Scandinavian Cardiovascular Journal

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/icdv20

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To cite this article: Inga L. Ingvarsdottir, Andreas Westerlind, Isabella Lepore, Tomas Gudbjartsson, Bengt Redfors & Göran Dellgren (2025) Cardiogenic shock and extracorporeal membrane oxygenation: etiology and 1-year survival, Scandinavian Cardiovascular Journal, 59:1, 2481179, DOI: 10.1080/14017431.2025.2481179

To link to this article: https://doi.org/10.1080/14017431.2025.2481179

SCANDINAVIAN CARDIOVASCULAR JOURNAL
2025, VOL. 59, NO. 1, 2481179
https://doi.org/10.1080/14017431.2025.2481179

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RESEARCH ARTICLE

Cardiogenic shock and extracorporeal membrane oxygenation: etiology and 1-year survival

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ABSTRACT

Objectives. Venoarterial extracorporeal membrane oxygenation (VA-ECMO) is used to provide cardiorespiratory support in cardiogenic shock (CS), but selection of patients and timing of ECMO-start remain a challenge. This study aims to describe the 1 year outcome of VA-ECMO for CS with focus on etiology and severity of shock. *Methods*. VA-ECMO was used on 371 occasions between 2004 and 2019 at our center. Of these, 177 patients received VA-ECMO for CS and were included in this retrospective single-center study. Univariable and multivariable logistic regression models were used to determine predictors of all-cause mortality at 1 year. *Results*. Patients were grouped according to underlying etiology: non-ischemic heart failure (NIHF, $N = 49$), ischemic heart disease (IHD, $N = 83$) and miscellaneous diagnoses (Misc, $N = 45$). Markers of disease severity were lower for patients with NIHF. One year survival was 40% for all patients, 57%, 36% and 27% for the NIHF-, IHD and Misc-groups, respectively ($p < .01$). Univariable logistic regression analysis identified several variables associated with 1-year mortality, such as underlying etiology, pH and lactate, while biventricular failure was associated with a better prognosis. However, in the multivariable analysis, only ECPR remained significantly associated with increased mortality (OR 3.67, (CI 1.66–8.31), $p < .01$) *Conclusions*. In this retrospective study of VA-ECMO for CS, we found an acceptable one-year survival rate of 40%, with a more favorable outcome for NIHF-patients. The negative association of ECPR with a higher 1 year mortality suggests the importance of patient selection as well as timing of the VA-ECMO before deterioration to cardiac arrest.

ARTICLE HISTORY
Received 14 November 2024
Revised 21 January 2025
Accepted 13 March 2025

KEYWORDS
Extracorporeal membrane oxygenation; mechanical circulatory support; cardiogenic shock; cardiopulmonary resuscitation; outcome

Introduction

Cardiogenic shock (CS) has various etiologies all of which culminate in an impairment of the myocardium resulting in decreased cardiac output, end-organ damage, and death if uncorrected. Even with the underlying cause addressed, CS carries a high mortality, ranging from 30 to 60% in most studies [1–5]. Cardiogenic shock can be treated with careful resuscitation and pharmacological interventions; however, if refractory to conventional treatment, mechanical circulatory support (MCS) devices can be utilized to restore cardiac output and maintain tissue perfusion [6–8]. Venoarterial extracorporeal membrane oxygenation (VA-ECMO) is a short-term MCS that can provide a rapid cardiorespiratory support; where the primary aim is to bridge the patient to recovery, alternatively to other (long-term) MCS devices, organ transplantation or to a decision to withdraw support [5,9]. Nevertheless, timing of the ECMO start and patient selection remain a challenge as various factors affect prognosis. Lower mortality rates have been reported for patients with myocarditis as compared to other etiologies [10–12], and a recent meta-analysis concluded that mortality after VA-ECMO in patients with CS differs significantly on etiology [13]. However, no adjustments for the severity of shock or incidence of ECPR could be made. Still we have seen that mortality in patients with myocarditis as well as pulmonary embolism treated with VA-ECMO increases if implemented during extracorporeal cardiopulmonary resuscitation (ECPR) [12,14–17]. Thus, the aims of this study were to describe the 1-year outcome of VA-ECMO for CS with special focus on the etiology and severity of the shock.

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/14017431.2025.2481179.

Patients and methods

The study was approved by the Research Ethics Board at the Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden, following the Helsinki Declaration (Diary number 728-12, amendment 2020-04281). Informed consent was waved due to the retrospective nature of the research, using anonymous data for statistic calculation and reporting. Data was gathered from a local database with consecutively registered patients that have been treated with a short-term MCS device. Supplementary clinical data was collected from electronic patient databases and patient charts.

Patients and data collection

Between 2004 and 2019, 371 occasions of VA-ECMO were provided at Sahlgrenska University Hospital in Gothenburg, of which 177 non-surgical adult patients received VA-ECMO for refractory CS and were included in the study (Figure 1). The patients were consecutively registered, and all included patients were entered into the statistical analysis, also those who died during an ECMO cannulation attempt. The underlying diagnosis of all patients were then grouped into: (i) ischemic heart disease (IHD), presenting with acute myocardial infarction, (ii) non-ischemic heart failure (NIHF, including cardiomyopathy, myocarditis and valvular diseases) and (iii) miscellaneous (MISC, including pulmonary emboli, infectious diseases, pulmonary hypertension and intoxication) (Supplementary Table 1). In some cases, the diagnosis was uncertain at the start of ECMO but was later established and registered in the patient charts. The events registered refers to the actual event leading to ECMO decision. The following pre-ECMO interventions were registered: dialysis, intubation, treatment with vasopressors and/or inotropes, percutaneous coronary intervention (PCI) and insertion of an intra-aortic balloon pump (IABP). Cardiopulmonary resuscitation (CPR) prior to ECMO was defined as CPR in the 24 h preceding ECMO. ECPR was defined as ECMO start with simultaneous CPR (without recovery of spontaneous circulation). SOFA score [18] and SAVE score [10] were calculated retrospectively. Weaning was defined as successful when the patient had survived for at least 48 h and without the need for a new unplanned MCS device. Patients could also be bridged to recovery by another MCS device, cardiac surgery, or an organ transplantation procedure.

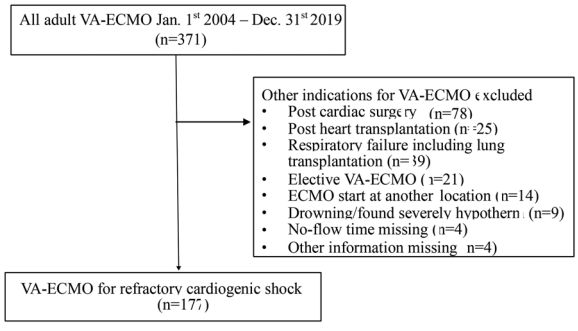

Figure 1. Patient selection.

Blood gas analysis on day 0 were the last available results preceding ECMO-start. The following complications were registered: problems with cannulation; continuous renal replacement therapy (CRRT) on ECMO; stroke (radiographically verified ischemic or hemorrhagic stroke) on ECMO; leg ischemia requiring an operation; and bleeding requiring an operation. Infectious related complications were not included as they were deemed too unreliably documented for retrospective analysis. Cerebral performance category (CPC) scores were registered according to patient status at discharge, with CPC score of 1 and 2 considered good neurological outcome [19].

Extra corporeal membrane oxygenation system

Different pump systems were used over the study period, but until end of 2011 the Rotaflow system (Maquet, Rastatt, Germany) was most used, with a few exceptions using the Medtronic Bio-Medicus Centrifugal Pump (Medtronic, Minneapolis, MN) or the Levitronix CentriMag (Levitronix LLC, Waltham, MA). From the year 2012, the Cardiohelp (Maquet, Rastatt, Germany) system was and is still used almost exclusively.

Decision and cannulation

VA-ECMO support was initiated as a rescue therapy, when all other treatment modalities had been either considered or applied and subsequently failed. Therefore, all patients included would be categorized as SCAI stage D or E. The decision for initiation of ECMO was generally made jointly by a cardiothoracic surgeon and a cardiothoracic intensivist/anesthetist, taking into account patient age, comorbidities and, if ECPR, duration of low-flow. As anticipated, selection of patients changed throughout the study period, especially with regards to ECPR. Before cannulation, which could be performed in an operation theatre, in the catheterization laboratory or occasionally in the hospital wards, 5000–10,000 units of heparin were administered intravenously. While on ECMO heparin anticoagulation was continued, the dosages based on patient status and activated partial thromboplastin time (APTT), with a main APTT target range of 50–60. Most patients had peripheral veno-arterial cannulation, and the correct positioning of the catheters was confirmed by radiography or ultrasound. Further details on the ECMO cannulation can be seen in Supplementary Table 2.

Weaning procedure

Patients were evaluated daily for the possibility of weaning from the circulatory support. If the patient's hemodynamic condition improved and transesophageal echocardiography (TEE) revealed good recovery of heart contractility, weaning was attempted. A left ventricular velocity time integral (VTI) of ≥10–12 cm, coupled with hemodynamic stability at an ECMO flow rate of 0.5–1.5 L per minute, was typically considered the threshold for weaning.

Statistical analysis

Statistical analysis was performed in R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria (R 4.2.2.) with RStudio (version 2022.12.0 + 353)). The continuous variables were reported as median with interquartile range. The different etiology groups were compared using Pearson's Chi-squared test and Kruskal–Wallis rank sum test or Fisher's exact test. Univariable and multivariable logistic regression models were used to determine predictors of mortality at 1 year. For purpose of the logistic regression model missing values for lactate (n = 17), pH (n = 11), SOFA score (n = 20) and SAVE score (n = 13) were imputed by classification and regression trees, using the mice package in R. The linearity of the logits of the continuous variables was assessed with the Box–Tidwell test as well as visually by scatter plots. Variables were selected into the multivariable model with regards to the research question, univariable analysis and previous research, while avoiding related variables in the model. One year survival was analyzed using Kaplan–Meier's estimates and groups compared with log-rank test and a pairwise comparison using the log-rank test. A p value of <.05 was considered as statistically significant.

Results

Patient characteristics

Forty-nine patients (28%) received VA-ECMO because of NIHF; 83 patients (47%) because of IHD and 45 patients (25%) for other/miscellaneous diagnoses (Misc) (Table 1). The groups differed significantly in many aspects, notably markers of disease severity were different between the groups as the NIHF group had a lower SOFA score pre-ECMO and fewer patients that suffered CA. The NIHF

Table 1. Patient characteristics.

Characteristic	Overall, n = 177[a]	NIHF, n = 49[a]	IHD, n = 83[a]	Miscellaneous, n = 45[a]	p Value
Male gender	126 (71%)	30 (61%)	69 (83%)	27 (60%)	<.01
Age, median (IQR)	51 (39–60)	36 (27–53)	59 (51–66)	48 (38–53)	<.01
Range	18, 82	18, 65	29, 77	20, 82	
BMI, median (IQR)	26 (23–29)	24 (22–27)	26 (24–30)	26 (23–29)	.03
Range	16.3, 43.0	17.3, 40.4	16.3, 43.0	18.5, 41.6	
Hypertension	57 (32%)	8 (16%)	39 (47%)	10 (22%)	<.01
Chronic kidney disease	7 (4.0%)	3 (6.1%)	2 (2.4%)	2 (4.4%)	.5
Diabetes mellitus	23 (13%)	2 (4.1%)	18 (22%)	3 (6.7%)	<.01
Ischemic heart disease	38 (21%)	2 (4.1%)	35 (42%)	1 (2.2%)	<.01
Atrial fibrillation	18 (10%)	9 (18%)	6 (7.2%)	3 (6.7%)	.12
Event					<.01
Arrhythmia	66 (37%)	18 (37%)	36 (43%)	12 (27%)	
LV failure	23 (13%)	5 (10%)	17 (20%)	1 (2.2%)	
RV failure	21 (12%)	3 (6.1%)	4 (4.8%)	14 (31%)	
BV failure	25 (14%)	20 (41%)	4 (4.8%)	1 (2.2%)	
PEA	21 (12%)	1 (2.0%)	14 (17%)	6 (13%)	
Asystole	21 (12%)	2 (4.1%)	8 (9.6%)	11 (24%)	
CPR					.01
No	46 (26%)	22 (45%)	17 (20%)	7 (16%)	
In-hospital	76 (43%)	16 (33%)	41 (49%)	19 (42%)	
Out-of-hospital	55 (31%)	11 (22%)	25 (30%)	19 (42%)	
ECPR	107 (60%)	22 (45%)	54 (65%)	31 (69%)	.03
PCI prior to ECMO	48 (27%)	3 (6.4%)	44 (53%)	1 (2.2%)	<.01
Transport prior to ECMO	21 (12%)	9 (18%)	9 (11%)	3 (6.7%)	.2
Dialysis prior to ECMO	13 (7.4%)	6 (13%)	2 (2.4%)	5 (11%)	.048
Intubated (h), median (IQR)	1 (1–2)	1 (1–2)	1 (1–1)	1 (1–2)	.5
Range	0, 432	0, 240	0, 30	0, 432	
SOFA score, median (IQR)	12.0 (9–13)	11.0 (9–12)	12.0 (10–13)	13.0 (11–14)	<.01
Range	3.0, 21.0	4.0, 17.0	3.0, 15.0	5.0, 21.0	
Platelet count, median (IQR)	199 (135–265)	181 (125–268)	218 (158–269)	139 (106–242)	.02
Range	7, 911	33, 390	7, 911	19, 383	
Creatinine (µmol/L), median (IQR)	118 (94–153)	131 (94–165)	116 (95–137)	115 (94–167)	.5
Range	42, 526	42, 526	57, 419	55, 301	
Bilirubin (µmol/L), median (IQR)	11 (7–23)	17 (9–28)	9 (7–13)	14 (7–38)	.010
Range	1, 140	1, 87	2, 110	3, 140	
pH, median (IQR)	7.14 (7–7.32)	7.26 (7.1–7.36)	7.13 (7–7.3)	7.12 (6.95–7.26)	.09
Range	6.56, 7.55	6.64, 7.55	6.56, 7.52	6.62, 7.52	
HCO_3 (mmol/L)					.076
4.8–14.9	48 (42%)	7 (25%)	29 (51%)	12 (41%)	
15–35	66 (58%)	21 (75%)	28 (49%)	17 (59%)	
Lactate (mmol/L), median (IQR)	9.6 (4.8–13.4)	7.4 (4–11.5)	9.6 (4.6–13.6)	10.9 (7.7–15.0)	.04
Range	0.8, 25.0	1.0, 21.6	0.8, 23.5	1.0, 25.0	
Year period					.14
2004–2010	25 (14%)	11 (22%)	10 (12%)	4 (9%)	
2010–2015	52 (29%)	17 (35%)	24 (29%)	11 (24%)	
2015–2020	100 (56%)	21 (43%)	49 (59%)	30 (67%)	

AMI: acute myocardial infarction; BV: biventricular; CPR: cardiopulmonary resuscitation; ECPR: extracorporeal CPR; IHD: ischemic heart disease; LV: left ventricle; NIHF: non-ischemic heart failure; PEA: pulseless electric activity; RV: right ventricle; SOFA: sequential organ failure assessment.
[a]n (%).

group also had more patients on ECMO primarily because of biventricular failure (Table 1). The incidence of each etiology group (NIHF, IHD or Misc) did not differ significantly in the different time periods of the study, although there were more patients with a low pH, low serum bicarbonate, a higher SOFA score and a higher incidence of ECPR during the last years of the study (Supplementary Table 3).

ECMO weaning and early outcome

Mean time on ECMO was 3.9 days (SD 3.9); ranging from 0 to 27 days and with a longer ECMO run for patients with NIHF (p value <.01) compared to the other two etiology groups. Sixty-four patients (36%) received IABP, more commonly in the IHD group (p value <.001) and where 12 of them (6.8%) had started the IABP treatment prior to ECMO start. Altogether 70 patients (40%) were weaned off ECMO without the need for an unplanned MCS within 48 h, while 38 patients (21%) were bridged through various mechanical support and/or surgical strategies, which was more common in the NIHF group (Table 2 and Figure 2). Finally, 69 patients (39%) could neither be weaned off ECMO nor bridged, and subsequently died after a duration of VA-ECMO of a mean of 1.9 days (range 0–11 days). The mean length of stay was 25 days after ECMO start; with 77 patients surviving to discharge.

A good neurological outcome (CPC score 1–2) was observed for 67 patients, or 87% of the patients discharged alive. Ten patients had a CPC score of 3 or 4 when they were discharged to another hospital.

Major complications of ECMO treatment are shown in Table 2 with the only difference between etiology groups being bleeding requiring an operation, which was more common in the NIHF group.

Late outcome after weaning and survival

One year survival was 40% for the whole cohort. When stratified for patients with NIHF, IHD and miscellaneous, the 1-year survival was 57%, 36% and 27%, respectively (p < .01, Table 2) (Figure 3). Furthermore, survival at 1 year was significantly inferior for those undergoing ECPR (24% vs. 64%, p < .01) (Figure 4). Additionally, there was no significant difference in survival relative to different time periods of the study (Suppl. Table 2). At one year post ECMO,

Table 2. Early and late outcome.

Characteristic	Overall, n = 177[a]	NIHF, n = 49[a]	IHD, n = 83[a]	Miscellaneous, n = 45[a]	p Value
IABP					<.01
No	112 (64%)	37 (77%)	32 (39%)	43 (96%)	
Pre-ECMO	12 (6.8%)	0 (0%)	12 (14%)	0 (0%)	
Per/post-ECMO	52 (30%)	11 (23%)	39 (47%)	2 (4.4%)	
Distal limb perfusion catheter	110 (72%)	28 (70%)	58 (82%)	24 (57%)	.02
Days on ECMO, mean (SD)	3.9 (3.9)	6.0 (5.1)	3.5 (2.8)	2.2 (3.1)	<.01
Range	0.0, 27.0	0.0, 27.0	0.0, 13.0	0.0, 15.0	
Successful weaning					
No	69 (39%)	11 (22%)	32 (39%)	26 (58%)	
Yes	70 (40%)	17 (35%)	37 (45%)	16 (36%)	
To VV-ECMO	4 (2.3%)	3 (6.1%)	0 (0%)	1 (2.2%)	
To organ transplant	6 (3.4%)	3 (6.1%)	1 (1.2%)	2 (4.4%)	
To long-term MCS	24 (14%)	14 (29%)	10 (12%)	0 (0%)	
To surgery	4 (2.3%)	1 (2.0%)	3 (3.6%)	0 (0%)	
Problems w/cannulation	16 (9%)	5 (10%)	6 (7.2%)	5 (11%)	.7
Lactate day 1, mean (SD)	2.60 (1.73)	2.87 (1.96)	2.44 (1.26)	2.59 (2.38)	.6
Range	0.70, 12.40	0.80, 8.50	0.90, 6.20	0.70, 12.40	
Lactate day 2, mean (SD)	2.27 (2.69)	2.46 (1.79)	1.95 (1.37)	2.88 (5.51)	.15
Range	0.40, 27.80	0.80, 9.10	0.60, 10.50	0.40, 27.80	
CRRT on ECMO	65 (37%)	25 (51%)	25 (30%)	15 (34%)	.05
Stroke on ECMO	24 (14%)	5 (10%)	15 (18%)	4 (8.9%)	.3
Leg ischemia w/operation	12 (6.8%)	5 (10%)	6 (7.2%)	1 (2.2%)	.3
Bleeding w/reoperation	33 (19%)	13 (27%)	17 (20%)	3 (6.7%)	.04
Discharge status					.01
Dead	100 (56%)	18 (37%)	51 (61%)	31 (69%)	
Assisted living	1 (0.6%)	0 (0%)	0 (0%)	1 (2.2%)	
Home	47 (27%)	18 (37%)	21 (25%)	8 (18%)	
Other hospital	29 (16%)	13 (27%)	11 (13%)	5 (11%)	
CPC score if discharged alive					.8
1–2	67 (87%)	26 (84%)	28 (88%)	13 (93%)	
3–4	10 (13%)	5 (16%)	4 (13%)	1 (7%)	
Outcome at 1 year					
Native cardiac recovery	51 (29%)	14 (29%)	25 (30%)	12 (27%)	
Cardiac transplantation	18 (10%)	14 (29%)	4 (4.8%)	0 (0%)	
Long-term MCS	1 (0.6%)	0 (0%)	1 (1.2%)	0 (0%)	
Cardiac death	38 (21%)	6 (12%)	20 (24%)	12 (27%)	
CNS death	41 (23%)	9 (18%)	19 (23%)	13 (29%)	
Other death	28 (16%)	6 (12%)	14 (17%)	8 (18%)	
1 year survival	70 (40%)	28 (57%)	30 (36%)	12 (27%)	<.01

CPC: cerebral performance category; CRRT: continuous renal replacement therapy; IABP: intra-aortic balloon pump; ICU: intensive care unit; IHD: ischemic heart disease; MCS: mechanical circulatory support; NIHF: non-ischemic heart failure; VV-ECMO: venovenous-ECMO.
[a]n (%).

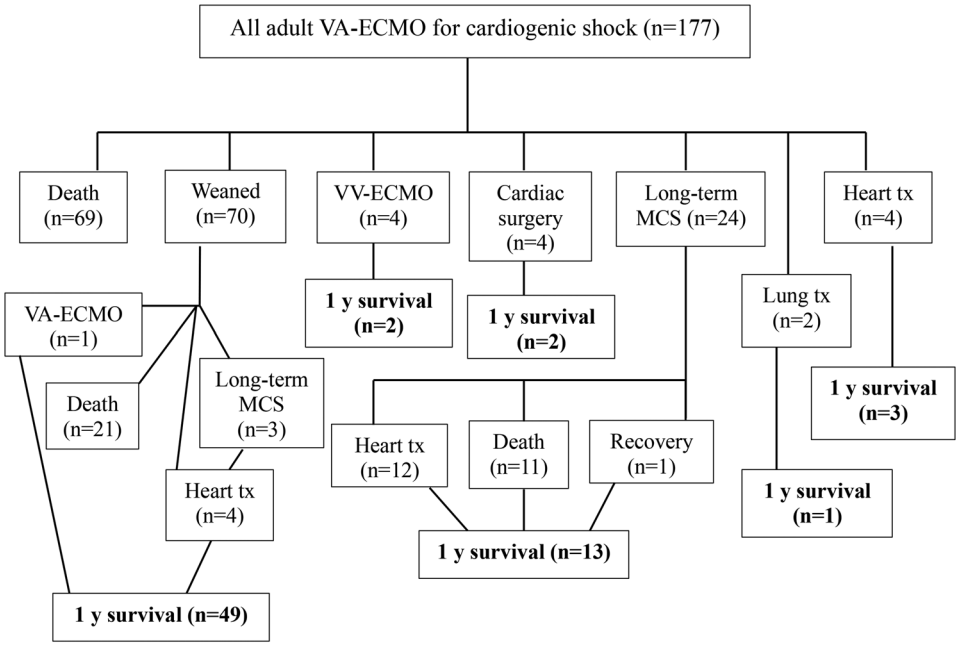

Figure 2. Weaning and 1 year survival. MCS: mechanical circulatory support; VA-ECMO: venoarterial-ECMO; VV-ECMO: venovenous-ECMO; Tx: transplantation; y: year.

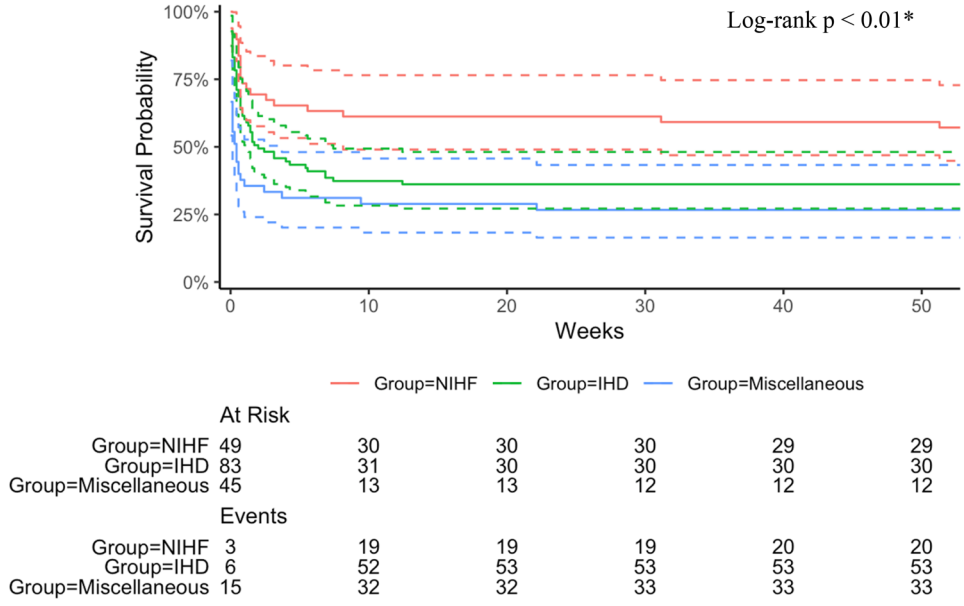

Figure 3. Survival curves according to KM survival analyses stratified for etiology with a 95% CI. CI: confidence interval; IHD: ischemic heart disease; NIHF: non-ischemic heart failure. *Pairwise comparison revealed a significant difference between all groups ($p < .05$).

18 (10%) of the patients had undergone cardiac transplantation; majority ($n = 14$) of them belonging to the NIHF group.

Predictors of 1-year mortality

Table 3 shows the univariable logistic regression analysis of the variables that were associated with 1 year mortality, namely underlying etiology groups, previous hypertension, the event leading to ECMO start, occurrence of CA, with out-of-hospital CA associated with a greater mortality risk (OR 4.59 (CI 1.99–11.1), $p < .01$), SOFA and SAVE scores and pH and lactate levels. Biventricular failure was however associated with a better prognosis (OR 0.21 (CI 0.07–0.55)). In multivariable analysis, only ECPR was independently associated with a higher 1-year mortality (OR 3.67, CI 1.66–8.31, $p < .01$) (Table 3).

Discussion

This retrospective study of patients that received VA-ECMO for CS at our center shows an acceptable 1-year survival of 40%, which is in line with other studies [20,21]. Most of the survivors had recovered without further support at 1 year, with 18 patients surviving after a cardiac transplantation

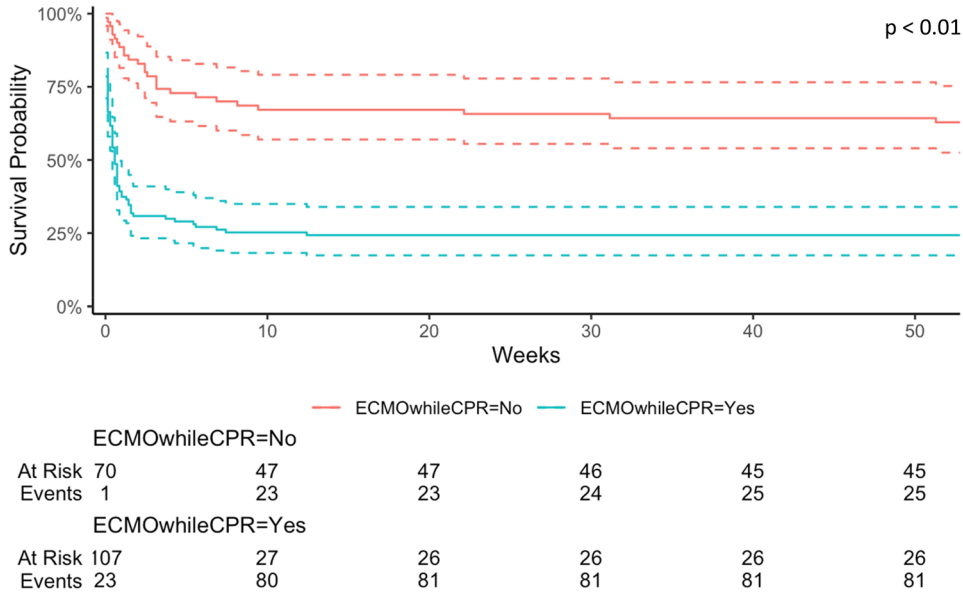

Figure 4. Survival curves according to KM survival analyses stratified for ECPR with a 95% CI. CI: confidence interval; CPR: cardiopulmonary resuscitation; ECMO: extracorporeal membrane oxygenation; ECPR: extracorporeal CPR.

Table 3. Logistic regression analyses.

		Univariable			Multivariable		
Characteristic	*N*	OR[a]	95% CI[a]	*p* Value	OR[a]	95% CI[a]	*p* Value
Group	177			.007			
NIHF		–	–		–	–	
IHD		2.36	1.15, 4.90	.020	1.46	0.62, 3.45	.4
Miscellaneous		3.67	1.57, 8.99	.003	2.59	1.01, 6.89	.051
Sex	177			.10			
Male		–	–		–	–	
Female		0.58	0.30, 1.12	.10	0.76	0.35, 1.64	.5
Age (years)	177			.5			
18–59		–	–		–	–	
60–82		1.27	0.64, 2.57	.5	1.35	0.59, 3.16	.5
BMI	177	1.06	0.99, 1.13	.090	1.06	0.99, 1.14	.11
Hypertension	177	2.10	1.08, 4.23	.033			
PCI prior to ECMO	175	0.88	0.45, 1.74	.7			
Dialysis prior to ECMO	176	1.03	0.33, 3.55	>.9			
Intubated (h)	176	1.00	0.99, 1.01	.7			
Number of vasopressors	177	0.69	0.47, 1.02	.061			
Event	177			.001			
Arrhythmia		–	–				
LVF		0.49	0.18, 1.28	.15			
RVF		0.87	0.32, 2.48	.8			
BVF		0.21	0.07, 0.55	.002			
PEA		3.21	0.96, 14.7	.084			
Asystole		1.34	0.47, 4.17	.6			
CPR	177			.001			
No		–	–				
In-hospital		2.18	1.04, 4.65	.041			
Out-of-hospital		4.59	1.99, 11.1	<.001			
ECPR	177	5.27	2.77, 10.3	<.001	3.67	1.66, 8.31	<.01
SOFA score	177	1.25	1.12, 1.41	<.001			
SAVE score	177	0.91	0.86, 0.97	.002			
pH	177	0.07	0.01, 0.27	<.001			
Lactate	177	1.12	1.06, 1.19	<.001	1.05	0.97, 1.13	.2
Year period	177			.061			
2004–2010		–	–				
2010–2015		1.17	0.45, 3.07	.7			
2015–2020		2.30	0.94, 5.68	.066			

BMI=Body mass index, BVF: biventricular failure; CPR: cardiopulmonary resuscitation; ECPR: extracorporeal CPR; ICM: ischemic cardiomyopathy; IHD: ischemic heart disease; LVF: left ventricular failure; NIHF: non-ischemic heart failure; PEA: pulseless electric activity; RV: right ventricular failure; SOFA: sequential organ failure assessment.

[a]OR: odds ratio; CI: confidence interval.

and one patient still needing a long-term ventricular assist device. Furthermore, a significantly reduced mortality was noticed for patients receiving VA-ECMO for NIHF, followed by IHD, but the highest mortality was observed for patients with other causes for refractory CS (e.g. miscellaneous). This might be attributed to the degree of CS in the three different groups, as both SOFA score, lactate levels and the rate of CA were higher for patients in the miscellaneous groups and were associated with mortality according to our univariable analysis. That, while some of the previously reported factors associated with mortality, such as age and BMI [10,12], were not associated with outcome in our study.

However, the multivariable logistic regression analysis showed that ECPR, rather than the underlying etiology, was associated with increased mortality. This scenario was indeed less common in the NIHF group, although still occurring in almost half (45%) of those patients. It inevitably leads to the question of optimal timing of VA-ECMO for CS, as it would be preferable to avoid the progression of hypoperfusion leading to organ failure and/or CA (6). Previous research, mostly retrospective in nature, has suggested that early initiation of ECMO in the setting of AMI might improve survival [22]. This has nevertheless not been confirmed in randomized trials, perhaps related to the intrinsic risk by the VA-ECMO itself. The ECMO-CS clinical trial did not show improved clinical outcomes of immediate implementation of VA-ECMO compared with an early conservative strategy that permitted downstream use of VA-ECMO [23]. In that study, 39% of the early conservative group required downstream VA-ECMO support, although the primary composite endpoint of death from any cause, implantation of another MCS and/or resuscitated CA did not differ statistically between groups. Furthermore, the patients included suffered from a degree of cardiac shock best corresponding to SCAI stages D and E, and while retrospective research has shown higher mortality with increased inotropic support, the immediate implementation might have been too late for survival benefits [22]. Similarly, in the ECLS-SHOCK trial that included patients with CS of SCAI stages C, D and E following AMI, and with 78% of patients undergoing CPR before randomization, there was no reduction in mortality for patients receiving ECLS compared to medical treatment alone [24]. ECPR was however not mentioned in the ECLS-SHOCK trial. As the correlation of ECPR to mortality in our study was so strong, with only 24% of the patients that underwent ECPR alive at one year, it seems that a better timeframe for ECMO initiation might be identified to mitigate the progression of the CS to cardiac arrest, resulting in a restrictive use in well selected patients.

Nonetheless, complications of VA-ECMO are not negligible, including stroke, renal replacement therapy and leg ischemia (Table 2). Bleeding requiring an invasive procedure was more common in the NIHF group, which might be due to longer ECMO runs in that group. These results are comparable to a recent meta-analysis [21], even though direct comparison is difficult as heterogeneity between the different studies included regarding definitions and reporting is large.

At last, the importance of unloading the left ventricle has gained more traction recently, as the peripheral VA-ECMO can increase the afterload on the already struggling LV, risking a variety of complications [25,26]. While the pathophysiology deems LV unloading feasible it does add the risk of another MCS device. In our cohort, six patients received LV venting and 64 patients (36%) received IABP for unloading the LV, which is a considerably higher proportion than in two recent randomized trials [23,24].

Limitations

This is a retrospective cohort study with the limitations that entails such a study, e.g. missing data and selection bias. Furthermore, we did not have information on patients where ECMO was considered but deemed inappropriate, and these patients were therefore excluded. As such, we have only described the association between our variables and the outcomes but importantly not determine causation. Additionally, our research period includes evolving technique and patient selection globally with ECPR on the rise. That was even evident in our material, although with the relatively few patients in the early years, we did not find any difference in survival between time periods in our study (Suppl. Table 2). With these limitations in mind, we do however believe our study of 177 consecutive patients adds knowledge to this resource demanding treatment where randomized research remains limited and extremely complex.

Conclusions

In this retrospective study of 177 patients receiving VA-ECMO for CS at our center, we found an acceptable survival rate of 40% at one-year, with a more favorable outcome for patients with NIHF compared to other diagnosis of cardiogenic shock. The negative association of ECPR with a higher 1-year mortality suggests the importance of patient selection as well as timing of the VA-ECMO before deterioration to cardiac arrest.

Disclosure statement

GD has the following disclosures: receiving grants from the Swedish state under the agreement between the Swedish Government and the county councils, the ALF-agreement; receiving an institutional research grant from Astellas A/S for an investigator initiated ScanCLAD study (ClinicalTrials.gov identifier NCT02936505); institutional research grant from Abbott regarding a destination therapy study on LVAD (the SweVAD study, ClinicalTrials.gov identifier NCT02592499); Institutional research grant for industry-initiated study on organ preservation (NIHP trial, ClinicalTrials.gov identifier NCT03991923). XVIVO, board member.

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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