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Mid-Term Outcomes and Characteristics of Veno-Arterial ECMO in the Management of Refractory Post-Cardiotomy Cardiogenic Shock: Experience of the Cardiac Surgery Department at CHU Ibn Sina

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Abstract **Original Research Article**

Objectives: Post-cardiotomy cardiogenic shock remains a critical and life-threatening complication in cardiac surgery. This study aims to review and analyze our department's experience with the use of extracorporeal membrane oxygenation (ECMO) as a temporary mechanical circulatory support strategy in managing refractory post-cardiotomy cardiogenic shock. ***Methods****:* This is a retrospective study of veno-arterial ECMOs (V-A ECMO) implanted between 2013 and 2022 at the Ibn Sina University Hospital, following cardiac surgery. All adult patients who received a V-A ECMO implantation after cardiac surgery were included. The indications for ECMO were failure to wean from extracorporeal circulation or refractory cardiogenic shock occurring within the first or second postoperative day. Intra-aortic balloon pump (IABP) counter pulsation was systematically associated, either preoperatively or postoperatively. ***Results:*** Nine veno-arterial ECMOs were implanted for refractory cardiogenic shock following 5,438 cardiac surgeries, with an incidence of 0.16%. The overall survival rate was 55.5%, with a mean patient age of 61.9 ± 10.5 years. ECMO was implemented after valvular surgery (44.4%), coronary artery bypass grafting (44.4%), acute aortic dissection (11.1%), and post-infarction ventricular septal defect (33.3%). A third of the interventions were combined surgeries. The median ECMO support duration was 89 ± 11 hours, with a weaning rate of 44.4%. Survival rates at 1 month, 1 year, and 3 years were 55.5%, 44.4%, and 33.3%, respectively. Poor prognostic factors included age >65 years, EuroSCORE >8, and post-cardiotomy cardiogenic shock due to right or biventricular failure. Under ECMO, all patients had persistent hyperlactatemia (>10 mmol/L), myocardial and muscular lysis, and multivisceral organ failure (hepatic cytolysis, hyperbilirubinemia, renal dysfunction). They required maximal doses of vasopressors and inotropes, with ECMO duration >72 hours, mechanical ventilation >80 hours, ICU stay >15 days, and significant transfusion needs. Initially, 77.77% of patients presented with severe dyspnea (NYHA class III–IV). After a median follow-up of 3 ± 1 years, an improvement in quality of life was observed, with survivors classified as NYHA II. Among them, 66.66% were free from angina, while 33.33% experienced mild exertional angina (CCS I–II). ***Conclusions:*** In this study, the implantation of venous-arterial ECMO for refractory cardiogenic shock occurred in 0.16% of cardiac surgeries, with an overall survival rate of 55.5%. Adverse prognostic factors included age over 65 years, an EuroSCORE greater than 8, as well as right or biventricular failure prior to cardiac surgery, persistent hyperlactatemia, and multivisceral failure during the assistance. After a median follow-up of 3 years, the surviving patients showed an improvement in their quality of life, with a majority in NYHA class II, without angina or with mild angina.

Keywords: Extracorporeal membrane oxygenation V-A, Cardiac surgery, Refractory cardiogenic shock, Post-cardiotomy, Circulatory assistance.

1. INTRODUCTION

Refractory cardiogenic shock following cardiac surgery remains rare, with an incidence ranging between 3% and 5%, but is often fatal without mechanical circulatory support (MCS), with fewer than 25% of patients surviving to hospital discharge [1,2]. In complex clinical scenarios, several bailout strategies for MCS may be considered, with veno-arterial extracorporeal membrane oxygenation (VA ECMO) representing a favorable option for patients with severe postcardiotomy cardiogenic shock (PCS) [3]. However, ECMO is associated with one-month survival rates below 40%,

and the prognosis after weaning following cardiac surgery remains poor [4]. We report a monocentric retrospective series of ECMO implants in patients with refractory PCS. This study presents our own results regarding the implantation of VA ECMO in refractory cardiogenic shock post-cardiotomy, detailing patient profiles, the implantation procedure, as well as weaning and associated complications.

2. MATERIALS AND METHODS

Patients

This is a retrospective study that included nine adult patients who underwent venous-arterial ECMO (VA ECMO) between January 2013 and December 2022 in the cardiac surgery department of CHU Ibn Sina in Rabat. Data were collected from the operating room, intensive care unit, and cardiac surgery department databases. Preoperative clinical data were recorded, and the operative risk was estimated using the EuroSCORE II. Operative characteristics, such as the duration of cardiopulmonary bypass (CPB) and aortic clamping, as well as post-implantation outcomes, were analyzed. Serum levels of creatinine, bilirubin, and lactate were monitored throughout the ECMO support. Survivors, defined as those weaned from ECMO and discharged alive, were regularly contacted to collect their status and any medical events occurring since discharge. All adult patients who received venous-arterial ECMO for post-cardiotomy cardiogenic shock (PCCS) occurring within 48 hours after cardiac surgery were included. Indications included failure to wean from CPB despite maximal inotropic support, or refractory cardiogenic shock, defined by the inability to maintain adequate systemic perfusion (MAP > 80 mmHg, cardiac index > 1.8 L/min/m²), despite optimal volume status, high-dose inotropic treatment, and intra-aortic balloon pump (IABP) use.

Method

Femoral peripheral cannulation was performed in all patients using a modified Seldinger technique, with arterial cannulas ranging from 17 to 21 Fr and venous cannulas ranging from 18 to 32 Fr, adapted to the body surface area. ECMO was supported in normothermia with a circuit coated with heparin. An initial bolus of 5000 IU of heparin was administered, followed by a heparin-free window during the first four hours with maximum flow. In the absence of bleeding, a continuous infusion of unfractionated heparin was then started to maintain aACT between 150 and 180 seconds. The pump flow rate was adjusted to achieve a cardiac index between 2.2 and 2.8 L/min/m², a MAP > 65 mmHg, a left atrial pressure (LAP) < 20 mmHg, and a central venous pressure (CVP) < 10 mmHg. Echocardiography was regularly performed to adjust the pump flow, modulated according to MAP, SvO_2, lactate, and organ perfusion. Norepinephrine was administered after vascular filling to maintain a MAP > 65 mmHg, while dobutamine optimized left ventricular contractility. Pulmonary edema was treated with diuretics and adjustment of inotropes. In case of major hemorrhage, heparin was discontinued, and a high pump flow was maintained to prevent thrombosis. Blood transfusions aimed to maintain a hematocrit between 28 and 30%. Limb ischemias related to cannulation were treated by revising the reperfusion cannula, with angiography if necessary. Weaning was considered after 24 to 48 hours of hemodynamic stability, with a flow reduced to 1.0 L/min, stable renal and hepatic function, and minimal inotropic support. IABP was maintained until complete withdrawal of support in cases of persistent low flow.

Statistical Analysis

Quantitative variables are presented as means ± standard deviation, and qualitative variables as percentages. Hospital mortality, defined as death occurring during hospitalization or within 30 days after surgery, was the primary endpoint. Preoperative, perioperative, and postoperative data were detailed and short-term outcomes (hospital mortality) and long-term outcomes (1-year and 3-year survival) were assessed using survival analysis performed with the Kaplan-Meier method. Statistical analysis was conducted using SPSS software, and data were recorded in Word and Excel.

3. RESULT

3.1. Preoperative and Perioperative Patient Characteristics

Between January 2013 and December 2022, a total of 5,438 patients underwent cardiac surgery in our institution. Among them, 9 required veno-arterial extracorporeal membrane oxygenation (VA-ECMO) support for postcardiotomy cardiogenic shock (PCCS). Five patients (55.6%) were male. The mean age was 61,9 ± 10,5 years, and the mean body mass index (BMI) was 26,2 ± 4,1 kg/m². Regarding medical history, 6 patients (66,7%) had hypertension, 3 (33,3%) had diabetes mellitus, 2 (22,2%) had peripheral arterial disease, and 3 (33,3%) had chronic obstructive pulmonary disease. One patient (11,1%) had a neurological history (stroke or transient ischemic attack), and a history of smoking was reported in 5 patients (55,6%). According to the NYHA classification, one patient (11,1%) was in class I, one in class II, three (33,3%) in class III, and four (44,4%) in class IV. The mean left ventricular ejection fraction (LVEF) was 50,2%, and the mean systolic pulmonary artery pressure (sPAP) was 40,8 ± 16,1 mmHg. The mean preoperative serum creatinine level was 100,9 ± 29,8 µmol/L.

Regarding surgical procedures, 4 patients (44,4%) underwent valve surgery, 4 (44,4%) underwent coronary artery bypass grafting (CABG), 1 (11,1%) underwent surgery for aortic dissection, 3 (33,3%) underwent post-infarction ventricular septal defect (VSD) repair, and 3 (33,3%) underwent combined surgery, defined as the association of multiple major procedures during the same operation (e.g., CABG with valve or septal surgery).The mean EuroSCORE II was 7,6 ± 1,4%. The mean aortic cross-clamp time was 92,9

± 56,4 minutes, and the mean cardiopulmonary bypass (CPB) time was 190,2 ± 69,4 minutes. All patients (100%) received an intra-aortic balloon pump (IABP).

Table 1: Preoperative and Perioperative Patient Characteristics

Age (years)	61.9 ± 10.5
Body Mass Index (kg/m²)	26.2 ± 4.1
Hypertension	6 (66.7%)
Diabetes mellitus	3 (33.3%)
Peripheral arterial disease (PAD)	2 (22.2%)
Chronic obstructive pulmonary disease (COPD)	3 (33.3%)
Neurological history (stroke or TIA)	1 (11.1%)
Smoking history	5 (55.6%)
Male gender	5 (55.6%)
NYHA class	
Class I	1 (11.1%)
Class II	1 (11.1%)
Class III	3 (33.3%)
Class IV	4 (44.4%)
Left ventricular ejection fraction (LVEF, %)	50.2%
Systolic pulmonary artery pressure (sPAP, mmHg)	40.8 ± 16.1
Creatinine (µmol/L)	100.9 ± 29.8
Surgical procedure	
Valve surgery	4 (44.4%)
Coronary artery bypass grafting (CABG)	4 (44.4%)
Aortic dissection	1 (11.1%)
Post-infarction ventricular septal defect (VSD)	3 (33.3%)
Combined surgery	3 (33.3%)
EuroSCORE II (%)	7.6 ± 1.4
Aortic cross-clamp time (min)	92.9 ± 56.4
Cardiopulmonary bypass (CPB) time (min)	190.2 ± 69.4
Intra-aortic balloon pump (IABP)	9 (100%)

NYHA: New York Heart Association.
EuroSCORE: European System for Cardiac Operative Risk Evaluation.

3.2. Extracorporeal membrane oxygenation support parameters

The main characteristics of ECMO support are listed in **(TABLE 2)**.

The primary cause of post-cardiotomy cardiogenic shock (PCCS) was predominantly left ventricular failure, observed in 4 patients (44,44%), followed by right ventricular failure and biventricular failure, both present in 2 patients (22,22%). An unknown cause was noted in one patient (11,11%).

ECMO was initiated primarily due to failure to wean from cardiopulmonary bypass (CPB) in 5 patients (55,55%). In the remaining cases, ECMO was implemented within 24 hours post-surgery in 3 patients (33,33%) and between 24 and 48 hours in one patient (11,11%). Distal limb perfusion was ensured in the majority of patients (88,88%).

The mean blood flow indexed to body surface area was 1,9 L/min/m² [1,5; 2,3]. Arterial blood gas analysis showed a median pH of 7,24 [7,14; 7,34] and an elevated lactate level of 9,4 mmol/L [6,2; 15,7]. The median haemoglobin level was 8,5 g/dL [6,5; 12,0], while the median platelet count was 128 $\times 10^9$/L [59; 319].

Biological markers of tissue injury were elevated, with a median C-reactive protein (CRP) level of 260 mg/L [111 ; 409], troponin at 1 490 ng/mL [600 ; 2 380], creatine kinase (CK) at 1 584 U/L [772 ; 5 207], bilirubin at 3,4 mg/L [1,1 ; 13,1], and aspartate aminotransferase (AST) at 460 U/L [198 ; 2 102].Renal function was impaired, with a median creatinine level of 178,7 µmol/L [132,7 ; 224,7] and urea at 120 mg/dL [59 ; 193].

Hemodynamically, patients were receiving high doses of catecholamines, with a median adrenaline dose of 0,5 µg/kg/min [0,37; 0,81] and norepinephrine at 0,6 µg/kg/min [0,29; 0,92]. Positive inotropic support with dobutamine at doses greater than 5 µg/kg/min was administered to 7 patients (77,77%).

Table 2: Characteristics of venoarterial extracorporeal membrane oxygenation support

Cause of PCCS	
– LV failure	4 (44,44 %)
– RV failure	2 (22,22 %)
– Biventricular failure	2 (22,22 %)
– Unknown	1 (11,11 %)
Delay for ECMO initiation	
– Failure to wean from CPB	5 (55,55 %)
– <24 h	3 (33,33 %)
– <48 h	1 (11,11 %)
Distal leg perfusion	8 (88,88 %)
ECMO blood flow (L/min/m²)	1,9 (1,5 ; 2,3)
pH	7,24 (7,14 ; 7,34)
Lactate (mmol/L)	9,4 (6,2 ; 15,7)
Hemoglobin (g/dL)	8,5 (6,5 ; 12,0)
Platelets (×10^9/L)	128 (59 ; 319)
CRP (mg/L)	260 (111 ; 409)
Troponin (ng/mL)	1490 (600 ; 2380)
CK (U/L)	1584 (772 ; 5207)
Bilirubin (mg/L)	3,4 (1,1 ; 13,1)
AST (U/L)	460 (198 ; 2102)
Adrenaline (µg/kg/min)	0,5 (0,37 ; 0,81)
Norepinephrine (µg/kg/min)	0,6 (0,29 ; 0,92)
Inotropes (dobutamine >5 µg/kg/min)	7 (77,77 %)
Creatinine (mmol/L)	178,7 (132,7 ; 224,7)
Urea (mg/dL)	120 (59 ; 193)

LV: Left Ventricular RV: Right Ventricular PCCS: Post-Cardiotomy Cardiogenic Shock ECMO: Extracorporeal Membrane Oxygenation CPB: Cardiopulmonary Bypass CRP: C-reactive Protein CK: Creatine Kinase AST: Aspartate Aminotransferase.

3.3. Outcomes with venoarterial extracorporeal membrane oxygenation

Table 3: Outcomes with venoarterial extracorporeal membrane oxygenation

ECMO Duration (hours)	89 ± 11
ECMO Weaning Rate	4 (44,44 %)
Ventilation Time (hours)	105 ± 25
Extubation	4 (44,44 %)
Reintubation	1 (11,11 %)
ICU Stay (days)	14,2 ± 6,7
Red Blood Cell Units per Patient	4,5 ± 1,5
Fresh Frozen Plasma Units per Patient	3,2 ± 0,9
Complications During ECMO	
Pulmonary Edema	4 (44,44 %)
Pneumonia	4 (44,44 %)
Hemorrhage	2 (22,22 %)
Limb Ischemia	2 (22,22 %)
Stroke	1 (11,11 %)
Dialysis	2 (22,22 %)
Arrhythmia	1 (11,11 %)
Discharge Destinations After ICU	
Transfer to Another Hospital	2 (22,22 %)
Discharge to Home	2 (22,22 %)
Transfer to Rehabilitation Center	1 (11,11 %)
Hospital Mortality	4 (44,44 %)
Causes of Hospital Mortality	
Multiple Organ Failure	3 (75 %)
Septic Shock	1 (25 %)
Combined Causes	1 (25 %)
1-Year Mortality	5 (55,55 %)
3-Year Mortality	6 (66,66 %)

Hospital mortality is typically defined as deaths occurring during hospitalization or within 30 days of admission.
ICU: Intensive Care Unit FFP: Fresh Frozen Plasma MOF: Multiple Organ Failure.

The mean duration of ECMO support was 89 ± 11 hours, ECMO weaning was successful in 4 patients (44,44%), the median ventilation time was 105 ± 25 hours, with extubation occurring in 4 patients (44,44%), while 1 patient (11,11%) required reintubation, the median ICU stay was 14,2 ± 6,7 days, on average, patients received 4,5 ± 1,5 units of red blood cells and 3,2 ± 0,9 units of fresh frozen plasma per patient during their ICU stay, regarding complications occurring during MCS, pulmonary oedema and pneumonia were the most common, each occurring in 4 patients (44,44%), other complications included hemorrhage and limb ischemia, which affected 2 patients each (22,22%), while stroke occurred in 1 patient (11,11%), dialysis was required in 2 patients (22,22%), and arrhythmia was noted in 1 patient (11,11%), these complications are listed in (Table 3), when it came to discharge destinations after ICU, 2 patients (22,22%) were transferred to another hospital, 2 patients (22,22%) were discharged home, and another 1 patient (11,11%) was transferred to a rehabilitation center, the hospital mortality rate was 44,44%, with the main causes of mortality being multiple organ failure in 3 patients (75%), septic shock in 1 patient (25%), and combined causes in 1 patient (25%), in terms of medium-term survival, the 1-year mortality rate was 55,55%, and the 3-year mortality rate was 66,66%

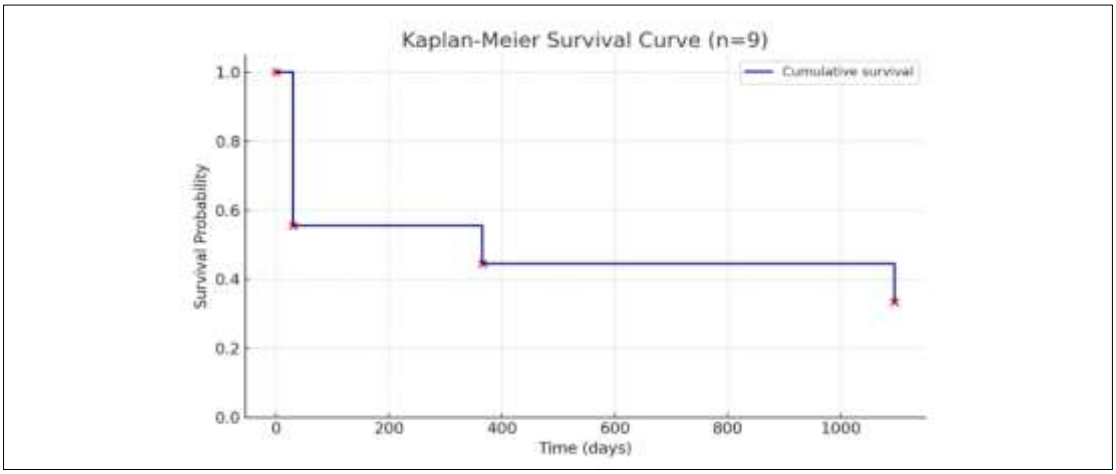

Figure 1: **Kaplan-Meier curve showing the survival of patients placed on VA ECMO**

3.4 Quality of life

Prior to the implantation of the veno-arterial ECMO, 77.77% of patients presented with severe dyspnea, classified as NYHA III or IV, indicating significant exertional limitations and even symptoms at rest. After a median follow-up of 3 ± 1 years, all surviving patients were classified as NYHA II, reflecting moderate limitations in ordinary physical activity. Regarding residual angina, 66.66% of the survivors were asymptomatic during daily activities, while 33.33% reported mild angina with moderate exertion (CCS I–II).

4. DISCUSSION

In our series, ECMO was primarily indicated in cases of failure to wean from cardiopulmonary bypass (CPB) and/or low cardiac output occurring within 48 hours postoperatively, despite maximal pharmacological support. The observed incidence was 0,16%, with a survival rate of 55,55%. This incidence, lower than those generally reported in the literature, may be attributed to strict selection criteria combined with a restrictive institutional policy. Conversely, the observed survival rate lies at the upper limit of published values, suggesting optimized and targeted management. For comparison, Wang et al (5)reported a survival rate of 34% at hospital discharge, while Guihaire *et al.,* [6] found an average of 42%. Overall, the literature describes an incidence ranging from 0,3 % to 1,7%, with survival rates varying between 28% and 51% Khorsandi *et al.,* [1] report a survival rate of 51%, while Chen *et al.,* [7] mention a rate of 39%. All the patients who died in our study were over 65 years old; 75% were women, 75% had systemic hypertension associated with pulmonary hypertension, and 75% were admitted for combined surgery, mainly valvular. Furthermore, all had an EuroSCORE greater than 8. These results are consistent with the literature, which identifies advanced age, female gender, combined surgery particularly valvular and a high EuroSCORE as factors associated with poor prognosis [8]. In our series, preoperative pulmonary hypertension was also identified as a poor prognostic factor, which contrasts with the results of the largest published series [9].

It is important to emphasize that all patients in our cohort underwent implantation of an intra-aortic balloon pump (IABP), the benefits of which are well documented in the literature. The concurrent placement of an IABP with ECMO helps reduce left ventricular afterload, thereby promoting better myocardial recovery, while limiting the incidence of pulmonary and cerebral oedema and reducing the duration of mechanical ventilation under ECMO [10,11].

The deceased patients in our study presented with post-cardiotomy cardiogenic shock, due to either right ventricular (RV) failure or biventricular failure. During ECMO support, all had lactate levels greater than 10 mmol/L, as well as myocardial and muscular lysis, accompanied by multivisceral organ failure, characterized by elevated AST, bilirubin, and biological renal failure. These patients were also on maximal doses of vasopressors and inotropic agents. This is highly consistent with the literature, which highlights that right ventricular (RV) failure is associated with an increased mortality rate of 20% [12]. Additionally, a persistently elevated lactate level and creatinemia under ECMO support, along with a higher vasoactive-inotropic score, have been linked to a higher mortality rate, as previously reported [13].

All deceased patients had an ECMO duration exceeding 72 hours, mechanical ventilation lasting more than 80 hours, an ICU stay longer than 15 days, and significant transfusion requirements. These findings are consistent with the literature, which highlights that intra-hospital mortality factors, such as prolonged ECMO, extended invasive ventilation, and complications related to severe multivisceral failures, are key elements in the rapid mortality under ECMO [14,15].

Compared to published studies, complications during assistance were less frequent in our cohort. This observation may be related to the preventive approach adopted by our center, as exemplified by the systematic implementation of reperfusion following an acute limb ischemia case, which helped reduce the incidence of this complication [16]. In our results, the 1-year survival rate was 44,4%, which is consistent with the literature: Magovern *et al.,* reported 47,6%, Ko *et al.,* 45,4%, Chen *et al.,* 24,1%, Guihaire *et al.,* 39,0%, and Biancari *et al.,* 31,0% [17,18,7,6,10]. The 3-year survival rate in our cohort was 33,3%, in line with the findings of Guihaire *et al.,* Biancari *et al.,* and Distelmaier *et al.,* [6,10,19].

Initially, 77.77% of patients presented with severe dyspnea (NYHA class III–IV); after a median follow-up of 3 ± 1 years, survivors were classified as NYHA II, with 66.66% free of angina and 33.33% experiencing mild exertional angina (CCS I–II), These results suggest that, despite the initial severity and complexity of management, survivors can achieve a satisfactory functional quality of life in the medium term [8]. This observation is consistent with data from the literature, which report that a majority of survivors regain functional autonomy and an acceptable quality of life after hospitalization [20-22].

4.1 Limites de l'étude

The statistical power of the present study is low, mainly due to the small sample size of the cohort, which includes a very limited number of patients. Moreover, the study is retrospective and monocentric, which limits the ability to generalize the results to other settings. Finally, this study only evaluates short- and medium-term outcomes, which limits the analysis to a short- and medium-term perspective without including long-term results.

Conflicts of interest: The authors declare having no conflicts of interest related to this article.

5. CONCLUSIONS

In this study, the implantation of venous-arterial ECMO for refractory cardiogenic shock occurred in 0.16% of cardiac surgeries, with an overall survival rate of 55.5%. Adverse prognostic factors included age over 65 years, an EuroSCORE greater than 8, as well as right or biventricular failure prior to cardiac surgery, persistent hyperlactatemia, and multivisceral failure during the assistance. After a median follow-up of 3 years, the surviving patients showed an improvement in their quality of life, with a majority in NYHA class II, without angina or with mild angina.

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