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Systematic review

Predictors of survival in adult patients receiving VA-ECMO in the emergency setting: a systematic review

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Abstract

Background: Venoarterial extracorporeal membrane oxygenation is used in ER as support for adult patients with refractory cardiogenic shock and cardiac arrest. Survival differs because candidates age varieties, arrest profile, shock etiology, low-flow duration, metabolic injury, and early complications. This systematic review analyzed predictors of survival in adults receiving VA-ECMO or ECPR during emergency presentation. **Methods:** We conduct a systematic review according to PRISMA principles. PubMed, Scopus, Web of Science, and the Cochrane Library were searched for adult studies evaluating VA-ECMO or ECPR in ER (emergency department cannulation, refractory cardiac arrest, out-of-hospital cardiac arrest, in-hospital cardiac arrest, and acute cardiogenic shock requiring urgent circulatory support). We consider original studies reporting survival or neurological survival with clinical, biochemical, procedural, or scoring predictors. **Results:** Ten original studies were included in the final synthesis. The strongest predictors were younger age, witnessed arrest, shockable rhythm, shorter CPR or low-

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flow duration, lower lactate, higher pH or bicarbonate, preserved organ function, successful early revascularization in ischemic shock, and higher SAVE scores. Adverse predictors included older age, prolonged low-flow duration, asystole, severe acidosis, high lactate, renal injury, coagulopathy, major bleeding, vascular complications, and need for renal replacement therapy. Data in infarct-related cardiogenic shock found no survival advantage from routine early VA-ECMO in unselected patients. **Conclusion:** Survival after emergency VA-ECMO is determined by a cluster of pre-ECMO, intra-resuscitation, and early post-cannulation factors rather than a single variable. Candidate selection using age, arrest rhythm, low-flow time, lactate, pH, organ dysfunction, and validated scores offers a practical approach for emergency decision-making.

Keywords: VA-ECMO; ECPR; emergency department; cardiogenic shock; cardiac arrest.

Introduction

Venoarterial extracorporeal membrane oxygenation (VA-ECMO) in ER provides temporary circulatory and gas-exchange support for patients with refractory cardiac arrest, severe cardiogenic shock, and rapidly deteriorating perfusion. Its ER use differs from elective mechanical support because clinicians make decisions under severe time pressure, with incomplete history, limited laboratory data, and evolving neurological uncertainty (1). Adult emergency VA-ECMO includes extracorporeal cardiopulmonary resuscitation, in which extracorporeal flow is established during CPR for selected refractory arrests (2).

International ECPR guidance emphasizes rapid implementation, witnessed arrest, immediate high-quality CPR, reversible cause, and a system capable of cannulation and post-arrest care as core selection elements (2). Adult VA-ECMO guidance for cardiac patients indicate determinants of outcome which include (shock etiology, end-organ injury, vascular access, left ventricular distension, anticoagulation, limb ischemia, and weaning strategy) (3).

Comparative data found better short-term survival and favorable neurological outcome with extracorporeal life support during cardiac arrest, and benefit signals were strongest in selected patients treated in organized systems (4). Complication data is central to survival prediction because bleeding, limb ischemia, renal failure, stroke, and infection add mortality risk after cannulation (5). A meta-analysis of VA-ECMO in cardiogenic shock reported pooled in-hospital mortality of 62%, with older age, infection, and ECMO support duration associated with higher mortality (6).

Prediction research moved from single variables to integrated clinical scores because VA-ECMO candidates have overlapping cardiac, metabolic, neurological, and procedural risks (7). Prediction models are heterogeneous because studies differ in emergency department cannulation, ECPR inclusion, postcardiotomy exclusion, shock phenotype, and outcome timing. This systematic review aimed to identify survival predictors in adult patients receiving VA-ECMO in the ER.

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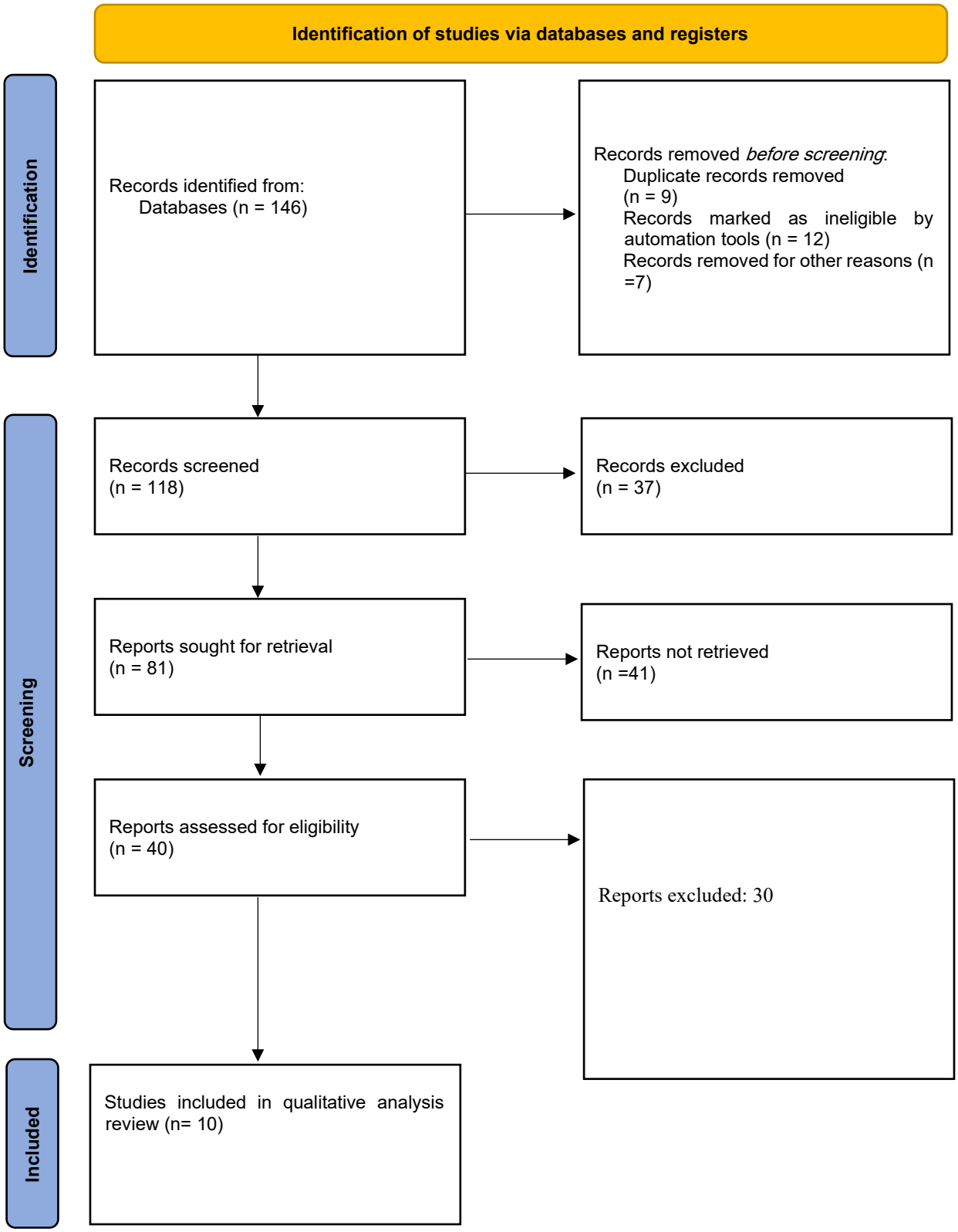
Methods

This study was conducted according to PRISMA principles. PubMed, Scopus, Web of Science, and the Cochrane Library were searched from database inception to 2026 (Fig 1). Search terms include controlled vocabulary and free-text terms related to "venoarterial extracorporeal membrane oxygenation," "VA-ECMO," "extracorporeal cardiopulmonary resuscitation," "ECPR," "emergency department," "cardiac arrest," "out-of-hospital cardiac arrest," "in-hospital cardiac arrest," "cardiogenic shock," "survival," "mortality," "predictors," and "risk score."

Eligible studies included adults aged 18 years or older receiving VA-ECMO or ECPR for emergency indications, including refractory cardiac arrest, out-of-hospital cardiac arrest, in-hospital cardiac arrest, acute myocardial infarction complicated by cardiogenic shock, and rapidly deteriorating cardiogenic shock. Original cohort studies, registry studies, propensity-matched studies, and randomized trials were eligible when they reported survival, discharge survival, 30-day survival, ICU survival, or favorable neurological survival. Reviews, guidelines, and meta-analyses were used for background and discussion only.

Studies were excluded when focused on pediatric patients, venovenous ECMO only, elective perioperative support, postcardiotomy-only cohorts, case reports, non-human research, conference abstracts without full data, or mixed ECMO cohorts without extractable VA-ECMO outcomes. Two-stage screening was planned using titles and abstracts first, followed by full-text review. Extracted data included author, year, country, design, setting, sample size, indication, outcome definition, survival rate, and reported predictors. A qualitative synthesis was used because the included studies differed in setting, population, predictor definition, and outcome timing.

Fig 1: PRISMA flow chart



Results

The included original studies consisted of ten studies covering refractory cardiogenic shock, emergency department VA-ECMO, ECPR, out-of-hospital cardiac arrest, and infarct-related cardiogenic shock (8-17) (Table 1&2). Survival prediction was consistent in-patient reserve before cannulation, arrest or shock severity before flow, and complications or failure of recovery after flow (8-17). The most reproducible favorable factors were younger age, shorter CPR duration, shockable rhythm, lower lactate, less acidosis, absence of renal failure, higher SAVE-related scores, and organized early reperfusion pathways (8-17).

Table 1. Characteristics of the included studies

Study	Design and setting	Population	Sample	Main outcome
Schmidt et al., 2015	International ELSO registry derivation and validation study	Adult refractory cardiogenic shock receiving VA-ECMO	3,846	Survival to hospital discharge
Muller et al., 2016	Multicenter cohort	AMI-related cardiogenic shock treated with VA-ECMO	138	ICU survival and longer-term outcome
Chen et al., 2016	Single-center ED cohort	Urgent VA-ECMO within 24 hours of ED arrival	154	90-day mortality
Lee et al., 2017	ED-based retrospective analysis of a prospective cohort	Sudden refractory cardiac arrest treated with ECPR	111	Survival to discharge
Stub et al., 2015	Prospective observational CHEER protocol study	Refractory IHCA and OHCA treated with ECPR bundle	26	Discharge survival with CPC 1
Yannopoulos et al., 2020	Phase 2 randomized trial	Refractory VF OHCA treated with ECMO-facilitated resuscitation	30	Survival to hospital discharge
Inoue et al., 2022	Multicenter SAVE-J II registry	Adult OHCA of presumed cardiac etiology treated with ECPR	1,644	Favorable neurological outcome and discharge survival
Ostadal et al., 2023	Randomized ECMO-CS trial	Severe or rapidly deteriorating cardiogenic shock	117	30-day composite outcome and mortality
Banning et al., 2023	Multicenter randomized trial	AMI-related cardiogenic shock after PCI	35	30-day all-cause mortality
Thiele et al., 2023	Multicenter randomized trial	AMI-related cardiogenic shock with planned revascularization	420	30-day all-cause mortality

According to SAVE score there is a 42% survival to hospital discharge in a large international refractory cardiogenic shock cohort and created a model using pre-ECMO variables (age, diagnosis, renal failure, organ failure, ventilation duration, cardiac arrest, pulse pressure, diastolic pressure, and bicarbonate) (8). Mortality predictors according to the ENCOURAGE study in AMI-related cardiogenic shock are, age over 60 years, female sex, body mass index over 25 kg/m², Glasgow Coma Scale below 6, creatinine over 150 µmol/L, lactate category, and prothrombin activity below 50% (9). The modified SAVE ER study found mortality of 64.9%, with lactate and SAVE score independently associated with outcome, and combined lactate plus SAVE score achieved an AUC of 0.843 (10).

The ED ECPR prediction study found 18.9% survival to discharge in 111 patients and identified survival predictors which include (age 56 years or less, CPR duration 55 minutes or less, first rhythm other than asystole, and any ROSC before ECPR) (11). The CHEER protocol reported 54% survival to discharge with full neurological recovery in a selected refractory arrest cohort treated with mechanical CPR, hypothermia, ECMO, and early reperfusion (12). The ARREST randomized trial showed discharge survival of 43% in the ECMO-facilitated group versus 7% in the standard ACLS group in selected refractory ventricular fibrillation OHCA patients (13).

The SAVE-J II registry showed 14.1% good neurological outcome and 27.2% survival to hospital discharge in 1,644 adult OHCA patients receiving ECPR (14). SAVE-J II showed outcome gradients by initial rhythm, with good neurological outcome of 16.7% for shockable rhythm, 9.2% for pulseless electrical activity, and 3.9% for asystole (14). The ECMO-CS, EURO SHOCK, and ECLS-SHOCK trials did not show a survival advantage for routine early VA-ECMO in broad cardiogenic shock trial populations, which supports selective use rather than unselected emergency deployment (15-17).

Table 2. Survival predictors identified in the included studies

Predictor domain	Positive predictors	Adverse predictors	Supporting studies
Demographic	Younger age; lower comorbidity burden	Older age; chronic renal disease; high comorbidity burden	Schmidt; Muller; Lee; Inoue (8,9,11,14)
Arrest profile	Witnessed arrest; shockable rhythm; any ROSC before ECPR	Asystole; unwitnessed arrest; no ROSC before ECPR	Lee; Yannopoulos; Inoue (11,13,14)
Time factors	Shorter CPR duration; shorter low-flow duration; rapid ECMO activation	CPR duration over 55–60 minutes; prolonged low-flow state	Lee; Stub; Inoue (11,12,14)
Metabolic injury	Lower lactate; higher bicarbonate; higher pH	High lactate; severe acidosis; low bicarbonate	Schmidt; Muller; Chen (8-10)
Organ dysfunction	Preserved renal, hepatic, and coagulation function	Creatinine elevation; coagulopathy; renal replacement therapy	Schmidt; Muller; Thiele (8,9,17)

Predictor domain	Positive predictors	Adverse predictors	Supporting studies
Scoring	Higher SAVE score; lower ENCOURAGE class; better modified SAVE class	Low SAVE score; high ENCOURAGE class; high lactate-adjusted risk	Schmidt; Muller; Chen (8-10)
Etiology and treatment pathway	Reversible cause; early coronary angiography or PCI when indicated	Nonreversible etiology; delayed reperfusion; severe neurological injury	Stub; Yannopoulos; Thiele (12,13,17)
Complications	Absence of major bleeding, limb ischemia, and stroke	Bleeding, vascular complications, infection, renal failure	Inoue; Thiele (14,17)

Discussion

This review found that ER VA-ECMO survival depends on a combined assessment of baseline reserve, resuscitation quality, metabolic injury, shock reversibility, and early complications (8-17). The consistency of age, low-flow duration, rhythm, lactate, pH, renal function, and validated scores in studies supports a multidomain selection strategy instead of reliance on a single cutoff (8-17). The data also separates ECPR in highly selected refractory ventricular fibrillation from routine early VA-ECMO in broad AMI-related cardiogenic shock (13,15-17).

Age is an adverse predictor in cardiogenic shock and ECPR cohorts (11,14). Age is a surrogate for physiological reserve, comorbidity burden, vascular access risk, frailty, and neurological vulnerability after low-flow states (8,14). Arrest rhythm and low-flow time were in the strongest ECPR-specific predictors (13,14). Shockable rhythm indicates a higher probability of primary cardiac etiology and reversible coronary pathology (13,14). Low-flow time represents cumulative ischemic injury, and studies showed worse outcomes when CPR duration approaches or exceeds 55 to 60 minutes before extracorporeal flow (11,14).

Lactate, pH, bicarbonate, creatinine, and coagulation markers were central biochemical predictors in shock and ED VA-ECMO cohorts (10). Lactate reflects tissue hypoperfusion, catecholamine exposure, hepatic clearance, and CPR duration, which explains its added value when combined with the SAVE score in the modified ED model (10). Creatinine and prothrombin activity in ENCOURAGE show that renal and coagulation injury before ECMO signal advanced shock severity rather than isolated pump failure (9).

Prediction scores translated multiple risk signals into practical bedside categories (8-10). SAVE is a validated adult VA-ECMO survival score for refractory cardiogenic shock, ENCOURAGE is tailored to AMI-related cardiogenic shock, and modified SAVE adds lactate for urgent ED VA-ECMO (8-10). ECMO-CS, EURO SHOCK, and ECLS-SHOCK did not confirm routine early VA-ECMO as a survival-improving strategy for all AMI-related cardiogenic shock patients (15-17). A meta-analysis of randomized trials also found no 30-day mortality reduction with routine early VA-ECMO in infarct-related cardiogenic shock and increased vascular complications (18). Bleeding, limb ischemia, stroke, infection, and renal replacement therapy reduce

the chance that restored circulation translates into survival with acceptable neurological function (5,14,17,18).

This review has limitations; the included studies mixed ED VA-ECMO, ECPR, OHCA, IHCA, and AMI-related cardiogenic shock, creating clinical heterogeneity. Most predictor data came from observational cohorts, while randomized trials tested treatment strategy. Meta-analysis was not performed because variables, timing, and outcomes differed between studies.

Conclusion

Adult survival after emergency VA-ECMO is most associated with younger age, shockable rhythm, witnessed arrest, shorter CPR or low-flow duration, lower lactate, less acidosis, preserved renal and coagulation function, reversible etiology, and absence of major complications. SAVE, ENCOURAGE, and modified SAVE scores provide structured prediction for different emergency VA-ECMO populations. Routine VA-ECMO for unselected infarct-related cardiogenic shock does not improve survival in randomized studies.

List of abbreviations

ACLS: Advanced cardiovascular life support
AMI: Acute myocardial infarction
AUC: Area under the receiver operating characteristic curve
CI: Confidence interval
CPC: Cerebral performance category
CPR: Cardiopulmonary resuscitation
ECPR: Extracorporeal cardiopulmonary resuscitation
ED: Emergency department
ECLS: Extracorporeal life support
ELSO: Extracorporeal Life Support Organization
IHCA: In-hospital cardiac arrest
ICU: Intensive care unit
OHCA: Out-of-hospital cardiac arrest
PCI: Percutaneous coronary intervention
ROSC: Return of spontaneous circulation
SAVE: Survival After Veno-Arterial ECMO
VA-ECMO: Venoarterial extracorporeal membrane oxygenation
VF: Ventricular fibrillation

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