration.[17,29] A serum potassium above 8 mM is considered a contra-indication to initiating ECLS.

2.5. Cannulation and ECLS initiation

Peripheral arterial and venous femoral cannulation is preferentially performed percutaneously by the intensivists using a Seldinger technique.[30] The entire procedure is performed under automatic chest compressions. Puncture of femoral vessels is systematically echo-guided. The cannulas are inserted in the appropriate vessels after successful placement of the leaders and progressive dilatation. When cannulation is deemed difficult, puncture of contralateral femoral vessels or surgical access of the groin is considered. During cannulation, the ECLS circuit is assembled and primed by trained personnel (physician or nurse). Before 2010, the ECLS circuit encompassed a Biomedicus® centrifugal pump and an Affinity® membrane oxygenator (Medtronic®, Minneapolis, MN, USA). Since 2010, an alternative ECLS circuit is used, containing a Rotaflow® centrifugal pump and a Quadrox® membrane oxygenator (Maquet®, Orleans, France). Both ECLS circuits are heparin-coated, biocompatible and their priming volume is of less than 1000 mL. Blood temperature is controlled through a thermal exchanger system. Arterial reperfusion of the lower limb is considered during the first hours, and is performed by cannulating the superficial femoral artery.

2.6. Patient and ECLS management

Mechanical chest compressions are stopped immediately after initiation of ECLS. The initial blood flow is adapted to core temperature (1.0 L min^{-1} m^2 below 20 °C, 1.5 L min^{-1} m^2 between 20 °C and 25 °C, 1.8 L min^{-1} m^2 between 25 °C and 30 °C and 2–2.5 L min^{-1} m^2 above 30 °C). Gas flow and oxygen fraction (FiO_2) are rapidly adapted to obtain normoxia (PaO_2: 90–100 mmHg) and normocapnia ($PaCO_2$: 35–45 mmHg). Blood gases were not corrected to the patient's temperature (alpha-stat management). Mechanical ventilation is maintained ultra-protective under ECLS with high PEEP (10–15 cmH_2O), low FiO_2 (21–30%), low respiration rate (6–10 min^{-1}) and the lowest tidal volume to keep the plateau pressure under 25 cmH_2O. Norepinephrine infusion is considered to maintain mean arterial blood pressure in the range of 60–70 mmHg. Fluids and blood products are administered to maintain blood flow in the target range and hemoglobin concentration above 8 g dL^{-1}. Sedation and analgesia are achieved with midazolam and sufentanil; atracurium is used for neuromuscular blockage. Tracheal aspirate culture is performed before initiating an empirical antibiotherapy. As *Aeromonas hydrophila* and *Pseudomonas aeruginosa* are known to be prevalent in the Seine water,[31] piperacilline/tazobactam is the primary choice for empirical antibiotherapy. Slow active rewarming via the thermal exchanger connected to the ECLS circuit is started after hemodynamic stabilization. During the first 24 h, the target temperature is 32–34 °C.[4,16] If ventricular fibrillation occurs during rewarming, electrical cardioversion is attempted only when core temperature is above 29 °C. After the first 24 h, complete and very slow rewarming (maximum 0.5 °C by hour) is targeted up to 36–37 °C and hyperthermia (>37.5 °C) is avoided. Neuromuscular blockade and sedation are subsequently discontinued.

ECLS weaning is considered after ROSC, rewarming and recovery of adapted mechanical cardiac activity (left ventricular ejection fraction >30% and absence of right ventricular failure as evaluated by transesophageal echocardiography) and in absence of severe respiratory failure (PaO_2/FiO_2 > 150 mmHg with a lung protective ventilation including a tidal volume of 6 ml kg^{-1} of predicted body weight and a plateau pressure less than 30 cmH_2O). Decannulation is performed by vascular surgeons.

2.7. ECLS withdrawal

According to French law and intensive care guidelines, withdrawal of life-sustaining treatments can be decided if such treatments are deemed futile. Specifically, in case of ECLS failure during the first 24 h (defined as an inability to maintain blood flow despite aggressive fluid therapy or massive doses of catecholamines, or the rapid development of multiple organ failure or incontrollable bleeding), ECLS is prematurely discontinued and the patient is declared deceased.

2.8. Data acquisition

Patients in CA after drowning in the Seine were identified from our ICU database or from the hospital database using the ICD-10 procedure coding system. Prehospital and hospital data were both