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Outcomes and Predictors of Mortality Following Veno-Arterial Extracorporeal Membrane Oxygenation

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Abstract

Objectives:To evaluate clinical outcomes and identify predictors of survival in patients receiving veno-arterial extracorporeal membrane oxygenation (VA-ECMO) following adult cardiac surgery.

Methods:This retrospective, single-center study included 105 patients who received VA-ECMO after cardiac surgery at Kaohsiung Chang Gung Memorial Hospital between October 2003 and December 2018. Surgical procedures included isolated coronary artery bypass grafting (CABG), combined CABG and valve surgery, isolated valve surgery, double valve surgery, surgery for acute aortic dissection, and heart transplantation. Survival during index hospitalization was analyzed using the Kaplan–Meier method and the log-rank test. For univariate analysis, age, body surface area, body weight, and ECMO duration were categorized using median values, whereas body mass index was analyzed in three categories. Multivariate Cox proportional hazard regression was performed using continuous covariates.

Results:Among the 105 patients, 31 underwent isolated CABG and 74 underwent other procedures, with comparable baseline characteristics. Univariate analysis identified age (p=0.0048), ECMO duration (p=0.0345), and operation type (p=0.0087) as factors associated with survival. Patients aged <60 years had better survival than those ≥60 years. Heart transplant recipients demonstrated the most favorable unadjusted survival; however, after exclusion, survival differences among other operative categories were not significant (p=0.20). In multivariable analysis, age was the only independent predictor of survival (hazard ratio: 1.0239; 95% confidence interval: 1.0001–1.0483; p=0.0488).

Conclusions:Age was the only independent predictor of survival in patients receiving VA-ECMO following cardiac surgery. These findings underscore the importance of age in risk stratification and patient selection for post-cardiotomy VA-ECMO.

Introduction

Cardiogenic shock remains one of the most devastating complications following adult cardiac surgery. Although relatively uncommon, it is associated with profound hemodynamic instability and extremely poor outcomes when refractory to conventional therapies, including inotropic support and intra-aortic balloon counterpulsation. In this context, veno-arterial extracorporeal membrane oxygenation (VA-ECMO) has emerged as an important rescue modality, providing temporary circulatory support, maintaining end-organ perfusion, and serving as a bridge to myocardial recovery, durable mechanical support, or transplantation. Contemporary expert consensus statements from the European Association for Cardio-Thoracic Surgery (EACTS), Extracorporeal Life Support Organization (ELSO), Society of Thoracic Surgeons (STS), and American Association for Thoracic Surgery (AATS), as well as ELSO guidelines, recognize post-cardiotomy extracorporeal life support as an established salvage strategy in carefully selected patients [1,2].

Despite advances in patient selection, cannulation strategies, and critical care management, outcomes after post-cardiotomy VA-ECMO remain poor. Recent systematic reviews, meta-analyses, and multicenter

studies consistently report early or in-hospital mortality rates approaching two-thirds of treated patients. Several prognostic factors have been proposed, including advanced age, pre-ECMO metabolic derangement, elevated lactate levels, right ventricular failure, and procedural complexity [3–6]; however, the relative contribution of individual factors varies across studies and institutions.[3,7] Therefore, center-specific outcome analyses remain clinically relevant for refining patient selection and identifying potentially modifiable risk factors.

Given the persistently high mortality associated with post-cardiotomy VA-ECMO and the heterogeneity of the surgical population, further evaluation of institutional outcomes is warranted. This study aimed to review our single-center experience with 105 patients who received VA-ECMO following adult cardiac surgery and to identify factors associated with overall survival during index hospitalization. We specifically examined the impact of demographic variables, anthropometric measures, ECMO duration, procedure type, limb ischemic complications, and timing of ECMO initiation on survival.

Materials and Methods

Study design and patient selection

This retrospective single-center study included 105 patients who received VA-ECMO following cardiac surgery at Kaohsiung Chang Gung Memorial Hospital between October 2003 and December 2018. Eligible patients were adults who underwent cardiac surgery and subsequently received postoperative VA-ECMO support. Patients were excluded if they had undergone non-cardiac or congenital heart surgery, had incomplete or unavailable medical records, or if their families declined further medical management. The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Kaohsiung Chang Gung Memorial Hospital (IRB No. 202600594B0).

Cardiac surgery and VA-ECMO management

All cardiac procedures were performed by three experienced cardiac surgeons. Surgical procedures included isolated coronary artery bypass grafting (CABG), combined CABG and valve surgery, isolated valve surgery, double valve surgery, surgery for acute aortic dissection, and heart transplantation. Postoperatively, patients were transferred to the intensive care unit, where VA-ECMO was initiated when clinically indicated. For subgroup analysis, patients were categorized into two groups: isolated CABG and other cardiac surgeries.

Outcome definition

The primary outcome was in-hospital survival during the index hospitalization. Survival status was determined from medical records. Patients discharged alive were censored at discharge, whereas in-hospital deaths were considered events. Kaplan–Meier survival analysis was used to estimate survival outcomes.

Statistical analysis

Statistical analyses were performed using MedCalc® Statistical Software version 20 (MedCalc Software Ltd, Ostend, Belgium; 2021). Continuous variables are presented as mean ± standard deviation, and categorical variables as number (percentage). Group comparisons were performed using the chi-square test or Fisher's exact test, as appropriate.

For Kaplan–Meier and univariate log-rank analyses, selected continuous variables (age, body surface area [BSA], body weight [BW], and ECMO duration) were dichotomized using median values (60 years, 1.7 m^2, 67 kg, and 83 h, respectively). Body mass index (BMI) was categorized as <19, 19–<24, and ≥24 kg/m^2. In contrast, in the multivariable Cox proportional hazards regression, all covariates were entered as continuous variables to preserve the statistical power and avoid information loss from categorization. All variables were entered using the entry method. All tests were two-sided, and a p-value <0.05 was considered statistically significant [8-10].

Results

Patients characteristics

A total of 105 patients who required VA-ECMO after cardiac surgery were included. Of these, 31 patients underwent isolated CABG and 74 underwent other cardiac surgeries. Baseline clinical characteristics and operative details are summarized in Table 1. The mean age was 66.7 ± 10.4 years in the isolated CABG group and 62.7 ± 13.5 years in the other-surgery group (p=0.14). No significant between-group differences were observed in BSA, BW, BMI, length of hospital stay, sex distribution, total ECMO duration, ischemic leg complications after ECMO, or initiation of ECMO during office hours (all p>0.05).

Univariate survival analysis

Univariate Kaplan–Meier analysis with the log-rank test identified three variables significantly associated with overall survival: age (p=0.0048), total ECMO duration (p=0.0345), and operation type (p=0.0087). Patients aged <60 years had significantly better survival rates than those aged ≥60 years. In addition, the ECMO duration dichotomized at 83 h was significantly associated with survival, as was the type of cardiac surgery performed.

Survival curves are shown in Figure 1A. Among surgical subgroups, heart transplantation recipients demonstrated the most favorable survival pattern. However, after excluding these patients, survival differences among the remaining operative categories were no longer statistically significant (p=0.20; Figure 1B). Detailed survival results are presented in Table 2.

Multivariable Cox regression analysis

Multivariable Cox proportional hazards regression analysis included age, BSA, BW, BMI, sex, total ECMO duration, ischemic leg after ECMO, initiation of ECMO during office hours, and operation type. Only age

remained an independent predictor of overall survival (hazard ratio [HR]: 1.0239; 95% confidence interval [CI]: 1.0001–1.0483; p=0.0488).

ECMO initiation during office hours and operation type showed borderline associations with overall survival, but did not reach statistical significance (HR: 1.6750; 95% CI: 0.9520–2.9469; p=0.0735; and HR: 0.8349; 95% CI: 0.6772–1.0293; p=0.0911, respectively). All other variables were not independently associated with overall survival. Detailed results are presented in Table 3.

Discussion

In this retrospective single-center cohort of 105 patients requiring VA-ECMO after adult cardiac surgery, age, total ECMO duration, and operation type were associated with survival in univariate analysis; however, only age remained an independent predictor in the multivariable Cox regression model. In addition, heart transplant recipients demonstrated the most favorable unadjusted survival pattern (Fig. 1A), but this difference was no longer significant after exclusion of the transplant subgroup (Fig. 1B). Overall, these findings suggest that age was the most robust and independent determinant of in-hospital survival in our cohort.

The adverse impact of older age on survival is consistent with existing literature on post-cardiotomy VA-ECMO. A multicenter study and meta-analysis by Biancari et al. showed significantly higher hospital mortality in patients aged ≥ 70 years compared with younger patients[3,4]. Similarly, more recent multicenter and single-center studies have identified age as an independent predictor of mortality in postcardiotomy ECMO, with worse outcomes observed in patients older than 60 years [11,12]. From a biological perspective, advanced age likely reflects reduced physiological reserve, increased frailty, greater comorbidity burden, and diminished tolerance to ischemia–reperfusion injury, systemic inflammation, and end-organ dysfunction after major cardiac surgery. Collectively, our findings reinforce the importance of age in risk stratification when considering VA-ECMO for post-cardiotomy shock.

In contrast, total ECMO duration and operation type were associated with survival in univariate analysis but lost significance after multivariable adjustment. ECMO duration may reflect disease severity and recovery trajectory rather than exerting an independent causal effect, as it is influenced by underlying shock severity, myocardial recovery, and ECMO-related complications. Similarly, the apparent survival differences across operative categories were largely driven by the heart transplant subgroup; after its exclusion, intergroup differences were no longer significant. This suggests that the operative category alone may not adequately capture the underlying severity profile of patients requiring postcardiotomy VA-ECMO, particularly in a heterogeneous cohort that combines CABG, valve procedures, aortic dissection surgery, and transplantation [1,2].

Although ECMO initiation during office hours did not reach statistical significance in our multivariate model, the borderline association observed may reflect differences in case urgency, perioperative timing, staffing patterns, or circumstances under which refractory shock develops, rather than a direct temporal

effect. Given the small sample size, this finding should be interpreted with caution and regarded as hypothesis-generating only. Likewise, ischemic leg complications after ECMO were not associated with survival; however, the low event rate limited statistical power.

Our study has several limitations. First, this was a retrospective analysis from a single center, and the sample size was modest, which increased the possibility of selection bias and limited generalizability. Second, the study period was long, spanning > 15 years, during which time the perioperative management, ECMO technology, and institutional practice patterns may have changed. Third, the operative population was heterogeneous and included patients who underwent isolated CABG, combined CABG and valve surgery, isolated valve surgery, double-valve surgery, acute aortic dissection surgery, or heart transplantation. Fourth, several prognostically important variables reported in previous studies, such as lactate concentration [5,6], vasoactive-inotropic requirements [13], pre-ECMO end-organ dysfunction, and detailed hemodynamic parameters, were not included in the current model. Previous studies and recent meta-analytic work [7] suggest that these factors may have substantial prognostic relevance and should be incorporated into future analyses.

In conclusion, postcardiotomy VA-ECMO remains a high-risk salvage therapy. In our single-center study, age was the only independent predictor of in-hospital survival. Although ECMO duration and operation type were associated with survival in the univariate analysis, these associations were not sustained after adjustment. These findings highlight the importance of careful patient selection—particularly in older individuals—and underscore the need for larger multicenter studies incorporating detailed physiological and biochemical variables to improve risk stratification and optimize patient selection.

Abbreviations

AATS – American Association for Thoracic Surgery

BMI – Body mass index

BSA – Body surface area

BW – Body weight

CABG – Coronary artery bypass grafting

CI – Confidence interval

EACTS – European Association for Cardio-Thoracic Surgery

ECMO – Extracorporeal membrane oxygenation

ELSO – Extracorporeal Life Support Organization

HR – Hazard ratio

ICU – Intensive care unit

IRB – Institutional Review Board

STS – Society of Thoracic Surgeons

VA-ECMO – Veno-arterial extracorporeal membrane oxygenation

Declarations

Ethics approval and consent to participate

The experimental protocol was established according to the ethical guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Chang Gung Memorial Hospital. In this retrospective study, the requirement for informed consent was waived, and the study protocol was approved by the Ethics Committee of Chang Gung Memorial Hospital (Institutional Review Board number: 202600594B0).

Consent for publication

Not applicable

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Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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Competing interests

None

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Tables

Table 1: Baseline characteristics and operative details in 105 patients requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO) following cardiac surgery

Parameters		Cardiac Surgery		
		Simple CABG	Other Surgery	p-value
Number		31	74	
Age		66.7 ± 10.4	62.7 ± 13.5	0.14
BSA (Body Surface Area)		1.74 ± 0.2	1.69 ± 0.27	0.36
BW (Body Weight)		69.14 ± 13.8	66.57 ± 19.0	0.49
BMI (Body Mass Index)		25.8 ± 4.2	25.0 ± 5.5	0.48
Length of stay		38.9 ± 33.3	51.3 ± 53.6	0.24
Sex	Male	24	49	0.26
	Female	7	25	
Total ECMO time (HRs)		107.8 ± 102.2	116.9 ± 126.0	0.72
Ischemic leg after ECMO	No	31	68	0.12
	One leg	0	3	
	Two legs	0	3	
Set in office time	Yes	9	34	0.11
	No	22	40	

T = the extent of the tumor, N = the extent of spread to the lymph nodes,* = Statistically significant. x^2 test or Fisher's exact test was used for statistical analysis.

Table 2: Results of univariate log-rank analysis of prognostic factors for overall survival in 105 patients requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO) following cardiac surgery

Factors	No. of patients	Survival Data		
		30-Days Mortality (%)	In-Hospital Mortality (%)	p
Age				
≧60	67	50	91	0.0048*
<60	38	26	77	
BSA				
≧1.7	51	42	64	0.66
<1.7	54	42	92	
BW				
≧67	45	45	72	0.98
<67	60	40	91	
BMI				
≧24	55	39	90	0.87
19≦BMI<24	42	47	84	
<19	8	37	100	
Sex				
Male	73	43	83	0.99
Female	32	38	92	
Total ECMO time (HRs)				
≧83	52	32	87	0.0345*
<83	53	51	85	
Ischemic Leg after ECMO				
No	99	40	87	0.54
One leg	3	67	67	
Two legs	3	67	100	
Initiation ECMO during office hours				

Yes	43	45	90	0.32
No	62	40	85	
Operation Type				
CABG	31	45	100	0.0087*
CABG+Valve	14	44	81	
Valve	29	45	77	
Double Valve	8	40	100	
Dissection	14	57	100	
Heart Transplant	10	0	58	

BSA = body surface area (m^2), BW = body weight (kg), BMI = body mass index (kg/m^2), CABG = coronary artery bypass graft, * = Statistically significant. x^2 test or Fisher's exact test was used for statistical analysis.

Table 3: Results of the multivariable analysis (Cox proportional hazards regression) of prognostic factors for overall survival in patients requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO) following cardiac surgery

Covariate	b	Std. Error	Exp (b)	95% CI of Exp (b)	p-value
Age	0.02364	0.012	1.0239	1.0001 to 1.0483	0.0488*
BSA	5.9766	4.1917	394.1067	0.1066 to 1457616	0.1539
BW	-0.1256	0.09272	0.8819	0.7354 to 1.0577	0.1754
BMI	0.1575	0.1357	1.1706	0.8972 to 1.5274	0.2458
Sex	-0.0808	0.3695	0.9223	0.4471 to 1.9029	0.8268
Total ECMO time	-0.0013	0.0012	0.9987	0.9962 to 1.0011	0.2943
Ischemic Leg	0.1172	0.3065	1.1243	0.6166 to 2.0500	0.7022
Initiation ECMO during office hours	0.5158	0.2882	1.6750	0.9520 to 2.9469	0.0735
Operation	-0.1805	0.1068	0.8349	0.6772 to 1.0293	0.0911

BSA = body surface area (m^2), BW = body weight (kg), BMI = body mass index (kg/m^2), CABG = coronary artery bypass graft, * = Statistically significant.

Figures

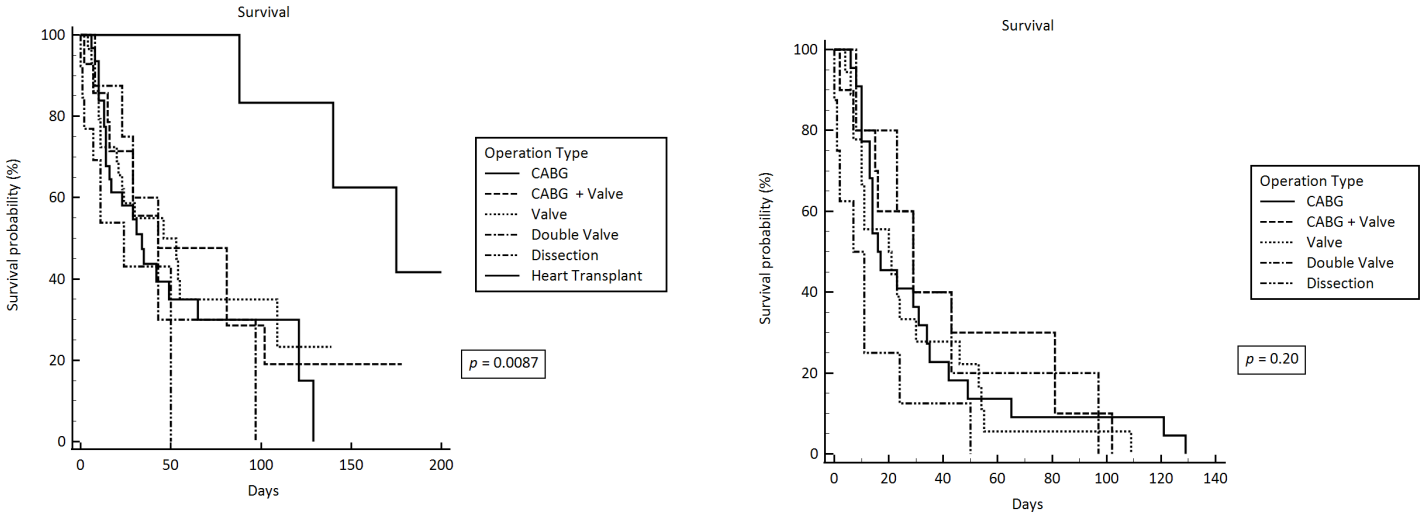


Figure 1

Kaplan–Meier survival curve in 105 patients requiring veno-arterial extracorporeal membrane oxygenation following cardiac surgery. (1A) All surgeries. (1B) Excluding heart transplant.