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Short paper

Heart rhythm at hospital admission: A factor for survival and neurological outcome among ECPR recipients?

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ABSTRACT

Background: The initial rhythm is a known predictor of survival in extracorporeal cardiopulmonary resuscitation (ECPR) patients. However, the effect of the rhythm at hospital admission on outcomes in these patients is less clear.

Methods: This observational, single-center study assessed the influence of the rhythm at hospital admission on 30-day survival and neurological outcomes at discharge in patients who underwent ECPR for out-of-hospital cardiac arrest (OHCA).

Results: Between January 2012 and December 2023, 1,219 OHCA patients were admitted, and 210 received ECPR. Of these, 196 patients were analyzed. The average age was 52.9 years (±13), with 80.6 % male. The median time to ECPR initiation was 61 min (IQR 54–72). Patients with ventricular fibrillation as both the initial and admission rhythm had the highest 30-day survival rate (52 %: 35/67), while those with asystole in both instances had the lowest (6 %: 1/17, log-rank $p < 0.00001$). After adjusting for age, sex, initial rhythm, resuscitation time, location, bystander, and witnessed status, asystole at admission was linked to higher 30-day mortality (OR 4.03, 95 % CI 1.49–12.38, $p = 0.009$) and worse neurological outcomes (Cerebral Performance Category 3–5) at discharge (OR 4.61, 95 % CI 1.49–17.62, $p = 0.013$).

Conclusions: The rhythm at hospital admission affects ECPR outcomes. Patients presenting with and maintaining ventricular fibrillation have a higher chance of favorable neurological survival, whereas those presenting with or converting to asystole have poor outcomes. The rhythm at hospital admission appears to be a valuable criterion for deciding on ECPR initiation.

Background

Extracorporeal cardiopulmonary resuscitation (ECPR) is a complex intervention for selected cardiac arrest patients, but identifying appropriate candidates during cardiopulmonary resuscitation (CPR) is challenging due to time constraints and a lack of reliable predictors.[1–3] There is no consensus on inclusion or exclusion criteria, leading to significant variability between centers.[1–6]

Initial rhythm is an independent predictor of survival and neurological outcomes in out-of-hospital cardiac arrest (OHCA) patients, including those receiving ECPR.[7] Additionally, rhythm conversion from non-shockable to shockable rhythms has been linked to better outcomes, though evidence on the impact of admission rhythm on ECPR outcomes is limited.[8–10] This registry-based study analyzed the relationship between initial rhythm and rhythm at hospital admission on ECPR outcomes.

Abbreviations: CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; ECG, Electrocardiogram; ECPR, extracorporeal cardiopulmonary resuscitation; EMS, emergency medical service; ERC, European Resuscitation Council; ESC, European Society of Cardiology; ICU, intensive care unit; OHCA, out-of-hospital cardiac arrest; OR, odds ratio; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; SD, standard deviation; VA ECMO, veno-arterial extracorporeal membrane oxygenation; VF, ventricular fibrillation.

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Methods

Study setting and population

The prehospital CPR system and its outcomes in Prague, Czech Republic, have been described previously.[11] Since 2012, the emergency medical service (EMS) in Prague, Czech Republic, has collaborated closely with the General University Hospital's cardiac arrest center to transport patients without return of spontaneous circulation (ROSC) for ECPR. This study includes all patients aged ≥ 18 years with OHCA, resuscitated between January 2012 and December 2023, who were transported to our center and received ECPR. Patients from the Prague-OHCA trial (2013–2022) who received ECPR were also analyzed.[1]

Data acquisition

The Prague OHCA register prospectively collects detailed data on prehospital and hospital treatment and outcomes of OHCA. Initial electrocardiogram (ECG) rhythms are evaluated by EMS physicians, while intensive care unit (ICU) physicians assess rhythms at hospital arrival. All other cardiac arrest data are entered into the database according to Utstein recommendations.[12]

Procedures

All OHCA patients admitted to the hospital were treated according to the ERC (European Resuscitation Council) and ESC (European Society of Cardiology) guidelines at the time. Upon hospital admission, the ICU doctor checks the patient's status, including heart rhythm and ROSC. If eligible, veno-arterial extracorporeal membrane oxygenation (VA ECMO) cannulation is initiated by trained physicians.

Outcomes

The primary outcome was 30-day survival, and the secondary outcome was neurological status at discharge, assessed using the Cerebral Performance Category (CPC), where CPC 1–2 indicates a good outcome and CPC 3–5 indicates a poor outcome.

Statistical analysis

Numeric variables are expressed as medians with interquartile ranges, and categorical variables as counts with percentages. ANOVA was used for numeric variables, while categorical variables were compared using the $\chi 2$ or Fisher's exact test. The relationship between the time to ECMO initiation and the rhythm at hospital arrival was analyzed using Welch's test. Survival was analyzed with Kaplan-Meier and the log-rank test. Logistic regression assessed the association of hospital arrival rhythm with 30-day mortality and neurological outcomes, adjusting for baseline and resuscitation factors, with results expressed as odds ratios (ORs). $P < 0.05$ was considered significant. Analyses were performed using R software, version 4.2.3.

Results

Baseline and resuscitation characteristics

From January 2012 to December 2023, 1,219 adult OHCA patients were admitted, with 210 (17.2 %) receiving ECPR and 196 (16.1 %) included in the final analysis (Fig. 1). Baseline characteristics by initial rhythm are detailed in Supplementary Table 1.

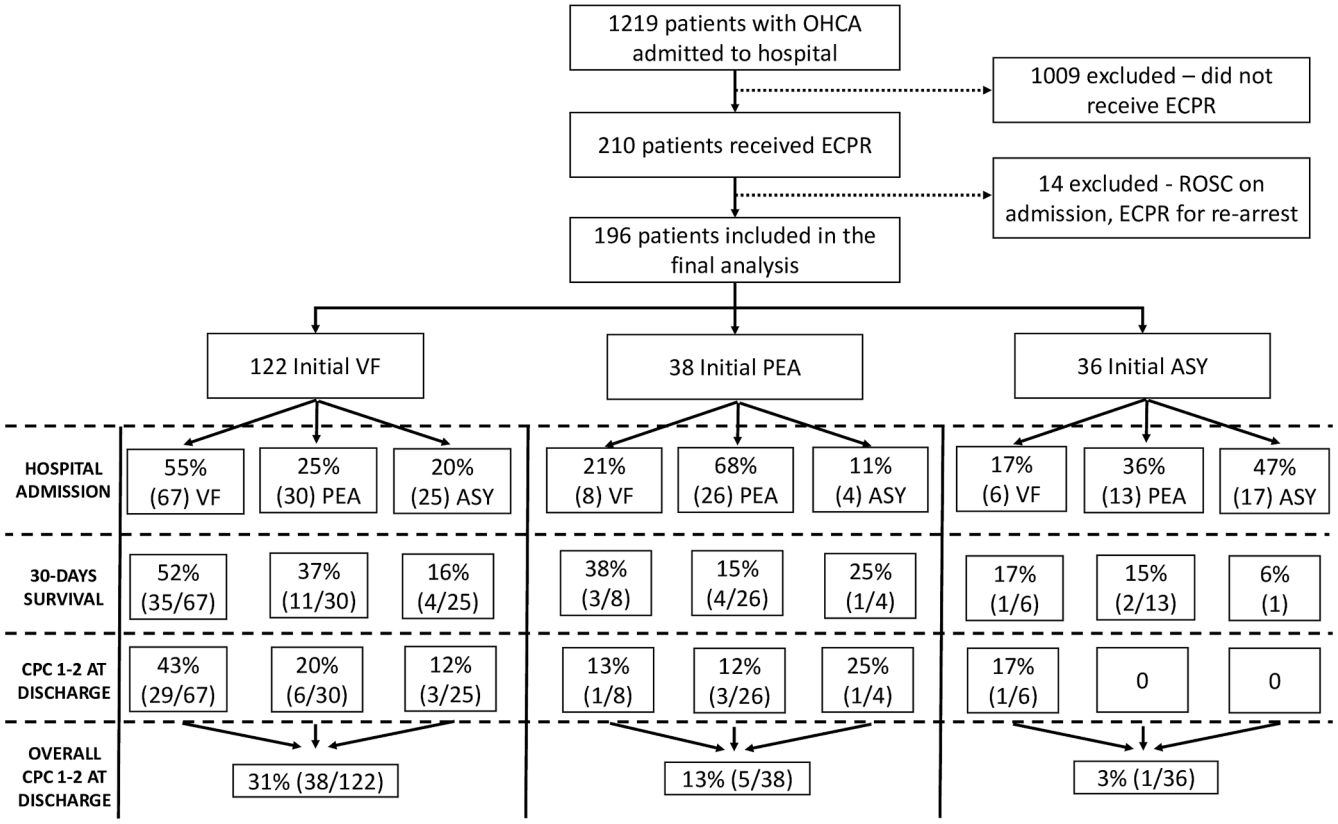

Fig. 1. Patient flow chart. ASY asystole, ECPR extracorporeal cardiopulmonary resuscitation, OHCA out-of-hospital cardiac arrest, PEA pulseless electrical activity, ROSC return of spontaneous circulation, VF ventricular fibrillation.

Relationship between time to ECMO initiation and rhythm at hospital arrival

The mean time to ECMO initiation was 61.3 min (standard deviation [SD] ± 16) for patients presenting with VF at hospital arrival, 61.8 min (SD ± 16.4) for those with PEA, and 70.7 min (SD ± 20.4) for the asystole group (p = 0.023).

Conversion between initial rhythm and rhythm at hospital arrival

Rhythm conversion proportions are shown in Fig. 1. Among initial ventricular fibrillation (VF) patients, 55 % sustained VF, 25 % converted to pulseless electrical activity (PEA), and 20 % converted to asystole. For initial PEA patients, 68 % remained in PEA, 21 % converted to VF, and 11 % to asystole. In the asystole group, 47 % remained in asystole, 36 % converted to PEA, and 17 % to VF.

30-day survival

For initial VF patients, the 30-day survival was 40.9 % (50/122), with the highest survival in those sustaining VF (52 %), followed by VF-to-PEA conversion (37 %) and VF-to-asystole conversion (16 %) (Fig. 2, log rank p < 0.0001). In the PEA group, survival was 21 % (8/38), with highest in PEA-to-VF (38 %), followed by sustained PEA (15 %) and PEA-to-asystole (25 %) (log rank p < 0.0001). Initial asystole patients had an 11.1 % (4/36) survival, with survival rates of 17 % for asystole-to-VF, 15 % for asystole-to-PEA, and 6 % for sustained asystole (log rank p < 0.0001).

Neurological outcomes at discharge

A favorable neurological outcome was observed in 31.1 % (38/122) of the VF cohort, with the best outcomes in sustained VF (43 %), followed by VF-to-PEA (20 %) and VF-to-asystole (12 %) (Fig. 1). In the PEA group, favorable outcomes were 13 % for PEA-to-VF, 11.5 % for sustained PEA, and 25 % for PEA-to-asystole. In the asystole group, the only favorable outcome (2.8 %, 1/36) was in a patient who converted to VF.

Multivariate logistic regression of 30-day mortality

Logistic regression showed that admission asystole was associated with significantly higher 30-day mortality (odds ratio (OR) 4.03, 95 % CI 1.49–12.38, p = 0.009) compared to VF. Admission PEA showed a non-significant trend towards higher mortality (OR 1.89, 95 % CI 0.86–4.23, p = 0.12) compared to VF (Table 1).

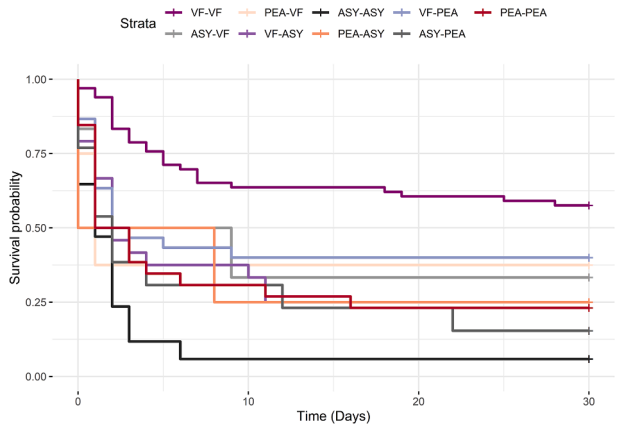

Fig. 2. Kaplan–Meier plot showing cumulative patient survival from index cardiac arrest to 30-days follow-up according to the initial rhythm and rhythm at hospital arrival. ASY asystole, PEA pulseless electrical activity, VF ventricular fibrillation.

Multivariate logistic regression of neurological outcome at discharge

Admission asystole was also associated with significantly higher odds of poor neurological outcomes (CPC 3–5) (OR 4.61, 95 % CI 1.49–17.62, p = 0.013) compared to VF. A significant trend was noted for admission PEA with poor neurological outcomes (OR 2.97, 95 % CI 1.23–7.64, p = 0.019) (Table 2).

Discussion

This prospective study highlights key differences in survival and neurological outcomes among ECPR recipients based on hospital arrival rhythms. Patients in VF had the best outcomes, while those in or converting to asystole had the worst. Despite extensive EMS efforts, many patients with initial VF and PEA converted to asystole, significantly worsening their prognosis. Admission asystole was associated with a fourfold increase in death and poor neurological outcomes, even after adjusting for covariates. The conversion to asystole may indicate prolonged hypoperfusion (e.g., no-flow time, low-flow time, CPR quality) and a stage where the heart and brain may have entered a metabolic phase leading to irreversible cell injury, at which point the benefit of ECPR may have already vanished.[8–9,13]

Our study also confirms that initial asystole is linked to poorer outcomes, whereas patients with initial VF benefit most from ECPR.[7] Given current and previous data, excluding patients with initial asystole from ECPR, especially those who remain in asystole after conventional CPR, seems reasonable, as no study has demonstrated a survival benefit justifying ECPR in this group.[1,7]

Despite the small sample size for initial non-shockable rhythms in our study, we analyzed asystole and PEA separately due to prior evidence showing worse outcomes with asystole compared to PEA in the OHCA population.[8] Our study also demonstrated differences in survival and neurological outcomes between PEA and asystole. However, larger studies are needed to clarify the role of PEA in the ECPR population.[1]

Previous data from non-ECPR OHCA populations partially support our findings, indicating that conversion from initial non-shockable rhythms to shockable rhythms is associated with better outcomes, still depending on the initial rhythm.[8] Unlike many prior studies, our analysis also included rhythm conversions from VF to non-shockable rhythms, which appear to be even more prognostically significant.

Our results are consistent with multicenter observational studies from Japan (JAAM-OHCA registry), which found poorer outcomes in OHCA patients who converted from a shockable to a non-shockable rhythm upon hospital arrival compared to those who maintained a shockable rhythm.[13] Unlike the JAAM-OHCA registry study, which focused on rhythm conversion in general OHCA patients, our research specifically analyzed all rhythm conversions, including those with initial non-shockable rhythms, and concentrated exclusively on ECPR

Table 1
Multivariate logistic regression analysis of 30-day mortality.

Factor	Odds Ratio	Confidence Interval	P value
Male gender	1.59	(0.65,3.90)	0.305
Age (years)	**1.03**	**(1.00,1.06)**	**0.047**
Witnessed arrest (yes)	2.27	(0.64,8.29)	0.200
Bystander CPR (yes)	2.34	(0.45,11.36)	0.298
Time of resuscitation (min)	**1.02**	**(1.00,1.05)**	**0.036**
Public place of cardiac arrest	0.71	(0.32,1.56)	0.401
Initial asystole rhythm	**7.36**	**(2.12,33.85)**	**0.004**
Initial PEA rhythm	2.51	(0.96,7.04)	0.066
Admission asystole rhythm	**4.03**	**(1.49,12.38)**	**0.009**
Admission PEA rhythm	1.89	(0.86,4.23)	0.117

Abbreviations: CPR: cardiopulmonary resuscitation, PEA: pulseless electrical activity.

Table 2
Multivariate logistic regression analysis of poor neurological outcome (CPC 3–5) at hospital discharge.

Factor	Odds Ratio	Confidence Interval	P value
Male gender	1.55	(0.58,4.02)	0.371
Age (years)	**1.04**	**(1.01,1.07)**	**0.018**
Witnessed arrest (yes)	2.54	(0.62,11.03)	0.196
Bystander CPR (yes)	1.31	(0.14,8.30)	0.786
Time of resuscitation (min)	1.02	(1.00,1.05)	0.097
Public place of cardiac arrest	0.76	(0.30,1.81)	0.541
Initial asystole rhythm	**22.25**	**(3.56,457.85)**	**0.006**
Initial PEA rhythm	1.51	(0.54,4.55)	0.438
Admission asystole rhythm	**4.61**	**(1.49,17.62)**	**0.013**
Admission PEA rhythm	**2.97**	**(1.23,7.64)**	**0.019**

Abbreviations: CPR: cardiopulmonary resuscitation, PEA: pulseless electrical activity.

recipients.

Another Japanese observational study, SAVE-J, focused on rhythm conversions among ECPR recipients with initial shockable rhythms but analyzed PEA and asystole conversions together.[13] Our study, however, found significantly worse outcomes for asystole compared to PEA, aligning with prior research in non-ECPR OHCA populations.[8,12] While SAVE-J reported minimal neurological benefit from ECPR in patients who converted from VF to PEA/asystole,[14] our data challenge this conclusion. We observed a 37 % survival rate and 20 % good neurological outcomes in patients who converted from VF to PEA, and a 16 % survival rate with 12 % good neurological outcomes in those who converted from VF to asystole, indicating that these patients can benefit from ECPR.[14].

Recently, a large single-center study from the University of Minnesota ECPR patient cohort was published, utilizing a machine learning model to predict favorable neurological outcomes following ECPR.[10] In this study, the rhythm at the time of cannulation was the most predictive variable among the 11 variables analyzed.[10] This finding aligns with our results and emphasizes the prognostic significance of rhythm prior to ECMO cannulation. However, in contrast to our study, the Minnesota ECPR cohort consisted solely of patients with an initial presentation of VF.[10]

Our findings suggest that both initial and admission rhythms, along with other key prognostic factors, can guide ECPR decision-making. Currently, no single criterion predicts survival with perfect accuracy, so ECPR decisions should involve a combination of criteria assessed by experienced, highly trained teams.[10,3–6] If larger studies confirm our results, they could impact routine clinical practice by making rhythm at hospital arrival a useful and easily recognizable parameter for ECPR teams, who often have limited information and time for decisions.[1,2]

The main limitations include the observational design, which may introduce selection bias, and the limited sample size for non-shockable rhythms, highlighting the need for larger studies. Our focus on initial and admission rhythms without analyzing the timing of conversions may limit patient stratification insights. Finally, as a single-center study from a specialized tertiary center, the generalizability of our findings may be limited.

Conclusions

This study highlights the rhythm at hospital arrival as a significant predictor of survival and neurological outcomes in ECPR for OHCA. Patients with sustained VF have the best outcomes, while those converting to asystole have poor prognoses. Initial asystole is strongly linked to unfavorable outcomes, challenging the benefit of ECPR over conventional CPR if asystole persists despite initial efforts. Combining the rhythm at hospital arrival with other prognostic factors could improve patient stratification and lead to more effective ECPR interventions.

Declarations

Ethics approval and consent to participate

The register and database used for clinical research were approved by the Institutional Review Board of the General University Hospital and First Faculty of Medicine, Charles University in Prague (14/20 VFN IGP). All ECPR patients who regained normal neurologic function, or their legal representatives if they did not regain consciousness, were asked to provide their written consent with registry enrollment and data use. Consent requirements were waived for participants without known legal representatives who died or had severe neurological deficits and were unable to provide informed consent.

CRediT authorship contribution statement

Daniel Rob: Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Klaudia Farkasovska:** Writing – review & editing, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Petra Kavalkova:** Writing – review & editing, Visualization, Validation, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Milan Dusík:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Stepan Havranek:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Jan Pudil:** Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Eliska Mockova:** Writing – review & editing, Visualization, Validation, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Jaromir Macoun:** Writing – original draft, Visualization, Validation, Software, Investigation, Formal analysis, Data curation, Conceptualization. **Jan Belohlavek:** Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization.

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Declaration of competing interest

The corresponding author (JB) has received lecture honoraria from the Abiomed, Getinge, Xenios, Resuscitec, Novartis, Astra-Zeneca, Boegringer-Ingelheim.The remaining authors report no conflict of interest.

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