Extracorporeal life support for cardiogenic shock: influence of concomitant intra-aortic balloon counterpulsation

Sun Kyun Ro a,b, Joon Bum Kimb,*, Sung Ho Jung b, Suk Jung Choo b, Cheol Hyun Chung b and Jae Won Lee b

a Department of Thoracic and Cardiovascular Surgery, Hanyang University Guri Hospital, Seoul, South Korea
b Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, South Korea

* Corresponding author. Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, 388-1 Pungnap-dong, Songpa-gu, Seoul 138-736, South Korea. Tel: +82-2-3010-5416, fax: +82-2-3010-6966; e-mail: jbkim1975@amc.seoul.kr (J.B. Kim).

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Abstract

OBJECTIVES: Intra-aortic balloon counterpulsation (IABP) during extracorporeal life support (ECLS) for cardiogenic shock may improve pulsatility and coronary perfusion, thereby promoting recovery of cardiac function. However, the risks and benefits of IABP during ECLS in real clinical settings have not been evaluated. This study aims to evaluate the effect of IABP on the early outcome of ECLS for cardiogenic shock.

METHODS: We evaluated 253 adult patients (aged 58.8 ± 15.3 [mean ± standard deviation] years, 154 males) undergoing ECLS for cardiogenic shock from January 2005 to August 2012. Of them, 60 patients underwent concomitant IABP (IABP group) and 193 underwent ECLS only (control group). In-hospital outcomes were compared using the inverse probability of treatment weighting based on propensity scores.

RESULTS: The indications for ECLS were low cardiac output after cardiac surgery in 118 patients (46.6%), heart failure in 71 (28.1%), acute myocardial infarction in 49 (19.4%) and others in 15 (5.9%). Successful ECLS weaning rate was significantly higher in the IABP group than in the control group (61.7 vs 42.0%, P = 0.008); however, there was no significant difference in in-hospital mortality between the two groups (68.6 vs 72.0%, P = 0.58). After adjustment for propensity of treatment assignment conditional on baseline characteristics, the IABP group showed a decreased risk of weaning failure (odds ratio [OR] 0.51; 95% confidence interval [CI] 0.28–0.92, P = 0.024) but with a similar risk of in-hospital mortality (OR 0.85; 95% CI 0.46–1.60; P = 0.62) compared with the control group.

CONCLUSIONS: The use of IABP during ECLS increased a successful ECLS weaning rate, but was not translated into improved survival. Studies on larger populations may verify the survival effect of IABP during ECLS.

Keywords: Extracorporeal life support • Cardiogenic shock • Intra-aortic balloon counterpulsation

INTRODUCTION

Since the intra-aortic balloon counterpulsation (IABP) was introduced in 1968 [1], it has become the most widely used mechanical assistance device for cardiogenic shock [2]. The American College of Cardiology and American Heart Association (ACC/AHA) ST-elevation myocardial infarction (STEMI) guidelines and the European Society of Cardiology (ESC) STEMI guidelines strongly recommend IABP support for the patients with cardiogenic shock (Class IB and Class IC recommendations, respectively) [3, 4]. These guidelines are supported by animal studies which demonstrate that the use of IABP can salvage infarcted myocardium [5] and a meta-analysis of cohort studies [6]. Recently, more powerful clinical evidences corroborated by a meta-analysis of randomized studies and a large randomized, controlled trial, however, have disproved the survival benefit of IABP support in patients with cardiogenic shock complicating acute myocardial infarction [6, 7].

Extracorporeal life support (ECLS) for patients presenting with cardiogenic shock refractory to the conventional therapy is a widely accepted treatment modality. Theoretically, two beneficial effects of the adjunctive IABP support may be expected in patients undergoing ECLS for cardiogenic shock: (i) to provide pulsatility which cannot be obtained by a centrifugal pump generally used in ECLS and (ii) to reduce afterload. Nevertheless, little information is available about the efficacy of IABP support adjunctive to ECLS in the real clinical setting. Moreover, refractory cardiogenic shock necessitating ECLS, the most severe form of cardiogenic shock, has not been a matter of concern in the clinical trials mentioned above [7].

Therefore, we aimed to evaluate the effect of concomitant IABP support on the early outcomes of patients undergoing ECLS for refractory cardiogenic shock, compared with those undergoing ECLS alone.
Study populations

Extracorporeal membrane oxygenation (ECMO) database, including baseline patient characteristics, detailed information concerning ECMO set-up, periprocedural complications and in-hospital outcomes, has been prospectively collected at Asan Medical Center, Seoul, Korea. In this database from January 2005 to August 2012, we identified 339 adult patients (aged ≥18 years) who underwent veno-arterial ECMO support. Excluding 86 patients with shocks other than cardiogenic aetiology, 253 patients (aged 58.8 ± 15.3 years [mean ± standard deviation], 154 males) who underwent ECLS to treat refractory cardiogenic shock were finally enrolled in our study. Of these patients, 60 underwent IABP concomitant with ECLS (IABP group), and 193 were treated with ECLS alone (control group).

The study was approved by the institutional ethics committee/review board of the Asan Medical Center, Seoul, Korea, and the requirement for informed patient consent was waived in view of the retrospective nature of the study.

Extracorporeal life support set-up and management

The ECLS system consisted of a centrifugal pump, a hollow-fibre membrane oxygenator with an integral heat exchange and a heparin-bound circuit. Three types of ECLS system were used: the Capiox emergency bypass system (Terumo, Tokyo, Japan), the PLS system (Marquet, Hirrlingen, Germany) and the Bio-Consol 560 system (Medtronic, Minneapolis, MN, USA).

An intravenous heparin bolus (100 U/kg) was initially administered prior to the implantation of cannulae. After the implantation procedures, an intravenous heparin was continuously infused to maintain the activated clotting time within a range of 180–200 s. Since 2010, Nafamostat mesilate (Futhan; Torii Pharmaceutical, Tokyo, Japan) has been used as an alternative anticoagulant to heparin for patients with high bleeding risk in order to reduce bleeding complications [8].

The common femoral artery and the femoral or internal jugular veins were accessed for a peripheral cannulation in most patients (244 patients, 96.4%), whereas central or mixed cannulations were intraoperatively performed via the ascending aorta and the right atrium or superior vena cava in 10 (3.6%) patients. In case of peripheral cannulation, 14- to 21-Fr arterial cannulae and 17- to 24-Fr venous drainage cannulae, which were selected according to individual patients' body surface area, have been introduced percutaneously using the Seldinger technique unless the cut-down procedure was inevitable.

We have tried to insert an antegrade perfusion catheter for distal limb perfusion just distal to the arterial cannulation site. The dorsalis pedis and posterior tibial arteries of the affected limb were serially assessed using a small portable Doppler device. When ischaemic signs were notified, the arterial cannula on the affected side was removed and a new arterial cannula was inserted on the opposite side. In some patients with renal insufficiency, a haemofiltration unit was integrated into the circuit.

ECLS blood flow was aimed at a cardiac index of 2.4 l/min/m² or more as possible. The mean arterial pressure was maintained at 60–70 mmHg by administration of vasoconstrictors, rather than inotropic agents, in order to allow the heart to be recovered. Blood products were appropriately transfused to maintain haematocrit at 30–35% and platelet count over 100 000/mm³.

Mechanical decompression of the left heart was attempted whenever manifestations of the left ventricular (LV) distention accompanied by pulmonary oedema were notified. The LV vent cannula was inserted through the right superior pulmonary vein via a median sternotomy or was implanted percutaneously via an atrial septostomy in the latest cases.

IABP was employed at the discretion of the attending surgeons or physicians prior to the initiation of ECLS. The IABP device was percutaneously inserted through the femoral artery using the Seldinger technique. The tip of the balloon was confirmed by a portable chest X-ray and placed just distal to the left subclavian artery. IABP support was initiated with the use of 1:1 electrocardiographic triggering.

Haemodynamic parameters such as mean arterial pressure, pulse pressure, central venous pressure and pulmonary artery pressure and laboratory parameters, such as arterial lactate level and mixed venous saturation, were monitored to determine the timing of weaning off ECLS. The initiation of weaning off ECLS was determined by echocardiographic findings showing adequate ventricular filling and ejection fraction over 30–35% at ECLS flow of a cardiac index of 1.0 l/min/m². When the haemodynamic stability was maintained at ECLS flow of 0.5 l/min/m² over 30 min following gradual reduction of ECLS flow, ECLS was removed at the bedside. Weaning from the IABP was initiated after removal of ECLS and achieved by means of reduction of the trigger ratio. Successful weaning was defined as hospital survival longer than 48 h after removal of ECLS [9].

Statistical analysis

Categorical variables were presented as numbers and percentages, and continuous variables were expressed as mean ± standard deviation (SD) or median with range. Baseline characteristics of the IABP group and the control group were compared using the χ²-test and Fisher’s exact tests for categorical variables and the Student’s unpaired t-test or the Mann–Whitney U-test for continuous variables, as appropriate. To reduce the impact of treatment selection bias and potential confounders in an observational study, we performed rigorous adjustment for differences in the baseline patient characteristics between groups by using the inverse probability of treatment weighting (IPTW) model based on propensity scores and weighted logistic regression models [10, 11]. With this technique, weights for the IABP group were the inverse of propensity score, and those for the control group were the inverse of 1 – propensity score. The propensity scores were estimated without regard to outcome variables through binary logistic regression analysis. All prespecified covariates listed in Table 1 were included in full non-parsimonious models for the IABP group vs the control group. The discrimination and calibration ability of the propensity score model was assessed using the C-statistic and the Hosmer–Lemeshow statistic. Stabilized weights were used to reduce the weights of either those treated subjects with low propensity scores or those untreated subjects with high propensity scores [12]. The actuarial survivals of the IABP group and the control group were calculated using the Kaplan–Meier method, with the log-rank test used for the comparison between the two groups. Multivariable risk factors for in-hospital mortality were obtained using the logistic regression model. Variables with a P-value of ≤0.20 on univariate analyses were candidates for the
RESULTS

Baseline characteristics

Aetiologies of cardiogenic shock were low cardiac output after cardiac surgery in 118 (46.6%) patients, heart failure in 71 (28.1%), acute myocardial infarction in 49 (19.4%), pulmonary thromboembolism in 9 (3.6%), sustained ventricular arrhythmias in 5 (2.0%) and cardiac trauma in 1 (0.4%). Eighty (31.6%) patients underwent cardiac surgery in 118 (46.6%) patients, including 3 patients who underwent heart transplantation following the employment of ECLS, were successfully weaned from the ECLS. Of these patients, 73 (61.9%) survived to discharge. The 30-, 60- and 90-day mortality rates were 66.0, 69.6 and 70.0%, respectively. Although the successful weaning, 30-day survival and hospital survival rates in the IABP group were higher than those in the control group, the statistical significance was observed only on the successful weaning rate (61.7 vs 42%, \(P = 0.008\); 40 vs 32.1%, \(P = 0.26\); 31.4 vs 28%, \(P = 0.58\) (Figs 1 and 2A). After balancing the baseline characteristics of each group using IPTW, the results were consistent (56.7 vs 40.9%, \(P = 0.032\); 38.3 vs 31.6%, \(P = 0.33\); 30.0 vs 28.0%, \(P = 0.76\)) (Fig. 2B).

The OR of the IABP support during ECLS, compared with ECLS alone, was estimated without adjustment and with adjustment using propensity scores and IPTW (Table 4). IABP support significantly lowered the risk of weaning failure before and after the baseline adjustment. However, both groups had similar risks for in-hospital mortality regardless of the statistical adjustment. During a median follow-up period of 17.7 (range 1.1–86.5) months, there were 5 and 8 deaths after discharge in the IABP group and the control group, respectively (Fig. 1). The survival curves did not show statistical difference between groups (log-rank test, \(P = 0.22\), Fig. 3).

To evaluate risk factors for in-hospital mortality, multivariate logistic regression analyses were performed. Old age (OR 1.02; 95% CI 1.00–1.04; \(P = 0.036\)) and high arterial lactate level obtained prior to the initiation of ECLS (OR 1.12; 95% CI 1.00–1.19; \(P < 0.001\)) were independent risk factors for in-hospital mortality.

Table 1: Baseline characteristics

<table>
<thead>
<tr>
<th></th>
<th>IABP ((N = 60))</th>
<th>No IABP ((N = 193))</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender, (n) (%)</td>
<td>43 (71.7)</td>
<td>111 (57.5)</td>
<td>0.050</td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.1 ± 11.4</td>
<td>57.1 ± 16.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body surface area ((m^2))</td>
<td>1.72 ± 0.22</td>
<td>1.69 ± 0.19</td>
<td>0.23</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.1 ± 3.3</td>
<td>23.3 ± 3.6</td>
<td>0.14</td>
</tr>
<tr>
<td>Diabetes mellitus, (n) (%)</td>
<td>19 (31.7)</td>
<td>39 (20.2)</td>
<td>0.065</td>
</tr>
<tr>
<td>Hypertension, (n) (%)</td>
<td>32 (53.3)</td>
<td>67 (34.7)</td>
<td>0.010</td>
</tr>
<tr>
<td>Chronic renal failure, (n) (%)</td>
<td>2 (3.3)</td>
<td>14 (7.3)</td>
<td>0.37</td>
</tr>
<tr>
<td>Liver cirrhosis, (n) (%)</td>
<td>1 (1.7)</td>
<td>18 (9.3)</td>
<td>0.052</td>
</tr>
<tr>
<td>Pre-ECLS condition, (n) (%)</td>
<td>23 (38.3)</td>
<td>54 (28.0)</td>
<td>0.055</td>
</tr>
<tr>
<td>Medical</td>
<td>27 (45.0)</td>
<td>120 (62.2)</td>
<td></td>
</tr>
<tr>
<td>Surgical</td>
<td>10 (16.7)</td>
<td>19 (9.8)</td>
<td></td>
</tr>
<tr>
<td>Medical, but surgery after ECLS</td>
<td>19 (31.7)</td>
<td>61 (31.6)</td>
<td>0.99</td>
</tr>
<tr>
<td>Pre-ECLS laboratory findings*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total bilirubin (mg/dl)</td>
<td>1.8 ± 2.6</td>
<td>3.6 ± 6.8</td>
<td>0.002</td>
</tr>
<tr>
<td>Platelet count, (\times 10^9)</td>
<td>172.6 ± 81.9</td>
<td>140.4 ± 90.7</td>
<td>0.015</td>
</tr>
<tr>
<td>Creatinine (mg/dl)</td>
<td>1.8 ± 1.4</td>
<td>1.8 ± 1.4</td>
<td>0.89</td>
</tr>
<tr>
<td>pH</td>
<td>7.29 ± 0.15</td>
<td>7.25 ± 0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>Arterial lactate (mmol/l)</td>
<td>8.3 ± 4.5</td>
<td>9.3 ± 4.9</td>
<td>0.16</td>
</tr>
</tbody>
</table>

*Blood sampling prior to the initiation of the ECLS.

IABP: intra-aortic balloon pump; ECLS: extracorporeal life support; E-CPR: extracorporeal cardiopulmonary resuscitation.
Table 2: Adjusted data with use of the IPTW

<table>
<thead>
<tr>
<th></th>
<th>IABP (N = 60)</th>
<th>No IABP (N = 193)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender (%)</td>
<td>56.7</td>
<td>60.6</td>
<td>0.59</td>
</tr>
<tr>
<td>Age (years)</td>
<td>61.1 ± 11.6</td>
<td>59.1 ± 15.9</td>
<td>0.29</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.68 ± 0.25</td>
<td>1.69 ± 0.19</td>
<td>0.64</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.6 ± 3.5</td>
<td>23.5 ± 3.5</td>
<td>0.91</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>25.0</td>
<td>24.9</td>
<td>0.98</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>40.0</td>
<td>38.9</td>
<td>0.87</td>
</tr>
<tr>
<td>Chronic renal failure (%)</td>
<td>5.0</td>
<td>6.2</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Liver cirrhosis (%)</td>
<td>1.7</td>
<td>7.3</td>
<td>0.13</td>
</tr>
<tr>
<td>Pre-ECLS condition (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical</td>
<td>27.1</td>
<td>30.2</td>
<td>0.80</td>
</tr>
<tr>
<td>Surgical</td>
<td>62.7</td>
<td>57.8</td>
<td></td>
</tr>
<tr>
<td>Medical, but surgery after ECLS</td>
<td>10.2</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>E-CPR (%)</td>
<td>26.7</td>
<td>32.1</td>
<td>0.42</td>
</tr>
<tr>
<td>Pre-ECLS laboratory findings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total bilirubin (mg/dl)*</td>
<td>2.8 ± 4.6</td>
<td>3.1 ± 6.1</td>
<td>0.70</td>
</tr>
<tr>
<td>Platelet count (×10³)*</td>
<td>151.7 ± 76.4</td>
<td>146.8 ± 92.9</td>
<td>0.71</td>
</tr>
<tr>
<td>Creatinine (mg/dl)*</td>
<td>1.8 ± 1.4</td>
<td>1.8 ± 1.3</td>
<td>0.92</td>
</tr>
<tr>
<td>pH*</td>
<td>7.30 ± 0.14</td>
<td>7.27 ± 0.17</td>
<td>0.15</td>
</tr>
<tr>
<td>Arterial lactate (mmol/l)*</td>
<td>9.0 ± 4.3</td>
<td>8.9 ± 4.9</td>
<td>0.94</td>
</tr>
</tbody>
</table>

*Blood sampling prior to the initiation of the ECLS.
IABP: intra-aortic balloon pump; ECLS: extracorporeal life support; E-CPR: extracorporeal cardiopulmonary resuscitation.

Table 3: Extracorporeal life support data

<table>
<thead>
<tr>
<th></th>
<th>IABP (N = 60)</th>
<th>No IABP (N = 193)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of haemofiltration, n (%)</td>
<td>7 (11.7)</td>
<td>19 (9.8)</td>
<td>0.69</td>
</tr>
<tr>
<td>Duration of ECLS (h)</td>
<td>91.1 (IQR 109.0)</td>
<td>65.7 (IQR 104.1)</td>
<td>0.012</td>
</tr>
<tr>
<td>Duration of IABP (h)</td>
<td>110.3 (IQR 119.7)</td>
<td>-</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Left ventricular venting, n (%)</td>
<td>1 (1.7)</td>
<td>5 (2.6)</td>
<td></td>
</tr>
</tbody>
</table>

ECLS: extracorporeal life support; IABP: intra-aortic balloon pump.

Figure 1: Flow chart of the outcomes for ECLS according to the use of IABP.
DISCUSSION

Although the current guidelines recommend the use of IABP in patients with cardiogenic shock complicating acute myocardial infarction [3, 4], the IABP in acute myocardial infarction complicated by cardiogenic shock (IABP-SHOCK II) trial has corroborated the powerful evidences against the guidelines [7]. In this trial, the use of IABP in patients for whom early revascularization was planned did not reduce 30-day mortality, compared with conventional therapy. The investigators on this trial demonstrated that the

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**Figure 2:** Comparison of the early outcomes between the IABP group and the control group. (A) Unadjusted outcomes. (B) Adjusted outcomes using IPTW. IABP: intra-aortic balloon pump.

**Figure 3:** Survival curves of the IABP group and the control group. IABP: intra-aortic balloon pump.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>OR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaning failure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>0.45</td>
<td>0.25–0.81</td>
<td>0.008</td>
</tr>
<tr>
<td>Propensity scorea</td>
<td>0.42</td>
<td>0.22–0.80</td>
<td>0.009</td>
</tr>
<tr>
<td>IPTWb</td>
<td>0.51</td>
<td>0.28–0.92</td>
<td>0.024</td>
</tr>
<tr>
<td>In-hospital death</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>0.84</td>
<td>0.45–1.57</td>
<td>0.58</td>
</tr>
<tr>
<td>Propensity scorea</td>
<td>0.84</td>
<td>0.42–1.66</td>
<td>0.61</td>
</tr>
<tr>
<td>IPTWb</td>
<td>0.85</td>
<td>0.46–1.60</td>
<td>0.62</td>
</tr>
</tbody>
</table>

*aCovariance adjustment on propensity score.  
bAdjustment with the use of IPTW.  
OR: odds ratio; CI: confidence interval; IPTW: inverse probability of treatment weighting.

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positive effect of IABP on haemodynamics, multiorgan dysfunction and systemic inflammatory response was modest and might not be sufficient to reduce mortality. However, they included a higher percentage of patients with mild or moderately severe cardiogenic shock complicating acute myocardial infarction, whereas our study included patients presenting with the most severe form of cardiogenic shock resulting from all aetiologies.

The early mortality of cardiogenic shock has remained high despite aggressive treatment modalities such as revascularization and the use of IABP [13]. Even though it has been reported that ECLS improves the early outcomes of cardiogenic shock complicating ischaemic heart disease [14–16], the hospital outcomes of ECLS for cardiogenic shock are still unsatisfactory. Reviewing the recent studies, in patients undergoing ECLS for cardiogenic shock, 39–55% failed to wean from ECLS and 58–76% died before discharge [17–21]. Considering these catastrophic results, it is necessary to exert every effort to improve early outcomes in this clinical setting.

Theoretically, two beneficial impacts of IABP support can be adjunctively expected, synergizing the effect of ECLS on patients with refractory cardiogenic shock. First, IABP support can easily establish pulsatile flow during ECLS using a non-pulsatile centrifugal pump. Several studies have reported that the pulsatility created by adjunctive IABP support has improved organ perfusion and recovery [22, 23]. Secondly, IABP support can provide systolic unloading, which reduces the oxygen consumption of the left ventricle. The importance of ventricular unloading has been proved by the experimental study performed in a canine infarction model [5]. Sufficient ventricular unloading may be expected with the combination of IABP and ECLS, which can effectively reduce afterload and preload, respectively. Conversely, the IABP support may also have some negative effect on survival. Although life-threatening complications of IABP are rare, occurrence of them such as limb ischaemia may lead to a grim prognosis in extremely severe patients requiring ECLS. Additionally, inhomogeneous perfusion to vital organs resulting from IABP use during the retrograde perfusion of ECMO may adversely affect the outcomes. Some investigators reported that the microvascular flow was impaired during IABP use in cardiogenic shock patients [24].

The IABP support concomitant to ECLS tends to be more frequently utilized in 56–74% [17, 20, 21], compared with 25–40% of IABP utilization rate in patients with cardiogenic shock complicating acute myocardial infarction [2]. This relatively high utilization rate of IABP during ECLS might reflect on the expectation of some advantageous effect. However, the clinical benefit has been demonstrated in only a few studies. Onorati et al. [22] reported favourable influence of IABP on renal function during coronary revascularization with non-pulsatile cardiopulmonary bypass and Madershahian et al. [23] demonstrated that the use of IABP improved bypass graft flow during ECLS. Moreover, little is known about the clinical correlation between concomitant IABP and successful weaning from ECLS through a literature review. On the other hand, in the recent study analysing 517 patients with post-cardiomyopathy cardiogenic shock requiring ECLS, there was a trend towards a higher rate of implantation of IABP in the hospital survivors than in the non-survivors without statistical significance (OR 0.79; 95% CI 0.48–1.30; P = 0.351) [20].

On analysis of the balanced model of our study, a successful weaning rate is higher in the IABP group (56.7 vs 40.9%, Fig. 2B) and the use of IABP support reduced the risk for weaning failure, compared with the control group (OR 0.51; 95% CI 0.28–0.92; P = 0.024). Nevertheless, improved successful weaning was not translated into improved hospital survival, regretfully. There was only a trend towards a higher rate of hospital survivors in the IABP group than in the control group (30 vs 28%, Fig. 2B). Neither the difference of survival rates between groups nor the influence of the implantation of IABP on the hospital mortality was statistically significant.

Deaths in patients presenting with cardiogenic shock usually results from haemodynamic deterioration, concomitant multigorgan dysfunction and/or development of the systemic inflammatory response syndrome [25]. Clinically, main causes of hospital death after weaning from ECMO support were multiorgan failure or pulmonary infection [19, 21]. In our study, high arterial lactate level prior to the initiation of ECLS is one of the independent risk factors for in-hospital mortality. In this context, occurrence of irreversible concomitant multiorgan damages and/or development of the systemic inflammatory response syndrome, which cannot be easily resolved by the recovery of cardiac function with the assistance of IABP and ECMO supports, might lead to hospital death after weaning from ECLS.

Our current study has some limitations. First, there may be a selection bias in our study as a nature of non-randomized study, even though we performed rigorous adjustment for differences in the baseline patient characteristics between groups with the use of IPTW model based on propensity scores. Secondly, the utilization rate of IABP support during ECLS was only 23.7%, which is relatively lower than those of the previous studies. Thirdly, the aetiology of cardiogenic shock is somewhat heterogeneous. That might mask the clinical benefit of adjunctive IABP in specific clinical settings such as ischaemic heart disease or post-cardiomyopathy cardiogenic shock. On subgroup analysis performed in ischaemic patients, however, hospital survival rates were similar in the IABP and control groups (66.7 vs 70.3%, P = 0.72), whereas the successful weaning rate was higher in the IABP group than in the control group (62.7 vs 37.8%, P = 0.021). Despite the consistent results of our study even in the ischaemic patients, a subgroup analysis according to the aetiology of cardiogenic shock should be included if a randomized controlled study concerning this issue is conducted.

In conclusion, the concomitant use of IABP support during ECLS improved successful weaning from ECLS, but did not reduce hospital mortality. Despite the adjunctive advantages of IABP support demonstrated by several studies, the survival benefit of IABP support is still unclear. A large randomized, controlled study may verify the impact of adjunctive IABP support during ECLS on survival.

Conflict of interest: none declared.

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[13] Madershahian N, Liakopoulos OJ, Wippermann J, Salehi-Gilani S, Wittwer T, et al. Analysis of intra-aortic balloon pump use as a function of time throughout the study period, or did you use more balloon pumps recently when your clinical experience was greater, and you may have accordingly obtained better results. Can you comment on whether more balloon pumps were used in the recent period?

[14] Dr Ro: Okay.

APPENDIX. CONFERENCE DISCUSSION

Dr P. Achouh (Paris, France): In a retrospective review of their prospective data-base, the authors address a very interesting question, which is the benefit of intra-aortic balloon pump use in ECLS patients with cardiogenic shock. There is not a lot of data out there, and there are conflicting positions among different surgical teams regarding this subject.

Unfortunately, the study population is very heterogeneous, and I am not sure that the statistical method used is sufficient to address such bias. The eventual benefit of the ECLS and intra-aortic balloon pump combination may vary with the aetiology of cardiogenic shock. The intra-aortic balloon pump is not as helpful in PE patients as in post-infarction cardiogenic shock. In other words, even though the balloon pump benefit might be the highest in ischaemic cardiogenic shock, only 19% of the patients in this study had ischaemic aetiology.

In their introduction and later in their discussion, the authors speculate that pulling out due to intra-aortic balloon pump is better than nonpulsatile flow. This assumption, which is supported by a couple of studies on coronary and renal blood flow, has not been confirmed by clinical practice and by the growing number of patients implanted with nonpulsatile flow pumps. Another comment is that the definition of ECLS weaning in the paper is limited to 48 h survival, which seems to me to be a weak endpoint in this paper.

I have three questions for the author. The first question is, did you find any difference in the need for left ventricular sump or venting in the patients who had intra-aortic balloon pump compared to the patients who did not have intra-aortic balloon pump?

Secondly, you say in your paper that the balloon pump was inserted before ECLS at the discretion of the physician. Was that part of a therapeutic escalation protocol or was the decision to insert the balloon pump taken simultaneously with that of the ECLS? In other words, did you place the balloon pump first and when the patient didn’t get better, you used the ECLS, or did you decide to place both at the same time and then you started with the balloon pump insertion?

Thirdly, you have three patients who were transplanted successfully. Can you tell me to which group they belonged and whether they were weaned off ECLS before transplant?

And before you answer the questions, I am just going to conclude by saying that even though this paper has the merit of tackling an important question, which is the benefit of balloon pump insertion in ECLS patients, we cannot really draw any conclusions based on these results. As the authors themselves admitted, larger randomized studies are needed to answer such a question in a more targeted subgroup of patients. Such patients with cardiogenic shock after myocardial infarction.

Dr Ro: The first question is about the LV venting?

Dr Achouh: Yes. Did you notice that there was less need for left ventricular venting in the balloon pump group compared to the other group of patients?

Dr Ro: LV venting is very crucial for the heart failure patients but, unfortunately, at the early period of our hospital, LV venting was rarely performed. But these days we have aggressively performed LV venting via septostomy through the femoral vein. So LV venting may be very helpful for ventricular unloading as you mentioned.

And the second question regarding IABP implantation, there is no standardized protocol in our hospital because we cannot predict whether the patient will be stabilized or not with only IABP support. On the other hand, after the ECLS was implanted first, we did not insert the IABP in most cases because the benefit of IABP is not clear.

The third question?

Dr Ro: The transplant patients.

Dr Ro: Of the three patients who underwent heart transplantation, two belong to the postcardiotomy group and one to the heart failure group. They were all weaned off the ECLS in the operating suite.

Dr C. Bowles (Middlesex, UK): I have one question relating to the rates of balloon pump use as a function of time throughout the study, because you may have used more balloon pumps recently when your clinical experience was greater, and you may have accordingly obtained better results. Can you comment on whether more balloon pumps were used in the recent period?

So was your rate of balloon pump use with ECLS constant throughout the study period, or did you use more balloon pumps with the ECLS recently?

Dr Ro: I didn’t explore the trend of the IABP implantation, I’m sorry.