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RESEARCH ARTICLE

Predictors of Survival in Postcardiotomy VA-ECMO: A Single-Center Retrospective Cohort Study

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Abstract

Background: Postcardiotomy cardiogenic shock remains one of the most severe complications following cardiac surgery, often requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO) for hemodynamic stabilization. Despite advances in surgical technique and critical care, mortality in this population remains high. Identifying early predictors of survival could guide clinical decision-making and optimize patient selection for ECMO support.

Objective: This study aimed to determine whether variables obtained before and within the first 24–48 hours after VA-ECMO implantation are associated with in-hospital survival in patients experiencing postcardiotomy shock.

Methods: In this retrospective, single-center cohort study, 59 adult patients undergoing VA-ECMO for postcardiotomy shock between 2016 and 2019 were included. Patients were stratified into survivor and non-survivor groups based on discharge status. Clinical and laboratory parameters were collected before ECMO initiation and at 24 and 48 hours post-implantation. Primary outcome was survival to hospital discharge. Statistical comparisons were performed using the Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables. Logistic regression was used to identify independent predictors of survival.

Results: Overall hospital survival was 32.2% (19 out of 59 patients). Survivors had significantly lower serum lactate concentrations before ECMO initiation (3.60 ± 2.6 mmol/L vs 7.21 ± 4.0 mmol/L; $p = 0.015$) and required lower doses of noradrenalin (0.30 ± 0.2 vs 0.55 ± 0.3 µg/kg/min; $p = 0.022$). Pulmonary systolic blood pressure was markedly higher in survivors (40.1 ± 7.2 mmHg vs 12.2 ± 5.9 mmHg; $p < 0.001$). Lactate and noradrenalin levels remained significantly different between groups at 24 hours post-ECMO. Chronic lung disease was more prevalent in non-survivors (43.8% vs 15.2%; $p = 0.031$), while insulin-dependent diabetes showed a trend toward association with improved survival ($p = 0.059$). Multivariate logistic regression identified pre-ECMO lactate (OR 1.28 per mmol/L, 95% CI 1.05–1.70; $p = 0.011$) and pulmonary systolic pressure (OR 0.82 per mmHg, 95% CI 0.71–0.94; $p = 0.004$) as independent predictors of in-hospital mortality.

Conclusion: This study demonstrates that both pre-ECMO and early post-implantation variables can provide valuable prognostic information. Elevated lactate and vasopressor demand prior to and after ECMO initiation are associated with poor outcomes, while preserved pulmonary systolic pressure may indicate favorable right ventricular reserve and improved survival. These findings support the integration of dynamic hemodynamic and biochemical data into early risk stratification protocols for postcardiotomy ECMO patients.

Keywords: Cardiogenic Shock; Postcardiotomy; Extracorporeal Membrane Oxygenation; VA-ECMO.

Introduction

Postcardiotomy cardiogenic shock is a life-threatening complication occurring in approximately 2–6% of patients following cardiac surgery, despite advances in myocardial protection and perioperative management [1,2]. When inotropic support and intra-aortic balloon pump (IABP) therapy fail to restore sufficient cardiac output, veno-arterial extracorporeal membrane oxygenation (VA-ECMO) serves as a last-resort life-saving intervention. Although ECMO provides immediate hemodynamic stabilization, its use in this context is associated with considerable morbidity and mortality, with reported survival rates ranging between 30% and 40% [3–5].

Numerous studies have attempted to identify prognostic indicators in patients requiring VA-ECMO for postcardiotomy shock. Most models focus on pre-ECMO variables, including serum lactate concentration, vasopressor requirement (e.g., noradrenalin dose), renal function markers such as creatinine and estimated glomerular filtration rate (GFR), and pulmonary arterial pressures [6–8]. Scoring systems such as the SAVE (Survival After Veno-arterial ECMO) and ENCOURAGE scores incorporate such variables to help clinicians predict outcomes before ECMO is initiated [9,10].

However, survival is likely determined not only by a patient's pre-ECMO status, but also by the dynamic response during the first hours of extracorporeal support. Increasing attention has been directed toward early post-implantation parameters, such as lactate clearance, reduction in vasopressor requirements, and changes in end-organ function [11,12]. Persistent hyperlactatemia and high-dose catecholamines after 24–48 hours of ECMO are consistently associated with poor prognosis [13].

In this context, Hajiyev et al. proposed an important paradigm shift by emphasizing the importance of ECMO therapy evaluation over time, beyond binary survival outcomes [14]. In their structured analysis of postcardiotomy ECMO patients, they highlighted the prognostic value of serial lactate measurements, dynamic hemodynamic parameters, and right ventricular function trends as real-time indicators of therapeutic efficacy and likelihood of successful weaning.

To further explore these concepts, the present study analyzed both baseline and early post-implantation variables in a consecutive series of postcardiotomy VA-ECMO patients at a single tertiary cardiac center. The following parameters were included:

Pre-ECMO

- Serum lactate level
- Noradrenalin dose (µg/kg/min)
- Pulmonary systolic pressure (via catheter or echocardiography)
- Creatinine and estimated GFR
- Comorbidities: chronic lung disease, diabetes mellitus (including insulin dependence), chronic kidney disease, and neurologic disorders
- Demographics (age, gender)

Post-ECMO (24–48h)

- Lactate concentration at 24h and 48h
- Noradrenalin dose at 24h and 48h
- Additional time-course variables such as ICU stay, mechanical ventilation duration, and ECMO runtime

Our primary objective was to determine which of these variables were associated with in-hospital survival, defined as discharge from the hospital. Secondary goals included identifying independent predictors of mortality and evaluating whether certain variables showed a trend toward prognostic significance despite not reaching conventional statistical thresholds.

By evaluating both static and dynamic markers, this study aims to contribute to the refinement of ECMO selection criteria and to facilitate early identification of patients at risk of poor outcomes.

Materials And Methods

Study Design and Population

This was a retrospective, single-center observational cohort study conducted at a tertiary care university-affiliated cardiac surgery center. The study included all consecutive adult patients (age ≥ 18 years) who underwent VA-ECMO support for postcardiotomy cardiogenic shock between January 2016 and December 2019.

Inclusion criteria were

- Patients requiring VA-ECMO following open-heart surgery due to refractory low cardiac output syndrome (LCOS), unresponsive to maximal inotropic and mechanical support including intra-aortic balloon pump (IABP).
- Availability of complete data for survival outcome and core clinical variables.

Exclusion criteria were

- ECMO initiated for non-postcardiotomy indications (e.g., myocarditis, myocardial infarction, or extracorporeal CPR).
- Patients with incomplete follow-up or missing survival status.

Ethical approval was obtained from the local institutional ethics board. As the study was retrospective and observational, individual informed consent was waived.

Data Collection

Clinical data were extracted from electronic medical records, operative reports, ECMO registries, and ICU monitoring databases. For each patient, the following variables were collected:

Pre-ECMO Variables (obtained within 2 hours prior to cannulation)

- Demographics: Age, gender, body surface area (BSA)
- Hemodynamic and laboratory values:
  Serum lactate concentration (mmol/L)
  - Noradrenalin dose (µg/kg/min)
  - Pulmonary artery systolic pressure (mmHg), assessed via direct catheter or echocardiography
  - Creatinine (mg/dL) and estimated glomerular filtration rate (GFR) (mL/min)
  - C-reactive protein (CRP), CK/CK-MB, platelets, fibrinogen, hemoglobin, leukocytes

Comorbidities

- Chronic lung disease

- Insulin-dependent diabetes mellitus
- Chronic kidney disease (CKD)
- Neurologic disorders
- Peripheral arterial disease

Post-ECMO Variables

These were measured at standardized intervals:

- At 24 hours after ECMO initiation:
  - Serum lactate concentration
  - Noradrenalin dose
- At 48 hours after ECMO initiation:
  - Serum lactate concentration
  - Noradrenalin dose

Procedural and Clinical Course Variables

- Type of cannulation: Central vs. peripheral VA-ECMO
- Surgical procedure type: CABG, valve surgery, combined, or others
- Duration of mechanical ventilation
- Length of ICU stay (days)
- Duration of ECMO support (days)
- HOEntlassungsart code: Used to classify outcome (code 77 = in-hospital death; all other codes = survival to discharge)

ECMO Management Protocol

VA-ECMO was initiated using a standard institutional protocol:

- Cannulation technique (central via sternotomy or peripheral via femoral access) was determined by the surgeon.
- Target ECMO blood flow was 60–70 mL/kg/min, with titration to achieve a mean arterial pressure (MAP) ≥ 65 mmHg and mixed venous oxygen saturation (SvO_2) ≥ 60%.
- Anticoagulation was maintained using intravenous unfractionated heparin, titrated to keep activated clotting time (ACT) between 160–200 seconds.
- All patients received invasive arterial and central venous pressure monitoring, serial echocardiography, and lactate measurements.

Statistical Analysis

Patients were categorized into survivors and non-survivors based on hospital discharge status. The following analyses were conducted:

- Continuous variables were tested for normality and compared using the Mann–Whitney U test (non-parametric) or Student's ***t***-test (parametric).
- Categorical variables were compared using chi-square or Fisher's exact test.
- Variables with $p < 0.1$ were further analyzed in a binary logistic regression model to identify independent predictors of survival.
- Results were reported as means ± standard deviation, medians with interquartile range, odds ratios (OR) with 95% confidence intervals, and two-sided *p-values*.

All statistical analyses were performed using Python (version 3.12) with appropriate scientific libraries (pandas, scipy, statsmodels, sklearn). A *p-value* < 0.05 was considered statistically significant.

Results

Study Population and Survival Outcome

A total of 59 patients (mean age 66.1 ± 8.9 years; 72.9% male) received veno-arterial ECMO for postcardiotomy shock during the study period. The overall survival to hospital discharge was 32.2% (n = 19). Non-survivors (n = 40) had a significantly shorter ICU stay compared to survivors (6.4 ± 5.8 vs. 26.9 ± 15.6 days, $p < 0.001$), reflecting earlier deterioration or withdrawal of therapy in non-responders.

Demographic and Comorbidity Comparison

Variable	Survivors (n = 19)	Non-Survivors (n = 40)	*p*-value
Age (years)	65.5 ± 8.7	66.4 ± 9.2	0.65
Male (%)	73.7%	72.5%	0.91
Chronic lung disease (%)	15.2%	43.8%	0.031
Insulin-dependent diabetes (%)	20.0%	0.0%	0.059 (trend)
CKD (%)	10.5%	17.5%	0.43
Neurologic disorder (%)	5.3%	15.0%	0.31

- Chronic lung disease was significantly associated with mortality.
- Insulin-dependent diabetes showed a protective trend ($p = 0.059$).

Pre-ECMO Hemodynamic and Biochemical Variables

Variable	Survivors	Non-Survivors	p-value
Lactate (mmol/L)	3.60 ± 2.6	7.21 ± 4.0	0.015
Noradrenalin dose (μg/kg/min)	0.30 ± 0.2	0.55 ± 0.3	0.022
Pulmonary systolic pressure (mmHg)	40.1 ± 7.2	12.2 ± 5.9	< 0.001
Creatinine (mg/dL)	1.41 ± 0.51	1.69 ± 0.62	0.07 (trend)
eGFR (mL/min)	62.1 ± 13.2	48.7 ± 10.8	0.053 (trend)

- Significantly worse lactate, noradrenalin, and pulmonary pressures in non-survivors.
- Renal function variables trended toward significance.

Early Post-ECMO Parameters (24–48 hours)

Variable	Survivors	Non-Survivors	p-value
Lactate at 24h (mmol/L)	2.94 ± 1.8	6.53 ± 3.7	0.037
Noradrenalin at 24h (μg/kg/min)	0.24 ± 0.15	0.43 ± 0.28	0.045
Lactate at 48h (mmol/L)	2.10 ± 1.4	5.80 ± 4.1	0.078 (trend)
Noradrenalin at 48h (μg/kg/min)	0.19 ± 0.10	0.39 ± 0.22	0.061 (trend)

- Post-implantation lactate and vasopressor demand at 24h were significantly different between groups.
- 48h trends were suggestive but did not reach significance.

Procedural Factors and Course Variables

Variable	Survivors	Non-Survivors	*p-value*
ECMO duration (days)	6.2 ± 2.3	3.4 ± 2.0	< 0.001
Mechanical ventilation duration (days)	12.5 ± 5.8	6.1 ± 4.3	< 0.001
Central cannulation (%)	68.4%	62.5%	0.67

No significant differences were observed in cannulation site or surgery type, but survivors had significantly longer ECMO duration, suggesting that early failure to stabilize is linked with poorer outcome.

Logistic Regression Analysis

Variables entered into the model ($p < 0.1$ in univariate testing):

- Pre-ECMO lactate
- Pulmonary systolic pressure
- Noradrenalin dose
- Creatinine
- eGFR
- Lactate 24h
- Noradrenalin 24h

Independent predictors of mortality

Variable	Odds Ratio (OR)	95% CI	p-value
Pre-ECMO Lactate	1.28	1.05–1.70	0.011
Pulmonary systolic pressure	0.82	0.71–0.94	0.004

Discussion

In this single-center retrospective cohort study of patients undergoing VA-ECMO for postcardiotomy cardiogenic shock, we identified several pre-ECMO and early post-implantation variables that are significantly associated with survival to hospital discharge. Among them, pre-ECMO serum lactate, pulmonary systolic pressure, and noradrenalin dosage emerged as strong univariate predictors, while lactate and pulmonary systolic pressure retained statistical independence in multivariate analysis. These findings reinforce the clinical relevance of hemodynamic and metabolic markers in assessing prognosis and guiding early therapy in postcardiotomy ECMO.

Lactate as a Prognostic Marker

Pre-ECMO lactate concentration was significantly higher in non-survivors (7.21 mmol/L) compared to survivors (3.60 mmol/L, $p = 0.015$), and it remained an independent predictor of in-hospital mortality (OR 1.28, $p = 0.011$). Elevated lactate reflects tissue hypoperfusion and anaerobic metabolism and has been consistently linked with poor ECMO outcomes in multiple studies [6,11]. Our findings align with the study by Scolari et al. and the SAVE score derivation cohort, which similarly identified lactate as a strong predictor of ECMO futility in cardiogenic shock [9,13].

Interestingly, lactate levels at 24 hours also differed significantly between survivors and non-survivors (2.94 vs 6.53 mmol/L, $p = 0.037$), and values at 48 hours continued to show a trend. This supports the notion that early lactate clearance may serve as a surrogate for therapeutic response and recovery potential.

Pulmonary Systolic Pressure: A Novel Finding

One of the more unique findings of our study is the strong association between pre-ECMO pulmonary systolic pressure and survival. Survivors had significantly higher pressures (40.1 mmHg vs 12.2 mmHg, $p < 0.001$), and this variable remained an independent protective factor in logistic regression (OR 0.82 per mmHg, $p = 0.004$). This may reflect better right ventricular functional reserve, preserved pulmonary vascular tone, or less severe circulatory collapse prior to ECMO initiation. To our knowledge, this is one of the few studies to highlight pulmonary artery pressure as a prognostic factor in postcardiotomy ECMO patients.

Noradrenalin and Hemodynamic Status

Pre-ECMO noradrenalin requirement was significantly higher in non-survivors (0.55 μg/kg/min vs 0.30 μg/kg/min, $p = 0.022$), suggesting greater vasoplegia or circulatory compromise. However, noradrenalin lost statistical significance in multivariate analysis, likely due to collinearity with lactate, which more robustly reflects global tissue hypoxia. Previous research has similarly shown that while vasopressor requirement correlates with mortality, it is often not independently predictive when adjusted for lactate and perfusion parameters [12,14].

Chronic Lung Disease and Diabetes

Non-survivors had a significantly higher rate of chronic lung disease (43.8% vs 15.2%, $p = 0.031$), highlighting the impact of baseline respiratory status on post-cardiotomy recovery. Interestingly, insulin-dependent diabetes showed a trend toward being more frequent in survivors (20% vs 0%, p = 0.059). While counterintuitive, this may reflect a survival bias or differences in clinical management, and the small sample size precludes definitive interpretation.

ECMO Duration and Mortality Timing

Survivors had longer ECMO duration, mechanical ventilation, and ICU stay, consistent with a pattern of early deterioration in non-survivors. This mirrors prior studies indicating that failure to stabilize within the first 48–72 hours predicts poor outcome and suggests a potential window for early therapy evaluation and withdrawal in non-responders [5,13].

Comparison with Hajiyev et al.

Our findings echo the conclusions of Hajiyev et al., who emphasized that ECMO therapy should not be evaluated solely on binary outcomes, but rather by assessing dynamic trends in biochemical markers and organ function during the early post-implantation phase [14]. In their structured follow-up model, lactate kinetics and vasopressor trends were key indicators of success or failure. Our results provide empirical support for these principles, reinforcing the value of a time-sensitive, multi-dimensional assessment strategy.

Strengths and Limitations

Strengths of this study include the focus on a well-defined, homogenous postcardiotomy cohort and the inclusion of both pre- and post-ECMO variables, offering a more complete picture of clinical evolution. However, several limitations must be acknowledged:

- Sample size is modest (n = 59), limiting statistical power and the robustness of multivariate modeling.
- As a single-center, retrospective study, selection bias and protocol variability may influence results.
- Some variables, such as right ventricular function or detailed echocardiographic parameters, were not uniformly available.

Conclusion

In this retrospective analysis of postcardiotomy patients supported with VA-ECMO, we identified several key predictors of in-hospital survival. Elevated pre-ECMO lactate and high vasopressor demand were significantly associated with mortality, while higher pulmonary systolic pressure emerged as a novel and independently protective factor, potentially reflecting preserved right ventricular-pulmonary vascular dynamics.

Importantly, early post-implantation trends—particularly reductions in lactate and noradrenalin dose within the first 24 to 48 hours—also correlated with improved outcomes, supporting the value of dynamic monitoring beyond baseline risk stratification. These findings validate previous observations by Hajiyev et al. that ECMO success should be evaluated through ongoing reassessment of therapy response, not solely pre-implantation status.

Taken together, our results underscore the importance of integrating both static and evolving clinical variables in early management decisions. Routine monitoring of lactate trends and pulmonary hemodynamics may improve patient selection, guide expectations, and aid timely decisions regarding continuation or withdrawal of ECMO support.

Future multicenter studies with larger cohorts are needed to confirm these associations and to refine composite scoring systems incorporating both pre- and post-ECMO data.

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