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Systematic review

Extra-corporeal cardiopulmonary resuscitation in the emergency department for refractory cardiac arrest: a systematic review

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Abstract

Background: Extracorporeal cardiopulmonary resuscitation (ECPR) is a rescue strategy for RCA, and its value in emergency department (ED) settings still uncertain as outcomes depend on patient selection, timing, and system organization. **Methods:** This systematic review followed PRISMA principles and included original studies evaluating ECPR or ED extracorporeal membrane oxygenation for refractory cardiac arrest (RCA). PubMed/MEDLINE, Scopus, and Web of Science were searched. Eligible studies reported survival, neurological outcomes, workflow measures, or ECPR-related process outcomes. Data were analyzed narratively because of clinical and methodological heterogeneity. **Results:** We include seven original studies published between 2012 and 2025. Studies were conducted in the United States, South Korea, Austria, China, and Japan, with sample sizes ranging from 29 to 192 patients. Emergency ECPR was feasible when delivered through structured protocols and trained teams. Survival to discharge or longer-term survival varied in studies, and neurological recovery was reported in selected patients with witnessed arrest, shockable rhythm, shorter low-flow or ACLS duration, and rapid access to extracorporeal support. Dedicated ECLS teams and hybrid ED systems shortened ECPR initiation times. **Conclusion:** Emergency ECPR benefit highly selected RCA patients when delivered within organized and experienced systems.

Keywords: Extracorporeal cardiopulmonary resuscitation; Extracorporeal membrane oxygenation; extracorporeal membrane oxygenation; Emergency department; refractory cardiac arrest

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Introduction

Cardiac arrest is a major emergency condition with high mortality despite improvements in cardiopulmonary resuscitation, defibrillation, emergency medical services, and post-resuscitation care [1]. Out-of-hospital cardiac arrest (OHCA) is important as many patients fail to achieve sustained return of spontaneous circulation after conventional advanced life support, and neurological survival decreases as the duration of low-flow circulation increases [2]. Conventional CPR provides temporary perfusion, and its physiological support is limited, time-dependent, and often insufficient in refractory cardiac arrest (RCA) [3]. Current resuscitation guidelines consider ECPR as a rescue option for selected patients when standard advanced cardiovascular life support is failing and when it can be delivered within an appropriately trained and equipped system [1,4].

ECPR refers to the use of venoarterial extracorporeal membrane oxygenation during ongoing cardiac arrest to provide circulatory and oxygenation support while the underlying reversible cause is treated [3]. The theoretical value of ECPR is that it can restore systemic perfusion more effectively than chest compressions alone, reduce prolonged low-flow injury, and permit interventions such as coronary angiography, percutaneous coronary intervention or treatment of pulmonary embolism when clinically indicated [5]. This benefit is expected in patients with reversible causes, witnessed arrest, early bystander CPR, shockable rhythm, short no-flow duration, and rapid access to extracorporeal support [5,6].

The emergency department (ED) is important location for ECPR because it is the first hospital site where refractory OHCA patients arrive while still receiving active resuscitation. Early ED experience showed that trained ED physicians could initiate ECPR using a structured algorithm, with five neurologically intact survivors in eight patients who had successful ED bypass initiation [7]. Further ED-based evidence suggested benefit in selected refractory ventricular fibrillation, where ECPR was associated with higher sustained return of spontaneous circulation and better neurological function at discharge compared with conventional CPR [8].

A meta-analysis focused on ED-initiated ECPR for OHCA found no clear overall improvement in neurological outcome [9]. Randomized trials have also produced different results, with benefit in highly selected single-center systems and neutral findings in broader multicenter implementation [5,6]. ED workflow studies examined how dedicated ECLS teams or hybrid EDs shorten preparation and ECPR initiation time [10,11]. The present systematic review aimed to summarize the characteristics, workflow measures, survival outcomes, neurological outcomes, and main findings of original studies evaluating ECPR initiated in the ED or emergency-care pathway for patients with RCA.

Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review aimed to analyze original studies evaluating ECPR initiated in the ED for patients with RCA. The research question focused on ECPR in the ED setting was associated with survival and neurological outcome, improved workflow, or

reduced time to extracorporeal support in patients who failed to respond to conventional CPR.

A systematic electronic literature search was performed using PubMed/MEDLINE, Scopus, and Web of Science. The search included combinations of keywords and controlled terms related to ECPR, ECMO, ED, RCA, OHCA, in-hospital cardiac arrest, survival, and neurological outcome. The search terms included: “extracorporeal cardiopulmonary resuscitation,” “ECPR,” “extracorporeal membrane oxygenation,” “ECMO,” “emergency department,” “emergency room,” “refractory cardiac arrest,” “cardiac arrest,” “out-of-hospital cardiac arrest,” and “OHCA.” Boolean operators were used to combine terms, including “AND” and “OR.” The search was limited to studies involving human subjects. No restriction was applied to country or clinical setting as long as the study involved ED or emergency-care ECPR.

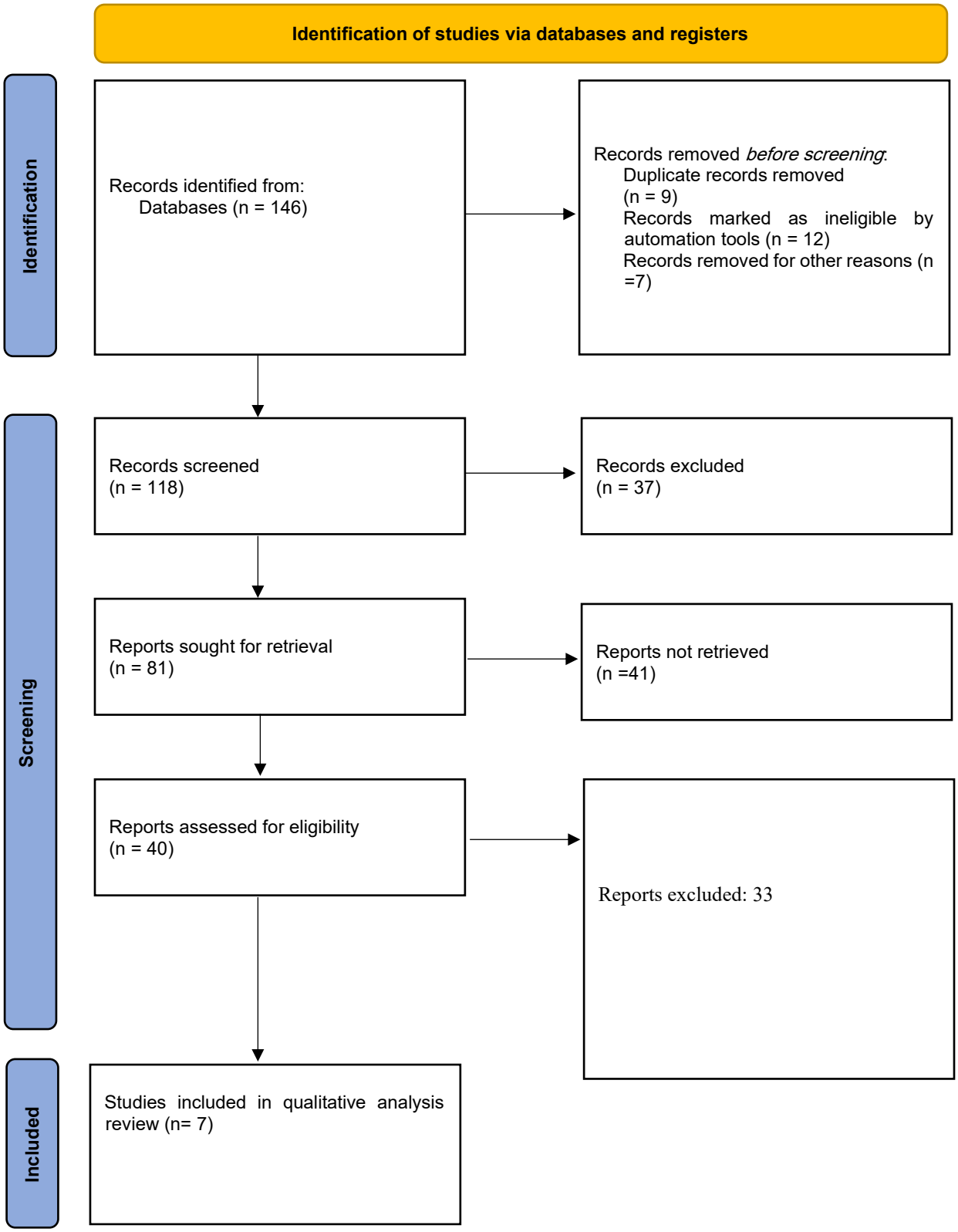
Studies were eligible for inclusion if they were original research articles reporting patient-level or cohort-level data on ECPR or emergency physician/ED-initiated ECMO for RCA. Eligible study designs included retrospective observational studies, prospective cohorts, registry-based studies, comparative cohort studies, and clinical trials. Studies were included when reported relevant outcome (survival to hospital discharge, 30-day survival, six-month survival, favorable neurological outcome, cerebral performance category, return of spontaneous circulation, ECPR initiation time, cannulation-related complications, or workflow-related measures). We exclude systematic reviews, meta-analyses, narrative reviews, editorials, commentaries, guidelines, conference abstracts without sufficient data, protocols, simulation-only studies, animal studies, or studies not focused on ECPR in RCA.

All retrieved records were screened according to PRISMA principles. Titles and abstracts were reviewed to remove clearly irrelevant articles and non-original publications. Full texts of eligible studies were then assessed against the inclusion and exclusion criteria. Duplicate records were removed before final selection. Review articles and meta-analyses were not included as original studies, but their reference lists were checked to identify eligible primary studies from electronic databases.

Data were extracted using a structured extraction form. Extracted variables included first author, publication year, country, study design, study setting, study period, sample size, patient population, ECPR selection criteria, comparator group where available, time-related ECPR measures, survival outcomes, neurological outcomes, and major complications. The main outcomes of interest were survival to hospital discharge and favorable neurological outcome. Secondary outcomes included ROSC, survival at 30 days or six months, ECPR establishment time, ECMO weaning, and cannulation-related adverse events.

Because the included studies were clinically and methodologically heterogeneous, the findings were analyzed qualitatively. Differences in study design, patient selection, ECPR protocols, comparator groups, and outcome definitions were considered during interpretation.

Fig 1: PRISMA flow chat



Results

We include 7 studies published between 2012 and 2025, conducted in the United States, South Korea, Austria, China, and Japan. All studies evaluated ECPR or ED-initiated ECMO for RCA in emergency care settings. The study designs were retrospective observational studies, retrospective registry analyses, or retrospective analyses of prospectively collected cohorts. The sample size varied between studies, ranging from 29 patients in the Chinese ED ECPR team study to 192 patients in the Vienna ECPR program study (Table 1).

The earliest included study reported the feasibility of ED-initiated ECPR using a structured three-stage ED algorithm. In this study, 42 patients presented with cardiopulmonary collapse during the one-year study period, 18 met the algorithm criteria, eight admitted after successful ED ECPR, and five survived to hospital discharge neurologically intact (Table 2). Emergency physicians initiated ECMO in 58 patients, including 44 venoarterial cases, of which 43 were ED ECPR cases. Eleven patients survived to hospital discharge, including nine with cerebral performance category score 1. Adjusted analysis showed higher survival to discharge in ECPR patients compared with concurrent ECPR-eligible controls, although propensity analysis showed only a favorable non-significant trend (Table 2).

In the Korean ED cohort, ECPR was attempted in 100 RCA patients who did not respond to advanced cardiac life support. Fourteen patients survived to discharge, and 12 survivors had good neurological outcomes. Survival decreased with increasing age and longer ACLS duration, and most deaths occurred within the first 24 hours after ECPR (Table 2).

The Austrian checklist validation study included 92 adult non-traumatic RCA patients treated with ED eCPR. Overall, 45 patients achieved ROSC after eCPR, 14 survived for 30 days, and 12 survived for six months. Patients fulfilling all six checklist criteria had higher 30-day survival and six-month survival (Table 2). Two studies focused mainly on ED workflow and system improvement. In the Chinese study, establishment of a 24-hour ECLS team reduced ECMO pipeline prefilling time, ECPR establishment time, and item preparation time. ROSC recovery increased from 37.50% to 77.78%, ECPR weaning increased from 25.00% to 38.89%, and survival increased from 20.0% to 36.8% (Table 2). In the Japanese ED study, hybrid ED installation shortened the time from hospital arrival to ECPR initiation (Table 2).

The largest included study evaluated the Vienna ECPR program after restructuring. Among 192 ED-treated eCPR patients, survival with favorable neurological outcome at six months was 25% and improved yearly from 15% in 2020 to 37% in 2023. This improvement occurred with increased witnessed arrest, bystander CPR, shockable rhythm, and reduced low-flow duration (Table 2).

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Table 1. Characteristics of the included studies

Study	Country and setting	Design	Study period	Population and sample	Outcome
Bellezzo et al., 2012 [7]	USA; urban ED, Sharp Memorial Hospital	Retrospective observational case series	1 year, Apr 2010–Mar 2011	42 non-trauma patients with ongoing CPR, refractory shock, or ED cardiac arrest; 18 met ED ECPR algorithm criteria; 8 had successful bypass initiation	Feasibility of emergency physician-initiated ED ECPR
Shinar et al., 2019 [12]	USA; single community hospital	Retrospective analysis of prospectively identified cases	2010–2017	58 emergency physician-initiated ECMO cases; 43 ED ECPR cases	Outcomes of emergency physician-initiated ECPR compared with eligible controls
Han et al., 2019 [13]	South Korea; tertiary hospital ED	Retrospective analysis based on a prospective CPR cohort	May 2006–Dec 2017	100 ED ECPR patients with RCA; 75 OHCA and 25 ED arrests	Predictors of survival and post-ECPR management
Poppe et al., 2020 [14]	Austria; General Hospital of Vienna ED	Retrospective observational registry study	Jan 2013–Dec 2018	92 adult non-traumatic RCA patients treated with ED eCPR	Validation of a six-criteria checklist for ECPR candidate selection
Liu et al., 2024 [10]	China; ED, Aerospace Center Hospital	Retrospective comparative study	May 2018–Apr 2022	29 ED ECPR patients; 10 conventional coordination mode and 19 after 24-h ECLS team establishment	Effect of a dedicated 24-h ECLS team on early ED ECPR workflow
Nakata et al., 2024 [11]	Japan; Tohoku University Hospital ED	Retrospective single-center cohort study	Apr 2013–Apr 2022	69 adult OHCA patients with presumed cardiac etiology who underwent ECPR; 36 conventional ED and 33 hybrid ED	Effect of hybrid ED on ECPR initiation time and outcomes
Magnet et al., 2025 [15]	Austria; Vienna ED ECPR program	Retrospective registry study	2020–2023	192 adult IHCA/OHCA patients treated with ED eCPR	Effect of program restructuring, protocols, and experience on ECPR outcomes

ACLS, advanced cardiac life support; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECLS, extracorporeal life support; ECPR, extracorporeal cardiopulmonary resuscitation; ED, ED; ECMO, extracorporeal membrane oxygenation; IHCA, in-hospital cardiac arrest; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation; VA-ECMO, venoarterial extracorporeal membrane oxygenation.

Table 2. Main outcomes of included studies

Study	ECPR/process outcome	Survival outcome	Neurological outcome	Main result
Bellezzo et al., 2012 [7]	Stage 1 completed in 18/18 eligible patients; Stage 2 completed in 12/18; successful cardiopulmonary bypass in 8 patients	5/8 patients with successful bypass initiation survived to hospital discharge	All 5 survivors were neurologically intact	ED ECPR was feasible when performed by trained emergency physicians using a staged algorithm
Shinar et al., 2019 [12]	43 ECPR cases were initiated in the ED; most had witnessed arrest, bystander CPR, and shockable rhythm	Article reports 11/44 ED VA-ECMO patients survived to discharge; ECPR-only table showed 10 survivors among 43 ECPR cases	9 survivors had CPC 1; 2 survivors had CPC 3 after ischemic stroke	Adjusted analysis showed higher survival with ECPR versus conventional CPR controls: OR 8.4, 95% CI 1.2–60.4
Han et al., 2019 [13]	19/100 patients were successfully weaned from ECPR	14/100 patients survived to discharge	12/100 had CPC 1 at discharge	Younger age and shorter ACLS duration were associated with better survival; most deaths occurred within 24 hours after ECPR
Poppe et al., 2020 [14]	45/92 patients achieved ROSC after eCPR; 27/92 met all checklist criteria	14/92 survived 30 days; 12/92 survived 6 months	Patients meeting all criteria had higher favorable neurological outcome at 6 months	Meeting all checklist criteria was associated with higher 30-day survival: OR 6.0, 95% CI 1.78–20.19
Liu et al., 2024 [10]	ECPR establishment time decreased from 62.35 ± 29.61 min to 30.98 ± 13.41 min after 24-h ECLS team implementation	Survival increased from 2/10 to 7/19 patients	4/29 patients had favorable neurological prognosis at discharge	Dedicated 24-h ECLS team shortened preparation, priming, and ECPR establishment time
Nakata et al., 2024 [11]	Median hospital-arrival-to-ECPR time decreased from 35 min in conventional ED to 24 min in hybrid ED	Survival outcome did not differ between groups	Favorable neurological outcome did not differ: 16.7% conventional ED vs 12.1% hybrid ED	Hybrid ED shortened ECPR initiation time but did not improve neurological outcome in this cohort
Magnet et al., 2025 [15]	Program restructuring was associated with increased case volume and reduced low-flow duration	Survival with favorable neurological outcome at 6 months was 48/192 overall	Favorable neurological outcome increased yearly: 15% in 2020, 19% in 2021, 23% in 2023 and 37% in 2023	Outcomes improved with center experience, protocols, training, patient selection, and process standardization

ACLS, advanced cardiac life support; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECLS, extracorporeal life support; ECPR, extracorporeal cardiopulmonary resuscitation; ED, ED; ECMO, extracorporeal membrane oxygenation; IHCA, in-hospital cardiac arrest; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation; VA-ECMO, venoarterial extracorporeal membrane oxygenation.

Discussion

In the present study we found that emergency-care pathway ECPR is feasible in selected patients with RCA, and its benefit depends on patient selection, arrest characteristics, time to extracorporeal support, and local system organization. The included studies showed survival and neurological recovery in some patients who would have a poor prognosis after prolonged conventional CPR, especially when ECPR was delivered through structured ED protocols or mature cardiac arrest systems [7,12–15]. The findings support ECPR as a rescue strategy rather than a universal intervention for all RCA patients [3].

Factors associated with better survival and neurological outcome were; younger age, shorter low-flow or ACLS duration, witnessed arrest, bystander CPR, and shockable rhythm[13–15]. This agrees with the Prague OHCA secondary analysis, where ECPR was associated with improved 180-day survival in patients without prehospital ROSC, while shockable rhythm, younger age, and shorter resuscitation time were linked with better outcomes [16].

The present study findings show that ED workflow is important to ECPR success. In the Chinese ED study, a dedicated 24-hour ECLS team reduced ECPR establishment time and improved early process outcomes, while the Japanese hybrid ED study shortened hospital-arrival-to-ECPR time without a significant improvement in favorable neurological outcome [10,11]. Reducing time is necessary but not sufficient, because survival depends also on prehospital delay, arrest biology, cannulation success, post-arrest care, and case selection [2]. The EROCA trial showed the difficulty of achieving rapid prehospital transport and ED ECPR flow [2].

The ARREST trial showed higher survival to hospital discharge with early ECMO-facilitated resuscitation compared with standard ACLS in refractory ventricular fibrillation OHCA, while the INCEPTION trial found no significant difference in 30-day survival with neurological outcome between extracorporeal and conventional CPR [17,18]. The long-term Prague OHCA follow-up reported higher long-term survival with the ECPR-based approach but no significant difference in neurological outcome [19].

The review has important limitations; most included ED-focused studies were retrospective, single-center, and clinically heterogeneous, with differences in eligibility criteria, timing definitions, comparator groups, and neurological outcome assessment. Complications were incompletely reported, although bleeding, vascular injury, renal replacement therapy, and post-cardiac arrest brain injury remain important concerns after ECPR. Emergency ECPR most justified in highly selected RCA patients within organized systems capable of rapid transport, immediate cannulation, and advanced post-resuscitation care.

Conclusion

This systematic review indicates that emergency ECPR is a good rescue intervention for selected patients with RCA, and its effectiveness depends on strict patient selection, short low-flow duration, rapid cannulation, trained teams, and organized post-resuscitation care. The included studies reported variable neurological outcomes, with better results in patients with witnessed arrest, shockable rhythm, bystander CPR, and structured ECPR pathways. Workflow improvements

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shortened preparation and initiation times, although this did not improve neurological recovery.

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