*Salud, Ciencia y Tecnología*. 2025; 5:1955
doi: 10.56294/saludcyt20251955

SYSTEMATIC REVIEW

# Impact of Extracorporeal Membrane Oxygenation (ECMO) in Patients with Refractory Cardiogenic Shock: Analysis of Mortality and Hemodynamic Recovery. A Systematic Review

## Impacto de la Oxigenación por Membrana Extracorpórea (ECMO) en Pacientes con Shock Cardiogénico Refractario: Análisis de la Mortalidad y la Recuperación Hemodinámica. Una Revisión Sistemática

Melina Carlos Tovar[1], Mitchell Walter Carbajal Alvarado[2], Cesar Augusto Flores Dueñas[3], Natalia Quintero Serrano[4], Luisa Alejandra Penagos Ochoa[5], Jessica Samantha Rea Fernández[6], Javier Ignacio Soto Espinoza[7], Mishelle Estefania Garces Lopez[8]

[1]Instituto mexicano del seguro social, Internal Medicine. Torreón, México.
[2]Cefies Q, Medical Technology. Lima, Perú.
[3]Instituto de Investigaciones en Ciencias Veterinarias. Baja California, México.
[4]Fundación universitaria de Ciencias de la Salud FUCS, Toxicology Department. Bogotá, Colombia.
[5]Fundacion Universitaria Sanitas, Medical Department. Bogotá, Colombia.
[6]Universidad de Cuenca, Medical Department. Cuenca, Ecuador.
[7]Universidad San Sebastián, Medical Department. Santiago de Chile, Chile.
[8]EMI FALCK, Medical Department. Quito, Ecuador.

**Cite as:** Carlos Tovar M, Carbajal Alvarado MW, Flores Dueñas CA, Quintero Serrano N, Penagos Ochoa LA, Rea Fernández JS, et al. Impact of Extracorporeal Membrane Oxygenation (ECMO) in Patients with Refractory Cardiogenic Shock. Analysis of Mortality and Hemodynamic Recovery. A Systematic Review. Salud, Ciencia y Tecnología. 2025; 5:1955. https://doi.org/10.56294/saludcyt20251955

**Submitted:** 23-01-2025 **Revised:** 12-04-2025 **Accepted:** 08-08-2025 **Published:** 09-08-2025

**Editor:** Prof. Dr. William Castillo-González

**Corresponding Author:** Melina Carlos Tovar

## ABSTRACT

**Introduction:** extracorporeal membrane oxygenation (ECMO) is an advanced life support for critically ill patients with refractory cardiogenic shock. However, evidence on its impact on mortality, hemodynamic recovery, and complications remains heterogeneous.
**Objective:** this review aims to systematically evaluate ECMO's impact on mortality and hemodynamic recovery in adult patients with refractory cardiogenic shock, addressing gaps and variations in existing literature.
**Method:** this systematic review followed PRISMA guidelines. Databases searched were PubMed, Cochrane Library, and Google Scholar. Two reviewers independently selected studies, extracted data, and assessed quality using the Newcastle-Ottawa Scale. Findings were synthesized narratively due to study heterogeneity.
**Results:** mortality rates ranged widely from 33 to 75 %, reflecting differences in patient populations and timing of ECMO initiation. Early ECMO initiation within less than one hour of shock onset was associated with a 47 percent reduction in mortality risk. In-hospital mortality was approximately 40 %, increasing to nearly 60 % at one-year follow-up. Success rates for weaning patients off ECMO varied between 53 % and 88 %. Hemodynamic improvements following ECMO support included increased blood pressure, improved left ventricular ejection fraction, and decreased serum lactate levels. Complications were frequent and diverse, predominantly bleeding, stroke, renal failure, and limb ischemia. Bleeding complications are strongly correlated with mortality.
**Conclusions:** ECMO provides crucial circulatory support in refractory cardiogenic shock, improving hemodynamic parameters but with persistently high mortality and complication rates. Early initiation and careful patient selection are vital for optimizing outcomes, underscoring the need for multidisciplinary management and further high-quality prospective studies.

**Keywords:** Extracorporeal Membrane Oxygenation; Refractory Cardiogenic Shock; Mortality; Hemodynamic Recovery; Complications; Systematic Review.

**RESUMEN**

**Introducción:** la oxigenación por membrana extracorpórea (ECMO) es un soporte vital avanzado para pacientes críticos con shock cardiogénico refractario. Sin embargo, la evidencia sobre su impacto en la mortalidad, la recuperación hemodinámica y las complicaciones sigue siendo heterogénea.
**Objetivo:** esta revisión tiene como objetivo evaluar sistemáticamente el impacto de la ECMO en la mortalidad y la recuperación hemodinámica en pacientes adultos con shock cardiogénico refractario, abordando las lagunas y variaciones en la literatura existente.
**Método:** esta revisión sistemática siguió las directrices PRISMA, incluyendo estudios en pacientes adultos con shock cardiogénico refractario tratados con VA-ECMO. Las bases de datos consultadas fueron PubMed, Cochrane Library y Google Scholar. Dos revisores seleccionaron los estudios de forma independiente, extrajeron los datos y evaluaron la calidad mediante la escala de Newcastle-Ottawa. Los hallazgos se sintetizaron narrativamente debido a la heterogeneidad del estudio.
**Resultados:** las tasas de mortalidad oscilaron entre el 33,1 % y el 75 %, lo que refleja diferencias en las poblaciones de pacientes y el momento del inicio de la ECMO. El inicio temprano de la ECMO en menos de una hora desde el inicio del choque se asoció con una reducción del 47 % en el riesgo de mortalidad (cociente de riesgos instantáneos: 0,53) La mortalidad intrahospitalaria fue de aproximadamente el 40 %, aumentando a casi el 60 % al año de seguimiento. Las tasas de éxito para los pacientes que dejaron de recibir la OMEC variaron entre el 53 % y el 88 %. Las mejoras hemodinámicas después del soporte de ECMO incluyeron aumento de la presión arterial, mejora de la fracción de eyección del ventrículo izquierdo y disminución de los niveles séricos de lactato. Las complicaciones fueron frecuentes y diversas, predominando el sangrado, el accidente cerebrovascular, la insuficiencia renal y la isquemia de las extremidades. Las complicaciones hemorrágicas están fuertemente correlacionadas con la mortalidad.
**Conclusiones:** la ECMO proporciona un soporte circulatorio crucial en el shock cardiogénico refractario, mejorando los parámetros hemodinámicos pero con tasas de mortalidad y complicaciones persistentemente altas. El inicio temprano y la selección cuidadosa de los pacientes son vitales para optimizar los resultados, lo que subraya la necesidad de un tratamiento multidisciplinario y de estudios prospectivos adicionales de alta calidad.

**Palabras clave***:* Oxigenación por Membrana Extracorpórea; ECMO; Shock Cardiogénico Refractario; Mortalidad; Recuperación Hemodinámica; VA-ECMO; Complicaciones; Revisión Sistemática.

## INTRODUCTION

Refractory cardiogenic shock presents as persistent tissue hypoperfusion despite administration of adequate doses of two vasoactive medications and treatment of the underlying aetiology.[1] About 5,10 % of patients with acute MI experience cardiogenic shock, which is a significant cause of mortality in recent studies,[2] with up to 35-50 % of people not surviving.[3] Early revascularization can help, but cardiogenic shock is still linked to a high death rate in the acute phase.[4] Although this fixes the blockage in the artery, it might not give enough help to the endangered heart tissue. Maintaining stable circulation with sufficient oxygen-rich blood to the organs is a crucial management task. Doctors may boost cardiac output using medication, inotropes, and vasopressors, yet because of the chances of increased myocardial oxygen use and blood vessel contraction, they must carefully limit these treatments.[5] Advanced systems for mechanical support of the heart have been built to help with issues of hemodynamic instability in patients with cardiogenic shock. Most healthcare providers rely on the intra-aortic balloon pump more than on any other assist device. In patients with acute coronary syndrome and severe or refractory cardiogenic shock, IABP has a class IIb position in European guidelines. However, it should not be given routinely to patients with cardiogenic shock who have had an ACS without mechanical complications.[6,7]

Until 2021, the use of ECMO across more than 543 centers reportedly exceeded 170 000 cases. There were gradually more ECMO support cases over the last 10 years, especially after the coronavirus disease 2019 (COVID-19) outbreak. Among adult ECMO patients, the survival rate until discharge or transfer was 49 %, and it stood at 58 % for respiratory failure and 45 % for heart failure.[8] Nevertheless, the data included come only from the ELSO registered centers, so data from other centers are not considered, and there may be a risk of bias. The overall benefits, any negative side effects, and the rate of deaths in these situations are yet to be fully established. Severe cardiogenic shock continues to be linked with a high risk of death.[9,10] While numerous

studies with more patients are starting to discuss adverse events connected to ECMO, the statistics are still not very consistent, which is partly due to the small patient groups in most studies.[11] Several studies have focused on how well ECMO helps, but because of certain issues in their designs, opinions about its use are still divided[12,13] Previous meta-analyses, including the systematic review by Rajsic et al.[14], reported a pooled in-hospital mortality rate of approximately 62 % in patients receiving ECMO support for cardiogenic shock, identifying advanced age (>60 years), shorter ECMO duration, and infection as key predictors of mortality. However, these analyses primarily included patients with cardiogenic shock of varying severity and did not specifically focus on refractory cardiogenic shock, a subgroup characterized by persistent haemodynamic instability despite conventional therapies. This distinction is critical, as refractory cardiogenic shock represents a population with more severe circulatory compromise and potentially different response profiles to ECMO support. Therefore, there is a pressing need for an updated systematic review concentrating specifically on ECMO use in refractory cardiogenic shock to better understand its efficacy, associated complications, and impact on mortality in this particularly high-risk cohort. This study aims to systematically evaluate ECMO's impact on mortality and hemodynamic recovery in refractory cardiogenic shock, addressing gaps in current evidence and variations in reported clinical outcomes.

## METHOD

### Study Design and Registration

We conducted a systematic review by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to assess the impact of extracorporeal membrane oxygenation (ECMO) on mortality and hemodynamic recovery in patients with refractory cardiogenic shock. The primary objective was to evaluate mortality rates associated with ECMO support in patients experiencing refractory cardiogenic shock. Secondary objectives included analysis of hemodynamic recovery parameters and reported ECMO-related complications.

### Eligibility Criteria

Studies were eligible for inclusion if they met the following criteria:

- Population: adults (≥18 years) with refractory cardiogenic shock unresponsive to ≥2 vasoactive agents.
- Intervention: extracorporeal membrane oxygenation (ECMO), primarily venoarterial ECMO (VA-ECMO)
- Comparison: implicit comparisons such as early vs late ECMO initiation or conventional management.
- Outcome: mortality, hemodynamic recovery, ECMO weaning success, and complications (e.g., bleeding, stroke)
- Included a minimum sample size of 10 patients to ensure sufficient statistical power.
- Published in English in peer-reviewed journals.

### Exclusion criteria

- Pediatric populations (<18 years).
- Studies focusing exclusively on ECMO as a bridge to transplantation or durable mechanical circulatory support devices.
- Case reports, small case series (<50 patients), conference abstracts without full data, and non-English publications.
- Studies overlap data with other included cohorts to avoid duplication.

### Search Strategy

A comprehensive literature search was performed in Medline (PubMed), Embase, and Scopus databases from inception to (insert last search date, e.g., May 1, 2025). The search combined keywords and MeSH terms related to ECMO, cardiogenic shock, mortality, hemodynamic recovery, and complications. Example search terms included "extracorporeal membrane oxygenation," "ECMO," "venoarterial ECMO," "cardiogenic shock," "mortality," "hemodynamics," and "complications." Boolean operators such as "AND" and "OR" were used to optimize the search. Additionally, the reference lists of included articles and relevant reviews were screened manually for further eligible studies. Grey literature and clinical trial registries were also consulted. Authors were contacted where full texts or clarifications were required.

### Study Selection

Two independent reviewers screened titles and abstracts for eligibility. Full texts of potentially relevant articles were retrieved and reviewed against the inclusion criteria. Discrepancies were resolved through discussion or consultation with a third reviewer.

**Data Extraction**

Relevant data were independently extracted by two reviewers using a standardized data collection form. Extracted information included study design, sample size, patient demographics (age, sex), ECMO type and duration, mortality outcomes, hemodynamic parameters (e.g., blood pressure, cardiac output, left ventricular ejection fraction), and reported complications. Where necessary, data were converted or calculated for consistency (e.g., converting percentages to absolute numbers or vice versa, standardizing ECMO duration to days). Any disagreements were resolved by consensus.

**Quality Assessment**

The methodological quality of included cohort studies was assessed independently by two reviewers using the Newcastle–Ottawa Scale (NOS) for observational studies. A randomized controlled trial is assessed using RoB 2.0. Any conflicts in quality scoring were resolved through consensus.

**Data Synthesis**

Due to significant heterogeneity in study designs, patient populations, intervention protocols, and outcome definitions, a qualitative narrative synthesis was conducted. Key findings related to mortality outcomes, hemodynamic recovery, and ECMO-related complications were extracted and summarized descriptively. Results were presented in tabular format to facilitate comparison across studies, highlighting similarities and differences in clinical outcomes, patient characteristics, and treatment approaches.

## RESULTS

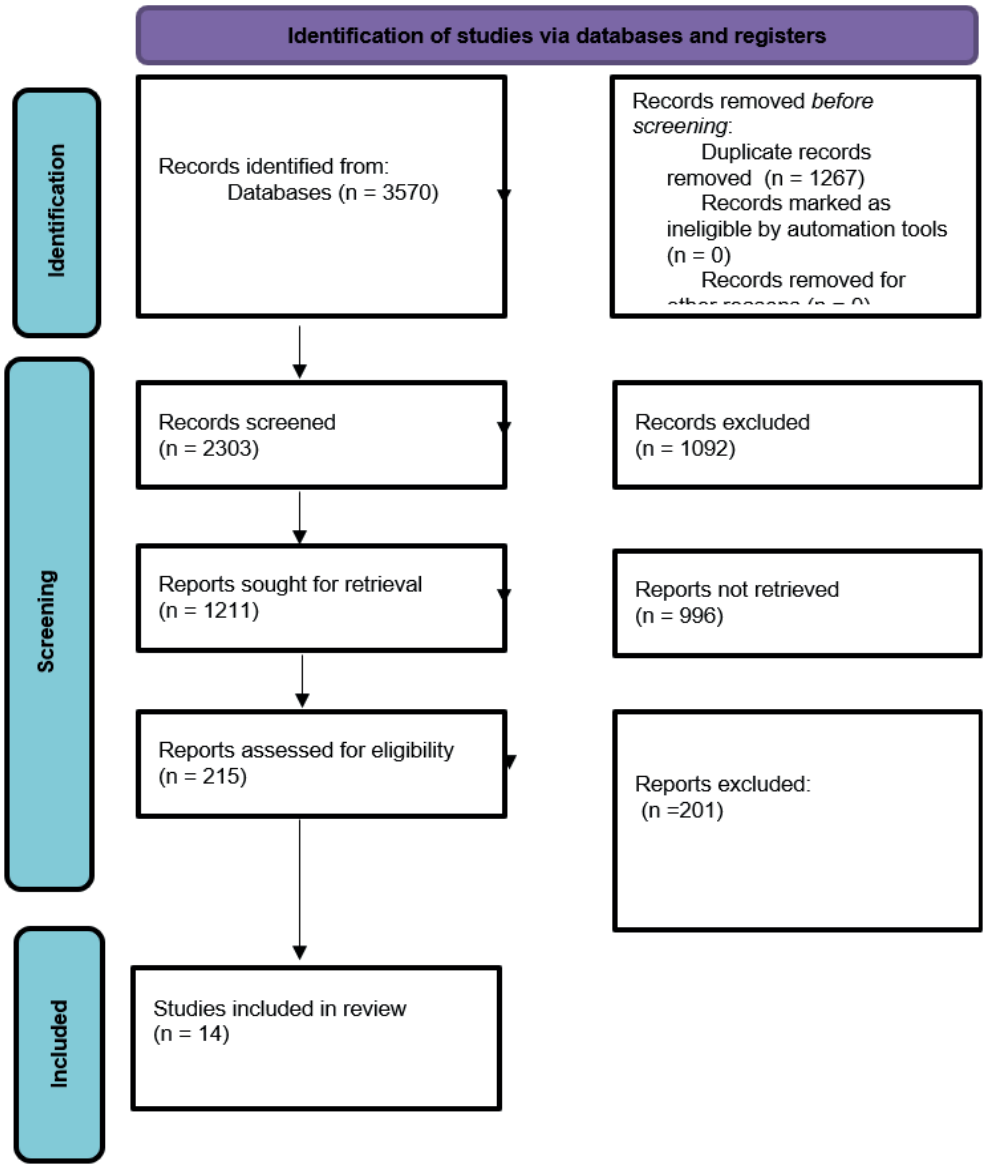


**Figure 1.** PRISMA Flow Diagram

**Table 1.** Characteristics and results of the studies reviewed

| Author(s) | Study Design | Patient Population | Age (years) | ECMO Type (VA/VV) | Mortality Rate (%) | Key Complications Reported | Hemodynamic Outcomes | Follow-up Duration | Other Findings |
|---|---|---|---|---|---|---|---|---|---|
| Lee et al.[15] | Multicenter retrospective/ prospective observational registry study | 362 refractory cardiogenic shock patients (≥19 years) | ≥19 (adults) | VA ECMO | 40,9 % (30-day mortality) | Stroke (ischemic/ hemorrhagic), limb ischemia, ECMO-site bleeding, gastrointestinal bleeding (no significant differences among groups) | Improved hemodynamics with early ECMO: reduced shock time; vasoactive inotropic score standardized; improved organ perfusion implied by outcomes | 30 days (primary); 1 year (secondary outcomes) | Early ECMO support (<0,9 g shock-to-ECMO time) was associated with significantly lower 30-day mortality (HR 0,53), lower in-hospital mortality, reduced ECMO weaning failure, better 1-year composite outcomes, and improved neurological status at discharge; adverse events did not differ significantly by ECMO timing. |
| Rastan et al.[16] | Retrospective cohort | 517 adults with refractory postcardiotomy cardiogenic shock (PCS) | Mean 63,5 ± 11,2 years | VA ECMO | In-hospital mortality ~75 % (389/517) | Cerebrovascular events (17,4 %), GI complications (18,8 %), renal replacement therapy (65 %) | Successful ECMO weaning in 63,3 %; cardiac index and echocardiography used for monitoring; IABP used in 74,1 % | Mean 3,2 years (hospital survivors) | ECMO is an acceptable rescue therapy for refractory PCS with high mortality but possible long-term survival; older age, diabetes, and renal insufficiency predict mortality; hemodynamic recovery is assessed daily to guide weaning; 24,8 % were discharged alive. |
| Rajsic et al.[17] | Retrospective | 453 refractory cardiogenic shock | Mean 60,9 ± 14,2 | VA-ECMO | 40,4 % in-hospital mortality overall; mortality within 30 days was 33,1 %, 40,8 % at 365 days | Hemorrhage (46 %), thromboembolic events (25 %), sepsis (18 %) | Cardiac function monitored regularly with echocardiography; ECMO weaning based on hemodynamic improvement and blood flow reduction; no direct quantitative hemodynamic data presented, but outcomes linked to SAPS III and SOFA cardiovascular scores | Median ICU length of stay was 17 days (range 1–170 days); follow-up for mortality extended to 1 year, with 59,2 % survival beyond one year | VA-ECMO provides potential lifesaving support in refractory cardiogenic shock with 40 % mortality; Hemorrhage was the most frequent and critical complication, significantly associated with mortality. Despite substantial risks, VA-ECMO rescues a subset of critically ill patients. |

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| Po-Shun Hsu et al.[18] | Retrospective observational cohort study. | 51 adult patients with refractory cardiogenic shock after cardiac surgery | Mean 63,0 ± 15,7 | Venoarterial (VA) | 67 % in-hospital; 49 % 30-day; 65 % 3-month; 29 % 1-year survival | Acute renal failure (75 %), femoral bleeding, limb ischemia (amputation in 2), bacteraemia (34 %) | 53 % successfully weaned from ECMO; poor LVEF, low SBP, severe metabolic acidosis predicted failure to wean | 1 year | ECMO provides effective temporary circulatory support in refractory postcardiotomy cardiogenic shock; main mortality causes include heart failure with multi-organ failure and infections; pre-ECMO predictors of failure include low LVEF (<40 %), low SBP (<90 mmHg), severe metabolic acidosis; peri-ECMO predictors include low ECMO venous saturation and elevated lactate; careful patient selection is crucial for outcomes. |
| Li et al.[19] | Retrospective observational study | 23 refractory cardiogenic shock patients | Median 55 (IQR 48–68) | VA ECMO | 56,5 % (discharge survival 43,5 %) | Cerebral hemorrhage, multiple organ failure, arrhythmias, and poor ECMO venous drainage | Improved blood pressure (systolic/diastolic) and left ventricular ejection fraction were observed before ECMO removal; lactic acid levels improved during ECMO support. | Until hospital discharge | ECMO weaning rate 60,9 %; survival linked to reversibility of primary disease; survivors showed better hemodynamic parameters (BP, LVEF) before ECMO removal. |
| Chonde et al.[20] | Retrospective cohort | 51 hospitalized patients with refractory cardiac arrest or postarrest cardiogenic shock | Mean 54,0 ± 10,9 | VA-ECMO (presumed, as ECPR/PACS usually VA) | 74,6 % (overall mortality at 1 year); 25,4 % survived ≥ 1 year | Not explicitly stated, but common ECMO complications are expected | Improvement in hemodynamics implied by higher survival in the PACS group | 1 year | ECMO use in PACS patients is associated with significantly better 1-year survival (46,7 %) than in refractory cardiac arrest (ECPR) patients (16,7 %), suggesting hemodynamic recovery is more successful in PACS. |

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|---|---|---|---|---|---|---|---|---|---|
| Salazar Elizalde et al.[21] | Retrospective cohort | 16 adults with refractory cardiac failure after open-heart surgery, Chile | Mean 58 ± 8,2 | VA ECMO | 44 % in-hospital mortality (7/16) | Surgical bleeding requiring reoperation (56 %), limb ischemia (44 %), higher mortality with longer ECMO support, and higher lactic acid levels | ECMO weaning achieved in 88 %; hemodynamics optimized with MAP 65-70 mmHg, $SvO_2$ >65 %, LVEF >25 % before weaning | 1 year | VA ECMO supports hemodynamic recovery with an 88 % weaning rate; however, mortality remains high at 44 % in the hospital and 62 % at one year. Early weaning and controlled lactic acid levels are linked to better survival. |
| Jentzer et al.[23] | Retrospective cohort study | 8619 adult patients with cardiogenic shock receiving ECMO (excl. post-op) | Median 56,7 (IQR 44,8–65,6) | Venoarterial (VA) | 52,6 % overall | Higher mortality with delayed initiation; acidosis is more severe in the early ECMO group | Full hemodynamic support via VA ECMO | In-hospital mortality (duration from admission to ECMO initiation) | Earlier ECMO initiation (within 24 hours of admission) was associated with lower in-hospital mortality (51,6 % vs. 54,7 %, p=0,007) Each 12-hour delay increased mortality odds by 6 %. Timing had less effect in severe shock cases. Supports early initiation to improve survival and hemodynamic recovery. |
| Chung et al.[24] | Prospective observational | 134 patients with profound cardiogenic shock after CPR undergoing ECMO rescue | Mean 51,8 | VA-ECMO | 57,5 | Acute respiratory failure, pulmonary edema, bleeding, vascular complications | Successful weaning from ECMO was achieved in 50,7 %; mean systolic BP before ECMO was 49,8 mmHg; cardiac function was monitored by echo for recovery. | In-hospital | High mortality is associated with profound cardiogenic shock; successful ECMO weaning and APACHE II score <22 predicted better survival; ECMO improved hemodynamics, allowing stabilization and potential recovery |
| Fux et al.[25] | Retrospective cohort | 76 non-surgical patients with refractory CS | Median 52 (IQR 37–60) | VA | 90-day: 49 %; In-hospital: 50 % | CPR before VA-ECMO (54 %), high arterial lactate, multi-inotrope use | 37 % successfully weaned; 13 % to HTx; 4 % to LVAD | 90 days | Arterial lactate and several inotropes/vasopressors were independent predictors of mortality; early shock severity was linked to outcome. |

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|---|---|---|---|---|---|---|---|---|---|
| Ostadal et al.[28] | Multicenter Randomized Controlled Trial (ECMO-CS) | 117 patients with rapidly deteriorating or severe cardiogenic shock | Median 66 (IQR 59–73) | VA-ECMO | 50,0 % (Immediate ECMO) vs 47,5 % (Conservative) | Sepsis, pneumonia, stroke, leg ischemia, bleeding | No significant difference in MAP, lactate clearance, or vasopressor need between groups | 30 days | Immediate VA-ECMO did not significantly reduce mortality (50 % vs 47,5 %) or improve hemodynamic recovery compared to an early conservative strategy with downstream ECMO use. |
| Movahed et al.[26] | Retrospective database analysis (NIS 2016–2020) | 13 160 (ECMO group) out of 796 585 total, Adults with cardiogenic shock (no Impella/IABP) | Mean 53,7 ± 15,4 (ECMO patients) | VA-ECMO | 47,9 % (ECMO group) | High rates of major complications (e.g., lactic acidosis, renal replacement therapy, mechanical ventilation) | ECMO patients had severe hemodynamic compromise requiring mechanical support. | In-hospital (until discharge or death) | ECMO use is associated with significantly higher inpatient mortality (~48 %) compared to no device (~33 %) Despite mechanical support, ECMO patients have very high mortality, with no clear improvement in hemodynamic recovery outcomes reported in this dataset. |
| Jentzer et al.[22] | Retrospective registry-based cohort study using ELSO data | 12 106 adult patients with cardiogenic shock receiving VA ECMO (both medical and post-cardiotomy) | Median 57,9 (IQR: 46,8–66,1) | VA ECMO only | 55,2 % overall | High acuity, including vasopressor/MCS need | Incremental worsening with higher SCAI shock stage; lower likelihood of native heart survival in stages D–E | In-hospital (median ECMO duration: 120 hours) | Higher SCAI shock stages at ECMO initiation predicted increased mortality; SCAI classification was a strong prognostic tool; hemodynamic support needs before ECMO initiation significantly influenced outcomes |
| Guihaire et al.[27] | Retrospective single-centre cohort study | 92 postcardiopulmonary bypass cardiogenic shock (PCCS) patients after cardiac surgery | Median 63 (range 17–83); survivors: 56,8±15,5, non-survivors: 63,5±11,4 | VA-ECMO | 61 % (1-month survival 42 %, 6-month survival 39 %) | Renal and hepatic dysfunction, elevated lactate, high inotropic score | Survivors had significantly lower lactate (2,3±0,4 mmol/l vs 4,1±0,6), better LV ejection fraction (52,5 % vs 44,1 %), and improved renal/hepatic function at 24h | Up to 6 months (HRQoL at 2 years assessed) | ECMO improved short-term survival in PCCS; better hemodynamic recovery (e.g., lactate clearance, improved organ function) predicted survival; high lactic acid, poor LV function, and valvular surgery were associated with mortality. |

**Table 2.** Quality assessment of cohort studies by Newcastle Newcastle-Ottawa Scale

| Study (Author) | Representativeness of Exposed Cohort (1) | Selection of Non-exposed Cohort (1) | Ascertainment of Exposure (1) | Outcome Not Present at Start (1) | Comparability (Design/Analysis) (2) | Assessment of Outcome (1) | Follow-up Long Enough (1) | Adequacy of Follow-up (1) | Total NOS Score (out of 9) |
|---|---|---|---|---|---|---|---|---|---|
| Lee et al.[15] | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 9 |
| Rajsic et al.[17] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Po-Shun Hsu et al.[18] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Li et al.[19] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Chonde et al.[20] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Rastan et al.[16] | 1 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 8 |
| Salazar Elizalde et al.[21] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Jentzer et al.[23] | 1 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 8 |
| Chung et al.[24] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Fux et al.[25] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |
| Jentzer et al.[22] | 1 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 8 |
| Guihaire et al.[27] | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 7 |

A comprehensive search of electronic databases yielded a total of 3570 records. After the removal of 1267 duplicate entries, 2303 records remained for screening. Upon title and abstract screening, 2088 records were excluded based on irrelevance to the inclusion criteria. A total of 215 full-text articles were then assessed for eligibility. Of these, 201 articles were excluded due to reasons such as lack of relevant outcomes, inappropriate study design, or non-ECMO populations. Ultimately, 14 studies met the inclusion criteria and were included in the final qualitative synthesis of this review. Table 1 summarizes clinical studies on VA-ECMO in refractory cardiogenic shock, highlighting patient characteristics, mortality rates, complications, hemodynamic outcomes, and follow-up data to assess treatment effectiveness and risks. Table 2 evaluates cohort study quality using the Newcastle-Ottawa Scale, with scores ranging from 7 to 9 indicating moderate to high quality.

The PRISMA flow diagram (figure 1) illustrates the selection process in detail.

**Mortality Outcomes**

Across the studies reviewed, ECMO use in refractory cardiogenic shock was associated with consistently high mortality rates, although outcomes varied depending on factors such as patient condition, timing of intervention, and institutional protocols.[15,16] Lee et al.[15] reported a 30-day mortality of 40,9 %, with significantly lower mortality in patients who received early ECMO support, specifically those with a shock-to-ECMO time of less than 0,9 hours, suggesting a narrow therapeutic window for improving survival outcomes. Similarly, Rajsic et al.[17] documented an in-hospital mortality of 40,4 %, which increased to 59,2 % at one year, highlighting the importance of long-term follow-up when assessing treatment success. Po-Shun Hsu et al.[18] observed a markedly higher in-hospital mortality rate of 67 %, which may be attributed to the postoperative nature of the patient population and advanced age, with only 29 % surviving to one year. Li et al.[19] found a mortality rate of 56,5 %, with 43,5 % of patients surviving to hospital discharge, indicating a moderate level of success in a smaller cohort.

In contrast, Chonde et al.[20] reported a one-year mortality rate of 74,6 %, though postarrest cardiogenic shock (PACS) patients had better survival outcomes (46,7 %) compared to those undergoing extracorporeal cardiopulmonary resuscitation (ECPR). Rastan et al.[16] highlighted an in-hospital mortality rate of 75 %, with only 24,8 % of patients discharged alive, reflecting the dire condition of postcardiotomy shock patients. Meanwhile, Salazar Elizalde et al.[21] found a lower in-hospital mortality rate of 44 %, coupled with a high ECMO weaning success rate of 88 %, suggesting favorable initial outcomes; however, complications post-weaning significantly impacted overall survival. Across studies, in-hospital mortality consistently ranged from 47,5 % to 57,5 %. Jentzer et al.[22,23] found earlier ECMO initiation—within 24 hours—reduced in-hospital mortality (51,6 % vs. 54,7 %, p=0,007), with a 6 % increase in mortality odds for every 12-hour delay. Similarly, Jentzer et al.[22] reported an overall mortality rate of 55,2 % in a large ELSO-based cohort, noting that higher SCAI shock stages predicted worse outcomes

Chung et al.[24] observed a 57,5 % in-hospital mortality in patients with profound CS post-CPR. Fux et al.[25] showed a 50 % in-hospital and 49 % 90-day mortality, with pre-ECMO CPR and elevated arterial lactate as major contributors. Movahed et al.[26] reported a 47,9 % inpatient mortality for ECMO recipients compared to 33 % in non-device users. In contrast, Ostadal et al. found no significant difference in mortality between immediate and delayed ECMO initiation in a randomized trial (50,0 % vs. 47,5 %). Guihaire et al.[27] highlighted a 61 % hospital mortality in postcardiotomy patients, with 42 % surviving at one month. In summary, mortality ranged from 40 % to 75 % across studies, influenced by the timing of ECMO initiation, underlying pathology, and institutional experience. Early initiation and the reversibility of the underlying cause consistently emerged as predictors of improved survival.

**Hemodynamic Recovery**

Most studies demonstrated that ECMO support led to measurable hemodynamic improvements, although the extent and method of assessment varied. Lee et al.[15] found that early ECMO initiation significantly reduced the duration of shock, improved vasoactive inotropic scores, and enhanced both organ perfusion and neurological outcomes, thereby confirming ECMO's effectiveness in restoring cardiovascular stability. Rajsic et al.[17] reported improved hemodynamic status as evidenced by decreased SAPS III and SOFA cardiovascular scores, although they did not provide direct quantitative measures. According to Po-Shun Hsu et al.[18], 53 % of patients were successfully weaned from ECMO; however, those with low left ventricular ejection fraction (LVEF), hypotension, and severe metabolic acidosis were less likely to achieve weaning, underscoring the critical role of pre-ECMO cardiac performance. Li et al.[19] observed hemodynamic stabilization through improved blood pressure, LVEF, and reduced lactate levels during ECMO support, confirming its short-term circulatory benefits. Chonde et al.[20] did not provide direct hemodynamic data but inferred improved outcomes based on higher survival rates among PACS patients, suggesting ECMO's benefit in carefully selected groups. Rastan et al.[16] utilized cardiac index and echocardiographic parameters to guide management, with 63,3 % of patients successfully weaned, demonstrating that continuous monitoring is essential to optimize recovery. Finally, Salazar Elizalde et al.[21]

reported an ECMO weaning rate of 88 %, linking successful recovery to lower lactic acidosis levels, though prolonged ECMO duration was associated with worse prognosis.

Jentzer et al.[23] demonstrated that early initiation enhanced hemodynamic recovery, particularly in less severe shock. Chung et al.[24] reported that ECMO helped restore perfusion in patients with extremely low systolic blood pressure (mean 49,8 mmHg), achieving 50,7 % weaning success. Fux et al.[25] noted 37 % weaning, indicating partial hemodynamic stabilization. In Guihaire et al.[27], survivors had lower lactate (2,3 vs. 4,1 mmol/l) and improved ejection fraction (52,5 % vs. 44,1 %), showing measurable hemodynamic gains. However, Ostadal et al.[28] found no significant differences in MAP or lactate clearance between immediate and conservative strategies, suggesting timing may not always affect recovery metrics. Overall, hemodynamic recovery was frequently achieved, particularly in cases involving reversible cardiac failure and timely ECMO intervention. Reported successful weaning rates ranged from 53 % to 88 %, with notable improvements in blood pressure, LVEF, lactate clearance, and reduced vasopressor dependency.

**Complications**

The reviewed studies consistently highlighted the high rate and diversity of complications associated with ECMO, reflective of both the procedure's invasiveness and the fragility of the patient population. Lee et al.[15] documented complications such as stroke, limb ischemia, and various bleeding events. Importantly, they found no significant differences in complication rates based on ECMO timing, suggesting that these risks are intrinsic to ECMO itself rather than to the timing of its initiation. Rajsic et al.[17] reported hemorrhage in 46 % of cases, thromboembolic events in 25 %, and sepsis in 18 %, with hemorrhagic events showing the strongest correlation with mortality. According to Po-Shun Hsu et al.[18], complications included acute renal failure in 75 % of patients, bacteraemia in 34 %, and limb ischemia, illustrating the frequent occurrence of renal and infectious complications. Li et al.[19] observed cerebral hemorrhage, arrhythmias, and ECMO drainage issues, indicating complications that spanned both systemic and mechanical origins. Although Chonde et al.[20] did not provide detailed complication data, the variability in survival outcomes implies that unreported adverse events likely played a role in determining prognosis. Rastan et al. reported cerebrovascular events in 17,4 % of patients, gastrointestinal complications in 18,8 %, and renal failure requiring dialysis in 65 %, demonstrating the multi-organ vulnerability induced or exacerbated by ECMO. Salazar Elizalde et al.[21] noted bleeding complications requiring reoperation in 56 % of patients and limb ischemia in 44 %, with both higher lactate levels and longer ECMO duration being predictive of mortality. In summary, complications such as bleeding, stroke, renal dysfunction, limb ischemia, and infection were prevalent across studies.[22] Bleeding, in particular, was consistently associated with poor outcomes, underlining the importance of meticulous anticoagulation management and close monitoring by experienced multidisciplinary teams.

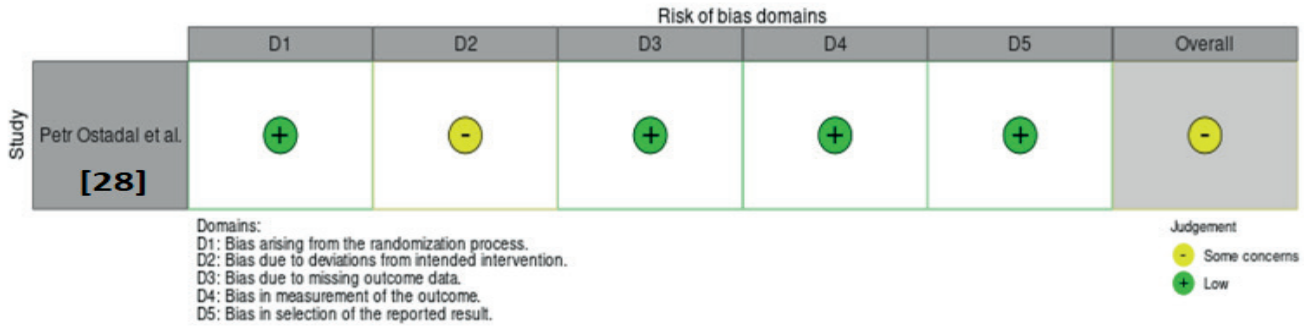


**Figure 2.** Quality assessment of RCTs by RoB 2.0

## DISCUSSION

This systematic review synthesizes existing literature on the use of extracorporeal membrane oxygenation (ECMO) in patients with refractory cardiogenic shock, revealing that while ECMO remains a vital life-sustaining intervention, it is associated with persistently high mortality rates. Across the included studies, mortality rates ranged broadly from approximately 40 % to 75 %, depending on patient selection, timing of ECMO initiation, and underlying pathology.[15,17,16] Our findings align with the meta-analytic estimate reported by Rajsic et al.[14], which identified a 62 % pooled in-hospital mortality. Notably, studies such as Lee et al.underscore the importance of early ECMO initiation, where shock-to-ECMO time under 0,9 hours significantly improved survival outcomes

and neurological outcomes.[15] This reinforces the hypothesis that prompt mechanical circulatory support can mitigate the progression of end-organ hypoperfusion and reduce mortality.[15,21]

Hemodynamic recovery was a common but variably reported outcome. Our review corroborates findings from Li et al.[19] and Po-Shun Hsu et al.[18], who demonstrated improvements in left ventricular ejection fraction (LVEF), blood pressure stabilization, and lactate clearance with ECMO support. Successful weaning rates varied from 53 % to as high as 88 %, reflecting differences in patient populations and management strategies.[18,21] These data highlight the potential for VA-ECMO to serve as a bridge to recovery or further interventions, although the heterogeneity of cardiac dysfunction severity poses challenges in standardizing prognostic indicators.[22,27,28,29]

Complications remain a substantial barrier to improved outcomes. Bleeding was the most consistently reported adverse event, occurring in nearly half of the patients and correlating strongly with mortality.[23,30,31] Other frequent complications included renal failure necessitating replacement therapy, limb ischemia, stroke, and infections, echoing the findings of [16,26]. These complications reflect both the invasive nature of ECMO and the fragile clinical status of cardiogenic shock patients. Importantly, some studies suggested a paradoxical association between higher rates of cannulation site bleeding and reduced mortality, indicating complex interactions between anticoagulation management and patient outcomes that warrant further investigation.[17] Compared to previous literature, our review supports current clinical guidelines emphasizing early patient selection and initiation of VA-ECMO to optimize survival. However, the persistent high mortality and complication rates underline the urgent need for standardized protocols, improved anticoagulation strategies, and rigorous prospective trials to validate optimal timing and patient management approaches.[14,32,33,34,35] This systematic review is limited by the predominance of retrospective cohort studies, heterogeneity in patient populations, and variability in ECMO protocols across centers, which may bias mortality and complication estimates. The lack of randomized controlled trials restricts the strength of causal inferences regarding VA-ECMO effectiveness. Furthermore, inconsistent reporting of outcomes and complications limits meta-analytic precision. Despite these limitations, findings underscore the critical importance of early intervention and patient selection. Clinically, the review highlights the need for standardized protocols and multidisciplinary care to optimize ECMO outcomes and supports further rigorous trials to clarify its role in cardiogenic shock management. Overall, while VA-ECMO offers a lifesaving option for refractory cardiogenic shock, its effectiveness is tempered by significant risks, necessitating multidisciplinary expertise and continuous outcome monitoring.

## CONCLUSIONS

This systematic review concludes that extracorporeal membrane oxygenation (ECMO) is a potentially life-saving intervention for patients with refractory cardiogenic shock. However, its benefits are closely linked to early initiation, appropriate patient selection, and delivery within experienced, multidisciplinary centers. Despite improvements in hemodynamic parameters, ECMO is associated with high mortality and significant risks, such as bleeding, renal failure, and stroke. These findings highlight the need for careful clinical decision-making and the development of standardized protocols. Future research should focus on prospective, controlled studies to refine selection criteria, optimize timing, and reduce complications, thereby improving overall outcomes in critical care cardiology.

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## FINANCING

The authors did not receive financing for the development of this research.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHORSHIP CONTRIBUTION

*Conceptualization:* Melina Carlos Tovar, Mitchell Walter Carbajal Alvarado, Cesar Augusto Flores Dueñas,

Natalia Quintero Serrano, Luisa Alejandra Penagos Ochoa, Jessica Samantha Rea Fernández, Javier Ignacio Soto Espinoza, Mishelle Estefania Garces Lopez.

*Data curation:* Melina Carlos Tovar, Mitchell Walter Carbajal Alvarado, Cesar Augusto Flores Dueñas, Natalia Quintero Serrano, Luisa Alejandra Penagos Ochoa, Jessica Samantha Rea Fernández, Javier Ignacio Soto Espinoza, Mishelle Estefania Garces Lopez.

*Formal analysis:* Melina Carlos Tovar, Mitchell Walter Carbajal Alvarado, Cesar Augusto Flores Dueñas, Natalia Quintero Serrano, Luisa Alejandra Penagos Ochoa, Jessica Samantha Rea Fernández, Javier Ignacio Soto Espinoza, Mishelle Estefania Garces Lopez.

*Drafting - original draft:* Melina Carlos Tovar, Mitchell Walter Carbajal Alvarado, Cesar Augusto Flores Dueñas, Natalia Quintero Serrano, Luisa Alejandra Penagos Ochoa, Jessica Samantha Rea Fernández, Javier Ignacio Soto Espinoza, Mishelle Estefania Garces Lopez.

*Writing - proofreading and editing:* Melina Carlos Tovar, Mitchell Walter Carbajal Alvarado, Cesar Augusto Flores Dueñas, Natalia Quintero Serrano, Luisa Alejandra Penagos Ochoa, Jessica Samantha Rea Fernández, Javier Ignacio Soto Espinoza, Mishelle Estefania Garces Lopez.