

Clinical paper

Pulse pressure as a prognostic marker in patients receiving extracorporeal life support[☆]Byoung-Won Park^a, Dae-Chul Seo^a, In-Ki Moon^a, Jin-Wook Chung^{a,*}, Duk-Won Bang^a, Min-Su Hyon^a, Sung-Koo Kim^a, Won-ho Chang^b, Wook Youm^b^a Division of Cardiology, Department of Internal Medicine, Soonchunhyang University Hospital, Seoul, Republic of Korea^b Department of Chest Surgery, Soonchunhyang University Hospital, Seoul, Republic of Korea

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ABSTRACT

Background: It is not easy to predict the prognosis of patients receiving extracorporeal life support (ECLS) because of the highly variable situation around its implementation. We evaluated the role of pulse pressure (PP), which is available on real-time basis, as a hemodynamic prognostic marker during ECLS. **Methods:** From January 2009 to August 2011, data from 69 patients who were treated with ECLS for at least 6 h in a single center for any cause was collected. We calculated the mean PP over the first 6 h after ECLS implantation and examined if there was any correlation between mean PP and the study endpoints, in-hospital death and ECLS weaning failure.

Results: The causes of ECLS were of cardiac origin in 36 patients (52%). 27 patients (39.1%) weaned off ECLS and 13 patients (18.8%) survived to discharge. In Cox regression analysis (with age, Killip class ≥ 3 , ECLS implementation during cardiopulmonary resuscitation (CPR), CPR duration, out-of-hospital arrest, initial laboratory results including blood gas analysis, initial systolic blood pressure (SBP), mean SBP over the first 6 h after ECLS implantation, mean PP over the first 6 h after ECLS implantation as independent variables), mean PP over the first 6 h after ECLS implantation (hazard ratio [95% confidence interval] = 0.96[0.94–0.98], $P < 0.001$) and out-of-hospital arrest (HR[95%CI] = 2.04[1.14–3.62], $P = 0.02$) were independent predictors of in-hospital mortality and mean PP over the first 6 h after ECLS implantation (HR[95% CI] = 0.95[0.93–0.98], $P < 0.001$) was the sole independent predictor of weaning failure.

Conclusion: Higher mean PP over the initial 6 h after ECLS implementation independently predicted successful weaning and survival. Our findings may help better predict and analyze prognosis in patients receiving ECLS.

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1. Introduction

Extracorporeal Life Support (ECLS) is a life-saving tool for patients with refractory shock who need mechanical circulatory support.^{1,2} With the introduction of miniaturized pumps and bio-compatible circuits, the indications for ECLS have expanded to include diverse medically emergent cases. However, it is not easy to determine clear-cut indications for ECLS and its use sharply raises medical costs and resource utilization. Because of this, identification of factors associated with better prognosis is important.

Advanced age, female sex, stroke, renal failure, acidosis, hypoglycemia and ECLS under cardiopulmonary resuscitation have been

reported as poor prognostic markers in patients receiving ECLS.^{3,4} However, the prognostic role of hemodynamic parameters has not been well elucidated. Because ECLS is usually initiated under emergency or urgent situations, initial hemodynamic parameters cannot be measured exactly or may be unreliable.

Pulse pressure (PP) is a well known hemodynamic parameter that correlates to cardiac output.⁵ After ECLS implantation, PP is always available on real-time basis in the intensive care setting. The objective of this study is to test the role of mean PP as a hemodynamic prognostic marker in patients receiving ECLS.

2. Patients and methods

This retrospective study was approved by our Institutional Review Boards, which exempted informed consent. Between January 2009 and August 2011, 79 consecutive patients were treated with venoarterial (using the femoral vein and artery) ECLS in a single center for any indication. Of those, we included the 69 patients in this analysis whose ECLS duration was at least 6 h. 10

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out-of-hospital arrest patients were excluded because they died within the first 6 h after initiation of ECLS. We calculated mean PP over the first 6 h after ECLS implantation.

The extracorporeal system consisted of a centrifugal pump, polypropylene hollow fiber membrane oxygenator, and a heparin-coated circuit (Capiiox EBS circuit; Terumo Inc, Tokyo, Japan). The most valuable benefit of this system is its autoprime, requiring less than 5 min to prime the circuit before use.⁶ Five thousands IU of unfractionated heparin was administered 5 min before femoral arterial cannulation unless another anticoagulant had been administered. Cannulation was achieved percutaneously in the femoral artery and vein using the Seldinger technique. Once the cannulation was established, ECLS was initiated on the patient; if successful, cardiopulmonary resuscitation (CPR) was discontinued. ECLS was applied in the emergency room, intensive care unit, operating room, or cardiac catheterization lab setting. To prevent limb ischemia, distal perfusion was optimized in 11 patients (15.9%) through a 7 Fr catheter introduced distally to the cannulation site and connected to the side-arm of the return arterial cannula. If possible, hemoglobin was maintained above 8–9 g/dl and platelet count above $50,000 \mu\text{L}^{-1}$ to minimize complications of bleeding. We used low molecular weight heparin or unfractionated heparin to reduce thromboembolic complications during ECLS treatment if not contraindicated. Generally, no attempt was made to wean patients off ECLS until 12–24 h of support was given. When a weaning attempt was made, transthoracic echocardiography was used to monitor heart function. During weaning, flows were gradually reduced to 1 L/min/m^2 . Inotropic agents were used to facilitate weaning in most patients. Patients who maintained adequate ventricular function and stable vital signs were decannulated. Survival for 48 h after weaning with mean systolic blood pressure higher than 90 mmHg was considered as a successful weaning.

2.1. Statistical analysis

The statistical analysis was performed using the SPSS 14.0K software (SPSS, Chicago, IL, USA). Categorical variables were compared with χ^2 or Fisher's exact tests. Continuous variables were compared with unpaired Student's *t*-test. Cox regression analysis was performed to determine independent predictors of weaning or survival to discharge. Age, Killip class ≥ 3 , ECLS implementation during cardiopulmonary resuscitation (CPR), CPR duration, out-of-hospital arrest, initial blood gas analysis, serum creatinine, initial systolic blood pressure (SBP), mean SBP over the first 6 h after ECLS implantation, mean PP over the first 6 h after ECLS implantation were included as independent variables for this analysis. Statistical significance was considered to be $P < 0.05$.

3. Results

3.1. Patient characteristics

In 36 patients (52%), the causes of ECLS were of cardiac origin. The most common cardiac cause was acute myocardial infarction ($n = 22$, 61% of cardiac causes, 31.9% of total). Among non-cardiac causes, respiratory failure was most common ($n = 13$, 39.4% of non-cardiac causes, 18.8% of total), followed by sepsis ($n = 11$, 33% of non-cardiac causes, 15.9% of total), pulmonary thromboembolism ($n = 3$, 9.1% of non-cardiac causes, 4.3% of total), subarachnoid hemorrhage ($n = 3$, 9.1% of non-cardiac causes, 4.3% of total), trauma ($n = 2$, 6.1% of non-cardiac causes, 2.9% of total), and hypovolemic shock ($n = 1$, 3.0% of non-cardiac causes, 1.4% of total). 27 patients (39.1%) weaned off ECLS and 13 patients (18.8%) survived to discharge. Among the 27 patients who were successfully weaned, cardiac disease was the cause in 15 patients (55.6%), respiratory

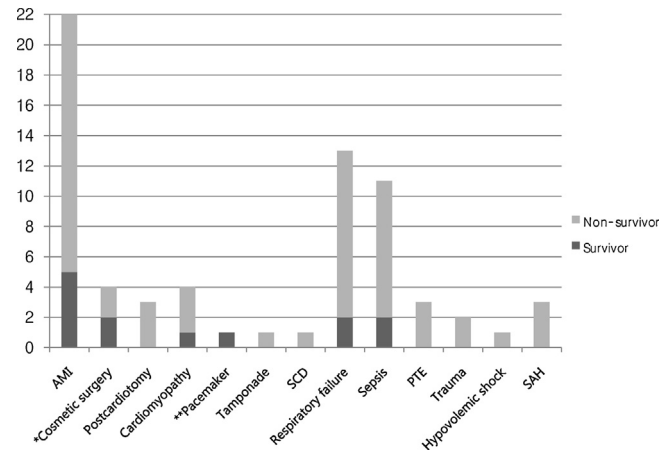


Fig. 1. Number of total and survived patients according to the causes of extracorporeal life support. AMI, acute myocardial infarction; *cosmetic surgery, cardiac arrest during cosmetic surgery; **pacemaker, refractory ventricular fibrillation during pacemaker insertion; SCD, sudden cardiac death; PTE, pulmonary thromboembolism; SAH, Subarachnoid hemorrhage.

failure in 6 patients (22.2%), sepsis in 5 patients (18.5%), and subarachnoid hemorrhage in 1 patient (3.7%). Of the 13 survivors, cardiac disease was the cause in 9 patients (69.2%), respiratory failure in 2 patients (15.4%), and sepsis in 2 patients (15.4%). Among the 9 surviving cardiac disease patients, acute myocardial infarction was the cause in 5 patients (38.5%), cardiac arrest during cosmetic surgery in 2 patients (15.4%), cardiomyopathy in 1 patient (7.7%), and refractory ventricular fibrillation during pacemaker insertion in 1 patient (7.7%) (Fig. 1). Demographic data and clinical features of the two sets of groups are compared (survivors versus non-survivors, weaning success versus weaning failure) in Table 1. Mean PP over the first 6 h after ECLS implantation was significantly different in both sets of groups (39.6 ± 7.1 mmHg in survivors versus 28.1 ± 16.0 mmHg in non-survivors, $P < 0.001$; 37.9 ± 11.2 mmHg in weaning success versus 25.3 ± 15.8 mmHg in weaning failure, $P < 0.001$). Mean SBP over the first 6 h after ECLS implantation was significantly different in both sets of groups (95.8 ± 23.6 mmHg in survivors versus 79.4 ± 41.3 mmHg in non-survivors, $P = 0.03$; 90.7 ± 25.7 mmHg in weaning success versus 72.1 ± 47.6 mmHg in weaning failure, $P = 0.04$). Initial PCO_2 was significantly lower in survivors (31.2 ± 11.6 mmHg in survivors versus 49.8 ± 27 mmHg in non-survivors, $P < 0.001$). Pre-ECLS SBP was significantly high in the weaning success group (62.2 ± 45.0 mmHg in weaning success versus 38.8 ± 41.0 mmHg in weaning failure, $P = 0.03$).

3.2. Cox regression analysis for survival and weaning

Cox regression analysis showed mean PP over the first 6 h after ECLS implantation (hazard ratio (HR)[95% confidence interval (CI)] = $0.96[0.94-0.98]$, $P < 0.001$) and out-of-hospital arrest (HR[95%CI] = $2.04[1.14-3.62]$, $P = 0.02$) were independent predictors of in-hospital mortality; mean PP over the first 6 h after ECLS implantation (HR[95% CI] = $0.95[0.93-0.98]$, $P < 0.001$) was the sole independent predictor of weaning failure (Table 2).

Kaplan–Meyer curves showed that in-hospital mortality was significantly lower in patients with 6 h mean $\text{PP} \geq 30$ mmHg ($n = 38$) than in those with 6 h mean $\text{PP} < 30$ mmHg ($n = 31$) (Log Rank $P < 0.001$); ECLS weaning failure was significantly lower in patients with 6 h mean $\text{PP} \geq 30$ mmHg than in those with 6 h mean $\text{PP} < 30$ mmHg (Log Rank $P < 0.001$) (Fig. 2).

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