In-hospital extracorporeal cardiopulmonary resuscitation for patients with an out-of-hospital cardiac arrest in a semi-rural setting

ter Avest, E.; Tunnicliff, M.; Griggs, J.; Griffiths, D.; Cody, D.; Nelson, M.; Hurst, T.; Lyon, R. M.

Published in:
Resuscitation plus

DOI:
10.1016/j.resplu.2022.100339

RESUSCITATION PLUS 12 (2022) 100339

Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Clinical paper

In-hospital extracorporeal cardiopulmonary resuscitation for patients with an out-of-hospital cardiac arrest in a semi-rural setting: An observational study on the implementation of a helicopter emergency medical services pathway

E. ter Avest[a,b,*], *M. Tunnicliff*[a,c], *J. Griggs*[a], *D. Griffiths*[a], *D. Cody*[d], *M. Nelson*[a,d], *T. Hurst*[e,f], *R.M. Lyon*[a,g]

Abstract

Aim: In this study, we aimed to investigate the efficacy of a helicopter emergency medical service (HEMS) facilitated pathway for in-hospital extracorporeal cardiopulmonary resuscitation (ECPR) for patients with an out of hospital cardiac arrest (OHCA) in a semi-rural setting.

Methods: We retrospectively reviewed all patients with an OHCA attended by a UK HEMS service between 1 January 2018 and 20 September 2021, when a dedicated ECPR pathway was in effect to facilitate transport of eligible patients to the nearest ECLS centre. The primary endpoint was the number of patients meeting ECPR eligibility criteria at three pre-defined time points: at HEMS dispatch, during on-scene evaluation and upon arrival in hospital.

Results: During the study period, 162 patients attended met ECPR pathway dispatch criteria. After on-scene evaluation, 74 patients (45%) had a return of spontaneously circulation before arrival of HEMS, 60 (37%) did not meet eligibility criteria regarding initial rhythm or etiology of the OHCA, and 15 (9%) had deteriorated (mainly into asystole) and were no longer suitable candidates upon arrival of HEMS. Eleven patients were eligible for ECPR and transported to hospital in arrest, and a further two patients were transported for post-ROSC ECLS. Nine patients deteriorated during transport and were no longer suitable ECPR candidates upon arrival. ECLS was successfully initiated in two patients (one intra-arrest, and one post-ROSC).

Conclusion: In-hospital ECPR is of limited value for patients with refractory OHCA in a semi-rural setting, even when a dedicated pathway is in place. Potentially eligible patients often cannot be transported within an appropriate timeframe and/or deteriorate before arrival in hospital.

Keywords: Extracorporeal cardiopulmonary resuscitation (ECPR), Helicopter emergency medical service (HEMS)

Introduction

Extracorporeal cardiopulmonary resuscitation (ECPR) can be used as a treatment for patients with an out of hospital cardiac arrest (OHCA) when standard resuscitation fails.[1,2] In these patients, ECPR is used as a technique to provide oxygenated circulation especially to the brain, thereby extending the time window to diagnose and treat the primary underlying cause of the arrest, such as a primary cardiac cause, intoxication, a pulmonary embolism, or hypothermia. Over the past decade, a 10-fold increase in ECPR utilisation has been observed.[3] So far however, the effect on outcome is unclear. Several studies have demonstrated positive results of ECPR on neurologically intact survival,[4–6] but more recent registry

Abbreviations: **AED**, Automatic External Defibrilator, **CCP**, Critical Care Paramedic, **ECPR**, extracorporeal cardiopulmonary resuscitation, **HEMS**, Helicopter emergency medical service, **OHCA**, Out of hospital cardiac arrest, **KSS**, Air Ambulance Charity Kent, Surrey and Sussex

* Corresponding author at: Kent, Surrey & Sussex Air Ambulance Trust, Redhill Airfield, Redhill, Surrey RH1 5YP, UK.

E-mail address: ewoudteravest@aakss.org.uk (E. ter Avest).

https://doi.org/10.1016/j.resplu.2022.100339

Received 14 September 2022; Received in revised form 22 November 2022; Accepted 24 November 2022

studies could not demonstrate a beneficial effect on outcome.[7,8] Moreover, ECPR has a significant risk of complications (leg ischaemia, bleeding from the insertion site, infection and intracranial haemorrhage), and comes with significant cost and logistical challenges. Therefore, ECPR is only offered as a treatment to patients most likely to benefit and have a positive outcome. Common inclusion criteria are refractory cardiac arrest, younger age and a witnessed arrest with minimal no-flow and low-flow times.[9,10]

As pre-hospital ECPR is only offered by a few services worldwide (either as a routine treatment[6,11–12] or in a trial setting,[13,14] currently many OHCA patients eligible for ECPR are conveyed from the location of their arrest to hospitals with Extracorporeal life support (ECLS) facilities, with ongoing resuscitation. As previous studies have demonstrated that ECPR outcome is dependent on no-flow- and low-flow times,[15,16] there is a considerable time pressure to start ECPR promptly. ECPR should ideally be initiated within 60–90 min of arrest.[17,18] However, this can be challenging with pre-hospital scene times often extending beyond 20 min,[19] and prolonged transport times to hospital, especially in semi-rural areas. Helicopter emergency medical services (HEMS) have the potential to facilitate expedited transport of potentially eligible patients to hospitals with ECLS facilities. Therefore, in the present study, we aim to investigate the efficacy of the implementation of a HEMS-facilitated pathway for in-hospital ECPR for patients suffering from an OHCA in a semi-rural setting.

Methods

Study setting and design

We performed a retrospective analysis of all patients with an OHCA attended by Air Ambulance Charity Kent Surrey and Sussex (KSS) between 1 January 2018 (3 months after the introduction of a dedicated ECPR pathway) and 20 September 2021 (date of pausing the pathway due to the COVID-19 pandemic). We investigated how many potentially ECPR-eligible patients KSS was dispatched to, in how many of these patients ECPR eligibility criteria were met on-scene and upon arrival in hospital, and in how many patients ECPR was eventually initiated.

KSS is a HEMS service covering three counties in the southeast of England, with a resident population of 4.5 million. Two doctor/-paramedic teams respond in either a helicopter or response car from one base. The HEMS team is dispatched to both medical and traumatic emergencies by a previously published dispatch protocol.[20] In addition to this protocol, when the helicopter is off-line and crews respond in a rapid response vehicle, they can be auto-dispatched to high acuity emergency calls (including cardiac arrest calls) when they are the nearest available resource. The South East Coast Ambulance Service operates a Specialist Paramedic response model, deploying Critical Care Paramedics (CCPs) to work alongside ambulance crews at high acuity medical or traumatic incidents, therefore CCPs have greater exposure to OHCA patients. Dedicated joint ECPR pathway training for both Critical Care Paramedic and HEMS teams was undertaken prior to the inception of the pathway.

ECPR pathway and study population

From 29 September 2017, a dedicated pathway was established by KSS and King's College Hospital NHS Trust in London (KCH) to facilitate expedited transport of patients potentially eligible for ECPR in counties covered by KSS. According to this pathway, a HEMS team was dispatched to patients 18–60 years of age with a witnessed OHCA with minimal no-flow time (immediate bystander CPR). The dispatch pathway was not in effect during night-time hours (19.00–07.00), due to operational constraints of night HEMS operations.

Upon arrival on scene, Critical Care Paramedics and/or HEMS teams evaluated patients with an OHCA for potential ECPR eligibility. Patients were considered eligible for ECPR when they fulfiled *all* dispatch criteria and *in addition*:

- Had a shockable presenting rhythm (or in exceptional circumstances a pulseless electrical activity (PEA).
- Had a presumed cardiopulmonary or toxicological aetiology of their arrest.
- Did not have significant co-morbidity.
- Were eligible for mechanical CPR.
- Could be transported to the ECLS centre within 70 min of their arrest, in order to allow initiation of ECPR within 90 min of the arrest.

In addition, patients were considered for post-ROSC ECLS when they presented with a refractory cardiogenic shock following ROSC and in cases of deep accidental hypothermia. In these instances, no time limit was set for presentation to the ECPR centre.

Clinical endpoints

Primary endpoints were defined as the number of patients meeting ECPR eligibility criteria at three pre-defined time points: at dispatch, after pre-hospital evaluation by the HEMS team and after in-hospital evaluation by the receiving ECPR team. Secondary endpoints were dispatch efficacy (defined as the percentage of patients meeting eligibility criteria after on-scene evaluation compared to at the moment of dispatch), and the number of patients meeting the pre-defined timeline for ECPR.

Data acquisition

Data were retrieved from two sources: The KSS electronic patient record (Hemsbase 2.0 Medic One Systems, LTD. UK), and the KCH ICU records. The following data were obtained: total number of OHCA patients attended by HEMS, total number of patients meeting ECPR eligibility criteria at dispatch, after on-scene evaluation and after in-hospital evaluation, patient descriptors (age, gender, co-morbidity), mission descriptors (location of OHCA, timings [emergency call time, HEMS arrival on scene time, HEMS leaving scene time, HEMS arrival in hospital time]; clinical findings (initial rhythm, presumed etiology, ROSC on arrival HEMS [y/n]), patient conveyance to hospital [y/n], destination hospital, and outcome (ECPR initiated [y/n]; survival until hospital discharge [y/n]).

For patients attended by HEMS who were potentially eligible for ECPR, but who were not transported to the ECPR center, theoretical "most favorable transport times" were calculated to evaluate if they could have been presented within the establish time window, based on the distance to hospital in nautical miles (NM), the maximum cruising speed of the Augusta Westland 169 HEMS Helicopter (270 km/hr), and a minimum time of 15 min needed for loading a fully packaged patient and take off (as obtained from the cohort of potentially eligible patients who were transported to KCH), landing, handover, and 5 min from landing on the helipad to arrival in ED or the catheterization lab.

Ethical considerations

This project met National Institute for Healthcare Research (NIHR, UK) criteria for service evaluation and formal ethical approval was therefore not required. The project was approved by the KSS Research & Development Committee.

Statistical analysis

Data are represented as numbers (percentages). Average transport times from the location of the incident to the ECPR center were calculated by subtracting the "leaving scene time" from the "in hospital time". Missing data are reported in the results section according to the STROBE guideline.[21] All statistical analyses were conducted using SPSS 26.0 for Apple statistical package.

Results

Dispatch

During the study period 1050 patients with a cardiac arrest were attended by KSS HEMS, the majority of which (n = 706, 67 %) had a medical cause of their arrest. Not all these patients were attended with the aim of facilitating ECPR: 323 patients had an unwitnessed cardiac arrest and/or did not receive immediate bystander CPR and were seen by the HEMS team as it was the nearest medical resource. A total of 162 patients (15.4 %) met HEMS ECPR dispatch criteria (dispatch efficacy 234/706 = 33 %, Fig. 1).

On-scene evaluation

Upon arrival on scene, the HEMS team learned that a total of 102 patients had a shockable first rhythm. Of these, a cardiac- or pulmonary etiology, intoxication or hypothermia was present in 80 patients, whereas in 16 patients the cause of the arrest was noted as "unknown". For six patients no cause was registered. None of the patients had significant co-morbidity known to the HEMS team precluding potential ECPR.

Most patients had a ROSC upon arrival of the HEMS team (74/102, 72.5 %). Of these, 60 (81.1 %) did not receive any vasoactive medication after ROSC was obtained, whilst 14 patients (18.9 %) needed vasopressors post ROSC to support their blood pressures. Two patients who had regained ROSC were identified as potential post-ROSC ECLS candidates: One with a refractory cardiogenic shock despite vasopressor therapy, and one with therapy resistant VT due to an intoxication (Fig. 2).

A total of 28 patients were still in cardiac arrest upon arrival of the HEMS team. After on-scene evaluation, 11 of them met ECPR eligibility criteria. The majority of the non-eligible patients already had a (prolonged) asystole when the HEMS team arrived, or deteriorated in the presence of the HEMS team, and was not conveyed to hospital. Two patients were conveyed in arrest despite being considered ineligible for ECPR (due to exceeding the time-window for ECPR) with the aim of salvage PCI.

In total, 13 patients, were regarded as potential ECLS candidates after on-scene evaluation by the HEMS team (Fig. 2). Two were candidates for post-ROSC ECLS c and 11 were ECPR candidates. Details of these patients are represented in Table 1.

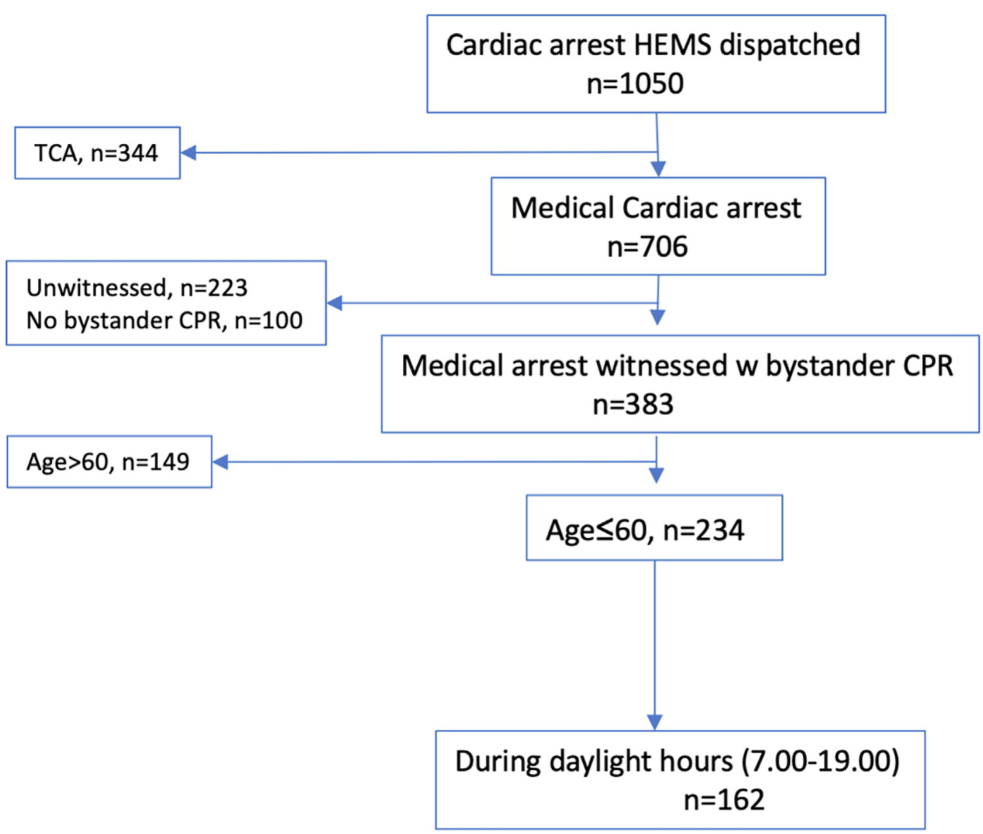

Fig. 1 – ECPR eligibility at dispatch.

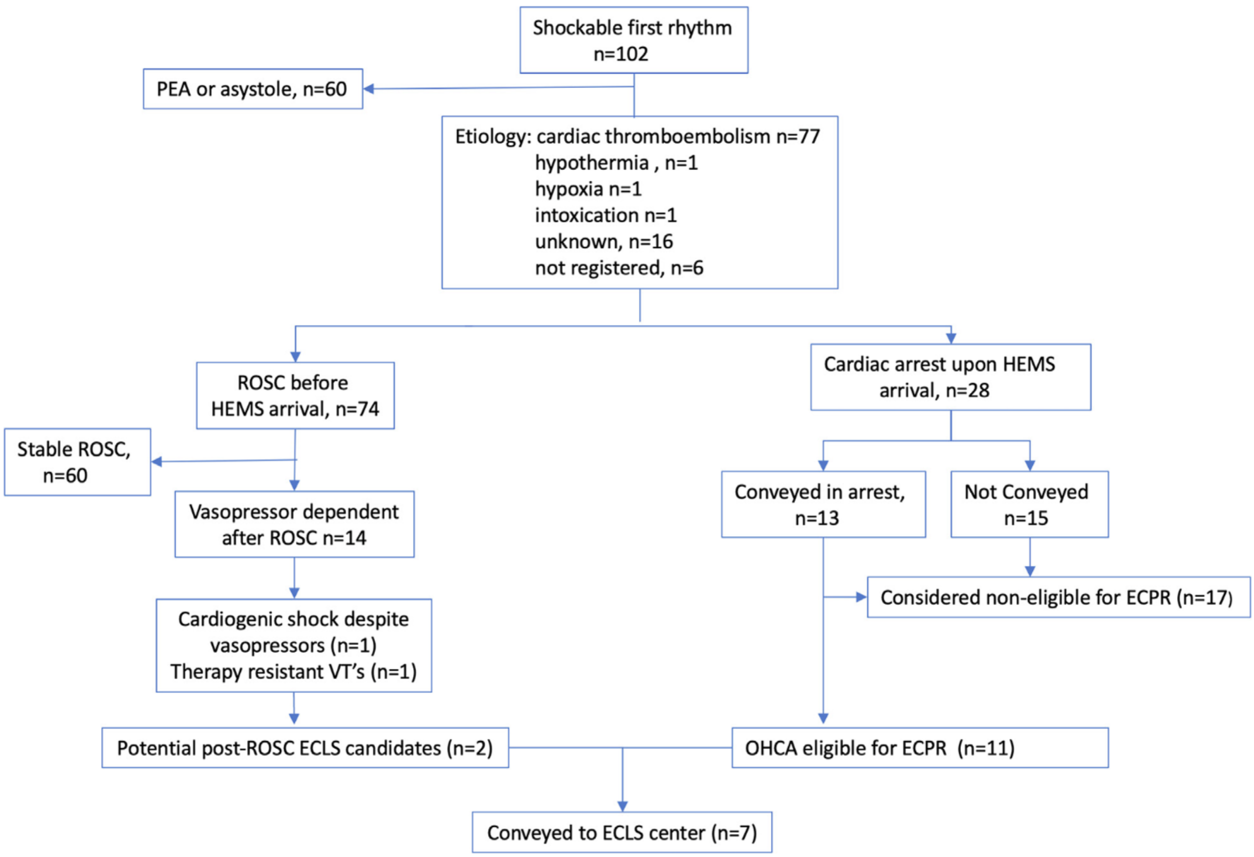

Fig. 2 – ECPR eligibility after on scene evaluation.

Table 1 – Patient characteristics of OHCA patients meeting ECPR eligibility criteria on-scene (n = 13).

Gender (M/F)	Age (y)	999 call- HEMS on scene (min)	Etiology	ROSC on arrival HEMS (Y/N)	Location arrest (NM to KCH)	Patient disposition (hospital type)	Rhythm on arrival hospital	ECPR (Y/N)	Survival (Y/N)
M	58	37	thromboembolic	Y	19	Other	Asystole	N	N
M	27	32	thromboembolic	N	45	Other	Asystole	N	N
M	52	56	thromboembolic	N	21	Other	Asystole	N	N
M	38	31	thromboembolic	N	32	ECPR center	Asystole	N	N
M	47	43	thromboembolic	N	16	Other	PEA	N	Y
M	48	14	thromboembolic	N	29	ECPR center	Asystole	N	N
M	44	31	thromboembolic	N	21	ECPR center	unknown	N	N
M	50	29	thromboembolic	N	22	ECPR center	Asystole	N	N
M	50	32	thromboembolic	N	38	ECPR center	Asystole	N	N
M	49	23	thromboembolic	N	39	Other	PEA	N	N
M	17	27	intoxication	Y	16	ECPR center	Sinus	Y*	Y
M	47	59	hypothermia	N	26	ECPR center	VF	Y	Y
M	50	43	thromboembolic	N	16	Other	PEA	N	N

NM; nautical miles (1 nautical mile equals 1 knot = 1.85 km); KCH, Kings College Hospital (ECPR center).* ECPR initiated post-ROSC.

In-hospital evaluation

Seven patients were conveyed to the ECLS centre, and ECLS was established in two patients: One with a refractive VF due to cold water immersion (body temperature 23 °C), and one with a cardio-vascular unstable ROSC after a cardiac arrest due to an intoxication with organic substances. In both patients VA-ECMO was established successfully, and both made a full neurological recovery. Five patients were no longer regarded as suitable candidates for ECPR upon arrival: Four had deteriorated during transport and arrived with an asystole and low ETCO2 values outside the pre-specified time-window for ECPR. One remained in VF but was declined for ECPR due to a prolonged resuscitation with a very low pH (6.8) at presentation. In-arrest PCI was performed in this patient with stenting of the LAD and circumflex artery, but no ROSC was obtained. Six patients were conveyed to a nearby hospital without ECLS capability, for logistical- (no helicopter transport available) or geographical (crew decided patient was too far away from the nearest ECLS center or attended too long after 999-call to meet timelines) reasons. All six arrived in cardiac arrest. ROSC was obtained in only one of them, after in-arrest PCI (Table 1).

During the study period two patients who did *not* fulfill pathway-eligibility criteria were also transported by the HEMS team to the ECLS center for consideration of ECPR: One patient with electrical burns (without cardiac arrest), and one patient with a PEA who was attended during the night-time hours. ECLS was not initiated in either patient.

Timelines

The average time from 999-call to HEMS arrival for the 11 patients who were in arrest and met ECPR eligibility criteria on scene was 34 min (range: 14–56 min), whereas the average time from 999 call to -hospital arrival was 86 min (range: 46–122 min). Of the 5/11 patients who were transported to the ECLS centre, only one arrived there within 70 min of the arrest. For the patients not transported to an ECLS center (6/11), theoretical most favorable transport times were calculated as described. Based on these timings, only one patient could potentially have been presented in the ECLS center within 70 min of the arrest.

Discussion

The present study demonstrates that in a semi-rural setting, in-hospital ECPR has a low potential to contribute to the outcome of patients suffering an OHCA, even when expedited helicopter transport is available. Timelines can seldom be met, and almost all potentially eligible patients deteriorate into asystole before they arrive in hospital. The rare exception to this is patients with a cardiac arrest due to special circumstances such as hypothermia, or patients who have a cardiogenic shock after ROSC is obtained and who might benefit from post-ROSC ECLS. It seems prudent to dispatch CCP and HEMS teams to these patients with a low threshold.

During an almost 4-year study period, 1050 patients with a cardiac arrest were attended. Only around 1.2 % of these fulfilled the ECPR-pathway criteria after on scene evaluation. The majority of patients either presented with a non-shockable rhythm, or had regained ROSC by the time of HEMS arrival by the use of an AED and/or treatment provided by the ground ambulance crews. Although HEMS teams can provide critical interventions (such as prehospital emergency anesthesia) to patients who have regained ROSC,[22] expedited transfer for the purpose of ECPR is often not indicated. The exception to this are patients with a vasopressor-resistant cardiogenic shock or cardiovascular instability due to recurrent dysrhythmias.[23] As these patients have a high potential to re-arrest, HEMS may facilitate a safe and expedited transport using mechanical CPR to a nearby ECLS centre as required.

ECPR is best implemented within a system that optimizes all aspects of cardiac arrest care.[1] Currently in the UK, bystander CPR is only attempted in 7 out of 10 patients with OHCA, and AED's are used in only 1 in 10 cardiac arrests.[24] When no bystander CPR is provided during the first minutes of the arrest, patients with initially shockable rhythms will eventually deteriorate into asystole, often before arrival of HEMS, as we have noted in our study population. This may explain the low number of potential eligible candidates (1.2%), compared to other studies.[7]

Those patients who had a shockable first rhythm upon arrival of the first ambulance crews often deteriorated over time into a non-shockable rhythm. This happened either before arrival of HEMS, in the presence of HEMS, or on route to hospital (if conveyed). Previous studies have demonstrated that this is a poor prognosticator when ECPR is initiated,[25] and therefore asystole on presentation is often regarded as a contraindication. The relatively high number of patients with a rhythm conversion is most likely the result of the prolonged travel times. In our cohort, it took HEMS on average 34 min to get to eligible patients, and only one patient could be presented in the ECLS center within 70 min of the arrest.[17,18]

Although robust data is currently still lacking, patients in rural settings far from ECPR centers could probably benefit from prehospital ECPR[26]. Prehospital initiation of ECPR has the potential to shorten low-flow time by 20 min,[6] thereby offering the opportunity to initiate ECPR immediately after the indication has been established. This could have made a difference to those patients in whom their initially shockable rhythm has deteriorated into asystole in the presence of the HEMS team either on scene or on route to the ECLS center. However, the applicability of these results to (semi)rural populations remains to be answered, as low-flow times are likely longer. The currently recruiting prospective On-Scene trial in the Netherlands[13] has the potential to answer this question.

Based on our findings, the added value of routinely dispatching HEMS to patients aged <60 years with a witnessed OHCA who received bystander CPR in a semi-rural setting seems limited. The value of a dedicated HEMS pathway to facilitate transport from the pre-hospital setting to an ECLS center mainly seems to be for patients who are *not* in cardiac arrest, such as patients with a cardiogenic shock or recurrent dysrhythmias due to intoxication with vasoactive substances, or for patients suffering from an OHCA due to hypothermia.[27] In these patients, timelines are less strict, and they are therefore more likely to be eligible (post ROSC) ECLS candidates upon arrival in the hospital. Early involvement of HEMS in the treatment of these patients seems prudent, and specific prompts in the dispatch process are therefore warranted.

Our study has several potential limitations. First, as this is a retrospective study, we were reliant on the available patient data. Although the number of missing data was low, as a result of mandatory dedicated entry fields for cardiac arrest in the electronic patient record, we cannot exclude that we have missed patients in our analysis who were attended by AAKSS for an OHCA during the study period, but not registered as such. Second, due to the semi-rural geography, HEMS was dispatched with a relatively low threshold, often before arrival of ambulance crews on scene. This resulted in many patients having regained ROSC upon arrival of the HEMS team. Although the vast majority of patients with a post-OHCA ROSC are no longer suitable ECLS candidates, the impact HEMS had on the treatment in these patients was not investigated in the current study, and therefore no conclusions can be drawn about the merit of HEMS for the attendance of patients with an OHCA in general. Third, as mentioned, the number of potentially eligible candidates after on-scene evaluation by HEMS was low for various reasons. Therefore, our results cannot be simply extrapolated to populations with a different EMS system or geography, or higher rates of bystander CPR/ higher AED availability. Such populations may have a higher ROSC rate on the one hand, but also less patients deteriorating into (unfavorable) non-shockable rhythms on the other hand.[28] The effect on the total number of eligible patients remains unclear.

Conclusion

In-hospital ECPR is of limited value for patients with refractory OHCA in a semi-rural setting, even when a dedicated pathway is in place. Potentially eligible patients often cannot be transported within an appropriate timeframe and/or deteriorate before arrival in hospital, However, having a dedicated pathway in place can have a positive impact on patients requiring ECLS who are not in cardiac arrest.

Funding source

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Credit author statement

EtA, JG, MT, TH, and RL were involved in the conception and design of the study. EtA, DG, DC, MN and MT collected the data. EtA, and RL drafted the manuscript, and MT, JG, DG, DC MN and TH revised it critically for important intellectual content. All authors gave final approval of the version to be submitted and agreed to be accountable for all aspects of the work.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ewoud ter Avest reports a relationship with Kent, Surrey and Sussex Airambulance Trust that includes: employment.

Author details

[a]Kent, Surrey and Sussex Air Ambulance Trust, Redhill Airfield, Redhill, Surrey, UK[b]Department of Emergency Medicine, University Hospital Groningen, the Netherlands [c]Kings College NHS Trust, Department of Emergency Medicine, UK [d]South East Coast Ambulance Service, UK [e]Kings College NHS Trust, Department of Intensive Care Medicine, UK[f]London's Airambulance, UK[g]School of Health Sciences, University of Surrey, UK

REFERENCES

1. Gottula AL, Neumar RW, Hsu CH. Extracorporeal cardiopulmonary resuscitation for out-of-hospital cardiac arrest - who, when, and where? Curr Opin Crit Care 2022;28:276–83.
2. Virani SS, Alonso A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, et al. Heart disease and stroke statistics-2021 update: a report from the American Heart Association. Circulation 2021;143: e254–74.
3. ECLS Registry Report of the ELSO Registry, accessed 28 June 2022 at https://www.el-so.org.
4. Shin TG, Choi JH, Jo IJ, Sim MS, Song HG, Jeong YK, et al. Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation. Crit Care Med 2011;39:1–7.
5. 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 2008;372:554–61.
6. Lamhaut L, Hutin A, Puymirat E, Jouan J, Raphale 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;117:109–17.
7. Alm-Kruse K, Sørensen G, Osbakk SA, Sunde K, Bendz B, Andersen GØ, et al. Outcome in refractory out-of-hospital cardiac arrest before and after implementation of an ECPR protocol. Resuscitation 2021;162:35–42.
8. 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. Eur Heart J 2020;41:1961–71.
9. Koen J, Nathanael T, Philippe D. A systematic review of current ECPR protocols. A step towards standardisation. Resusc Plus 2020;3 100018.
10. Miyamoto Y, Matsuyama T, Goto T, Ohbe H, Kitamura T, Yasunaga H, et al. Association between age and neurological outcomes in out-of-hospital cardiac arrest patients resuscitated with extracorporeal cardiopulmonary resuscitation: a nationwide multicentre observational study. Eur Heart J Acute Cardiovasc Care 2022;11:35–42.
11. 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.
12. Marinaro J, Guliani S, Dettmer T, Pruett K, Dixon D, Braude D. Out-of-hospital extracorporeal membrane oxygenation cannulation for refractory ventricular fibrillation: a case report. J Am Coll Emerg Physicians Open 2020;1:153–217.
13. On scene trial information, accessed 28-06-2022 at https://onscenetrial.com.
14. Singer B, Reynolds JC, Davies GE, Wrigley F, Whitbread M, Faulkner M, et al. on behalf of the International ECMO Network (ECMONet). Sub30: Protocol for the Sub30 feasibility study of a pre-hospital Extracorporeal membrane oxygenation (ECMO) capable advanced resuscitation team at achieving blood flow within 30 min in patients with refractory out-of-hospital cardiac arrest. Resusc plus 2020;4 100029.
15. Matsuyama T, Irisawa T, Yamada T, Hayakawa K, Yoshiya K, Noguchi K, et al. Impact of low-flow duration on favorable neurological outcomes of extracorporeal cardiopulmonary resuscitation after out-of-hospital cardiac arrest: a multicenter prospective study. Circulation 2020;141:1031–103.
16. Guy A, Kawano T, Besserer F, Scheuermayer F, Kanji HD, Christenson J, et al. The relationship between no-flow interval and survival with favourable neurological outcome in out-of-hospital cardiac arrest: Implications for outcomes and ECPR eligibility. Resuscitation 2020;155:219–25.
17. Hutin A, Abu-Habsa M, Burns B, Bernard S, Bellezo J, Shinar Z, et al. Early ECPR for out-of-hospital cardiac arrest: best practice in 2018. Resuscitation 2018;130:44–8.
18. Singer B, Reynolds JC, Lockey DJ, O'Brien B. Pre-hospital extra-corporeal cardiopulmonary resuscitation. Scand J Trauma Resusc Emerg Med 2018;26:21.
19. Hsu CH, Meurer WJ, Domeier R, Fowler J, Whitmnore 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.
20. Munro S, Joy M, de Coverly R, Salmon M, Williams J, Lyon RM. A novel method of non-clinical dispatch is associated with a higher rate of critical Helicopter Emergency Medical Service intervention. Scand J Trauma Resusc Emerg Med 2018;26:84.

21. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 2007;370:1453–7.
22. Lyon RM, Nelson MJ. Helicopter emergency medical services (HEMS) response to out-of-hospital cardiac arrest. Scand J Trauma Resusc Emerg Med 2013;21:1.
23. Vakil D, Soto C, D'Costa Z, Volk L, Kandasamy S, Lyer D, et al. Short-term and intermediate outcomes of cardiogenic shock and cardiac arrest patients supported by venoarterial extracorporeal membrane oxygenation. J Cardiothorac Surg 2021;16:290.
24. Perkins GD, Nolan JP, Soar J, Hawkes C, Wyllie J, Skellett S, et al. Resuscitation council UK 2021 Resuscitation guidelines, epidemiology of cardiac arrest guidelines. Accessed 28 June 2022 at https://www.resus.org.uk/library/2021-resuscitation-guidelines/epidemiology-cardiac-arrest-guidelines.
25. Maeda K, Inoue A, Kuroda Y, Inoue F, Suga M, Ijuin S, et al. Association Between Converting Asystole From Initial Shockable ECG Rhythm Before Extracorporeal Cardiopulmonary Resuscitation and Outcome. Shock 2021;56:701–8.
26. Hutin A, Ricard-Hibon C, Briole N, Dupin A, Raphalen JH, Mungur A, et al. First description of a helicopter-borne ECPR team for remote refractory Out-of-hospital cardiac arrest. Prehosp Emerg Care 2022;26:89–92.
27. Burke CR, Chan T, Brogan TV, Lequier L, Thiagarajan RR, Rycus PT, et al. Extracorporeal life support for victims of drowning. Resuscitation 2016;104:19–23.
28. Klee TE, Kern KB. A review of ECMO for aardiac arrest. Resuscitation Plus 2021;5 100083.