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Clinical characteristics and outcomes of patients with out-of-hospital cardiac arrest treated by repeated extracorporeal cardiopulmonary resuscitation: A multicenter retrospective cohort study

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Abstract

Aim: Retrospective analysis of clinical characteristics and outcomes of patients with out-of-hospital cardiac arrest (OHCA) treated with extracorporeal cardiopulmonary resuscitation (ECPR) requiring extracorporeal membrane oxygenation (ECMO) reinsertion or not.

Methods: Data from the Study of Advanced Life Support for Ventricular Fibrillation with Extracorporeal Circulation in the Japan II database were reviewed. Patients who received ECPR after OHCA between January 2015 and July 2021 and underwent ECPR weaning were divided into reinsertion and no-reinsertion groups. The primary outcome was the 30-day survival rate.

Results: Data from 1011 patients who underwent ECMO weaning ≥1 time and survived were analyzed (12 [1.2%], reinsertion; 999 [98.8%] no-reinsertion). The reinsertion group had a longer time to first ECMO weaning (median [interquartile range, IQR]: 3.0 [2.0–5.0] vs. 4.5 [3.2–6.8] days; $p=0.02$). The survival rates at 30 days (25.0% vs. 55.1%; $p=0.08$) and favorable neurological outcomes at discharge (8.3% vs. 30.5%; $p=0.18$) tended to be lower in the reinsertion group. Among patients who died within 30 days, medical costs were significantly higher in the reinsertion group (median [IQR]: \$36,628.2 [26,012.9–45,885.6] vs. \$16,456.6 [9341.2–24,880.6]; $p<0.01$). Intensive care unit (ICU) stay and mechanical ventilation duration were significantly longer in the reinsertion group.

Conclusion: Patients requiring ECMO reinsertion tended to have poor clinical outcomes and higher healthcare costs, highlighting the need for large-scale studies to develop ECPR protocols and optimize clinical benefits and resource allocation.

KEYWORDS
cardiopulmonary resuscitation, extracorporeal, extracorporeal membrane oxygenation, intensive care unit, out-of-hospital cardiac arrest

INTRODUCTION

The prognosis of out-of-hospital cardiac arrest (OHCA) remains poor, and survival rates after OHCA remain low.[1] The prevalence of extracorporeal cardiopulmonary resuscitation (ECPR) in patients with OHCA has increased worldwide.[2] However, previous studies[3–6] reported conflicting results regarding the effect of ECPR on neurological outcomes and survival in patients with OHCA without return of spontaneous circulation (ROSC). Consequently, there is limited high-quality evidence to support the clinical advantages of ECPR,[6–8] and concerns regarding its cost-effectiveness[7,8] persist.[7]

Although ECPR is potentially beneficial for patients with OHCA unresponsive to conventional cardiopulmonary resuscitation, the effectiveness and invasiveness of extracorporeal membrane oxygenation (ECMO) reinsertion after hospitalization require careful consideration.

While few studies have reported ECMO reinsertion after weaning,[9,10] there are no studies examining reinsertion rates and associated risk factors.

We aimed to elucidate the characteristics of patients who underwent ECMO reinsertion and assess clinical effectiveness, time course, and costs using real-world data.

MATERIALS AND METHODS

Study design and setting

In this national multicenter study, we retrospectively analyzed data from the SAVE-J II study, which evaluated the effectiveness of ECPR in Japan between January 1, 2013, and December 31, 2018.[11]

This study adhered to the principles of the 1964 Declaration of Helsinki and its subsequent amendments. It was approved by the Institutional Review Board of the University Hospital Medical Information Network Clinical Trials Registry (UMIN000036490) and Tokyo Medical and Dental University (M2019-018). The requirement for informed consent was waived due to its retrospective nature. All participating facilities provided ECPR 24/7, with over 90% of employed emergency physicians working round the clock. Ultrasonography was used to confirm the ECMO catheter insertion site and guidewire position in the inferior vena cava. The ECMO catheter's position was verified on radiography before ECMO activation or CT.

Study population

Data of patients aged ≥18 years with OHCA treated with ECPR were included. Patients with "Do Not Attempt Resuscitation (DNAR)" before ECPR were not included. Data of (1) patients who were transferred to a participating institution after receiving primary treatment at a different hospital, (2) patients who declined to participate, (3) patients whose first ECMO was initiated following ROSC or intensive care unit (ICU) admission, or (4) patients with missing data for ECMO weaning and reinsertion, were excluded.

Data collection

Age, sex, medical history, performance status (PS), witness of the cardiac arrest (CA) and bystander CPR, initial cardiac rhythm, timeline of events, and CA etiology were analyzed. Data on ECMO weaning characteristics, complications, cerebral performance category (CPC) score at discharge, survival at discharge, duration of ICU and hospital stay, mechanical ventilation duration, and hospitalization costs were analyzed.

Outcomes and definition

The primary outcome was survival at 30 days. The secondary outcomes were favorable CPC at discharge, hospital stay, ICU stay, ventilator days, and medical costs. The indications for ECPR were based on the guidelines of each institution. As there is no universally accepted definition of ECMO reinsertion and there are limited studies on reinsertion,[9,10] reinsertion was defined as a second ECMO insertion within 7 days after the first ECMO weaning with survival. ECMO insertion for OHCA performed in the ER was defined as first ECMO. Patients who died within a short period after weaning off and those who were withdrawn after the first ECMO implementation were considered ECMO weaning-off cases. Low-flow time was defined in three different scenarios: (1) if CA occurred in an ambulance, it was measured from the time of CA to the initiation of ECMO; (2) if bystanders performed CPR, it was measured from the emergency medical service (EMS) call to ECMO initiation; and (3) if no bystander performed CPR and CA did not occur in an ambulance, it was measured from the EMS arrival to ECMO initiation.

Hospitalization costs were calculated based on the insurance points for inpatient treatment. Costs were calculated up to the point of discharge excluding ICU management, emergency room, basic hospitalization, meal, and bed differential costs.[12] Patients who died before ICU admission were also included in the cost calculation. Medical costs were converted from Japanese yen (¥) to US dollars ($) ($1 = ¥150). The neurological status at discharge, evaluated using CPC scores, was categorized into good cerebral performance, moderate cerebral disability, severe cerebral disability, coma or vegetative state, and brain death. A CPC score of 1 or 2 was a favorable neurological outcome.[13]

Statistical analysis

Patients who survived ECMO weaning were categorized into the reinsertion and no reinsertion groups.

Analysis of variance was used to compare baseline characteristics and outcomes between the groups. The medical costs of patients who survived hospital discharge and those who died were compared among the groups.

In univariate analysis, continuous variables are reported as median (interquartile range [IQR]) and categorical variables as numbers (percentages). The Kolmogorov–Smirnov test was used to assess the normality of the continuous variable distribution. The duration from first ECMO

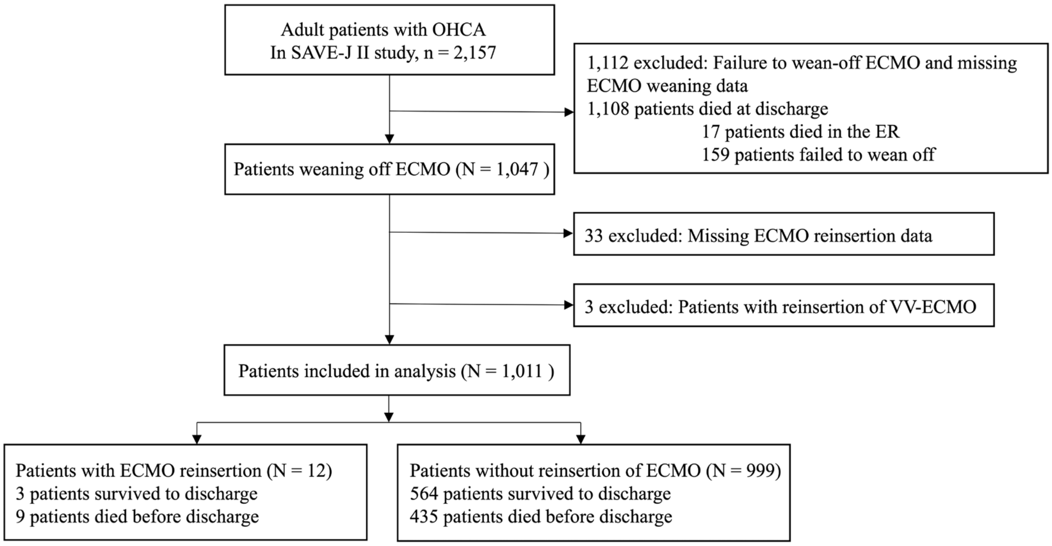

FIGURE 1 Flow diagram of patient selection.

insertion to first ECMO removal was compared between both groups.

R software (version 4.3.2, R Foundation for Statistical Computing) was used for statistical analysis. Statistical significance was set at $p < 0.05$.

RESULTS

Overall, 1011 patients were included (Figure 1) of whom 12 underwent ECMO reinsertion: three survived and nine died within 30 days. Of the remaining 999 patients, 564 survived, and 435 died within 30 days without ECMO reinsertion.

Table 1 presents patient baseline characteristics. ECMO reinsertion was performed in 12 (1.2%) patients. The rate of favorable PS before hospital arrival was higher in the reinsertion group (91.7% vs. 86.3%, $p < 0.01$) than that in the no-reinsertion group. The duration from the first ECMO insertion to the first weaning off was longer in the reinsertion group (median [IQR]: 4.5 [3.2–6.8] vs. 3.0 [2.0–5.0] days). Additionally, the retroperitoneal bleeding rate was higher in the reinsertion group.

Table 2 depicts the primary and secondary outcomes of both groups. Of the 1011 patients, 553 (54.7%) survived for 30 days. One hundred patients (9.9%) who were weaned off ECMO withdrew from life-sustaining therapy during the clinical course. In the reinsertion group, three patients (25.0%) survived for 30 days, and one (8.3%) had favorable neurological outcomes at discharge. The survival rates at 30 days (25.0% vs. 55.1%; $p = 0.08$) and favorable neurological outcomes at discharge (8.3% vs. 30.5%; $p = 0.18$) tend to be lower in the reinsertion group. There were no significant differences in total hospital stay. Meanwhile, ICU stay (median [IQR]: 15.5 [13.2–19.0] vs. 10.0 [5.0–15.0] days; $p = 0.02$) and mechanical ventilation duration (median [IQR]: 15.0 [12.0–17.0] vs. 8.0 [4.0–14.0] days; $p = 0.01$) were significantly longer in the reinsertion group.

For all patients, a median of $23,139.2 (US) was used during hospitalization (Table 3). The medical costs during hospitalization were higher in the reinsertion group, albeit significant. Among patients who died within 30 days, medical costs were significantly higher for the reinsertion group (median [IQR]: $36,628.2 [26,012.9–45,885.6] vs. $16,456.6 [9341.2–24,880.6]; $p < 0.01$).

Reinsertion occurred most frequently on day 0 (within 24 h after the first weaning) (4/12 [33.3%]) and day 1 (3/12 [25.0%]) (Figure 2). In the no-reinsertion group, 181/999 patients (18.1%) died on day 0.

DISCUSSION

Here, ECMO reinsertion was performed in ~1% of the patients who underwent ECPR. Those who underwent reinsertion tended to have worse clinical and neurological outcomes than those who did not. Notably, <10% of patients with reinsertion had favorable neurological prognoses, and the medical costs for patients who died within 30 days were ~2.2 times higher in the reinsertion group than in the no-reinsertion group.

The reinsertion group had a 1.5-day longer duration from initial ECMO implementation to weaning compared with the no-reinsertion group. Since increased patient severity makes ECMO weaning more challenging,[14] the difference in ECMO duration could be due to the difference in severity between both groups. ECMO complications were more frequent in the reinsertion group, suggesting prolonged ECMO weaning and complications during cannulation as risk factors for reinsertion. We speculate that these complications have an impact on length of stay and costs. Therefore, if an extended period is required to wean off ECMO and/or patients develop insertion-related complications, physicians should anticipate subsequent reinsertion. Although evaluating the potential for favorable outcomes and determining

TABLE 1 Patient characteristics and comparison between patients with or without ECMO reinsertion.

Variables	Overall $n=1011$	Reinsertion $n=12$	No-reinsertion $n=999$	p
Sex, female (%)	181 (17.9)	1 (8.3)	180 (18.0)	0.62
Age (median [IQR])	60.0 [48.0–68.0]	61.0 [50.5–70.5]	60.0 [48.0–68.0]	0.56
PS (%)				
0	873 (86.4)	11 (91.7)	862 (86.3)	<0.01
1	106 (10.5)	0 (0.0)	106 (10.6)	
2	9 (0.9)	0 (0.0)	9 (0.9)	
3	3 (0.3)	1 (8.3)	2 (0.2)	
4	1 (0.1)	0 (0.0)	1 (0.1)	
Past medical history				
Heart disease (%)	217 (21.5)	1 (8.3)	216 (21.6)	0.45
Hypertension (%)	331 (32.7)	4 (33.3)	327 (32.7)	1
Chronic kidney disease (%)	52 (5.1)	0 (0.0)	52 (5.2)	0.88
Diabetes mellitus (%)	208 (20.6)	2 (16.7)	206 (20.6)	1
Witness (%)	804 (79.5)	10 (83.3)	794 (79.5)	0.94
Bystander (%)	601 (59.4)	6 (50.0)	595 (59.6)	0.71
Shockable (%)	687 (68.0)	6 (50.0)	681 (68.2)	0.36
Arrest to hospital (minutes), (median [IQR])	32.0 [24.0–41.0]	29.0 [22.0–38.0]	32.0 [24.0–41.0]	0.64
Light reflex (%)				
Unknown	103 (10.2)	2 (16.7)	101 (10.1)	0.41
Negative	151 (14.9)	3 (25.0)	148 (14.8)	
Low-flow time (minutes), (median [IQR])	53.0 [42.0–65.0]	58.0 [54.0–72.5]	52.0 [42.0–65.0]	0.10
Day to ECMO weaning off (median [IQR])	3.0 [2.0–5.0]	4.5 [3.2–6.8]	3.0 [2.0–5.0]	0.02
Diagnosis at arrival (%)				
Internal	746 (73.8)	9 (75.0)	737 (73.8)	0.75
Internal non-heart	83 (8.2)	2 (16.7)	81 (8.1)	
External	57 (5.6)	0 (0.0)	57 (5.7)	
Complication				
Catheter malposition, receiving (%)	23 (2.3)	0 (0.0)	23 (2.3)	0.85
Catheter malposition, sending (%)	26 (2.6)	0 (0.0)	26 (2.6)	0.84
Retroperitoneal bleeding (%)	28 (2.8)	2 (16.7)	26 (2.6)	0.01
Cannula site bleeding (%)	195 (19.3)	5 (41.7)	190 (19.0)	0.14

Note: Data are presented as unweighted numbers (percentages) of patients unless otherwise indicated.

Abbreviations: ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pumping; IQR, interquartile range; PS, performance status.

eligible patients for continued ECPR is challenging, recognizing patients likely to benefit from ongoing ECPR and/or repeated ECMO therapy is crucial. Here, 100/1011 (9.9%) patients who were weaned off ECMO withdrew from life-sustaining therapy during the clinical course, potentially affecting the study results. However, compared with patients without reinsertion, patients with reinsertion had approximately half the survival rate, one-third the rate of good neurological prognosis, and incurred ~1.5 times the cost. Large-scale studies should further explore ECMO reinsertion and its associated risks.

Extracorporeal membrane oxygenation implementation in ICU patients who have undergone ECMO weaning partially resembles that in patients with intrahospital CA (IHCA) rather than that in patients with OHCA. Compared with OHCA, patients with IHCA who undergo ECMO have better prognoses.[15,16] Patients with IHCA who received ECPR exhibit higher survival rates than those who received conventional resuscitation (21.2% vs. 7.6%).[17] In other studies, among the 37.9% of patients who survived after receiving ECPR, 84% had favorable neurological outcomes.[18,19] The low-flow time in patients with IHCA is shorter than that in patients with OHCA.[15] The low-flow time in patients with IHCA was 20 mins shorter than that in patients with OHCA (49.6 ± 5.9 min vs. 72.2 ± 7.4 min) in a previous study,[20] possibly due to the immediate availability of witnesses and lack of transport time in IHCA cases. Although the low-flow time of reinsertion in this study was similar, the proportion of

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TABLE 2 Comparison between patients with and without ECMO reinsertion.

Outcome and strata	Overall (n = 1011)	Reinsertion (n = 12)	No-reinsertion (n = 999)	p	SMD
Primary outcome					
Survival at 30 days (%)	553 (54.7)	3 (25.0)	550 (55.1)	0.08	0.70
Secondary outcome					
Favorable CPC (%)	306 (30.3)	1 (8.3)	305 (30.5)	0.18	0.58
ICU stay (days), (median [IQR])	10.0 [5.0–15.0]	15.5 [13.2–19.0]	10.0 [5.0–15.0]	0.02	0.35
Hospital stay (days), (median [IQR])	20.0 [6.0–40.0]	17.0 [14.0–31.5]	20.0 [6.0–40.0]	0.75	<0.01
Ventilator duration (days), (median [IQR])	8.0 [4.0–14.0]	15.0 [12.0–17.0]	8.0 [4.0–14.0]	0.01	0.36

Note: Data are presented as unweighted numbers (percentages) of patients unless otherwise indicated.

Abbreviations: CPC, cerebral performance category; ECMO, extracorporeal membrane oxygenation; IQR, interquartile range; SMD, standardized mean difference.

TABLE 3 Comparison of medical cost with and without ECMO reinsertion.

Outcome and strata	Overall	Reinsertion	No-reinsertion	p	SMD
All patients	n = 1011	n = 12	n = 999		
Medical cost (US $), (median [IQR])	23,139.2 (14,322.5–35,259.7)	33,073.1 (23,541.9–49,269.1)	23,038.9 (14,309.1–35,155.3)	0.06	0.46
Patients survived at 30 days	n = 553	n = 3	n = 550		
Medical cost (US $), (median [IQR])	28,673.5 (19,898.4–41,859.7)	29,518.1 (22,539.7–55,907.5)	28,641.5 (19,900.8–41,703.0)	0.79	0.32
Patients died within 30 days	n = 439	n = 9	n = 430		
Medical cost (US $), (median [IQR])	16,802.5 (9374.2–25,142.6)	36,628.2 (26,012.9–45,885.6)	16,456.6 (9341.2–24,880.6)	<0.01	0.80

Note: Data are presented as unweighted numbers (percentages) of patients unless otherwise indicated.

Abbreviations: ECMO, extracorporeal membrane oxygenation; IQR, interquartile range; SMD, standardized mean difference; US$ 1 = ¥ 150.

favorable neurological status among surviving patients in the reinsertion group was lower than that in previous studies (33.3% vs. 84%).[17–19] While ECPR for IHCA and reinsertion are both in-hospital events with shorter low-flow times, differences in underlying conditions, patient background, and site of ECMO insertion (e.g., ICU) vary widely, making direct comparison difficult. Therefore, ECMO reinsertion in IHCA patients who have undergone ECPR should be conducted carefully. There was a significant difference in medical costs associated with IHCA and OHCA. One study reported that ECPR for IHCA is more expensive than ECPR for OHCA ($85,779 vs. $58,360). However, this was offset by the high proportion of good clinical and favorable neurological prognoses.[21] These costs included all expenses incurred from CA onset to patient discharge or death. Consequently, a direct comparison of costs between OHCA and IHCA is challenging, given that OHCA has a higher mortality rate on the day of admission. Unlike patients with IHCA who underwent ECPR in previous studies,[17–19,21,22] those with ECMO reinsertion had poor clinical prognoses and were less cost-effective in this study. Therefore, ECMO reinsertion for patients with OHCA could be less cost-effective than that for patients with IHCA. Although our results show that reinsertion was more costly, there is no need to restrict physicians' behavior. However, knowing the number of patients requiring ECMO reinsertion is crucial because ECPR resuscitation, including the amount of transfusion and perioperative critical care, requires a large amount of human and healthcare resources. Recognition of the risk and cost enables us to control the intensity of critical care and ensures the potential to optimize the implementation and indirectly improve the outcome of patients.

The strength of this study is that the data of 2157 patients who underwent ECPR using a real-world, large-scale database were analyzed. We included the largest number of patients to date who underwent ECMO reinsertion.

This study has some limitations. First, the retrospective design was susceptible to residual confounding factors, limiting the applicability of the study's findings. Second, the number of reinsertion cases was small, potentially introducing bias. Third, generalizability might be limited because almost all patients in the study cohort were Japanese and transported to each hospital based on the Japanese EMS system. The influence of differences in healthcare systems between countries cannot be fully excluded. Fourth, information on the method, reasons for

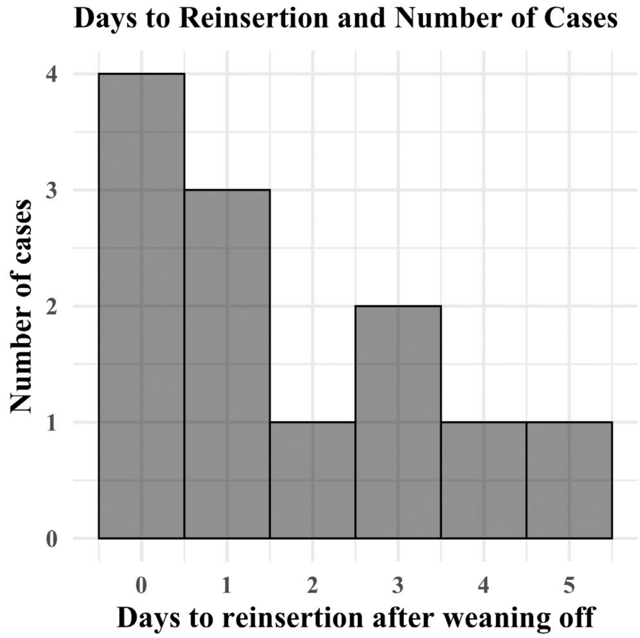

FIGURE 2 Days to reinsertion after extracorporeal membrane oxygenation (ECMO) weaning off and number of cases. The histogram displays the distribution of the number of days until reinsertion after weaning off the ECMO support. Each bar represents the number of reinsertion cases on a specific day after weaning.

reinsertion, and detailed disease or complications that caused reinsertion were not available. Owing to the study design, >1000 patients, including those who died without successful ECMO weaning, were excluded. Furthermore, 9.9% of all patients weaning ECMO withdrew life-sustaining therapy, and 18.1% of the no-reinsertion group died within 24 h of weaning, indicating that the no-reinsertion group included some patients who died because they could not be reinserted, potentially influencing the results. Additionally, adjusting the definition of reinsertion by changing the number of days could affect the results of this study, although there is no rigorous definition of reinsertion. Fifth, we included only data of patients who underwent ECPR, which may have resulted in the selection of only patients with better prehospital care or shorter response times. Lastly, data on the number of patients who were transferred early to other hospitals could not be obtained. Variations in hospital ECPR protocols and post-arrest care might have resulted in selection bias.

CONCLUSION

Patients with OHCA who underwent ECMO reinsertion after ECPR exhibited poorer neurological outcomes and lower survival rates, with medical costs ~$10,000 (USD) higher than those of patients who did not undergo ECMO reinsertion. Further research should investigate the risks and benefits of ECMO reinsertion and develop an optimal therapeutic strategy for patients with ECMO.

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CONFLICT OF INTEREST STATEMENT

Authors declare no conflict of interest for this article.

DATA AVAILABILITY STATEMENT

On reasonable request, data supporting the results of this study will be made available by the corresponding author.

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ETHICS STATEMENT

Approval of the research protocol: It was approved by the Institutional Review Board of the University Hospital Medical Information Network (UMIN) Clinical Trials Registry (UMIN000036490) and Tokyo Medical and Dental University (M2019-018).
Informed consent: Due to the retrospective nature of the study, written informed consent from participants was not required.
Registry and the registration no. of the study/trial: N/A.
Animal studies: N/A.

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REFERENCES

1. Myat A, Song K-J, Rea T. Out-of-hospital cardiac arrest: current concepts. Lancet. 2018;391(10124):970–9.
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.
3. Yannopoulos D, Bartos J, Raveendran G. Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial. Lancet. 2020;396(10265):1807–16.
4. Miraglia D, Miguel LA, Alonso W. Extracorporeal cardiopulmonary resuscitation for in- and out-of-hospital cardiac arrest: systematic review and meta-analysis of propensity score-matched cohort studies. J Am Coll Emerg Physicians Open. 2020;1(4):342–61.
5. Suverein MM, Delnoij TSR, Lorusso R. Early extracorporeal CPR for refractory out-of-hospital cardiac arrest. N Engl J Med. 2023;388(4):299–309.
6. Belohlavek J, Smalcova J, Rob D. Effect of intra-arrest transport, extracorporeal cardiopulmonary resuscitation, and immediate invasive assessment and treatment on functional neurologic outcome in refractory out-of-hospital cardiac arrest: a randomized clinical trial. JAMA. 2022;327(8):737–47.
7. Addison D, Cheng E, Forrest P. Cost-effectiveness of extracorporeal cardiopulmonary resuscitation for adult out-of-hospital cardiac arrest: a systematic review. Resuscitation. 2022;178:19–25.
8. Matsuoka Y, Goto R, Atsumi T. Cost-effectiveness of extracorporeal cardiopulmonary resuscitation for out-of-hospital cardiac arrest: a multi-centre prospective cohort study. Resuscitation. 2020;157:32–8.
9. Kamei H, Wakimoto Y, Harada K, Fukui A, Tanaka H, Shibahara H. Resuscitative hysterotomy in a patient with peripartum cardiomyopathy. J Obstet Gynaecol Res. 2019;45(3):724–8.
10. Mori K, Shimizu J, Takahashi Y. A pregnant patient with aortic regurgitation and symptoms of acute heart failure caused by peripartum cardiomyopathy: a case report. Open J Anesthesiol. 2017;7(6):152–9.
11. Inoue A, Hifumi T, Sakamoto T. Extracorporeal cardiopulmonary resuscitation in adult patients with out-of-hospital cardiac arrest: a retrospective large cohort multicenter study in Japan. Crit Care. 2022;26(1):129.
12. Naito H, Sakuraya M, Hongo T. Prevalence, reasons, and timing of decisions to withhold/withdraw life-sustaining therapy for out-of-hospital cardiac arrest patients with extracorporeal cardiopulmonary resuscitation. Crit Care. 2023;27(1):252.
13. Geocadin RG, Callaway CW, Fink EL. Standards for studies of neurological prognostication in comatose survivors of cardiac arrest: a scientific statement from the American heart association. Circulation. 2019;140(9):e517–e542.
14. Charbonneau F, Chahinian K, Bebawi E. Parameters associated with successful weaning of veno-arterial extracorporeal membrane oxygenation: a systematic review. Crit Care. 2022;26(1):375.
15. Andersen LW, Holmberg MJ, Berg KM, Donnino MW, Granfeldt A. In-hospital cardiac arrest: a review. JAMA. 2019;321(12):1200–10.
16. Penketh J, Nolan JP. In-hospital cardiac arrest: the state of the art. Crit Care. 2022;26(1):376.
17. Bian Y, Pan Y, Zheng J. Extracorporeal versus conventional cardiopulmonary resuscitation for in-hospital cardiac arrest: a propensity score matching cohort study. Crit Care Med. 2024;52(6):e268–e278.
18. Gravesteijn BY, Schluep M, Disli M. Neurological outcome after extracorporeal cardiopulmonary resuscitation for in-hospital cardiac arrest: a systematic review and meta-analysis. Crit Care. 2020;24(1):505.
19. D'Arrigo S, Cacciola S, Dennis M. Predictors of favourable outcome after in-hospital cardiac arrest treated with extracorporeal cardiopulmonary resuscitation: a systematic review and meta-analysis. Resuscitation. 2017;121:62–70.
20. Wengenmayer T, Rombach S, Ramshorn F. Influence of low-flow time on survival after extracorporeal cardiopulmonary resuscitation (eCPR). Crit Care. 2017;21(1):157.
21. Dennis M, Zmudzki F, Burns B. Cost effectiveness and quality of life analysis of extracorporeal cardiopulmonary resuscitation (ECPR) for refractory cardiac arrest. Resuscitation. 2019;139:49–56.
22. Bharmal MI, Venturini JM, Chua RFM. Cost-utility of extracorporeal cardiopulmonary resuscitation in patients with cardiac arrest. Resuscitation. 2019;136:126–30.

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