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Clinical paper

Estimated caseload for a rotary wing prehospital extra-corporeal cardio-pulmonary resuscitation service in North West England: A retrospective eligibility study

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Abstract

Background: Prehospital Extra-Corporeal Membrane Oxygenation Cardiopulmonary Resuscitation (ECPR) has the potential to improve survival from out of hospital cardiac arrest (OHCA). This study aims to estimate the potential caseload for an airborne ECPR service for refractory cardiac arrest in adults in North West England.

Methods: A retrospective analysis was carried out on cardiac arrest patients attended by The North West Air Ambulance Charity (NWAA) team, examining the time taken from the 999 call to emergency services, to team arrival at patient, this was used to create a mathematical model for travel times.

Secondly, a retrospective review of cardiac arrest cases attended by The North West Ambulance Service (NWAS) was performed. Two sets of criteria were applied to examine if prehospital cardiac arrest patients would be eligible for ECPR; a locally defined set (LIC), and an in-hospital criteria (AIC). Combined with our travel time model, we estimated the number of patients the service might see.

Results: Time taken for the NWAA team to reach cardiac arrest patients was given by the formula $y = 0.2237x + 20.135$ and there was a moderate linear distance and time correlation. 85 and 78 patients per annum would have been eligible, using the LIC and AIC, respectively. Using an estimated 30% survival rate 21.6–23.1 lives could be saved annually.

Conclusion: The two different criteria produced similar estimates of caseload. An ECPR service in this region would expect to treat to 1.4–1.5 patients per week, depending on the criteria used.

Trial registration: Not applicable.

Keywords: Extra-corporeal membrane oxygenation, Prehospital, Cardiac arrest, Cardio-pulmonary resuscitation

Background

Survival from out of hospital cardiac arrest (OHCA) in the UK has not improved significantly in the past 10 years.[1] Extra-Corporeal Membrane Oxygenation (ECMO) performs the role of the heart and lungs and ECMO cardiopulmonary resuscitation (ECPR), may be used as a treatment for patients in refractory cardiac arrest. However, ECPR must be started in a timely fashion, ensuring oxygenation of the brain before irreversible cerebral hypoxia occurs. The optimal time for starting ECPR is not known, but time to treatment is the main predictor of survival, and studies have demonstrated significantly poorer outcomes when full flow ECMO is achieved greater than 58 min after cardiac arrest.[2] A before and after study in Paris by Lamhaut et al.[3] demonstrated an improvement in survival from 8% to 29% with early ECPR initiation, partially achieved through deployment of a prehospital ECPR team with the initial ambulance response team which reduced low flow times from 90 to 70 min.

Outcomes of ECPR trials have been promising; the 2CHEER trial[4] demonstrated ECPR survival to hospital discharge with favourable neurological outcomes in 11/25 (41%) of patients, with a median low flow time of 57 mins. Other studies such as The CHEER3 trial have demonstrated prehospital ECPR is feasible, yielding a 100% success rate in establishing ECMO, and a survival rate of 40%.[5]

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https://doi.org/10.1016/j.resplu.2025.100948
Received 27 January 2025; Received in revised form 21 March 2025; Accepted 23 March 2025

The Sub30 trial[6] also demonstrated the feasibility of providing prehospital ECPR in an urban environment, achieving full ECMO flow within 32 minutes (22-37) of arriving on scene.. Further trials such as ERICA-ARREST,[7] APACAR2,[8] and ON-SCENE[9] may provide further information on feasibility and patient outcomes.

In an attempt to improve outcomes, an alternative treatment pathway was trialled, where patients in refractory cardiac arrest were directly transferred to the regional ECMO centre.[10] However, given the excessive low flow times and modest outcomes, consideration was given to a prehospitally delivered service, by placing it on the existing EPHC service run by The North West Air Ambulance Charity (NWAA). The model considered is to provide ECPR as an additional treatment modality to those currently provided by NWAA, delivered by the same team and via the same platforms, in a similar set up to the ON-SCENE trial. This offers the potential for a cost-effective strategy to deliver ECPR, as in many cases the NWAA team is already dispatched to these patients. To ensure timely arrival, the NWAA ECPR team is launched at the time of first contact with emergency medical services based on pre-arranged dispatch criteria. The current staffing model of NWAA is a 2-person Consultant Physician and Paramedic team; for ECPR it is proposed that a second Paramedic would be included, to make a team of 3. Currently, NWAA provide EPHC on both road and rotary wing platforms, and it is proposed that the ECPR service would be delivered in the same manner. For this study, which was to estimate the potential caseload of a proposed ECPR service, only rotary wing travel was considered, for practical reasons and to avoid overcomplexity.

Methods

This study was conducted in 2 parts. Firstly, to estimate response times, we used a calendar year of OHCA attended by the NWAA EPHC team. These were all medical arrests where the EHPC crew were at base when the team was alerted. Cases which started with road paramedic crew requests for additional support were excluded due to the inevitable delay in dispatch. Data were retrieved from the NWAA database (HEMSBase, MedicOne Systems) detailing the location of the arrest and the time taken to reach the patient's side (999 call to patient's side). This time includes the time taken to identify the call in the call centre, transfer the job to the on duty team, mobilisation of the helicopter, travel to landing site, landing and travel to the patient's side. This was then used to calculate the speed of the response and create an equation for response time for a given distance.

For the second part of the study, a retrospective review was performed of a database of patients who had sustained a cardiac arrest, attended by the ground-based North West Ambulance Service NHS Trust (NWAS).

Currently access to ECPR in the region is limited, with only an arranged pathway for severe hypothermia, and an ad-hoc set up for refractory cardiac arrest in proximity to the adult ECMO centre, therefore there is currently significant geographical inequity within the region. From an ethical perspective, patients with favourable parameters suffering a witnessed cardiac arrest have potential for a good outcome, but existing life support algorithms cater poorly for those in refractory arrest, or arrest from special circumstances. It is, in the authors' opinion, justifiable to offer life-sustaining therapy to enable these patients to get to hospital for treatment of potentially reversible underlying causes. The area covered by NWAS and NWAA is both urban and rural; Fig. 1 shows the major urban conurbations.

Data sources

NWAS maintains a database of all cardiac arrests attended by the service. This database includes time of call, geographic location of incident (a United Kingdom postcode), whether bystander CPR was performed, use of automated defibrillator, use of mechanical chest compression device, time of ROSC (if present), survival to discharge and a record of neurological outcome.

This study was approved by the NWAS NHS Trust Clinical Audit Department prior to commencement who determined that due to the retrospective nature of review with non-patient identifiable data, ethics approval was not required.

Study population

Data were examined from OHCA occurring between April 2022 to March 2023. A year of data was used to give a sufficient sample size. Owing to logistical and staffing factors, the proposed operational hours of the ECPR team were defined as 08:00 to 20:00, 7 days a week therefore arrests occurring outside these times were considered ineligible for treatment using the screening criteria below

Screening criteria

Two screening criteria were used to estimate eligibility. A regional criteria derived by local experts and based on criteria used in other studies, and those designed by the Alfred Healthcare Group, Australia for in hospital arrests,[11] which are similar to the CHEER3 criteria. These two criteria are shown in Table 1.

For the local inclusion criteria (LIC) a response time of 30 min was allowed, leaving a minimum of a further 30 min for decision making, cannulation and establishment on ECPR in under 60 mins due to the aforementioned poorer outcomes after over 58 min of low flow. The Alfred criteria (AIC) uses a composite score of age + duration of arrest, and for this study, we estimated the travel time using the formula described above, added the patient's age in years, and added an additional 5 min to allow a rapid decision at the patient's side. Therefore the maximum travel time from base would be 76.9 min (18 years + 76.9 min + 5 min = 99.9). Clearly this allows younger patients to potentially have a longer low flow time than 60 min using the AIC; the criteria allows for the fact that they may tolerate this better than older patients.

Results

The first part of the study assessed travel time from crew standby location to patient side. During a period of 12 calendar months, there were 35 arrests attended by the existing (non-ECPR) NWAA EPHC team in a helicopter. The distance from base was plotted against the response time (emergency services call to time by patient side). The line of best fit was $y = 0.2237x + 20.135$, shown in Fig. 2.

The Pearson Correlation was 0.488, demonstrating a moderate positive linear correlation and giving an R^2 of 0.238.

In the second part of the study, all cardiac arrests attended by NWAS within the entire service region were then assessed. During the study period (April 2022–March 2023, 0800–2000) there were 14,046 cardiac arrests. Selection of cases is shown in Fig. 3.

314 cases which were used for analysis. Basic data on these 314 patients are shown in Table 2

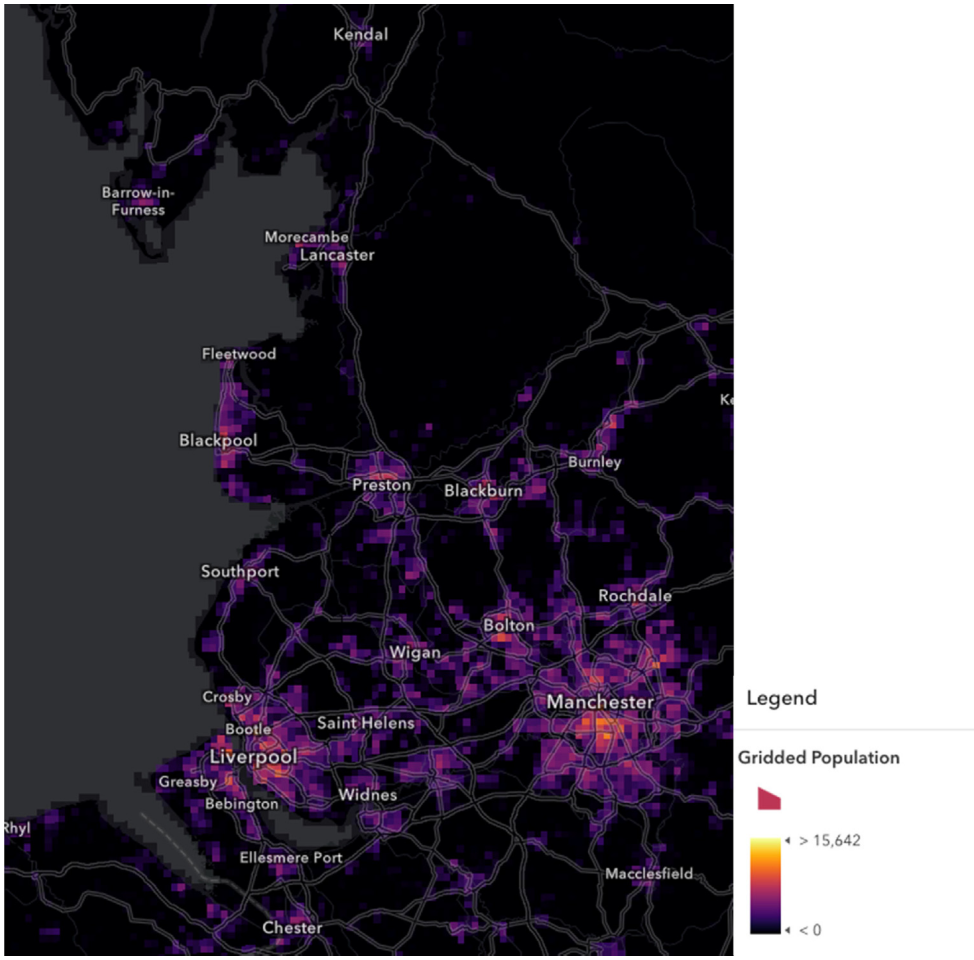

Fig. 1 – Population density of study area by 1 km^2 grid, arcgis.com.

Table 1 – ECPR inclusion and exclusion criteria timings.

ALFRED CRITERIA *MUST ALL BE PRESENT*	**LOCAL INCLUSION CRITERIA** *MUST ALL BE PRESENT*
Age + Time in min + 5 min 'decision time'* < 100	Age 18–60 years
(Time = ambulance call time to time of decision in min) *added for the purposes of this study, not present in standard criteria	End tidal CO_2 greater than 1.33 kPa (11 mmHg)
Witnessed cardiac arrest	VF, VT, PEA, or shocked by AED
Shockable initial rhythm	Witnessed cardiac arrest with bystander CPR
Bystander CPR within 5 min	No significant co-morbidity
No known end-stage disease	Less than or equal to 30 min from 999 call to patient side
ALFRED EXCLUSION CRITERIA Presence of any results in exclusion	
Age > 65	
End-tidal CO_2 less than 1.33 kPa (10 mmHg)	
Femoral cannulation impossible (e.g. iliofemoral occlusion / occluded IVC filter/severe peripheral vascular disease)	
Known aortic regurgitation > mild	
Presence of pericardial effusion or tamponade with suspected aortic dissection	

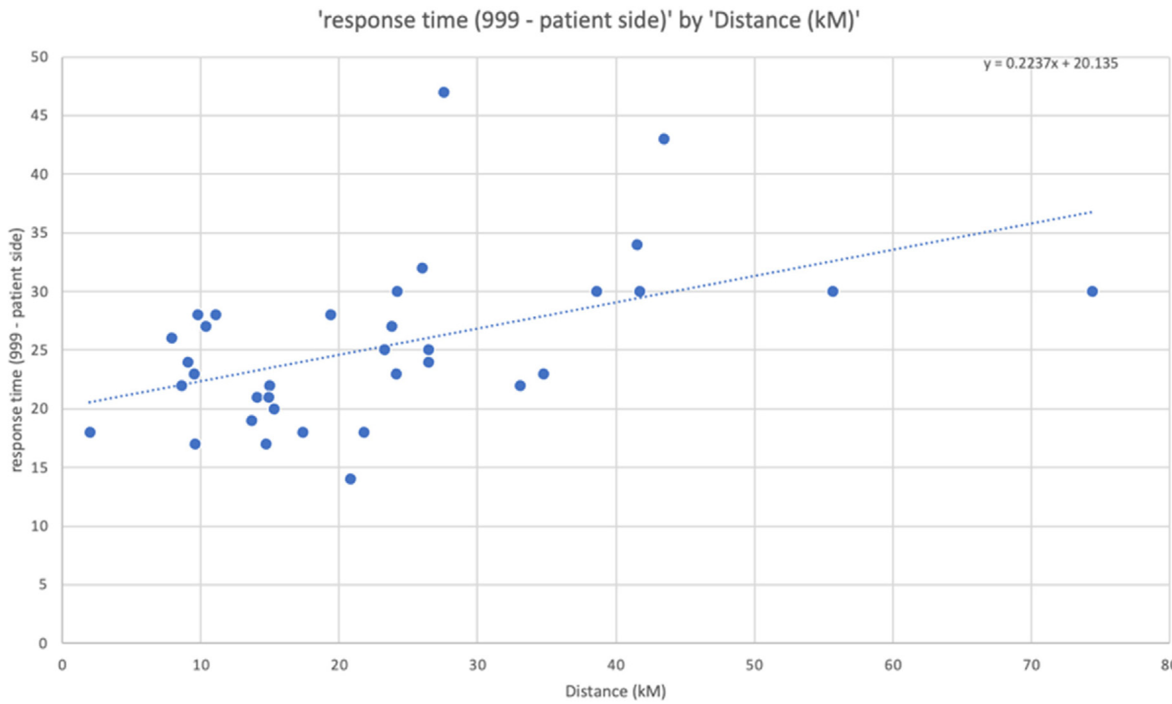

Fig. 2 – Distance (kM) plotted against response time (999 call time to patient side).

Of the 314 patients, 216 patients had no ROSC, or ROSC at greater than 30 min, these patients would therefore still be in arrest on the teams arrival and would therefore potentially be eligible for ECPR treatment. It was noted that patients who gained ROSC after 30 mins had only a 6.9% survival to hospital discharge (Table 3).

Table 4 shows the application of the 2 inclusion criteria and the estimated caseloads.

Discussion

The line of best fit demonstrates that there is a fixed time delay for job identification, team activation, lift and landing time, giving a minimum of approximately 20 min. The distance from base to the patient plays a relatively small role in determining travel time to a patient which would be in-keeping with the high ground speed of a rotary wing aircraft of approximately 2 miles per minute.

The use of a composite eligibility score for AIC, combined with the high estimated speed of travel means that a great majority of the patients scored less than 100 and were therefore included. In contrast, using LIC, many younger patients were excluded for being greater than 30 min travel time from the crew standby point, who might have gone on to have a good neurological outcome. However, the estimated number of patients (1.4 and 1.5) was similar with the two methods.

This study dovetails with the findings of Vos and colleagues,[13] who demonstrated that even in densely populated areas with short travel times, prehospital ECPR increases the number of eligible patients. The Sub30 trial, in a considerably more urban environment than this study, reported a collapse to scene time of 14 min.[14] Of note, although the team was dispatched on 18 occasions, only 5 patients met the full criteria and received ECPR. This reflects the fact that dispatch and treatment criteria differ; in this paper we have focussed on the latter and further work could be done to identify strong predictors for both dispatch and treatment to ensure efficient tasking.

Economically a model similar to the Sub30 team carries considerable expense, consisting of a team comprising a HEMS Consultant, an Advanced Paramedic and 2 Consultants in Intensive Care Medicine responding only to a small subset of cardiac arrest patients. In contrast to this our proposed model, which more resembles the ON-SCENE trial staffing carries a small additional staffing cost of one paramedic, with no additional transport costs or dispatch costs as the service already identifies and attends these patients. This would enable ECPR to be delivered in an extremely economical fashion, using existing infrastructure. Staff training would be required, this has been demonstrated by multiple services previously, most notably the Paris group,[3] using non ECMO specialist doctors to deliver pre hospital ECMO, and is currently being looked at specifically by the ON-SCENE trial.[9]

These results could be applicable to any physician-led EPHC service working in a mixed urban and rural environment, both within the United Kingdom and worldwide, with a similar distribution of ECMO centres. Survival from OHCA has been shown to be highly dependent on having a high-functioning healthcare system[15]; survival figures projected from other systems may not be valid in this setting. As a prediction model, these results are likely to represent an over-estimate as application of the criteria in this study will not necessarily translate into actual cases and there will be additional ineligibility identified once clinicians arrive at scene.

Study limitations

The retrospective nature of the study means that items may not be recorded accurately. 105 patients had no $ETCO_2$ information recorded, which excluded many from the LIC as the CO_2 must be

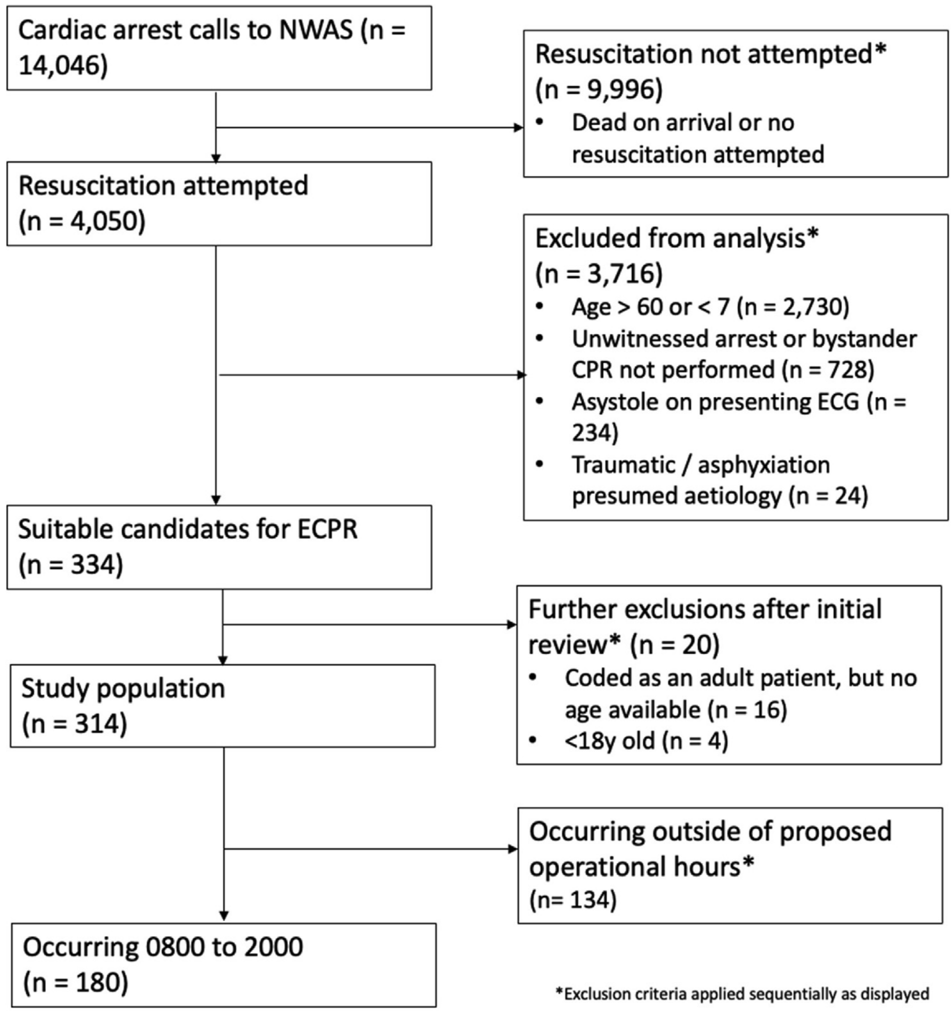

Fig. 3 – Consort diagram for case selection

Table 2 – Basic study population details.

	Number	Percent
Male	224	71.3
Mean age	52.1 years	
Mechanical CPR device used	240	76.4
First rhythm		
– Ventricular fibrillation or ventricular tachycardia	154	49.0
– Shocked by automated external defibrillator	60	19.1
– Pulseless electrical activity	100	31.8

Table 3 – Outcomes for selected arrest duration times.

Time to ROSC	Number	Survival to 30 days	Percent survival
Less than 30 min	98	49	50
30 to less than 60 min	51	5	
Greater than 30 min	56	7	
Greater than 60 min	5	2	
No ROSC time recorded	160	6	

Table 4 – Summary of estimated caseload, 30% estimated survival from ELSO.[12]

	LIC	AIC
Total cases	314	
Occuring within 30 min of standby location	243	N/A
Age + travel time + 5 min decision time < 100	N/A	293
Number eligible for ECPR	85	78
Eligible for ECPR but died	72	77
Estimated number of cases per week	1.4	1.5
Estimated number of survivors p.a. (assuming 30% survival)	21.6	23.1

above the threshold for consideration for ECPR. Conversely, the AIC was unaffected, as it uses low CO_2 as an exclusion criteria.

For 4 patients the postcode of the incident was incorrectly recorded and invalid, and therefore although their data could be used for baseline calculations, the distance and therefore ECPR eligibility could not be calculated. 20 patients in total were removed due to age discrepancies.

There would probably be a time period between the patient collapsing and contact with the call handler; therefore the arrest times likely underestimate the total time of cardiac arrest.

Conversely, there are a group of patients who gained ROSC between 30 and 60 min, therefore although included in the numbers, some of those would not have required ECPR, even though a team might have been dispatched – the patient may have had a ROSC with the ECPR team present.

The neurological outcome of patients who survived was provided by hospitals within the NWAS region. However, the method for collecting this data was incomplete, did not use a validated outcome score, and therefore it is difficult to determine functional outcome with any degree of reliability.

Rotary wing transportation was assumed for estimating time to travel to patients, however, there would be times when the aircraft would be off-line, therefore travel by road would be required. Daylight variability throughout the year would affect aircraft operations, including landing sites. In contrast, some arrests occurred so close to the standby location that in certain circumstances road transport may have been quicker than air. These factors were outside of the scope of this study.

There were some discrepancies in the data, for example, 6 patients had no ROSC time recorded but survived to discharge, which may reflect an omission in recording of the time.

Conclusions

An ECPR service in the North West of England could be expected to average 1.4–1.5 patients per week, depending on the eligibility criteria used. This has the potential to improve neurologically intact survival from OHCA.

Ethics approval and consent to participate

This was a retrospective data review and the NWAS audit department determined that ethical approval was not required.

Consent for publication

This publication contains no individual data.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to the fact they are controlled via a 3rd party (North West Ambulance Service NHS Trust) and although they contain no patient identifiers (name, ID, date of birth etc), they contain potentially patient-identifiable elements within the data (date, time, location of arrest). They may be available through the corresponding author on reasonable request.

Use of AI

No AI was used in the writing of this text, nor in the analysis of the data.

CRediT authorship contribution statement

John Weeks: Writing – review & editing, Writing – original draft, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Steve Bell:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Thomas Nelson:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation. **Ian Tyrrell-Marsh:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Funding

The North West Air Ambulance Charity kindly covered the costs of publication

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

For their kind assistance with this project, we would particularly like to thank:

- Clare Bradley, Clinical Audit Manager, North West Ambulance Service NHS Foundation Trust.
- Dr. Joshua Ihle and Dr. Sacha Richardson, The Alfred, Melbourne, Australia

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REFERENCES

1. Out of hospital cardiac arrest survival rates remain low in England latest data shows. https://www.bhf.org.uk/what-we-do/news-from-the-bhf/news-archive/2024/january/out-of-hospital-cardiac-arrest-survival-rates-remain-low-in-england-latest-data-shows (accessed 27th February 2025).
2. Inoue A, Hifumi T, Sakamoto T, Kuroda Y. Extracorporeal cardiopulmonary resuscitation for out-of-hospital cardiac arrest in adult patients. J Am Heart Assoc 2020;9(7)e015291. https://doi.org/10.1161/JAHA.119.015291. Epub 2020 Mar 24. PMID: 32204668; PMCID: PMC7428656.
3. Lamhaut L, Hutin A, Puymirat E, 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;117:109–17. https://doi.org/10.1016/j.resuscitation.2017.04.014. Epub 2017 Apr 14 PMID: 28414164.
4. Dennis M, Buscher H, Gattas D, et al. Prospective observational study of mechanical cardiopulmonary resuscitation, extracorporeal membrane oxygenation and early reperfusion for refractory cardiac arrest in Sydney: the 2CHEER study. Crit Care Resusc 2020;22(1):26–34. https://doi.org/10.51893/2020.1.oa3.
5. Richardson SAC, Anderson D, Burrell AJC, et al. Pre-hospital ECPR in an Australian metropolitan setting: a single-arm feasibility assessment—The CPR, pre-hospital ECPR and early reperfusion (CHEER3) study. Scand J Trauma Resusc Emerg Med 2023;31:100.
6. Singer B, Hla TTW, Abu-Habsa M, et al. Sub30: feasibility study of a pre-hospital extracorporeal membrane oxygenation (ECMO) in patients with refractory out-of-hospital cardiac arrest in London, United Kingdom. Resuscitation 2024;5:110455.
7. Aziz S, Barratt J, Wilson-Baig N, et al. A protocol for the ERICA-ARREST feasibility study of Emergency Resuscitative Endovascular Balloon occlusion of the Aorta in Out-of-Hospital Cardiac Arrest. Resusc Plus 2024;13(19)100688.
8. A comparative study between a pre-hospital and an in-hospital circulatory support strategy (ECMO) in refractory cardiac arrest (APACAR2). https://clinicaltrials.gov/study/NCT02527031 (accessed 27th February 2025).
9. Ali S, Moors X, van Schuppen H, et al. A national multi centre pre-hospital ECPR stepped wedge study; design and rationale of the ON-SCENE study. Scand J Trauma Resusc Emerg Med 2024;32(1):31.
10. Tyrell-Marsh I, Barker A, Ashworth A. Time for prehospital ECPR. Poster session presented at: State of The Art; 2019.
11. The Alfred ECPR inclusion criteria. https://ecmo.icu/ecpr-inclusion-criteria/# (accessed 25th of February 2025).
12. ELSO live registry dashboard of ECMO patient data. https://www.elso.org/registry/elsoliveregistrydashboard.aspx (accessed 7th June 2024).
13. Vos IA, Deuring E, Kwant M, et al. What is the potential benefit of pre-hospital extracorporeal cardiopulmonary resuscitation for patients with an out-of-hospital cardiac arrest? A predictive modelling study. Resuscitation 2023;189:109825. https://doi.org/10.1016/j.resuscitation.2023.109825. Epub 2023 May 11 PMID: 37178899.
14. Op. cit. Singer B et al.
15. Bartos JA, Yannopoulos D. Refractory cardiac arrest: where extracorporeal cardiopulmonary resuscitation fits. Curr Opin Crit Care 2020;26(6):596–602. https://doi.org/10.1097/MCC.0000000000000769. PMID: 33027149.

GLOSSARY

CPR: Cardiopulmonary resuscitation
ECMO: Extra-corporeal membrane oxygenation
ECPR: Extra-corporeal membrane oxygenation cardiopulmonary resuscitation
EPHC: Enhanced prehospital care
$ETCO_2$: End-tidal carbon dioxide
OHCA: out of hospital cardiac arrest
NWAA: North West Air Ambulance
NWAS: North West Ambulance Service
PEA: Pulseless electrical activity
PPCI: Primary Percutaneous Coronary Intervention
ROSC: Return of spontaneous circulation
VF: Ventricular fibrillation
VT: Ventricular tachycardia