Review

Discovery Medicine 2025; 37(198): 1200–1211
https://doi.org/10.24976/Discov.Med.202537198.106

Expert Consensus on Extracorporeal Cardiopulmonary Resuscitation for Out-of-Hospital Cardiac Arrest in China

Gengzhou Wei[1], Feier Song[1], Baojuan Liu[1], Wenqiang Jiang[1], Bei Hu[1], Guoqiang Zhang[2,*], Xin Li[1,*]

[1]Department of Emergency Medicine, Guangdong Provincial People's Hospital (Guangdong Academy of Medical Sciences), Southern Medical University, 510060 Guangzhou, Guangdong, China

[2]Department of Emergency Medicine, China-Japan Friendship Hospital, 100013 Beijing, China

*Correspondence: zhangchong2003@vip.sina.com (Guoqiang Zhang); sylixin@scut.edu.cn (Xin Li)

Published: 20 July 2025

Out-of-hospital cardiac arrest (OHCA) remains a critical public health challenge with high mortality and poor neurological outcomes. Extracorporeal cardiopulmonary resuscitation (ECPR) has emerged as a promising intervention for refractory OHCA, offering improved survival and neurological recovery compared with conventional cardiopulmonary resuscitation (CCPR). This expert consensus, developed by the Emergency Medicine Branch of the Chinese Medical Association and the Emergency Medicine Branch of the Guangdong Medical Doctor Association, presents evidence-based recommendations for pre-hospital ECPR implementation in China. Key areas include dispatch protocols, team composition and training, equipment logistics, indications and timing, procedural techniques, and patient transport. The consensus emphasizes initiation of ECPR within 20 minutes of CCPR, establishment of extracorporeal membrane oxygenation within 60 minutes of arrest, and maintenance of high-quality resuscitation during cannulation. Special considerations for unique settings, such as large public events, are also discussed. This document aims to standardize pre-hospital ECPR practices, optimize patient outcomes, and guide healthcare providers in delivering effective extracorporeal life support for OHCA.

Keywords: extracorporeal cardiopulmonary resuscitation (ECPR); extracorporeal membrane oxygenation (ECMO); out-of-hospital cardiac arrest (OHCA); CPR; cardiac arrest

Introduction

Out-of-hospital cardiac arrest (OHCA) has long been a critical public health issue and is associated with high mortality and morbidity. It remains a leading cause of death among adults in developed nations, with survival typically ranging from 10% to 30% [1]. The global incidence of OHCA in adults has been reported to be 95.9 per 100,000 annually [1,2]. Even among patients who achieve a return of spontaneous circulation (ROSC), in-hospital survival ranges from approximately 30% to 50% [3,4].

In China, the prospective, multicenter, population-based Baseline Investigation of Out-of-Hospital Cardiac Arrest (BASIC-OHCA) registry study reported an OHCA incidence of 95.7 per 100,000 individuals, with a higher incidence in men (114.8 per 100,000) than women (75.7 per 100,000). This suggests that over 750,000 OHCA cases occur annually, managed by emergency medical services (EMS). Although 31.8% of patients receive cardiopulmonary resuscitation (CPR), the survival to discharge or 30-day survival is only 1.2%, with 0.8% achieving favorable neurological outcomes [5]. These findings highlight the pressing need for improvements in both the treatment and long-term outcomes of cardiac arrest (CA) patients in China.

Despite the critical role of conventional CPR (CCPR) in emergency situations, its effectiveness in refractory CA remains limited, often resulting in poor outcomes.

In recent decades, various mechanical circulatory support systems have been developed to manage CA. Among these, extracorporeal membrane oxygenation (ECMO) is particularly notable for its ability to provide comprehensive circulatory support and pulmonary gas exchange, rapidly restoring organ perfusion in cases of right, left, or biventricular failure [6]. Extracorporeal cardiopulmonary resuscitation (ECPR), used in patients who fail to achieve ROSC through CCPR, has seen increasing global adoption [7,8]. Compared with CCPR, ECPR offers substantial advantages, including enhanced coronary perfusion pressure [9], higher ROSC rates [10], and improved defibrillation success [11]. Between 2009 and 2022, data from the Extracorporeal Life Support Organization (ELSO) revealed 14,097 adult ECPR cases, with 29.5% surviving to hospital discharge [12]. The ELSO data encompass a broader and more heterogeneous global population with variable care processes, inclusion criteria, and system capabilities, contributing to the overall lower survival rate. Furthermore, randomized controlled trials (RCTs) have demonstrated that ECPR improves survival and favorable neurological outcomes in CA patients compared with CCPR [7,13–16]. A Bayesian re-analysis of the Early Initiation of Extracorporeal Life Support in Refractory OHCA (INCEPTION) trial estimated a 42% posterior probability that ECPR would achieve a minimal clinically important difference (defined as a 5% absolute risk difference) in 30-day survival with a favorable neurological outcome for refractory OHCA compared with CCPR [17].

In a 9-year single-center retrospective observational study conducted in Paris, France, patients with OHCA due to acute coronary syndrome who received pre-hospital ECPR had a 21% one-year survival with good neurological outcomes (Cerebral Performance Category (CPC) 1 or 2). Among them, the median one-year New York Heart Association functional class score was 1, with half of the survivors recovering left ventricular ejection fraction to over 50%, and half returning to work [18]. This suggests that pre-hospital ECPR was both effective and feasible. International Consensus on CPR recommends that ECPR be considered a rescue treatment for selected OHCA patients when CCPR fails to restore spontaneous circulation [19]. **Supplementary Table 1** summarizes the selected studies reporting OHCA incidence, survival rates, and outcomes.

Models of ECPR for Out-of-Hospital Cardiac Arrest

Currently, three primary models for implementing ECPR in OHCA are utilized. The first model, and the most common approach globally, involves the transfer of the patient from the site of CA to the hospital for ECPR. In this model, hospital survival ranges from 15% to 39%, and favorable neurological outcomes occur in 18% to 26% of patients [20–24]. Nonetheless, the time taken for EMS to reach the site of arrest, administer basic life support (BLS), and transport the patient to the hospital presents significant limitations. Studies showed that the time from EMS arrival at the arrest site to hospital transfer often exceeded 30 minutes [25], and the time from arrest to arrival at the hospital emergency department typically exceeded 45 minutes [16]. As a result, achieving ECMO within 60 minutes was often not feasible. Data indicate that only 17% of patients receive ECPR within 60 minutes, a proportion that severely limits the application of this model [26]. An RCT conducted in Prague, Czech Republic, found that early transport of refractory OHCA patients for in-hospital ECPR did not significantly improve 180-day survival or neurological outcomes compared with on-site standard resuscitation [16]. In a multicenter RCT conducted in the Netherlands, the in-hospital ECPR group had a 20% survival with good neurological outcomes, while the CCPR group had a 16% survival, showing no significant statistical difference between the two groups [27]. These findings suggest that transporting patients for in-hospital ECPR might not be the ideal approach.

The second model, known as the "convergence model", was pioneered by the Minnesota Resuscitation Center [28], with additional reports from Sydney, Australia [26]. This model features an EMS team on standby to quickly respond when an OHCA patient requiring ECPR is identified. The team meets the EMS personnel at the nearest medical facility to initiate ECPR before the patient is transferred to a catheterization laboratory or ECMO center for further management. In this model, the Minnesota Resuscitation Center reported an ECPR survival to discharge of 47%, with favorable neurological outcomes in 43% of patients [28]. The high survival rate in the Minnesota cohort may be attributed to strict inclusion criteria (e.g., refractory ventricular fibrillation/ventricular tachycardia (VF/VT) only), shorter low-flow times enabled by rapid response protocols, centralized ECMO expertise, and a highly coordinated metropolitan care system [28]. Similarly, in Sydney, patients meeting the criteria for ECMO implantation within one hour had a significantly higher survival (22.4%) than those transferred to the hospital for ECPR (17%) [26]. Despite these advantages, this model requires extensive pre-planning, coordination across multiple government sectors, and logistical support, limiting its applicability to highly developed urban settings.

The third model involves on-site ECPR, where a trained ECPR team is dispatched directly to the OHCA site to evaluate the patient and, if appropriate, initiate ECPR. Although reports on this model are limited and mostly case reports, some data showed promising results. A study in Lyon, France, reported a survival to discharge of 23.3% for 30 patients who underwent pre-hospital ECPR from June 2017 to December 2021 [29]. Another 9-year (2015–2023) single-center retrospective study conducted in Paris, France, demonstrated that 21% of patients with refractory OHCA due to acute coronary syndrome treated with pre-hospital ECPR achieved one-year survival with favorable neurological outcomes [18]. In Sydney, a similar study found that on-site ECPR, with an average intubation time of 22 minutes, improved the average survival to 42.7%, significantly higher than the hospital-based ECPR and convergence models [26]. A comparison summarizing the advantages, limitations, and suitable clinical scenarios for the three ECPR implementation models in refractory OHCA is shown in Table 1 (Ref. [13–18,21–23]).

Although strong evidence is sparse, on-site ECPR has emerged as a feasible approach to OHCA with potential clinical advantages. Considering the diverse implementation models and the absence of standardized guidelines, the Emergency Medicine Branch of the Chinese Medical Association and the Emergency Medicine Branch of the Guang-

Table 1. Comparison among ECPR Models for OHCA.

Model	1. Transport Model	2. Convergence Model	3. On-Site Model
ECPR Location	Inside the hospital	Designated intermediate location	Scene
Transport Vehicle Configuration	Regular ambulance	Regular ambulance	MoICU
Mobile Intubation Team	None	Yes	Yes
Representative Regions	The choice for most pre-hospital ECPR cases [13–18]	A few regions, such as Paris and Sydney [21,22]	A few regions, such as Lyon [23]
Survival Rate	15–39%	22.4–47%	42.70%
Advantages	- Widely adopted globally.	- Faster ECMO initiation.	- Shortest low-flow time.
	- Utilizes existing hospital infrastructure.	- Coordinated care reduces delays.	- Immediate ECMO access.
Limitations	- Prolonged low-flow time.	- Requires extensive pre-planning.	- Resource-intensive (mobile ECMO teams).
	- Low survival.	- Limited to urban/metropolitan systems.	- Ethical issues and lack of a sterile environment.
Suitable Scenarios	- Limited ECMO resources.	- High-resource urban systems with centralized ECMO expertise.	- Regions with pre-hospital ECMO-trained teams.
	- Rural/remote areas with no mobile ECMO capabilities.	- Pre-established EMS-hospital protocols.	- High-volume urban EMS systems.
	- Time from CA to arrival at the hospital <30 minutes.		

ECPR, extracorporeal cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; MoICU, mobile intensive care unit; ECMO, extracorporeal membrane oxygenation; EMS, emergency medical services; CA, cardiac arrest.

dong Medical Doctor Association, in collaboration with domestic and international ECPR specialists, have developed this consensus document through multiple rounds of discussions. This consensus aims to establish standardized protocols for pre-hospital ECPR, including indications, establishment, management, and team construction, thereby serving as a comprehensive guide for ECMO practitioners in China.

Methodology for Consensus Development

Establishment of Consensus Writing and Expert Panels

The consensus writing team was primarily responsible for literature retrieval and screening, defining consensus topics and clinical questions, organizing expert discussions, collecting and synthesizing expert opinions, and revising the consensus content. A comprehensive literature search was conducted across PubMed (U.S. National Library of Medicine), the Cochrane Library, and the China National Knowledge Infrastructure (CNKI), covering publications from their inception to 30 November 2024. The search strategy was tailored to each database. For PubMed and Cochrane, Boolean search terms were used. Keywords included "extracorporeal membrane oxygenation", "ECMO", "extracorporeal cardiopulmonary resuscitation", "ECPR", "out-of-hospital cardiac arrest", and "pre-hospital". For CNKI, the Chinese equivalents of these terms were used in combination with Boolean operators to ensure comprehensive coverage. The literature selection prioritized systematic reviews, RCTs, cohort studies, case-control studies, and case series, with human subjects and in English or the Chinese language. The titles and abstracts were screened independently by two reviewers (GW and FS), and full texts assessed for eligibility. The expert panel reviewed the selected literature and contributed to evaluating and refining the consensus content based on the evidence.

Development of Consensus Topics and Key Content

This consensus was initiated and led by the Emergency Medicine Branch of the Chinese Medical Association and the Emergency Medicine Branch of the Guangdong Medical Doctor Association. The development process included topic selection and approval, formation of the expert writing group, identification of critical clinical questions, and development of the consensus framework based on literature review and expert experience. Consensus conferences and structured expert voting were conducted at each key step.

Expert Review, Voting, and Finalization of the Consensus

The initial draft of the consensus was prepared by the writing group and circulated to all expert panel members. Feedback was collected, analyzed, and incorporated into subsequent drafts. Disagreement among experts was resolved through structured discussion and additional voting rounds, following a modified Delphi method. During the final consensus meeting, each recommendation was subjected to anonymous voting. Experts rated their agreement with each statement using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). Recommendations that received ≥80% agreement (score of 4 or 5) were considered to have reached consensus. All final recommendations achieved this threshold, and most received unanimous or near-unanimous support. The writing group then approved the final version.

Pre-Hospital ECPR Dispatch Protocol

The dispatch center for OHCA cases should be determined based on the specific emergency response structure of each city. In cities where EMS is centrally coordinated by the 120 system (the emergency medical telephone number in mainland China). Dispatch center the dispatch center should serve as the primary command hub. Conversely, in cities where hospitals primarily manage EMS, the designated hospital's emergency service unit should function as the dispatch center. All pre-hospital emergency response teams providing OHCA care should operate under the centralized coordination of their respective dispatch center. ECPR-capable teams should be allocated according to the principle of geographical proximity, necessitating the clear identification and registration of all ECPR-qualified units within the system. These units should be integrated into the centralized dispatch network, with the central call-receiving system distributing case assignments systematically. Fig. 1 illustrates a recommended workflow from initial patient contact to initiation of ECPR. Each region should develop its own protocol based on the actual structure and capabilities of its local EMS.

Recommendation 1: *Establish a city-wide ECPR Resuscitation Alliance, centrally coordinated by the municipal emergency response center. All alliance members maintain dedicated pre-hospital ECPR teams on standby, ready for immediate deployment through the unified dispatch system.*

Recommendation 2: *Upon receiving a suspected CA call, emergency medical dispatchers immediately deploy an EMS team to the scene while providing telephone-guided chest compression instructions to the caller to minimize no-flow time. The dispatched EMS team promptly initiates BLS while rapidly assessing the patient's ECPR eligibility, simultaneously relaying this evaluation to the dispatch center. If the patient meets preliminary criteria for ECPR consideration, the dispatch center activates the nearest ECPR-capable unit to mobilize a specialized response team to the scene.*

Recommendation 3: *Each ECPR team is to maintain 24/7 on-call readiness and be capable of immediate mobilization upon receiving dispatch center activation, with the goal of achieving the shortest possible response time to the treatment site. A backup team should be on standby during active ECPR deployments.*

ECPR Team Qualifications and Training

The management of OHCA requires a highly trained and coordinated pre-hospital team. ECPR is a complex procedure that requires proficiency in femoral artery and vein cannulation, as well as the use of ultrasound guidance. Team members must be carefully selected and receive rigorous training, including continuous ECPR cannulation practice, regular case reviews, emergency drills, and periodic ECPR simulation exercises [30].

Recommendation 4: *The ECPR Alliance should establish specialized pre-hospital ECPR teams comprising emergency or intensive care physicians, pre-hospital nurses, surgical specialists, and other relevant personnel [31,32].*

Recommendation 5: *Team members must complete a minimum of 3 months of theoretical and practical training at an accredited ECMO center, while also demonstrating proficiency in resuscitation and critical care management.*

Recommendation 6: *Each ECPR team should operate with clearly defined roles to ensure efficient task distribution during high-stress scenarios (Fig. 2).*

ECPR Equipment and Logistics

The French EMS (Service d'Aide Médicale Urgente, SAMU) first proposed an ECPR protocol in 2011, establishing mobile intensive care units (MoICUs) to provide comprehensive care at an arrest site. MoICUs are fully equipped with essential medical devices, including ECMO, enabling immediate evaluation and intervention prior to patient transfer to the most suitable facility. The MoICU and ECPR team maintain 24/7 readiness for deployment to OHCA scenes. Within each city-wide ECPR alliance, all member institutions are equipped with MoICUs and operate in close coordination with the ECPR-providing teams. Upon receiving a dispatch order from the emergency command center, the MoICU and the express response team are immediately deployed to the scene. ECMO initiation is performed either on-site or within the MoICU, after which the patient is transported to a designated hospital for further treatment. This integrated model ensures seamless pre-hospital and in-hospital care, ensuring high-quality resuscitation while identifying the arrest etiology. Studies indicate that 59% of cardiac arrest causes can be identified within MoICUs [33].

Recommendation 7: *MoICUs should be established and equipped with portable ECMO machines, blood gas analyzers, ultrasound devices, defibrillators, electrocardiogram (ECG) machines, transport ventilators, infusion pumps, oxygen supplies, emergency medications, and other essential equipment.*

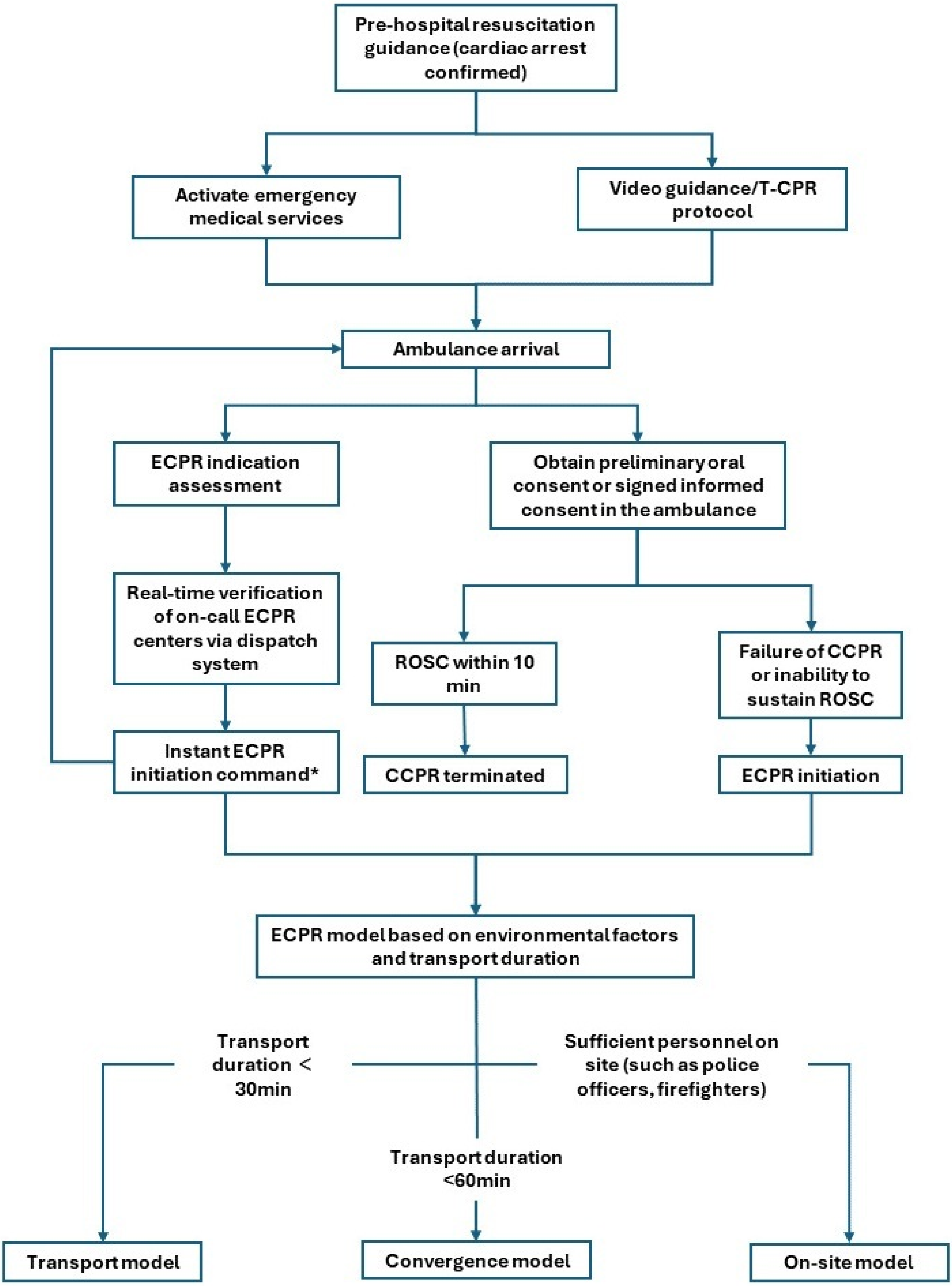
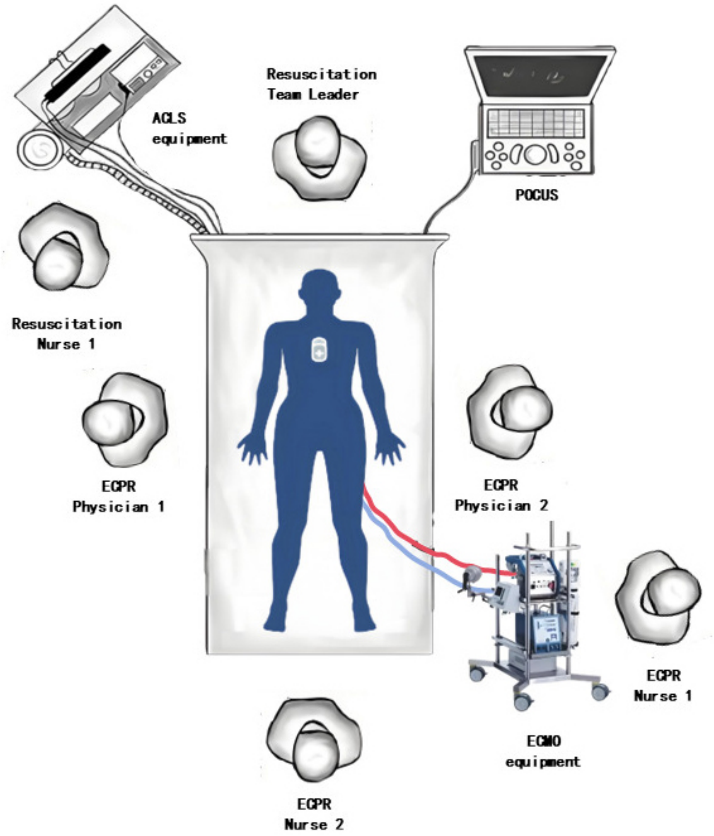


Fig. 1. Recommended workflow from initial patient contact to ECPR initiation. T-CPR, Telephone-assisted Cardiopulmonary Resuscitation; ECPR, extracorporeal cardiopulmonary resuscitation; CCPR, conventional cardiopulmonary resuscitation; ROSC, return of spontaneous circulation. *The location and strategy for ECPR initiation may be referred to in the relevant recommendations of this consensus. This flow chart was created using Microsoft Office LTSC Professional Plus 2024 PowerPoint (Microsoft Corporation, Redmond, WA, USA).



Resuscitation Team Leader (Physician or Senior Nurse):
- Obtain patient history from witnesses or family members and secure treatment informed consent for all interventions, including ECPR.
- Direct and supervise the implementation of Advanced Cardiovascular Life Support (ACLS) interventions.
- Establish advanced airway management and secure intravenous/intraosseous (IV/IO) access.
- Initiate the ECPR process.

Resuscitation Nurse 1:
- Manage ventilation support.
- Administer medications.
- Control time and ACLS processes.

Nurse/EMS Technician 2:
- Manage the scene.
- Operate mechanical CPR devices.

(At least 2) ECPR Physicians:
- Assess suitability for ECPR.
- Lead the team during ECMO implementation.
- Perform arterial and venous cannulation under real-time point-of-care ultrasound (POCUS) guidance.

ECPR Nurse 1:
- Prepare ECMO circuits.
- Manage critical nursing issues post-ECMO initiation.

ECPR Nurse 2:
- Assist the ECPR physician.
- Help EMS personnel manage the scene and coordinate patient care.

Fig. 2. ECPR Medical Team Position during resuscitation. This schematic was created using Microsoft Office LTSC Professional Plus 2024 PowerPoint (Microsoft Corporation, Redmond, WA, USA). ACLS, advanced cardiac life support; POCUS, point-of-care ultrasound; ECPR, extracorporeal cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation.

ECPR Indications and Timing

Bystander CPR and No-Flow Time

Early initiation of chest compressions and other BLS measures is critical in OHCA. Bystander CPR maintains essential blood flow to vital organs, reducing the risk of brain injury and improving long-term neurological outcomes [34]. Studies show that bystander-initiated CPR significantly enhances 30-day survival in witnessed CA cases. CPR within 5 minutes improves survival 2.3-fold, while CPR within 10 minutes increases survival 3-fold compared with no bystander CPR [35]. Initiating CPR within 5 to 10 minutes significantly improves OHCA prognosis, but benefits diminish if no-flow time exceeds 10 minutes [35]. ECPR should ideally begin within 5 minutes of bystander CPR, with a maximum delay of 10 minutes.

Recommendation 8: *Bystander CPR or a no-flow time of less than 5 minutes (ideally within 10 minutes) should be considered for ECPR eligibility.*

Shockable Rhythms and Transient ROSC

In determining whether to initiate ECPR, several factors must be considered. The presence of a shockable initial rhythm (such as ventricular fibrillation or pulseless ventricular tachycardia) or brief ROSC during resuscitation significantly influences prognosis. According to Bougouin *et al.* [36], based on a prospective registry of 13,191 OHCA cases in the Paris region from May 2011 to January 2018, an initial shockable rhythm in patients receiving ECPR was significantly associated with increased hospital survival (odds ratio 3.9). These findings suggest that the presence of a shockable rhythm at the time of arrest is a critical criterion for ECPR eligibility. As such, several guidelines have incorporated shockable initial rhythms as an indication for ECPR intervention [37].

Recommendation 9: *ECPR should be actively considered for patients with shockable initial rhythms, transient ROSC during resuscitation, shockable rhythms emerging during CPR, or recurrent CA episodes.*

Age Considerations

Age significantly influences prognosis following CA, with studies showing a negative correlation between age and favorable outcomes since older patients exhibit poorer survival and neurological recovery [36]. Some set an upper age limit of 70 years for ECPR inclusion [38,39], while others excluded patients aged 70–75 [40,41]. Both the Journal of the American College of Cardiology (JACC) Expert Consensus and the ELSO guidelines recommend a 70-year age limit for ECPR [37,42]. Domestic guidelines suggest an ECPR eligibility range of 18–70 years but emphasize individualized clinical application based on comprehensive assessments, including comorbidities and neurological prognosis. In selected cases with preserved organ function and favorable neurological outcomes, the age criteria might be extended [43].

Recommendation 10: *ECPR should primarily target patients under 70 years old, but age criteria may be extended for selected patients with preserved organ function and favorable neurological prognosis.*

Low-Flow Duration and Timing of ECMO

The no-flow duration is another critical determinant of ECPR suitability [44]. Prolonged ineffective circulation significantly worsens the prognosis. A retrospective cohort study of a single-center CA database by Reynolds *et al.* [45] revealed that conventional resuscitation was most effective within the first 10–15 minutes; beyond 15 minutes, the likelihood of favorable functional recovery dropped to approximately 2% [45]. Survival fell below 5% when ECPR was initiated after 20 minutes of CCPR [37]. A retrospective analysis of a prospective cohort from May 2006 to December 2013 by Kim *et al.* [46] found that a favorable neurologic outcome was associated with less than 21 minutes of CCPR, suggesting that ECPR should be considered an alternative strategy for OHCA patients who require prolonged resuscitation, particularly beyond 21 minutes. The Paris phase II study demonstrated successful ECPR initiation even after 20 minutes of CCPR, with favorable outcomes in some cases [47]. These findings aligned with recommendations from the European Resuscitation Council and expert consensus on percutaneous cannulation for ECPR that advocated ECMO support within 60 minutes of CA to restore effective circulatory flow [48]. Current evidence suggests that 60 minutes is the optimal window for achieving adequate circulatory support [20]. Cannulation for ECPR might reasonably begin after 10–20 minutes of failed resuscitation [37].

In light of the available evidence, we recommend initiating ECPR within 20 minutes of CCPR, with preparatory measures starting at approximately 10 minutes of CCPR, while ensuring adequate circulatory support within 60 minutes.

Recommendation 11: *ECPR should be initiated within 20 minutes of CCPR, with preparations beginning around the 10-minute mark, and ECMO should be established within 60 minutes of the CA event.*

Pre-ECPR Conventional Cardiopulmonary Resuscitation (CCPR)

Upon arrival at the emergency scene, at least one EMS-trained physician should lead the provision of BLS and ALS measures, including endotracheal intubation, intravenous access, and emergency medication administration. Standard advanced cardiovascular life support (ACLS) protocols should continue until successful ECMO cannulation and operation of the device.

Recommendation 12: *Maintain standard ACLS before initiating ECPR.*

During the ECMO cannulation process, uninterrupted chest compressions should be continued. Compressions should continue with minimal disruption during this critical phase, ensuring they do not significantly hinder the procedure. Compressions should continue until ECMO circulation is established with stable flow rates of 3 L/min [37]. We strongly recommend using mechanical chest compression devices since they reduce operator fatigue, minimize personnel requirements, and provide optimal working space for the team. These devices are particularly advantageous during cannulation, maintaining consistent compression quality and minimizing physical interference, especially when resuscitation is prolonged [49].

Recommendation 13: *Maintain continuous external chest compressions throughout ECPR cannulation and use mechanical chest compression devices.*

Sites for Pre-Hospital ECPR Implementation

OHCA may occur in diverse locations, including residential areas and public spaces such as plazas, subways, and bus stations. Selecting an appropriate ECPR initiation site requires careful consideration of multiple factors, including environmental contamination risks, crowd density, patient privacy, and equipment transportation logistics. Given the critical time requirement to establish ECPR within 60 minutes, the on-site resuscitation team leader should make a real-time decision based on environmental factors and transportation duration. This decision should consider whether to initiate ECPR at the scene, transport the patient to the nearest hospital with simultaneous activation of the ECPR team, or transfer directly to a hospital with established ECPR capabilities.

Recommendation 14: *If the anticipated transfer time exceeds the 60-minute window for establishing ECMO, strongly consider immediate transfer to a MoICU for ECPR initiation. In cases of limited physical space or restricted access (e.g., narrow stairwells or high-rise buildings), routinely use mechanical chest compression devices during transport to ensure uninterrupted high-quality resuscitation.*

Recommendation 15: *When sufficient personnel (e.g., police, firefighters, or security staff) are available, on-*

site ECPR in open spaces such as plazas, subways, or bus stations may be feasible. Personnel should use screens or barriers to protect patient privacy, evacuate non-essential bystanders, and follow proper sterile techniques to minimize contamination risks.

Recommendation 16: *If the estimated time to reach an ECPR-capable hospital is less than 30 minutes, in-hospital ECPR after transfer is recommended.*

ECPR Procedures and Techniques

For pre-hospital ECPR implementation, percutaneous vascular cannulation should be performed under real-time portable ultrasound guidance. Strict aseptic protocols should be adopted, including thorough disinfection, proper draping, and the use of sterile surgical attire (gowns and gloves) to minimize infection risks. Defibrillation is not required during this phase. Following guidewire insertion, proper positioning should be confirmed by ultrasound, avoiding reliance on vascular pulsation or blood color for vessel identification [48]. Arterial and venous cannula diameters should be selected according to the same standards as in-hospital ECPR protocols.

Recommendation 17: *The recommended cannula sizes are 15–17 Fr for the femoral artery and 19–25 Fr for the femoral vein [50].*

ECPR Patient Transport and Parameter Targets

ECMO equipment is complex, involving large components such as the ECMO machine, oxygen cylinders, and temperature control devices (e.g., water baths used in conjunction with heat exchangers to maintain optimal temperature). Conventional stretchers are often inadequate for pre-hospital transport. After performing ECPR on-site, patients need to be transferred to the MoICU using a custom transport stretcher while employing a targeted temperature management (TTM) strategy. To ensure the quality of ECMO transfer and improve patient survival, target values for parameters such as blood pressure, blood gas analysis, ventilator settings, hemoglobin level, and central venous oxygen saturation should be set [49]. Simultaneously, rapid bedside diagnostic testing should be performed in the MoICU to identify underlying etiologies, including troponin levels, cardiac enzymes, and D-dimer assays. Given the potential for oxygen supply-demand imbalance due to intrinsic factors or procedural blood loss, blood type and crossmatch should be initiated during MoICU transport. The receiving hospital must activate its emergency priority pathway to ensure timely access to blood products for potential transfusion.

Decisions regarding the continuation or withdrawal of life-sustaining treatment should not be made in the pre-hospital setting. Clinical decisions must be deferred until an in-hospital critical care environment is reached and following comprehensive evaluation, prognostication, and ethical consultation when necessary.

Recommendation 18: *Custom ECMO transport beds with dedicated compartments for the ECMO machine, oxygen tanks, and water reservoirs are recommended.*

Recommendation 19: *Essential post-ECMO initiation care protocols are recommended as follows:*

Targeted Temperature Management (TTM):

- *All patients should receive TTM after ECMO initiation.*

Hemodynamic Monitoring and Target Blood Pressure:

- *Insert a right radial artery catheter to monitor arterial blood pressure, maintaining a mean arterial pressure (MAP) above 65 mmHg.*

Arterial Blood Gas Analysis and Management:

- *Perform arterial blood gas analysis immediately post-ECMO initiation, targeting:*

pH > 7.2
Partial pressure of oxygen (PaO_2): 100–150 mmHg
Partial pressure of carbon dioxide ($PaCO_2$): 40–45 mmHg

Adjust oxygen concentration and gas flow rate to achieve these targets.

Ventilator Settings:

- *Set ventilator parameters to:*

Mode: Assist-Control/Volume Control (AC/VC)
Positive end-expiratory pressure (PEEP): 8 cmH_2O
Tidal volume: 6 mL/kg predicted body weight.

Central Venous Oxygen Saturation ($ScvO_2$):

- *Maintain central venous oxygen saturation ($ScvO_2$) at 60%–70%.*

Recommendation 20: *During transport, ECMO should maintain a target flow rate of 60–80 mL/kg/min. If the flow rate drops significantly or there is tubing oscillation, fluid should be administered (such as albumin) to increase effective blood volume. Anticoagulation should be closely monitored, with activated clotting time (ACT) level maintained above 300 seconds [51].*

Recommendation 21: *After ECMO establishment and restoration of spontaneous cardiac rhythm, obtain an ECG and perform comprehensive cardiac biomarker evaluation (e.g., troponin and cardiac enzymes). If acute myocardial infarction is suspected, prioritize immediate transfer via the emergency priority pathway for urgent coronary angiography and potential revascularization.*

ECPR in Special Situations

Reports indicate that ECPR can be successfully implemented in special circumstances, such as marathon races or extreme sports events [52], where MoICUs provide critical support for OHCA patients.

Recommendation 22: *Risk assessments should be conducted prior to large events, with steps taken to mitigate* *identified risks. Coordinate with event organizers, health authorities, and relevant agencies to prepare financial, human, and medical resources. Medical stations should be strategically positioned, equipped with MoICUs containing ECMO devices. All personnel involved in event medical support, including healthcare providers, medical volunteers, and EMS staff, should receive training in emergency resuscitation and ECPR indications to ensure readiness for such interventions.*

Limitation

The abovementioned ECPR models are primarily drawn from international experience and serve as reference frameworks. ECPR implementation in China should be adapted according to regional healthcare resources, EMS capabilities, and system readiness. Pilot studies in the Chinese emergency context are essential to develop locally appropriate ECPR models and assess their clinical effectiveness. It should also be noted that the current recommendations regarding ECPR indications, such as age limits and acceptable low-flow times, are primarily based on international evidence from well-established ECPR programs. Registries in China, while providing essential epidemiological data, do not report ECPR-specific outcomes. In the absence of domestic data for ECPR, the consensus panel adapted recommendations from international sources with caution and expert clinical judgment. Future prospective studies and the development of national ECPR registries are urgently needed to validate and refine these criteria within the Chinese population.

Conclusion

ECPR is a promising intervention for selected patients with OHCA who are unresponsive to conventional resuscitation. Timely identification, strict patient selection, and ECMO initiation within 60 minutes of collapse are key to improving outcomes. Favorable prognostic factors include witnessed arrest, initial shockable rhythm, bystander CPR, and transient ROSC.

Despite its complexity and resource demands, ECPR can significantly enhance survival and neurological recovery when implemented within coordinated systems of care. Strategies to reduce time to initiation include pre-hospital ECPR programs, regional ECPR networks with streamlined activation pathways, standardized inclusion protocols, and integration of EMS with hospital ECPR teams through real-time communication and simulation-based training. Pre-positioning ECMO equipment and raising awareness among providers and the public may further expedite deployment.

Large-scale, prospective studies are needed to refine indications, optimize workflows, and validate the efficacy of ECPR in OHCA management.

Abbreviations

OHCA, out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; ECPR, extracorporeal cardiopulmonary resuscitation; CCPR, conventional cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; CA, cardiac arrest; ROSC, return of spontaneous circulation; EMS, emergency medical services; CPC, Cerebral Performance Category; BLS, basic life support; RCT, randomized controlled trial; ELSO, Extracorporeal Life Support Organization; ALS, advanced life support; MoICU, mobile intensive care unit; ECG, electrocardiogram; JACC, Journal of the American College of Cardiology; ACLS, advanced cardiovascular life support; TTM, targeted temperature management; MAP, mean arterial pressure.

Availability of Data and Materials

Not applicable.

Author Contributions

GW contributed to the investigation. FS was responsible for formal analysis. BL contributed to visualization and data curation. WJ was involved in conceptualization. BH contributed to validation and methodology. GZ provided resources and contributed to methodology and validation. XL was involved in conceptualization, supervised the project, and was responsible for project administration. All authors were involved in the drafting and critical revision of the manuscript. All authors have read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

The Consensus Committee: Chunshui Cao (The First Affiliated Hospital of Nanchang University); Yu Cao (West China Hospital of Sichuan University); Xufeng Chen (Jiangsu Provincial People's Hospital); Ying Deng (The Second Affiliated Hospital of Harbin Medical University); Jianjun Gui (Shenzhen Bao'an Shiyan People's Hospital); Xiaotong Han (Hunan Provincial People's Hospital); Bei Hu (Guangdong Provincial People's Hospital); Wenqiang Jiang (Guangdong Provincial People's Hospital); Jian Kang (The First Affiliated Hospital of Dalian Medical University); Chuanbao Li (Qilu Hospital of Shandong University); Xin Li (Guangdong Provincial People's Hospital); Liwen Lyu (People's Hospital of Guangxi Zhuang Autonomous Region); Yanhong Ouyang (Hainan Provincial

People's Hospital); Lijie Qin (Henan Provincial People's Hospital); Zhenju Song (Zhongshan Hospital of Fudan University); Jihong Xing (The First Hospital of Jilin University); Feng Xu (Qilu Hospital of Shandong University); Jun Xu (Peking Union Medical College Hospital); Shanxiang Xu (The Second Affiliated Hospital of Zhejiang University School of Medicine; Xianliang Yan (Affiliated Hospital of Xuzhou Medical University); Guoqiang Zhang (China-Japan Friendship Hospital); Guangju Zhou (The Second Affiliated Hospital of Zhejiang University School of Medicine); Abdelouahab Bellou (Emergency Medicine Institute of Guangdong Provincial People's Hospital). The authors would like to extend their sincere gratitude to Dr. Haiwei He from Guangdong Provincial People's hospital for his assistance in editing and enhancing the figures. They are also deeply grateful to Dr. Francesca Rubulotta from McGill University and Dr. Robert Dunne from Wayne State University for their generous and constructive feedback on this article. Additionally, the authors thank Ms. Sarah Aglionby for editing the manuscript.

Funding

This study was funded by Noncommunicable Chronic Diseases-National Science and Technology Major Project (2023ZD0505500) and the National key research and development program intergovernmental key projects (2023YFE0114300).

Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.24976/Discov.Med.202537198.106.

References

[1] Wong CX, Brown A, Lau DH, Chugh SS, Albert CM, Kalman JM, *et al*. Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives. Heart, Lung & Circulation. 2019; 28: 6–14. https://doi.org/10.1016/j.hlc.2018.08.026.

[2] Porzer M, Mrazkova E, Homza M, Janout V. Out-of-hospital cardiac arrest. Biomedical Papers of the Medical Faculty of the University Palacky, Olomouc, Czechoslovakia. 2017; 161: 348–353. https://doi.org/10.5507/bp.2017.054.

[3] Lemiale V, Dumas F, Mongardon N, Giovanetti O, Charpentier J, Chiche JD, *et al*. Intensive care unit mortality after cardiac arrest: the relative contribution of shock and brain injury in a large cohort. Intensive Care Medicine. 2013; 39: 1972–1980. https://doi.org/10.1007/s00134-013-3043-4.

[4] Gräsner JT, Wnent J, Herlitz J, Perkins GD, Lefering R, Tjelmeland I, *et al*. Survival after out-of-hospital cardiac arrest in Europe - Results of the EuReCa TWO study. Resuscitation. 2020; 148: 218–226. https://doi.org/10.1016/j.resuscitation.2019.12.042.

[5] Zheng J, Lv C, Zheng W, Zhang G, Tan H, Ma Y, *et al*. Incidence, process of care, and outcomes of out-of-hospital cardiac arrest in China: a prospective study of the BASIC-OHCA registry. The Lancet. Public Health. 2023; 8: e923–e932. https://doi.org/10.1016/S2468-2667(23)00173-1.

[6] Rob D, Bělohlávek J. The mechanical support of cardiogenic shock. Current Opinion in Critical Care. 2021; 27: 440–446. https://doi.org/10.1097/MCC.0000000000000837.

[7] Yannopoulos D, Bartos J, Raveendran G, Walser E, Connett J, Murray TA, *et al*. Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial. Lancet (London, England). 2020; 396: 1807–1816. https://doi.org/10.1016/S0140-6736(20)32338-2.

[8] Bian Y, Pan Y, Zheng J, Zheng W, Qin L, Zhou G, *et al*. Extracorporeal Versus Conventional Cardiopulmonary Resuscitation for In-Hospital Cardiac Arrest: A Propensity Score Matching Cohort Study. Critical Care Medicine. 2024; 52: e268–e278. https://doi.org/10.1097/CCM.0000000000006223.

[9] Yannopoulos D, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, *et al*. Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation. 2005; 64: 363–372. https://doi.org/10.1016/j.resuscitation.2004.10.009.

[10] Stub D, Byrne M, Pellegrino V, Kaye DM. Extracorporeal membrane oxygenation to support cardiopulmonary resuscitation in a sheep model of refractory ischaemic cardiac arrest. Heart, Lung & Circulation. 2013; 22: 421–427. https://doi.org/10.1016/j.hlc.2012.11.020.

[11] Martin GB, Rivers EP, Paradis NA, Goetting MG, Morris DC, Nowak RM. Emergency department cardiopulmonary bypass in the treatment of human cardiac arrest. Chest. 1998; 113: 743–751. https://doi.org/10.1378/chest.113.3.743.

[12] Tonna JE, Boonstra PS, MacLaren G, Paden M, Brodie D, Anders M, *et al*. Extracorporeal Life Support Organization Registry International Report 2022: 100,000 Survivors. ASAIO Journal (American Society for Artificial Internal Organs: 1992). 2024; 70: 131–143. https://doi.org/10.1097/MAT.0000000000002128.

[13] Schmidt M, Burrell A, Roberts L, Bailey M, Sheldrake J, Rycus PT, *et al*. Predicting survival after ECMO for refractory cardiogenic shock: the survival after veno-arterial-ECMO (SAVE)-score. European Heart Journal. 2015; 36: 2246–2256. https://doi.org/10.1093/eurheartj/ehv194.

[14] Low CJW, Ling RR, Ramanathan K, Chen Y, Rochwerg B, Kitamura T, *et al*. Extracorporeal cardiopulmonary resuscitation versus conventional CPR in cardiac arrest: an updated meta-analysis and trial sequential analysis. Critical Care (London, England). 2024; 28: 57. https://doi.org/10.1186/s13054-024-04830-5.

[15] Low CJW, Ramanathan K, Ling RR, Ho MJC, Chen Y, Lorusso R, *et al*. Extracorporeal cardiopulmonary resuscitation versus conventional cardiopulmonary resuscitation in adults with cardiac arrest: a comparative meta-analysis and trial sequential analysis. The Lancet. Respiratory Medicine. 2023; 11: 883–893. https://doi.org/10.1016/S2213-2600(23)00137-6.

[16] Belohlavek J, Smalcova J, Rob D, Franek O, Smid O, Pokorna M, *et al*. Effect of Intra-arrest Transport, Extracorporeal Cardiopulmonary Resuscitation, and Immediate Invasive Assessment and Treatment on Functional Neurologic Outcome in Refractory Out-of-Hospital Cardiac Arrest: A Randomized Clinical Trial. JAMA. 2022; 327: 737–747. https://doi.org/10.1001/jama.2022.1025.

[17] Heuts S, van de Koolwijk AF, Gabrio A, Ubben JFH, van der Horst ICC, Delnoij TSR, *et al*. Extracorporeal life support in car-

diac arrest: a post hoc Bayesian re-analysis of the INCEPTION trial. European Heart Journal. Acute Cardiovascular Care. 2024; 13: 191–200. https://doi.org/10.1093/ehjacc/zuad130.
[18] Khoury J, Soumagnac T, Vimpere D, El Morabity A, Hutin A, Raphalen JH, *et al*. Long-term heart function in refractory out-of-hospital cardiac arrest treated with prehospital extracorporeal cardiopulmonary resuscitation. Resuscitation. 2025; 207: 110449. https://doi.org/10.1016/j.resuscitation.2024.110449.
[19] Berg KM, Bray JE, Ng KC, Liley HG, Greif R, Carlson JN, *et al*. 2023 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. Circulation. 2023; 148: e187–e280. https://doi.org/10.1161/CIR.0000000000001179.
[20] Wang CH, Chou NK, Becker LB, Lin JW, Yu HY, Chi NH, *et al*. Improved outcome of extracorporeal cardiopulmonary resuscitation for out-of-hospital cardiac arrest–a comparison with that for extracorporeal rescue for in-hospital cardiac arrest. Resuscitation. 2014; 85: 1219–1224. https://doi.org/10.1016/j.resuscitation.2014.06.022.
[21] Shin YS, Kim YJ, Ryoo SM, Sohn CH, Ahn S, Seo DW, *et al*. Promising candidates for extracorporeal cardiopulmonary resuscitation for out-of-hospital cardiac arrest. Scientific Reports. 2020; 10: 22180. https://doi.org/10.1038/s41598-020-79283-1.
[22] Tanimoto A, Sugiyama K, Tanabe M, Kitagawa K, Kawakami A, Hamabe Y. Out-of-hospital cardiac arrest patients with an initial non-shockable rhythm could be candidates for extracorporeal cardiopulmonary resuscitation: a retrospective study. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2020; 28: 101. https://doi.org/10.1186/s13049-020-00800-2.
[23] Ehara N, Hirose T, Shiozaki T, Wakai A, Nishimura T, Mori N, *et al*. The relationship between cerebral regional oxygen saturation during extracorporeal cardiopulmonary resuscitation and the neurological outcome in a retrospective analysis of 16 cases. Journal of Intensive Care. 2017; 5: 20. https://doi.org/10.1186/s40560-017-0216-1.
[24] Oliver M, Coggins A, Kruit N, Burns B, Plunkett B, Morgan S, *et al*. Implementing enhanced extracorporeal membrane oxygenation for CPR (ECPR) in the emergency department. International Journal of Emergency Medicine. 2024; 17: 71. https://doi.org/10.1186/s12245-024-00652-y.
[25] Dyson S. NSW Ambulance Cardiac Arrest Registry—2017 Report. Rozelle: New South Wales [NSW], Australia. 2019.
[26] Song C, Dennis M, Burns B, Dyson S, Forrest P, Ramanan M, *et al*. Improving access to extracorporeal membrane oxygenation for out of hospital cardiac arrest: pre-hospital ECPR and alternate delivery strategies. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine. 2022; 30: 77. https://doi.org/10.1186/s13049-022-01064-8.
[27] Suverein MM, Delnoij TSR, Lorusso R, Brandon Bravo Bruinsma GJ, Otterspoor L, Elzo Kraemer CV, *et al*. Early Extracorporeal CPR for Refractory Out-of-Hospital Cardiac Arrest. The New England Journal of Medicine. 2023; 388: 299–309. https://doi.org/10.1056/NEJMoa2204511.
[28] Bartos JA, Frascone RJ, Conterato M, Wesley K, Lick C, Sipprell K, *et al*. The Minnesota mobile extracorporeal cardiopulmonary resuscitation consortium for treatment of out-of-hospital refractory ventricular fibrillation: Program description, performance, and outcomes. EClinicalMedicine. 2020; 29-30: 100632. https://doi.org/10.1016/j.eclinm.2020.100632.
[29] Pozzi M, Cesareo E, Pinero D, Dubien PY, Richard JC. Prehospital extracorporeal cardiopulmonary resuscitation for refractory out-of-hospital cardiac arrest: Preliminary results of a multidisciplinary approach. Resuscitation. 2022; 176: 19–20. https://doi.org/10.1016/j.resuscitation.2022.04.031.
[30] Kruit N, Burrell A, Tian D, Barrett N, Bělohlávek J, Bernard S, *et al*. Expert consensus on training and accreditation for extracorporeal cardiopulmonary resuscitation an international, multidisciplinary modified Delphi Study. Resuscitation. 2023; 192: 109989. https://doi.org/10.1016/j.resuscitation.2023.109989.
[31] Mooney MR, Arom KV, Joyce LD, Mooney JF, Goldenberg IF, Von Rueden TJ, *et al*. Emergency cardiopulmonary bypass support in patients with cardiac arrest. The Journal of Thoracic and Cardiovascular Surgery. 1991; 101: 450–454.
[32] Bellezzo JM, Shinar Z, Davis DP, Jaski BE, Chillcott S, Stahovich M, *et al*. Emergency physician-initiated extracorporeal cardiopulmonary resuscitation. Resuscitation. 2012; 83: 966–970. https://doi.org/10.1016/j.resuscitation.2012.01.027.
[33] Chelly J, Mongardon N, Dumas F, Varenne O, Spaulding C, Vignaux O, *et al*. Benefit of an early and systematic imaging procedure after cardiac arrest: insights from the PROCAT (Parisian Region Out of Hospital Cardiac Arrest) registry. Resuscitation. 2012; 83: 1444–1450. https://doi.org/10.1016/j.resuscitation.2012.08.321.
[34] Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, *et al*. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. Circulation. 2009; 120: 1241–1247. https://doi.org/10.1161/CIRCULATIONAHA.109.852202.
[35] Rajan S, Wissenberg M, Folke F, Hansen SM, Gerds TA, Kragholm K, *et al*. Association of Bystander Cardiopulmonary Resuscitation and Survival According to Ambulance Response Times After Out-of-Hospital Cardiac Arrest. Circulation. 2016; 134: 2095–2104. https://doi.org/10.1161/CIRCULATIONAHA.116.024400.
[36] Bougouin W, Dumas F, Lamhaut L, Marijon E, Carli P, Combes A, *et al*. Extracorporeal cardiopulmonary resuscitation in out-of-hospital cardiac arrest: a registry study. European Heart Journal. 2020; 41: 1961–1971. https://doi.org/10.1093/eurheartj/ehz753.
[37] Richardson ASC, Tonna JE, Nanjayya V, Nixon P, Abrams DC, Raman L, *et al*. Extracorporeal Cardiopulmonary Resuscitation in Adults. Interim Guideline Consensus Statement From the Extracorporeal Life Support Organization. ASAIO Journal (American Society for Artificial Internal Organs: 1992). 2021; 67: 221–228. https://doi.org/10.1097/MAT.0000000000001344.
[38] Cesana F, Avalli L, Garatti L, Coppo A, Righetti S, Calchera I, *et al*. Effects of extracorporeal cardiopulmonary resuscitation on neurological and cardiac outcome after ischaemic refractory cardiac arrest. European Heart Journal. Acute Cardiovascular Care. 2018; 7: 432–441. https://doi.org/10.1177/2048872617737041.
[39] Yannopoulos D, Bartos JA, Martin C, Raveendran G, Missov E, Conterato M, *et al*. Minnesota Resuscitation Consortium's Advanced Perfusion and Reperfusion Cardiac Life Support Strategy for Out-of-Hospital Refractory Ventricular Fibrillation. Journal of the American Heart Association. 2016; 5: e003732. https://doi.org/10.1161/JAHA.116.003732.
[40] Grunau B, Scheuermeyer FX, Stub D, Boone RH, Finkler J, Pennington S, *et al*. Potential Candidates for a Structured Canadian ECPR Program for Out-of-Hospital Cardiac Arrest. CJEM. 2016; 18: 453–460. https://doi.org/10.1017/cem.2016.8.
[41] Wengenmayer T, Rombach S, Ramshorn F, Biever P, Bode C, Duerschmied D, *et al*. Influence of low-flow time on survival after extracorporeal cardiopulmonary resuscitation (eCPR). Critical Care (London, England). 2017; 21: 157. https://doi.org/10.1186/s13054-017-1744-8.
[42] Guglin M, Zucker MJ, Bazan VM, Bozkurt B, El Banayosy A, Estep JD, *et al*. Venoarterial ECMO for Adults: JACC Scientific Expert Panel. Journal of the American College of Cardiology. 2019; 73: 698–716. https://doi.org/10.1016/j.jacc.2018.11.038.

[43] China NHCotPsRo. Technical Operation Standards for Adult Extracorporeal Membrane Oxygenation (2024 Edition). Chinese Journal of Critical Care & Intensive Care Medicine (Electronic Edition). 2024; 427: 46–50. (In Chinese)

[44] Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, *et al*. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. Lancet (London, England). 2008; 372: 554–561. https://doi.org/10.1016/S0140-6736(08)60958-7.

[45] Reynolds JC, Frisch A, Rittenberger JC, Callaway CW. Duration of resuscitation efforts and functional outcome after out-of-hospital cardiac arrest: when should we change to novel therapies? Circulation. 2013; 128: 2488–2494. https://doi.org/10.1161/CIRCULATIONAHA.113.002408.

[46] Kim SJ, Jung JS, Park JH, Park JS, Hong YS, Lee SW. An optimal transition time to extracorporeal cardiopulmonary resuscitation for predicting good neurological outcome in patients with out-of-hospital cardiac arrest: a propensity-matched study. Critical Care (London, England). 2014; 18: 535. https://doi.org/10.1186/s13054-014-0535-8.

[47] Lamhaut L, Hutin A, Puymirat E, Jouan J, Raphalen JH, Jouffroy R, *et al*. A Pre-Hospital Extracorporeal Cardio Pulmonary Resuscitation (ECPR) strategy for treatment of refractory out hospital cardiac arrest: An observational study and propensity analysis. Resuscitation. 2017; 117: 109–117. https://doi.org/10.1016/j.resuscitation.2017.04.014.

[48] Schmitzberger FF, Haas NL, Coute RA, Bartos J, Hackmann A, Haft JW, *et al*. ECPR^2: Expert Consensus on PeRcutaneous Cannulation for Extracorporeal CardioPulmonary Resuscitation. Resuscitation. 2022; 179: 214–220. https://doi.org/10.1016/j.resuscitation.2022.07.003.

[49] Tonna JE, Selzman CH, Mallin MP, Smith BR, Youngquist ST, Koliopoulou A, *et al*. Development and Implementation of a Comprehensive, Multidisciplinary Emergency Department Extracorporeal Membrane Oxygenation Program. Annals of Emergency Medicine. 2017; 70: 32–40. https://doi.org/10.1016/j.annemergmed.2016.10.001.

[50] Burkhoff D, Sayer G, Doshi D, Uriel N. Hemodynamics of Mechanical Circulatory Support. Journal of the American College of Cardiology. 2015; 66: 2663–2674. https://doi.org/10.1016/j.jacc.2015.10.017.

[51] McMichael ABV, Ryerson LM, Ratano D, Fan E, Faraoni D, Annich GM. 2021 ELSO Adult and Pediatric Anticoagulation Guidelines. ASAIO Journal (American Society for Artificial Internal Organs: 1992). 2022; 68: 303–310. https://doi.org/10.1097/MAT.0000000000001652.

[52] Lebreton G, Pozzi M, Luyt CE, Chastre J, Carli P, Pavie A, *et al*. Out-of-hospital extra-corporeal life support implantation during refractory cardiac arrest in a half-marathon runner. Resuscitation. 2011; 82: 1239–1242. https://doi.org/10.1016/j.resuscitation.2011.04.002.