frontiers | Frontiers in Disaster and Emergency Medicine

TYPE Original Research
PUBLISHED 21 January 2026
DOI 10.3389/femer.2025.1724511

OPEN ACCESS

EDITED BY
Robert Ehrman,
Wayne State University, United States

REVIEWED BY
Csaba Dioszeghy,
Surrey and Sussex Healthcare NHS Trust, United Kingdom
Ismet Çelebi,
Gazi University, Türkiye

*CORRESPONDENCE
Gabriel Wardi
✉ gwardi@health.ucsd.edu

RECEIVED 14 October 2025
REVISED 16 December 2025
ACCEPTED 29 December 2025
PUBLISHED 21 January 2026

CITATION
Wardi G, Self M, Trivedi J, Odish M, Pollema T, Yi C, Parrott M, Longhurst CA, Tolia V, Castillo E and Chan T (2026) Impact of an extracorporeal CPR program on out-of-hospital cardiac arrest ambulance arrivals to an academic center emergency department.
Front. Disaster Emerg. Med. 3:1724511.
doi: 10.3389/femer.2025.1724511

Impact of an extracorporeal CPR program on out-of-hospital cardiac arrest ambulance arrivals to an academic center emergency department

Gabriel Wardi[1,2]*, Michael Self[1], Jal Trivedi[1], Mazen Odish[2], Travis Pollema[3], Cassia Yi[4], Michelle Parrott[4], Christopher A. Longhurst[5], Vaishal Tolia[1], Edward Castillo[1] and Theodore Chan[1]

[1]Department of Emergency Medicine, University of California, San Diego, San Diego, CA, United States, [2]Division of Pulmonary, Critical Care, and Sleep Medicine, University of California, San Diego, La Jolla, CA, United States, [3]Division of Cardiovascular and Thoracic Surgery, University of California, San Diego, La Jolla, CA, United States, [4]Department of Nursing, Clinical Mechanical Circulatory Program, University of California, San Diego, La Jolla, CA, United States, [5]Division of Biomedical Informatics, University of California, San Diego, La Jolla, CA, United States

Objectives: Extracorporeal cardiopulmonary resuscitation (ECPR) has seen increasing use globally as a life-saving intervention for patients with refractory cardiac arrest, including those suffering out-of-hospital cardiac arrests (OHCA) transported to the Emergency Department (ED). ECPR requires extensive resource commitment and outcome data for OHCA patients transported to ECPR capable EDs remain limited. The objective of this study was to evaluate the association of implementing an ED ECPR program on OHCA ambulance arrivals to an academic medical center ED.

Methods: We conducted a before-after study at an urban, academic, level 1 trauma, and STEMI-receiving center ED (annual census approximately 50,000). The regional county Emergency Medical Services (EMS) agency (population 3.1 million) initiated an ECPR pilot program to direct Advanced Life Support (ALS) 911 transports of refractory OHCA patients to a limited number of designated as ECPR receiving centers (i.e., ECPR-capable EDs). We analyzed ECPR, OHCA, and total ALS 911 EMS ED transports in the 6 months before (July–Oct 2024, pre-ECPR) and 6 months following (Dec 2024–May 2025, ECPR) county EMS agency designation as an ECPR receiving center. The implementation month, November, was excluded from all analyses. In addition, we compared these 6-month periods with the 6-month period 1 year prior to the implementation (July–Oct 2023, pre1y-ECPR). The number of OHCA per 1,000 ALS transports was compared for each of the three time periods using descriptive statistics and Fisher's exact testing as indicated, with a $p < 0.05$ considered statistically significant.

Results: After ECPR designation, there was an increase in OHCA transports compared with both the pre-ECPR and pre1y-ECPR periods (7.8 vs. 3.2 vs. 3.5 per 1,000 ALS transports, respectively, $p < 0.05$). Of note, only eight OHCA patients transported to the ED in the ECPR period met the County ECPR criteria, and only one was placed on veno-arterial extracorporeal membrane oxygenation.

Conclusion: Inclusion into a county wide ED ECPR program for refractory OHCA resulted in a significant increase in the number of OHCA and ALS transports to an academic medical center ED, even though many of these patients did not actually meet pre-determined criteria for ECPR activation from the field.

KEYWORDS

cardiac arrest, ECMO—extracorporeal membrane oxygenation, ECPR—extracorporeal cardiopulmonary resuscitation, emergency medicine, EMS—emergency medical services

Introduction

Despite advances in prehospital and bystander cardiopulmonary resuscitation (CPR), survival from out-of-hospital cardiac arrest (OHCA) remains poor at less than 10% on hospital discharge worldwide (1). In the past decade, extracorporeal cardiopulmonary resuscitation (ECPR) has emerged as an advanced early intervention to potentially improve favorable neurologic outcomes in cases of refractory OHCA. ECPR calls for the initiation and use of cardiopulmonary bypass primarily through veno-arterial extracorporeal membrane oxygenation (V-A ECMO) to maintain blood oxygenation and critical organ tissue perfusion (2). Pilot ECPR programs for OHCA have been launched in Europe, Asia, and the U.S. with some demonstrating positive results in terms of survival and neurologic outcomes (3–5). It is recommended by the American Heart Association when conventional CPR fails in institutions where required equipment and trained staff are available (2).

ECPR programs for OHCA however require significant resources including advanced hospital capabilities, cross-disciplinary collaboration, and close coordination between pre-hospital and hospital providers, agencies, and institutions (1). In particular, OHCA ECPR initiatives must have a strong foundation within the Emergency Medical Services (EMS) community to identify appropriate patients with OHCA in the field and initiate advanced ECPR measures expeditiously on hospital Emergency Department (ED) arrival.

In 2022, the San Diego metropolitan region launched a county-led regional ECPR system workgroup with multiple stakeholders to "develop a system for connecting selected patients in cardiac arrest to a time-critical intervention, specifically ECPR/ECMO" (6). A regional ECPR pilot program and protocols were approved by the County's EMS authority in mid-2023. In 2024, the region's only School of Medicine and academic medical center joined the pilot program. The feasibility of emergency physicians cannulating within this ECPR system has been described elsewhere (7).

In this study, we compared OHCA arrivals to the academic medical center ED before and after the implementation of ECPR for OHCA and its inclusion in a county wide EMS ECPR program. We sought to test the hypothesis that inclusion into the regional ECPR program would increase the frequency of patients with OHCA, including those who met and did not meet the county ECPR criteria, at our institution.

Materials and methods

Study design

We conducted a pre-post study following the initiation of OHCA ECPR program at an academic medical center participating in a regional community ECPR pilot program. This investigation was completed under institutional review board (IRB #161121). The study was conducted in accordance with strengthening the reporting of observational studies in epidemiology (STROBE) guidelines (8).

Setting

San Diego County, California's second-most populous county with 3.3 million residents, includes 22 hospital EDs receiving over 250,000 patients by Advanced Life Support (ALS) 911 prehospital ambulance response annually. In November 2024, UC San Diego Health, the County's only academic medical center, launched an OHCA ECPR program at its urban (Hillcrest) hospital facility and joined the San Diego county pilot program which launched July 2023. The hospital is a level 1 trauma center and cardiac STEMI and stroke receiving center. The ED has an annual census of approximately 50,000 patients.

Participants

We studied all OHCA patients arriving by 911 to the ED for the 6-month period after the implementation of the ECPR pilot program (ECPR: December 2024 through May 2025) at the academic medical center. We compared the ECPR group with two 6-month time periods before implementation: the 6 months immediately prior to the adoption of ECPR (pre-ECPR: June–October 2024), and the 6 months exactly 1 year before the ECPR comparison period and before the county pilot program launch (pre1y-ECPR: Dec 2023 through May 2024) to address any seasonal variation.

Intervention

As per County ECPR pilot program criteria, all prehospital OHCA patients with 911 response were directly transported to

a designated ECPR-capable center including the participating academic ED if they met the following inclusion criteria: age 18–70 years; witnessed arrest; bystander CPR initiated within 5 min; pulseless shockable cardiac rhythm; at least two defibrillation attempts in the field with refractory OHCA; mechanical CPR device initiation in the field; and approximate time from arrest to ECPR receiving center <45 min.

Outcomes

Data were prospectively collected for all OHCA patients arriving by ALS from EMS 911 records, as well as hospital ED electronic medical record (Epic Systems, Madison, WI). Center-level data elements included total ALS transports, OHCA patients, and ECPR eligibility and initiation rates. Individual patient data elements included initial rhythm, field interventions [bystander CPR (defined as any CPR performed by layperson or prehospital provider, ALS measures), patient response, hospital arrival presentation, arrival cardiac rhythm, and return of spontaneous circulation (ROSC)] from Utstein Criteria (9). The primary outcome measure was frequency of OHCA arrivals to the ED. Secondary outcomes included frequency and success of ECPR initiation.

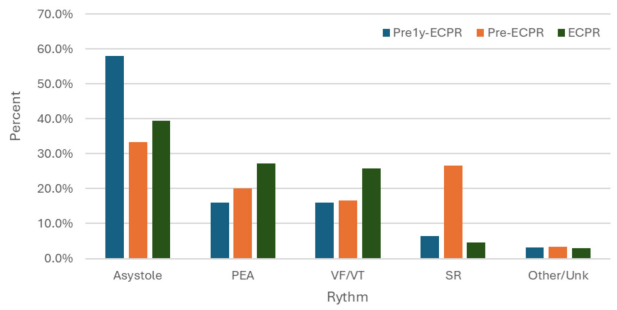

FIGURE 1
Initial rhythms of cardiac arrest as identified by prehospital personnel before and after joining the county ECPR pilot program. PEA, pulseless electrical activity; VF/VT, ventricular fibrillation/ventricular tachycardia; SR, sinus rhythm; Unk, unknown.

Analysis

We analyzed the three 6-months comparison time periods (ECPR, pre-ECPR, and pre1y-ECPR) using descriptive statistics and Fisher's exact test as indicated. Differenced and 95% confidence intervals are reported. A $p < 0.05$ was considered statistically significant for all analyses. During these periods, there were no changes in EMS policies, staffing or number of receiving hospitals within San Diego County. The implementation month at our institution, November 2024, was excluded from all analyses to allow for completeness of EMS education on the inclusion of our institution in the eCPR program (importantly, we did not have any ECPR activations during this month).

Results

During the ECPR period, the total ED census was 23,017 of which 8,486 patients arrived by 911 ALS transport, compared with an ED census of 23,489 and 9,303 ALS transports for the pre-ECPR period and census of 26,969 and 10,301 ALS transports for the pre1y-ECPR period. Per 1,000 ALS arrivals, OHCA transports were significantly higher (66 cases, or 7.8/1,000 ALS transports) after the initiation of the ECPR program compared with both the immediate pre-ECPR period (30 cases) and pre1y-ECPR period (3.2/1,000, diff 4.6; 95%CI 0.8, 8.0, and 31, 3.5/1,000, diff 4.3; 95% CI 1.1, 7.4), respectively, p's < 0.05.

Witnessed arrest, bystander CPR initiation prior to medic arrival, and ROSC in the field rates are noted in Table 1. Overall, rates of witnessed arrests and bystander CPR were similar across all three time periods, but rates of ROSC were significantly higher in the ECPR period and pre1y-ECPR compared to the 6-months period before ECPR.

Initial cardiac rhythms as documented by prehospital personnel are shown in Figure 1 as a proportion of OHCA arrivals. Rhythm on arrival to hospital ED are shown in Figure 2 as a proportion of OHCA arrivals. During the ECPR period, only eight of the 66 cases were determined to have met ECPR field criteria.

Discussion

In this study, we report the impact of the initiation of an ECPR program for pre-hospital OHCA arrivals at an academic

TABLE 1 Comparison of OHC a characteristics of all three time periods before and after joining the county ECPR pilot program.

	Time period					
	ECPR	Pre-ECPR	Pre1y-ECPR	ECPR vs. Pre	ECPR vs. Pre1y	Pre vs. Pre1y
	n (%)	*n* (%)	*n* (%)	Diff (95%CI)	Diff (95%CI)	Diff (95%CI)
Witnessed arrest	39 (59.1)	16 (53.3)	15 (48.4)	5.8 (−14.2, 44.0)	10.7 (−9.9, 30.5)	5.0 (−19.1, 28.2)
Bystander CPR	40 (60.6)	17 (56.7)	13 (41.9)	3.9 (−16.1, 24.5)	18.7 (−2.4, 37.6)	14.7 (−9.9, 37.0)
ROSC	35 (53.0)	9 (30.0)	19 (61.3)	23.0 (1.6, 40.7)*	8.3 (−12.7, 27)	31.3 (6.3, 51.3)*

*p-value < 0.05.
The amount of OHCA, witnessed arrests, bystander CPR, and ROSC rates during the three time points (pre1y-ECPR, pre-ECPR, and ECPR). ECPR, extracorporeal cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation. Pre1yr-ECPR: period Dec 2023 through May 2024. Pre-ECPR: 6 months prior to ECPR implementation (June–October 2024). ECPR: period after ECPR was started (December 2024 through May 2025).

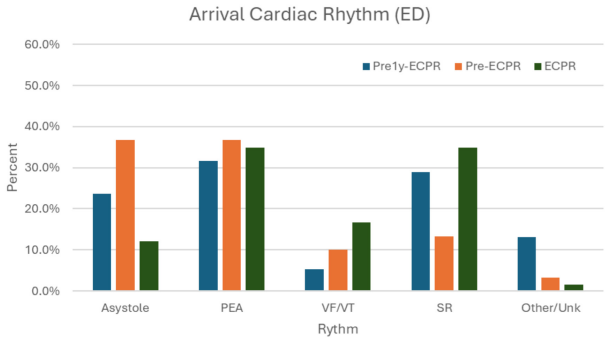

FIGURE 2
Rhythm of cardiac arrest at emergency department arrival before and after joining the county ECPR pilot program. PEA, pulseless electrical activity; VF/VT, ventricular fibrillation/ventricular tachycardia; SR, sinus rhythm; Unk, Unknown.

medical center as part of a regional ECPR pilot program. We found a significant increase in OHCA transports to the ED following designation as an ECPR-capable receiving center not explained solely by ECPR-eligible cases, overall ALS transports, or seasonal variation. The cause of this is uncertain and although we controlled for seasonal variation by including a prior year of data, random variation in incidence of OHCA from year to year may explain our findings. Alternatively, it is possible that increased awareness of our institution's involvement with the county wide ECPR pilot may have caused EMS personnel to transport more cardiac arrest patients to our institution.

The incidence of OHCA in the United States is approximately 350,000 cases per year (10). The emergence of ECPR as an advanced intervention to augment vital organ perfusion for patients with OHCA has shown promise as a resuscitative measure to improve outcomes compared to conventional CPR. Since its first reported use for cardiac arrest in the 1960s (11), the adoption of ECPR has grown markedly, particularly in the last decade (12). While the overall survival to hospital discharge is approximately 10% for OHCA, and even more dismal when resuscitative measures are prolonged, the utility of ECPR for OHCA remains unclear, with overall low rates of adoption and significantly less favorable outcomes in comparison to ECPR for in-hospital cardiac arrest (13). Our data demonstrate an increase in incidence of cardiac arrest arrivals, with a minority of cases meeting county ECPR criteria. While it is unclear why this occurred, such data might inform other health systems interested in potentially initiating an ECPR program for patients with OHCA.

Evidence for outcome benefit for ECPR in OHCA remains a work in progress. Recent randomized controlled trials of ECPR compared with standard resuscitation for OHCA have yielded varying results. The Advanced Reperfusion Strategies for Patients with OHCA and Refractory Ventricular Fibrillation (ARREST) trial conducted at a single center in the US with 30 patients randomized to ECPR or control showed significantly improved survival to hospital discharge (43 vs. 7%) for refractory ventricular tachycardia/fibrillation (VT/VF) such that the study was terminated early for benefit (3). The single centered Prague OHCA study involving 256 OHCA patients found a non-statistically significant improvement in survival with good neurologic outcome at 6 months for ECPR patients (31.5 vs. 22.0%), but was also terminated prematurely when a pre-specified 15% difference could not be achieved (5) In the multi-center Early Initiation of Extracorporeal Life Support in Refractory OHCA (INCEPTION) trial, 134 patients were randomized to ECPR vs. control demonstrating similar 30-day survival rates (20 vs. 16%) (4). However, meta-analysis including these three studies did find a survival benefit (14).

These seemingly varying results point to the challenges as well as opportunities for ECPR for OHCA (12). The implementation of these resource-intensive programs for the out-of-hospital setting requires an advanced, highly coordinated, multi-disciplinary (Emergency Medicine, Intensive Care, Cardiology, Cardiothoracic Surgery) system involving prehospital EMS, hospital EDs and ICUs working in concert to address patient and center factors impacting the effectiveness of ECPR. Patient factors include strict selectivity criteria based on arrest etiology and initial cardiac presentation and rhythm (i.e., refractory cardiac arrest), and time to initial resuscitation efforts (i.e., bystander CPR, prehospital personnel arrival). System factors include time to ECPR initiation (i.e., transport time to designated center, time to cannulation) as well as center training, experience and volume with ECMO and ECPR cases (15, 16).

The feasibility of translating these processes into effective clinical systems that improve patient-centered outcomes remains understudied and unclear. The Extracorporeal Cardiopulmonary Resuscitation for Refractory Out of Hospital Cardiac Arrest (EROCA) trial did not meet a pre-specified goal of transporting patients that were potential ECPR subjects within 30 min to an ECPR receiving center (16). Of the 15 patients enrolled in this study, less than 50% were cannulated within the goal of 30 min from ED arrival and none survived with favorable neurologic outcomes and. In contrast, Shinar et al. (7) recently demonstrated that the mean time from cardiac arrest to ECMO flow in San Diego County was 61 min with favorable neurologic survival in 32% (7/22) of patients who underwent ECPR. These findings highlight the variability in outcomes within the clinical operation of ED ECPR programs and the need for more research to identify effective systems within the complex EMS-health system environment.

The efforts to establish ECPR designated sites is one of the more recent initiatives toward regionalization of acute specialty care in the prehospital and ED setting. Over the past few decades, other areas have included trauma, ST elevation MI (STEMI), stroke, and pediatrics, whereby patients are preferentially transported by 911 ALS to designated hospitals with specific capabilities, often bypassing closer facilities (17). Recent data suggest that increased volume and experience with ECPR is associated with improved survival with favorable neurologic outcome (18). As the concept of cardiac arrest receiving centers continues to demonstrate improved outcomes, the inclusion of immediately available ECPR for select patients may provide an opportunity to further

improve favorable neurologic outcomes in select patients (19). Our findings also highlight a potential downside of regionalized care, as facilities that cannot support a resource-intensive ECPR program may lose valuable experience in managing patients with OHCA.

Not surprisingly, transports to designated facilities for either actual or potential diagnoses, such as acute stroke, can dramatically increase at these centers (20). However, significant challenges remain in terms of prehospital determination of patient eligibility for transportation to certain specialty centers which can be impacted by EMS personnel knowledge and experience, dissemination of information regarding specialty and regionalization criteria to prehospital agencies as well as the public, and patient preference and presentation (21). While speculative, it is possible that the new ECPR designation on the region's only academic medical center and its reputation, may have encouraged paramedics to transport more OHCA patients to that site regardless of whether the patient truly met county-determined ECPR criteria. Alternatively, changes in dispatch behavior, unrecognized regional public health trends, or coincidence may explain these findings, and further study is needed to better understand our results.

Limitations to this study include the fact that we focused on a single center, the region's academic medical center, and the relatively short time studied. Our comparison included the immediately preceding similar 6 months prior to initiation of the ECPR program, as well as a similar period 1 year before for potential yearly variations, though this may not have fully addressed seasonal or year to year changes seen over longer periods. We did not include a multivariate analysis, which may have impacted our results. Although we included some patient-level data, we chose to focus on EMS arrivals and additional studies are required to evaluate the association between joining an ECPR program and patient-level outcomes.

Conclusion

In this study, the initiation of an OHCA ECPR program at an academic medical center was associated with an increase in 911 ALS transports to the ED, not only for ECPR eligible candidates, but also for overall cardiac arrest patients. Future multi-center investigations are needed to confirm these findings.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of California, San Diego Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

GW: Writing – review & editing, Writing – original draft. MS: Writing – review & editing, Writing – original draft. JT: Writing – original draft, Writing – review & editing. MO: Writing – review & editing, Writing – original draft. TP: Writing – review & editing, Writing – original draft. CY: Writing – review & editing, Writing – original draft. MP: Writing – original draft, Writing – review & editing. CL: Writing – review & editing, Writing – original draft. VT: Writing – original draft, Writing – review & editing. EC: Writing – review & editing, Writing – original draft. TC: Writing – original draft, Writing – review & editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author TC declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

1. Yan S, Gan Y, Jiang N, Wang R, Chen Y, Luo Z, et al. The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis. *Crit Care Lond Engl.* (2020) 24:61. doi: 10.1186/s13054-020-2773-2

2. Perman SM, Elmer J, Maciel CB, Uzendu A, May T, Mumma BE, et al. 2023 American heart association focused update on adult advanced cardiovascular life support: an update to the American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation.* (2024) 149:e254–73. doi: 10.1161/CIR.0000000000001194

3. 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 center, open-label, randomized controlled trial. *Lancet.* (2020) 396:1807–16. doi: 10.1016/S0140-6736(20)32338-2

4. 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. *N Engl J Med.* (2023) 388:299–309. doi: 10.1056/NEJMoa2204511

5. 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) 327:737–47. doi: 10.1001/jama.2022.1025

6. The San Diego resuscitation consortium. (2023). *E. coli.* Available online at: https://www.sandiegocounty.gov/content/dam/sdc/ems/Medical_Director_Report/CoSD%20EMS%20San%20Diego%20Resuscitation%20Consortium%20Memo%2007-28-23.pdf (Accessed October 2, 2025).

7. Shinar Z, Levine S, Koenig KL, Assof M, King C, Evans S. Implementation of a regional emergency physician-initiated extracorporeal cardiopulmonary resuscitation system. *Ann Emerg Med.* (2025) 86:552–5. doi: 10.1016/j.annemergmed.2025.06.011

8. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet Lond Engl.* (2007) 370:1453–7. doi: 10.1016/S0140-6736(07)61602-X

9. Perkins GD, Jacobs IG, Nadkarni VM, Berg RA, Bhanji F, Biarent D, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update of the utstein resuscitation registry templates for out-of-hospital cardiac arrest: a statement for healthcare professionals from a task force of the International Liaison Committee on resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on resuscitation, heart and stroke foundation of Canada, Inter American Heart Foundation, resuscitation council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the council on cardiopulmonary, critical care, perioperative and resuscitation. *Resusc.* (2015) 96:328–40. doi: 10.1161/CIR.0000000000000144

10. Tsao CW, Aday AW, Almarzooq ZI, Alonso A, Beaton AZ, Bittencourt MS, et al. Heart disease and stroke statistics-2022 update: a report from the American Heart Association. *Circ.* (2022) 145:e153–639. doi: 10.1161/CIR.0000000000001052

11. Kennedy JH. The role of assisted circulation in cardiac resuscitation. *JAMA.* (1966) 197:615–8. doi: 10.1001/jama.1966.03110080055017

12. Abrams D, MacLaren G, Lorusso R, Price S, Yannopoulos D, Vercaemst L, et al. Extracorporeal cardiopulmonary resuscitation in adults: evidence and implications. *Intensive Care Med.* (2022) 48:1–15. doi: 10.1007/s00134-021-06514-y

13. 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. *Lancet Respir Med.* (2023) 11:883–93. doi: 10.1016/S2213-2600(23)00137-6

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. *Crit Care.* (2024) 28:57. doi: 10.1186/s13054-024-04830-5

15. Ubben JFH, Heuts S, Delnoij TSR, Suverein MM, van de Koolwijk AF, van der Horst ICC, et al. Extracorporeal cardiopulmonary resuscitation for refractory OHCA: lessons from three randomized controlled trials-the trialists' view. *Eur Heart J Acute Cardiovasc Care.* (2023) 12:540–7. doi: 10.1093/ehjacc/zuad071

16. Hsu CH, Meurer WJ, Domeier R, Fowler J, Whitmore SP, Bassin BS, et al. Extracorporeal cardiopulmonary resuscitation for refractory out-of-hospital cardiac arrest (EROCA): results of a randomized feasibility trial of expedited out-of-hospital transport. *Ann Emerg Med.* (2021) 78:92–101. doi: 10.1016/j.annemergmed.2020.11.011

17. Prekker ME, Rischall M, Carlson M, Driver BE, Touroutoutoudis M, Boland J, et al. Extracorporeal membrane oxygenation versus conventional rewarming for severe hypothermia in an urban emergency department. *Acad Emerg Med.* (2023) 30:6–15. doi: 10.1111/acem.14585

18. Magnet I, Behringer W, Eibensteiner F, Ettl F, Grafeneder J, Heinz G, et al. Extracorporeal cardiopulmonary resuscitation: outcomes improve with center experience. *Ann Emerg Med.* (2025) 85:421–7. doi: 10.1016/j.annemergmed.2024.12.004

19. Yeo JW, Ng ZHC, Goh AXC, Gao JF, Liu N, Lam SWS, et al. Impact of cardiac arrest centers on the survival of patients with non-traumatic out-of-hospital cardiac arrest: a systematic review and meta-analysis. *J Am Heart Assoc.* (2022) 11:e023806. doi: 10.1161/JAHA.121.023806

20. Sanossian N, Liebeskind DS, Eckstein M, Starkman S, Stratton S, Pratt FD, et al. Routing ambulances to designated centers increases access to stroke center care and enrollment in prehospital research. *Stroke.* (2015) 46:2886–90. doi: 10.1161/STROKEAHA.115.010264

21. Cone DC, Brooke Lerner E, Band RA, Renjilian C, Bobrow BJ, Crawford Mechem C, et al. Prehospital care and new models of regionalization. *Acad Emerg Med.* (2010) 17:1337–45. doi: 10.1111/j.1553-2712.2010.00935.x