Hospital-administered ECPR for out-of-hospital cardiac arrest: an observational cohort study

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Handling editor Darryl Wood

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/emermed-2023-213292).

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Presented in part at the London Trauma Conference in London, UK, 6–9 December 2022.

Received 17 April 2023
Accepted 17 August 2023

To cite: Puolakka T, Salo A, Varpula M, *et al*. *Emerg Med J* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/emermed-2023-213292

ABSTRACT

Background Extracorporeal cardiopulmonary resuscitation (ECPR) is a treatment method for refractory out-of-hospital cardiac arrest (OHCA) requiring a complex chain of care.

Methods All cases of OHCA between 1 January 2016 and 31 December 2021 in the Helsinki University Hospital catchment area in which the ECPR protocol was activated were included in the study. The protocol involved patient transport from the emergency site with ongoing mechanical cardiopulmonary resuscitation (CPR) directly to the cardiac catheterisation laboratory where the implementation of extracorporeal membrane oxygenation (ECMO) was considered. Cases of hypothermic cardiac arrest were excluded. The main outcomes were the number of ECPR protocol activations, duration of prehospital and in-hospital time intervals, and whether the ECPR candidates were treated using ECMO or not.

Results The prehospital ECPR protocol was activated in 73 cases of normothermic OHCA. The mean patient age (SD) was 54 (±11) years and 67 (91.8%) of them were male. The arrest was witnessed in 67 (91.8%) and initial rhythm was shockable in 61 (83.6%) cases. The median ambulance response time (IQR) was 9 (7–11) min. All patients received mechanical CPR, epinephrine and/or amiodarone. Seventy (95.9%) patients were endotracheally intubated. The median (IQR) highest prehospital end-tidal CO_2 was 5.5 (4.0–6.9) kPa. A total of 37 (50.7%) patients were treated with venoarterial ECMO within a median (IQR) of 84 (71–105) min after the arrest. Thirteen (35.1%) of them survived to discharge and 11 (29.7%) with a cerebral performance category (CPC) 1–2. In those ECPR candidates who did not receive ECMO, 8 (22.2%) received permanent return of spontaneuous circulation during transport or immediately after hospital arrival and 6 (16.7%) survived to discharge with a CPC 1–2.

Conclusions Half of the ECPR protocol activations did not lead to ECMO treatment. However, every fourth ECPR candidate and every third patient who received ECMO-facilitated resuscitation at the hospital survived with a good neurological outcome.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Extracorporeal cardiopulmonary resuscitation (ECPR) has shown the potential to prevent both death and severe disability in refractory out-of-hospital cardiac arrest (OHCA) but requires a complex chain of care.

WHAT THIS STUDY ADDS

⇒ ECPR protocol was activated in less than 3% of all OHCA cases and only half of the prehospital ECPR candidates eventually received ECPR at the hospital.

⇒ Every fourth ECPR candidate and every third ECPR patient survived with a good neurological outcome (cerebral performance category 1–2).

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These data encourage the further development of hospital-administered ECPR for OHCA.

INTRODUCTION

Extracorporeal cardiopulmonary resuscitation (ECPR) is a treatment method for refractory cardiac arrest (CA) which aims at rapid restoration of blood flow using venoarterial extracorporeal membrane oxygenation (ECMO). This enables the treatment of the underlying cause of the CA and the return of the patient's own circulation.[1] ECPR for out-of-hospital cardiac arrest (OHCA) can be implemented using either a prehospital or in-hospital approach. The prehospital approach involves a prehospital team cannulating the patient and initiating ECMO at the emergency site.[2 3] With the hospital-based approach, the patient is transported with ongoing cardiopulmonary resuscitation (CPR) to the hospital where cannulation and initiation of ECMO treatment takes place.[4–6]

ECPR is currently recommended in selected scenarios by the European Resuscitation Council.[1] Two randomised controlled trials have shown a clear trend for a positive outcome while the latest multicentre trial showed no benefit.[7–9] The ECPR trials have faced challenges due to complex study design, small sample size and prematurely terminated study protocols.[7–9] Since the implementation of an ECPR programme is challenging, more research is warranted.[10–12]

The aim of this study was to describe the real-life performance of a single-centre hospital-administered ECPR programme for OHCA by reporting the number of ECPR protocol activations, duration of prehospital and in-hospital time intervals, and whether the ECPR candidates were treated using ECMO or not. Secondary points of interest were the reasons for not implementing ECMO as well as the patient's survival with a good neurological outcome.

METHODS

Study design

This was an observational cohort study which included all cases of prehospital physician-led resuscitation attempts after the implementation of the ECPR protocol. The study duration was 6 years between 1 January 2016 and 31 December 2021. The data collection was retrospective and based on electronic prehospital and in-hospital patient records. The study manuscript was prepared according to STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines.[13]

Study setting

Helsinki University Hospital (HUS) is the largest academic hospital in Finland serving a population of 1600 000 in the Helsinki capital region.

The emergency medical services (EMS), governed by HUS, consist of basic life support and advanced life support (ALS) ambulances each staffed by two emergency medical technicians or paramedics.[14] Within the HUS area, there are two mobile intensive care units (MICUs) staffed by physicians: one operating by car within the city of Helsinki, while the other covers the rest of the HUS area, primarily by helicopter. The MICUs are dispatched to high-risk calls, including OHCA, and provide a teleconsultation service for ambulance crews. All EMS units are equipped with mobile computers (Toughbook CF-20, Panasonic, Osaka, Japan) and use an electronic patient reporting (EPR) system (Merlot Medi, CGI, Montreal, Canada) for all patient data.[15]

HUS has a 24/7 capability for emergency cardiology, cardiac surgery, cardiothoracic anaesthesia and critical care. The HUS unit for interventional cardiology performs 1600 percutaneous coronary interventions (PCIs) a year. The intensive care units (ICUs) have a total of 60 beds of which 10 are dedicated to cardiac surgery. The cardiac surgery ICU has 1200 treatment periods per year of which approximately 70 involve ECMO or ventricular assist devices (VADs).

The ECPR protocol

The ECPR programme for OHCA at HUS begun in January 2016 and operates 24/7. The implementation consisted of the introduction of an ECPR protocol for the EMS and an ECPR team model for the hospital to enable rapid initiation of ECMO and to minimise the CA-to-ECMO (or low-flow) time. Prior to this, resuscitation attempts in OHCA were made at the emergency site and patients were not transported with ongoing CPR apart from selected cases such as accidental hypothermia transported directly to the operating theatre.

The ECPR protocol can be activated by the prehospital physician when the patient meets the prespecified inclusion criteria (box 1). The EMS are responsible for airway management, drug administration and initiating mechanical chest compressions. Only physician-staffed MICUs and selected ALS units are equipped with a mechanical chest compression device (Lund University Cardiac Arrest System, Stryker Corporation, Kalamazoo, Michigan, USA).

A telephone prenotification is used to alert the in-hospital ECPR team. If the catheterisation laboratory is not available when the patient arrives, there is an option to implement ECMO in the operating room. The ECPR team consists of a cardiologist, cardiac anaesthesiologist, cardiac surgeon, perfusionist and assisting nursing staff.

The final decision to proceed with ECMO is made case-by-case by the in-hospital team after patient handover and acquiring an arterial blood gas sample. In the HUS ECPR protocol, factors associated with a poor prognosis and medical futility included an estimated CA-to-ECMO time >60 min, arterial pH <6.8, arterial pO_2 <6.7 kPa and arterial lactate >18 mmol/L. In the procedure the cardiologist punctures the femoral artery and vein using ultrasound and fluoroscopy guidance and inserts J-guidewires via the Seldinger technique. The cardiac surgeon then continues the cannulation percutaneously. Successful ECMO activation is followed by immediate coronary angiography and, if necessary, PCI to the culprit vessel. After the procedure, the patient is admitted to the cardiac surgery ICU where the patient stays for the remaining duration of ECMO treatment.

Box 1 The prehospital extracorporeal CPR inclusion criteria at the Helsinki University Hospital

- ⇒ Age under 70 years
- ⇒ Previously healthy (no terminal illness, independent in instrumental activities of daily living)
- ⇒ Witnessed arrest
- ⇒ Telephone-assisted CPR given
- ⇒ Ambulance response time <10 min
- ⇒ Shockable initial rhythm
- ⇒ Non-shockable rhythm can be considered in selected cases of pulmonary embolism or drug overdose
- ⇒ Patient has already received conventional ALS (at least three cycles of CPR, defibrillation and drug therapy)
- ⇒ Patient is endotracheally intubated
- ⇒ Mechanical CPR during transport is possible
- ⇒ ECMO is possible to arrange within 60 min of the cardiac arrest

ALS, advanced life support; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation.

Participants

All cases of OHCA in the HUS area with a prehospital physician on the scene were screened for ECPR criteria (box 1). Patients meeting the criteria received prehospital resuscitation and ambulance transport using mechanical chest compressions according to the ECPR protocol. All other patients received standard ALS resuscitation at the scene.

Data collection

The data collection was retrospective and followed Utstein definitions.[16] Patients with hypothermic CA were excluded due to significant differences in treatment principles and the chain of care. Data collection was fully based on electronic patient records to minimise missing data. The registered prehospital variables included patient sex, age, telephone-assisted CPR, use of mechanical compression device, airway device used, drug therapy given, patient's signs of life, prehospital end-tidal CO_2 ($etCO_2$) values, possible ECG analysis before the CA as well as EMS operational data and timestamps. Hospital phase data included timestamps for hospital arrival and ECMO initiation, duration of intensive care and time for total hospitalisation, and patient's cerebral performance class category. The relevant prehospital and in-hospital time intervals were calculated based on operational EMS timestamp data. Agonal breathing, blinking, biting teeth together, moving one's limbs, and requiring sedation or a neuromuscular blocking agent (NMBA) during chest compressions were all included as signs of life. The patients' survival to discharge and one year after OHCA were retrieved from hospital records. Similarly, the patients' need for VAD or participation in the organ donation programme as a donor or a recipient was assessed one year after the CA.

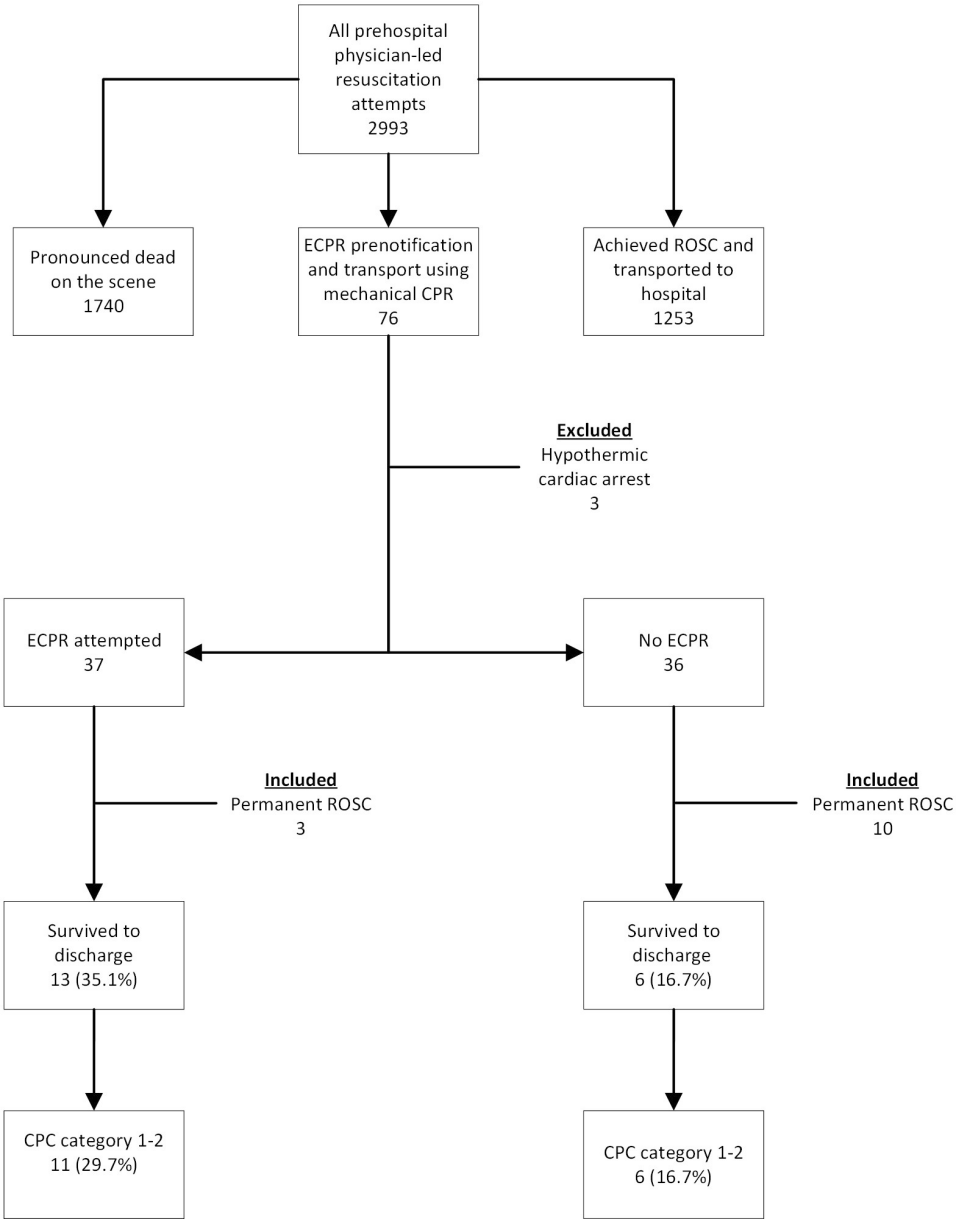

Figure 1 Description of the patient sample. CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECPR, extracorporeal cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Patient and public involvement

Patients and the public were not involved in the study due to the retrospective approach and register-based nature of the study.

Statistical analysis

The data was analysed using the SPSS V.28 statistical package. Descriptive data are presented as n (%), mean (SD) and median (IQR). Missing values were omitted from analysis. Student's t-test, Fisher's exact test and Mann-Whitney U test were used for comparison of groups where appropriate. Statistical significance was set at $p<0.05$.

RESULTS

ECPR candidates

During the study, the MICUs units took part in the management of a total of 2993 OHCA cases. The ECPR protocol was activated in 73 cases (2.4%) of normothermic OHCA (figure 1). The mean age of the ECPR candidates was 54.4 (±11.3) years and 67 (91.8%) of them were male (table 1). The arrest was witnessed in 67 (91.8%) and in 10 (13.7%) cases a preceding ECG meeting the criteria for ST-elevation myocardial infarction was registered before OHCA. The median ambulance response time was 9 (7–11) min and mechanical CPR was initiated in 11 (6–19) min after the first EMS unit reached the patient. The initial rhythm was shockable in 61 (83.6%) cases and the patient was defibrillated a median of 6 (4–10) times. Seventy (95.9%) patients were endotracheally intubated during prehospital care. Furthermore, all patients received mechanical CPR, epinephrine and/or amiodarone according to the resuscitation algorithm. One or more signs of life during CPR were recorded in 52 (71.2%) patients (table 2). Twenty-one (28.8%) patients received an NMBA and 14 (19.2%) were given sedation during CPR. The median highest registered prehospital $etCO_2$ during CA was 5.5 (4.0–6.9) kPa while the mean of all registered $etCO_2$ values during prehospital CPR was 3.8 (1.3) kPa. However, missing data in $etCO_2$ measurements was common – 32.9% and 30.1%, respectively.

Table 1 Description of the study sample

	N=73
Age (SD)	54.4 (±11.3)
Sex, male	67 (91.8)
Type of CA	
Witnessed	52 (71.2)
Non-witnessed	6 (8.2)
EMS already on-scene	15 (20.5)
Location	
Private home	35 (47.9)
Public outside	18 (24.7)
Public indoors (incl. place of work)	17 (23.3)
Other	3 (4.1)
Telephone-assisted bystander CPR*	47 (81.0)
Initial rhythm	
VF/VT	61 (83.6)
PEA	12 (16.4)
Intermittent ROSC	19 (26.0)
Permanent ROSC	13 (17.8)
Prehospital interventions	
Diagnostic ECG (STEMI) before CA	15 (20.5)
Endotracheal intubation	70 (95.9)
Epinephrine, mg (IQR)	5 (4–6)
Amiodarone, mg (IQR)	450 (300–450)
Mechanical CPR	73 (100.0)
Intravenous thrombolysis	7 (9.6)
Defibrillations (IQR)	6 (4–10)
Rhythm at hospital arrival	
VF	14 (19.2)
PEA	33 (45.2)
Asystole	10 (13.7)
Pulsating rhythm	12 (16.4)
Unknown	4 (5.5)
Hospital interventions	
Placed on ECMO	37 (50.7)
Coronary angiography	48 (65.7)
Cause of CA	
STEMI	36 (49.3)
Suspected ACS	32 (43.8)
Suspected pulmonary embolism	5 (6.8)
Hypothermia	n/a
Outcome	
Withdrawal from treatment	53 (72.6)
Survived to discharge	19 (26.0)
CPC 1–2†	17 (23.3)
Alive after 1 year†	18 (24.7)
Required VAD	0 (0)
Required organ transplant	0 (0)
Acted as organ donor	0 (0)

Data presented as n (%), mean (SD) or median (IQR).
*Excluding cases with EMS already on the scene.
†One patient with incomplete CPC data was lost to follow-up.
ACS, acute coronary syndrome; CA, cardiac arrest; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; EMS, emergency medical services; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; STEMI, ST-elevation myocardial infarction; VAD, ventricular assist device; VF, ventricular fibrillation; VT, ventricular tachycardia.

Table 2 Comparison of ECPR candidates who received venoarterial ECMO and conventional care

	ECMO (n=37)	Standard care (n=36)	P value
Age, years (SD)	51.9 (±12.1)	57.0 (±9.9)	0.056
Sex, male	34 (91.9)	33 (91.7)	1.000
Witnessed CA	34 (91.9)	33 (91.7)	1.000
Telephone assisted bystander CPR*	23 (79.3)	24 (82.8)	1.000
Shockable initial rhythm	29 (78.4)	32 (88.9)	0.345
Shockable rhythm at hospital arrival	11 (29.7)	3 (8.3)	0.035
Intermittent ROSC	11 (29.7)	8 (22.2)	0.595
Permanent ROSC	3 (8.1)	10 (27.8)	0.035
Time intervals, min (IQR)			
Response time	9 (7–12)	8 (7–10)	0.702
Mechanical CPR (after arriving at the scene)	10 (5–18)	11 (7–22)	0.599
OST	32 (26–42)	33 (25–40)	0.908
Transport	16 (13–24)	16 (11–22)	0.893
Handover	5 (3–7)	4 (3–6)	0.307
ECMO placement	23 (16–30)	n/a	n/a
CA to hospital arrival	56 (47–69)	57 (45–66)	0.716
CA to ECMO	84 (61–105)	n/a	n/a
CA to permanent ROSC	47 (46 n/a)	55 (39–64)	1.000
Signs of reactivity (≥1) during CA†	26 (70.3)	26 (72.2)	1.000
Made own breathing attempts	22 (59.5)	20 (55.6)	0.815
Opened eyes	5 (13.5)	6 (16.7)	0.754
Bit teeth together	6 (16.2)	6 (16.7)	1.000
Moved limbs	8 (21.6)	5 (13.9)	0.543
Received NMBA	13 (35.1)	8 (22.2)	0.302
Received sedation	6 (16.2)	8 (22.2)	0.564
Highest prehospital $etCO_2$, kPa (IQR)	5.1 (3.9–6.9)	5.6 (4.6–7.0)	0.891
Mean prehospital $etCO_2$, kPa (SD)	3.5 (±1.2)	4.1 (±1.4)	0.153
Interventions			
Diagnostic ECG (STEMI) before CA	6 (16.2)	9 (25.0)	0.398
Defibrillations (IQR)	5 (3–9)	7 (4–11)	0.098
Endotracheal intubation	36 (97.3)	34 (94.4)	0.615
Epinephrine, mg (IQR)	4 (3–5.5)	5 (3–6)	0.355
Amiodarone, mg (IQR)	450 (300–450)	450 (300–450)	0.422
Intravenous thrombolysis	5 (13.5)	2 (5.6)	0.430
Coronary angiography	32 (86.5)	16 (44.4)	<0.001
Outcome			
Survived to discharge	13 (35.1)	6 (16.7)	0.109
Alive after 1 year‡	12 (32.4)	6 (16.7)	0.173
CPC 1–2‡	11 (29.7)	6 (16.7)	0.267

Data presented as n (%), mean (SD) or median (IQR).
*Not including cases with EMS already on the scene.
†Including own breathing attempts, blinking eyes, trismus, limb movements, or the administration of NMBA or sedation.
‡One patient with incomplete CPC data was lost to follow-up.
CA, cardiac arrest; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation; EMS, emergency medical services; $etCO_2$, end-tidal CO_2; NMBA, neuromuscular blocking agent; OST, On-scene time; ROSC, return of spontaneous circulation; STEMI, ST-elevation myocardial infarction.

ECPR treatment

ECPR was attempted in 37 cases (56.0%). The patient was successfully connected to ECMO in 32 (86.4%). Five attempts failed due to cannulation failure, bleeding or thrombosis. In three (8.1%) of these cases, the patient had to be connected to ECMO after achieving permanent return of spontaneous circulation (ROSC) due to haemodynamic instability or imminent respiratory failure (figure 1). In six (16.2%) cases, the catheterisation laboratory was not available when the patient arrived and

ECMO was implemented in the operating room. ECMO cannulation took 23 (16–30) min. The total CA-to-door time was 56 (45–68) min and CA-to-ECMO time was 84 (71–105) min.

In the remaining 36 (44.0%) patients, ECPR was not attempted. In 10 (27.8%) cases the patient achieved ROSC and received standard postresuscitation care, in 4 (11.1%) the patient's medical history was not found to meet the inclusion criteria, in 3 (8.3%) the coronary angiography was attempted while still continuing chest compressions and in 1 (2.8%) case there was no available ICU capacity. The treatment was deemed to be medically futile by the ECPR team in 11 (30.5%) and the information was missing in 6 (16.7%) cases. The cases where ECMO was not attempted, or the attempt failed are listed in online supplemental file 1.

There were no significant differences in initial rhythm, whether the CA was witnessed or not, how often telephone-assisted CPR was given, the duration of prehospital time intervals, received prehospital treatment or the patient's signs of life during CA between the patients who received ECPR and those who did not (table 2). However, patients who received ECMO had more frequently a shockable rhythm at hospital arrival ($p<0.05$) and underwent coronary angiography during their hospital stay ($p<0.001$). Patients who received standard care had more often achieved permanent ROSC ($p<0.05$).

Outcome

A total of 19 (26.0%) of the ECPR candidates survived to discharge (table 3). Thirteen (68.4%) of the survivors received ECMO treatment and six (31.5%) received mechanical CPR and standard postresuscitation care (table 2). The number of patients with a cerebral performance category (CPC) 1–2 at discharge was 11 (84.6%) and 6 (100.0%), respectively. Although ECPR showed a trend to increase the likelihood of a favourable outcome, the finding was not statistically significant (tables 2 and 3).

Having one or more signs of life during the CA was more common in patients who eventually survived to discharge (89.5%) than those who died at hospital (64.8%) ($p<0.05$). All the surviving ECPR candidates had a shockable initial rhythm, but only two (10.5%) had a shockable rhythm on hospital arrival (table 3).

The total length of ICU and hospital stay for all ECPR candidates was longest for patients who survived to discharge (table 3). In other cases, ECPR attempt failed (5 cases, 9.3%), ECPR was not attempted at all (26 cases, 48.1%), or the treatment was withdrawn at an early stage in the ICU (22 cases, 40.7%) or the general ward (1 case, 1.9%)

One year after the CA, one patient in the ECMO group had died and another was lost to follow-up. A total of 18 (24.7%) ECPR candidates were alive and 17 (23.3%) had a CPC class 1–2 (tables 2 and 3). None of the surviving patients had received a VAD or an organ transplant, or acted as an organ donor.

Table 3 Comparison of patients who survived to discharge and died during the treatment period

	Survived to discharge (n=19)	Did not survive to discharge (n=54)	P value
Age, years (SD)	51.8 (±11.5)	55.3 (±11.2)	0.853
Witnessed CA	16 (84.2)	51 (94.4)	0.178
Outdoor location	7 (36.8)	11 (20.4)	0.215
Telephone assisted bystander CPR*	13 (92.9)	34 (79.1)	0.423
Shockable initial rhythm	18 (94.7)	43 (79.6)	0.166
Shockable rhythm at hospital arrival	2 (10.5)	12 (22.2)	0.331
Intermittent ROSC	6 (31.6)	13 (24.1)	0.552
Permanent ROSC	8 (42.1)	5 (9.3)	0.003
Time intervals, min (IQR)			
Response time	8 (7–11)	9 (7–11)	0.830
CA to hospital arrival	57 (44–63)	56 (47–69)	0.841
CA to permanent ROSC	47 (39–68)	55 (47–70)	0.242
CA to ECMO	85 (75–134)	84 (70–105)	0.707
Received ECMO	13 (68.4)	24 (44.4)	0.109
Signs of reactivity (≥1) during CA†	17 (89.5)	35 (64.8)	0.045
Made own breathing attempts	14 (73.7)	28 (51.9)	0.114
Blinked eyes	7 (36.8)	4 (7.4)	0.005
Bit teeth together	3 (15.8)	9 (16.7)	1.000
Moved limbs	6 (31.6)	7 (13.0)	0.087
Received NMBA	9 (47.4)	12 (22.2)	0.074
Received sedation	7 (36.8)	7 (13.0)	0.039
Highest prehospital $etCO_2$, kPa (IQR)	5.4 (4.7–6.6)	5.4 (3.9–7.0)	0.732
Mean prehospital $etCO_2$, kPa (SD)	3.6 (±0.8)	3.9 (±1.4)	0.488
Length of stay, days (IQR)			
ICU	7 (6–13)	1.2 (0.9–2.6)	<0.001
Whole hospital admission	17 (13–36)	0.09 (0.05–1.0)	<0.001
Outcome†*			
Alive after 1 year	18 (94.7)	n/a	n/a
CPC 1–2	17 (89.5)	n/a	n/a

Data presented as n (%), mean (SD) or median (IQR).
*Not including cases with EMS already on the scene.
†Including own breathing attempts, blinking eyes, trismus, limb movements, or the administration of NMBA or sedation.
CA, cardiac arrest; CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; EMS, emergency medical services; $etCO_2$, end-tidal CO_2; ICU, intensive care unit; NMBA, neuromuscular blocking agent; ROSC, return of spontaneous circulation.

DISCUSSION

In this single-centre study, less than 3% of all OHCA cases led to ECPR protocol activation, but every fourth ECPR candidate and every third patient who received hospital-administered ECPR survived with a good neurological outcome. These results are encouraging when compared with the survival rates achieved in earlier randomised controlled trials (20%–43%).[7–9] However, ECMO treatment itself was not associated with a favourable outcome. This can be explained by the fact that a number of patients received spontaneous ROSC with excellent neurological outcome without ECMO.

Using the currently available consensus-based inclusion criteria means that the number of patients with OHCA eligible for ECPR is small. This study is one of the few reports to be able to give a reliable estimation of all patients with OHCA eligible for ECPR. Previously, in a large observational study from Paris, ECPR was given to 525 out of 13 191 patients with OHCA (3.9%).[17] However, the drawback of this cohort was that during that time ECPR was still an emerging treatment and the treatment decision was left to the treating physician's discretion without clear inclusion criteria.

It is also important to acknowledge that several ECPR candidates will achieve ROSC during transport which can occur with a significantly longer delay than typically observed.[18] Despite that the median spontaneous ROSC delay in this study was well over 50 min, 75% of the patients with permanent ROSC in the non-ECMO group survived with a good outcome. This finding contradicts results from the earlier cohort study from

Minnesota where none of the >200 patients who were resuscitated for >40 min without ECPR survived with a good outcome.[5] However, the cohort was based on the ALPS Trial[19] which did not directly match the current inclusion criteria of ECPR. In this study, the ECPR candidates represented a very selective patient population who frequently showed multiple signs of life necessitating the use of NMBAs and sedation, and had high levels of $etCO_2$ reflecting the high quality of CPR.[20]

Earlier reports have shown that up to 30%–50% of ECPR candidates do not receive ECMO treatment.[21 22] The most common reason has been the anticipation of medical futility and concurrent discontinuation of life-sustaining care. Intriguingly, in this study the patients who did and did not receive ECMO showed no significant differences in the proportion of shockable initial rhythm, given telephone-assisted CPR, length of prehospital time intervals or $etCO_2$ levels. ECPR was also attempted more often when the patient still had a shockable rhythm at hospital arrival, although this patient group made up <10% of the survivors. Since the patient's survival in this selected group does not follow the rules of a typical OHCA, the decisions to withhold ECMO treatment should be as coherent and based on prespecified criteria as much as possible.

The performance of the EMS system was similar to earlier reports on ECPR. The ambulance response time was <10 min which is consistent with previous randomised controlled trials.[7–9] Belohlavek and colleagues registered a CA-to-door time of 49–60 min (median) between the invasive and standard care groups while in our study setting this was approximately 56 min. Thus, the achieved prehospital time was not much longer than previously reported in prehospital stroke care.[23] The door-to-ECMO time in this study (23 min) was in between the results from earlier randomised controlled trials (12–36 min) which emphasises the significance of team effort, cannulation experience and hospital case load in the ECPR process.[7–9] In the INCEPTION Trial, the arrest-to-hospital time was much faster (38 min, median) than reported earlier. This is explained by the care strategy which involved a 15 min time limit for prehospital resuscitation after which transport was initiated. However, it took twice as much time (74 min, median) to get the ECMO running which probably contributed to the negative result of the trial.[9] Despite that the fact that a number of studies have emphasised that a short arrest-to-ECMO time is critical for the patient's prognosis, a number of patients in this study survived with a good neurological outcome despite a low flow time of nearly 1.5 hours. This would suggest that the duration of low flow time alone does not determine the patient's outcome.

None of the study patients required a VAD or received an organ transplant within 1 year of the OHCA. Treatment for patients who did not survive was rapidly withdrawn, and their median length of stay was less than 1 day. None of the deceased ECPR candidates became organ donors. This might be explained by the small sample size and absence of a 'donor after circulatory death (DCD)' organ donation programme during this study. Since ECPR candidates represent a special population with favourable overall condition, their potential as organ donors is important to screen in the case they do not survive. According to a recent study, up to a third of ECPR patients who were referred to an organ procurement organisation eventually donated organs.[24]

The strength of this study is the consecutive patient sample based on a real life data set from a single EMS and hospital system. The EPR system used by the EMS enabled the collection of reliable prehospital data, including $etCO_2$ measurements and signs of life during CA. Limitations include a small sample size and the observational nature of the data. Although physician-staffed MICUs are dispatched to all cases of CA, this did not apply to situations where the physician-staffed units were unavailable due to another mission. Patient selection for ECMO placement was done on a case-by-case basis by the in-hospital team and was therefore subject to selection bias. Unfortunately, the patients' complete blood gas analysis results at hospital arrival were lost due to a systematic database error which also undermined further assessment of the treatment decisions. Moreover, neuron-specific enolase, an important prognostic biomarker, was not routinely measured from the ECPR patients in the ICU. Detailed information regarding complications of ECMO was unavailable to the investigators. Finally, the CPC is a relatively robust scale to assess the patient outcomes but lacks the estimation of physical activity, as well as working and psychological capability.

CONCLUSIONS

The ECPR protocol activations represented <3% of all physician-led resuscitation attempts in OHCA, and half of the ECPR protocol activations did not lead to ECMO treatment. However, every fourth ECPR candidate and every third patient who received ECPR at the hospital survived with a good neurological outcome (CPC category 1–2).

Contributors TP, AS, MV, JN, EW, KL and MK researched literature and conceived the study. TP, AS, JN and MV collected the study data. TP and AS were responsible for statistical analysis. TP, AS, MV, MBS and MK interpreted the results. TP wrote the first draft of the manuscript. All authors reviewed and edited the manuscript for important intellectual content and approved the final version. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. MK acted as the guarantor of the study.

Funding This study was supported by the Helsinki University Hospital (VTR-funding), the Laerdal Foundation for Acute Medicine (3624) (TP) and Viipurin tuberkuloosisäätiö (n/a) (TP).

Competing interests MBS reports speakers fees from BARD Medical (Ireland). Other authors report no competing interests.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. The study plan was approved by the institutional review board of the Helsinki University Hospital (HUS, HUS/230/2021). Due to the retrospective and register-based nature of the study, no informed consent or the evaluation by the ethical review board of HUS was required according to Finnish law on medical research.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data may be obtained from a third party and are not publicly available. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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