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Impact of independent early stage extracorporeal cardiopulmonary resuscitation in the emergency department following the establishment of an extracorporeal life support team

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A R T I C L E I N F O

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A B S T R A C T

Objective: In this paper, we present a comprehensive overview of our experience in establishing and leading distinct extracorporeal cardiopulmonary resuscitation (ECPR)-related teams to independently handle ECPR in the early stages in the emergency department.
Methods: A retrospective analysis was conducted on the clinical data of 29 patients who underwent ECPR treatment in the emergency room between May 2018 and April 2022. A control group, consisting of 10 patients treated between May 2018 and September 2019 was managed using a standard rescue coordination mode. The 19 patients who received ECPR between October 2019 and April 2022 were treated by members of the department's 24-h extracorporeal life support team. We compared the implementation and operational challenges faced by the two groups, including item preparation, circuit setup, and ECPR initiation times, among other factors.
Results: Gender, age, cardiac arrest risk factors, and other baseline data did not significantly differ between the two groups. Extracorporeal membrane oxygenation (ECMO) pipeline prefilling time (from 35.27±10.34 to 13.46±5.32), ECPR establishment time (from 62.35±29.61 to 30.98 ±13.41), and item preparation time (from 16.42±9.78 to 3.19±1.49) all considerably decreased when compared to the control group. The rate of return of spontaneous circulation recovery rose from 37.50 % to 77.78 % ($P < 0.05$). The consequences of gastrointestinal and pulmonary bleeding were greatly reduced while ECPR was being used, and the difference was statistically significant ($P < 0.05$). Significant improvements were made in the ECPR weaning rate (from 25.00 % to 38.89 %) and survival rate (from 20.0 % to 36.8 %).
Conclusion: The establishment of a 24-h extracorporeal life support team significantly reduced the time needed for rescue during the early stage of independent setup of ECPR in the emergency department and serves as a guide for effective care of critically ill patients.

1. Introduction

Extracorporeal cardiopulmonary resuscitation (ECPR) involves swiftly administering intravenous-to-arterial extracorporeal

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membrane oxygenation (ECMO) to provide temporary circulatory and oxygenation support to patients who cannot regain their normal heart rhythm following standard cardiopulmonary resuscitation or who struggle to maintain it due to repeated cardiac arrests, as long as the underlying reversible cause can be addressed [1,2]. Research has indicated that, when compared to traditional CPR, ECPR significantly enhances the prognosis and reduces the mortality rate among adult patients experiencing cardiac arrest (CA). The use of ECMO technology during CPR is recommended [3,4]. Furthermore, the likelihood of restoring normal heart rhythm and achieving early brain resuscitation is inversely related to the time it takes to initiate ECPR. It is crucial to initiate ECPR promptly during the early phases of emergency treatment for critically ill patients [5]. Based on clinical practice and a review of existing literature, it is evident that most hospitals in China require collaboration and coordination across various departments to execute ECPR successfully [6]. On receiving acutely ill and critically ill patients in the emergency department, the need for multi-departmental consultations and communication, equipment preparation, coordination of medical staff, and on-site rescue efforts prolong the time required to initiate ECPR, thus impacting its effectiveness [7]. In order to enhance the timeliness of emergency ECPR patient rescue, our department established a 24-h extracorporeal life support (ECLS) team within the emergency department since October 2019. This team is responsible for independently conducting ECPR, and the workflow has continuously been refined, yielding positive outcomes.

2. Participants and methods

2.1. Participants

We conducted a retrospective analysis of clinical data of 29 patients who underwent ECPR treatment in our hospital's emergency department between May 2018 and April 2022. To establish a control group, we selected 10 patients who received ECPR in the conventional coordination mode from May 2018 to September 2019. In October 2019, we established a 24-h ECLS team. From October 2019 to April 2022, 19 patients who underwent ECPR received treatment under the team cooperation mode.

The initiation criteria for ECPR in our department are as follows.

1. Patients who experienced cardiac arrest either within our hospital or outside it and were brought to our emergency department.
2. Patients under the age of 75 with potentially reversible causes of cardiac arrest.
3. Patients who did not achieve a return of spontaneous circulation (ROSC) despite receiving traditional CPR for over 15 min.
4. Received informed consent from the family members of patients.

2.2. Study methods

2.2.1. Different cardiopulmonary resuscitation rescue cooperation modes

2.2.1.1. Conventional rescue cooperation mode. The medical team working in the emergency department is actively engaged in the initial coordination process for ECPR. The director assesses the suitability and contraindications of ECPR before deciding whether to proceed with the treatment. Physicians are responsible for the initial evaluation, documentation, and catheterization of the patients' condition. This responsibility extends to the physicians on duty in the resuscitation room, intensive care unit, and emergency observation ward. The nursing staff take charge of managing the circuit and overall operation, including all nurses in the resuscitation room and the lead nurse in the intensive care unit and emergency observation ward. Routine training and performance evaluations are conducted for these healthcare personnel. The equipment utilized comprises the cardiopulmonary bypass system (SORIN GROUP SCPC), arterial intubation (MAQUET BE-PAL1523, BE-PAL1723), venous intubation (MAQUET BE-PVL2155, BE-PVL2155), Sorin membrane lung (D905 EOS), and Sorin pump head (Revolution 5) for ECMO.

2.2.1.2. 24-h ECLS team cooperation mode. The 24-h ECLS team comprises eight dedicated medical personnel stationed in the emergency department. The team leader, who heads the department, assumes responsibility for the final assessment of patients' suitability for ECPR, determining whether to initiate the procedure. Serving as the deputy team leader, the in-charge nurse oversees the coordination of materials, equipment, and personnel.

The medical team consists of three doctors holding titles of attending physician or higher, each possessing over 5 years of experience, competency in performing ECPR, and the ability to diagnose and treat associated complications.

The nursing team comprises three male nurses holding professional titles or higher, each with more than 5 years of experience, having completed over six months of ECPR technology training, received instruction on ECPR technology-related systems, and successfully passed related examinations. A minimum of two nurses must be present whenever ECPR is initiated.

Upon the arrival of a critically ill patient in the emergency department, the on-duty doctor conducts an initial assessment to determine whether the conditions for ECPR initiation are met. This information is promptly relayed to the team leader, who then issues the instructions for ECPR commencement. Subsequently, the triage nurse immediately contact the 24-h ECLS team members, who are required to reach the emergency rescue room within 10 min.

2.2.2. Development of the workflow of the 24-h ECLS team

After conducting a thorough literature review, consulting with experts, and engaging in discussions with our team members, we have developed a comprehensive plan for the workflow and associated systems of the 24-h ECLS team within the emergency department. This plan encompasses various aspects, including criteria for initiating ECLS and factors that may preclude its use, specifications for the initial response when initiating ECLS, managing human resources, establishing standard operating procedures for the circuit, outlining protocols for programmed mechanical ventilation and the weaning process, establishing procedures for connecting ECLS with continuous renal replacement therapy (CRRT), overseeing ECLS operation and monitoring, addressing alarm situations, ensuring the safe transportation of ECLS patients within and outside the hospital, creating an emergency plan for ECLS situations, and implementing a system for multidisciplinary case discussions.

2.2.3. Training of 24-h ECLS team members

The doctors and nurses in the 24-h ECLS team underwent comprehensive training and evaluation. This training involved several aspects: ECPR experts were brought in to deliver theoretical lectures, while engineers provided hands-on operational instruction to address potential issues with equipment. The training and assessment program encompassed various topics, including the fundamental principles of ECPR, collaboration in mechanical ventilation, key elements of prefilling, theoretical CPR knowledge, and the ability to complete ECPR pipeline prefilling within a 10-min timeframe. It also covered skills like replacing components of the ECPR system (such as the membrane oxygenator, centrifugal pump, and arteriovenous cannula), responding to emergencies and treating unexpected situations (such as pipeline blockages or thromboembolisms), and working cohesively with the CPR team.

For doctors, the training included mastery of ECPR principles, understanding indications and contraindications, knowledge of femoral artery and vein anatomy, proficiency in ultrasound-guided punctures and catheterizations, competence in incisions and catheterizations, and the ability to perform ultrasonic examinations of the heart and blood vessels. They were also required to be skilled in managing mechanical ventilation and the weaning process, overseeing ECPR operations, monitoring bedside coagulation function, handling intra-hospital and inter-hospital bedside transport, and being prepared for emergencies.

Nurses, on the other hand, needed to grasp the principles and monitoring of ECPR, as well as the preparation of equipment, pipeline connections, and priming. They were also trained in managing alarms during ECPR procedures and collaborating with various advanced technologies like the intra-aortic balloon pump (IABP) and CRRT.

In both theoretical and practical assessments, the maximum score was 100 points, with a passing threshold set at scores above 85. All team members were required to successfully pass these assessments. Furthermore, given the infrequent utilization of ECPR, a monthly simulation exercise was organized to enhance team collaboration, with team members receiving relevant training every two months to strengthen their skills.

2.2.4. Preparation of ECPR equipment and materials

To ensure that the ECPR equipment and materials remained in optimal condition and readily available around the clock, the 24-h ECLS team devised a specialized rescue cart and implemented checklists for items used in mechanical ventilation, catheterization, and the ECPR puncture bag. All other equipment and materials remained consistent with the control group. The team also established an inventory system for ECPR consumables, ensuring a fixed quantity, type, and designated storage location while conducting regular inspections, disinfection procedures, and specialized management of instruments and equipment. Consequently, this approach effectively eliminated issues such as labor inefficiency and lengthy preparation times associated with multiple individuals assembling materials on-site under the traditional rescue coordination method. Furthermore, the team developed a unique aseptic puncture towel for ECPR, which received national practical patent approval (ZL 2020 2 1738973.2).

2.2.5. Clear division of labor and implementation of ECPR

Once the critical condition of the patient had been initially assessed by the doctors in the resuscitation room, and it was confirmed that the patient met the criteria for initiating ECPR, the team leader issued the directive to start ECPR. The resuscitation room doctors were tasked with various responsibilities, including communicating and coordinating with family members, obtaining signed informed consent forms, contacting ultrasound specialists and departments related to cardiology, cardiac surgery, and respiratory, as well as facilitating multi-disciplinary consultations. They also continued to provide conventional CPR with the assistance of three on-duty nurses. This involved tasks such as mechanical ventilation, circulatory support, monitoring of blood gases and biochemical markers, administering medications as per the doctor's guidance, and documenting changes in the patient's condition comprehensively.

After the 24-h ECLS team members arrived at the resuscitation room, their roles were clearly defined as follows.

1. Team leader: Responsible for identifying the indications and contraindications for ECPR in patients and overseeing the management and execution of ECPR.
2. Two catheterization doctors: Utilizing ultrasound, their responsibilities included assessing arterial and vascular access for ECPR and performing catheterization procedures.
3. One sonographer: Tasked with evaluating cardiac anatomy, cardiac function, and continuous assessment of thoracoabdominal conditions.
4. Three team nurses: This group consisted of a circuit nurse, an instrument nurse, and a nurse leader. The circuit nurse was responsible for connecting the necessary pipelines, preparing the ECPR system for use, moving it to the patient's bed before catheterization completion, and ensuring proper power and air supply connections to maintain ECPR functionality while awaiting further instructions. The instrument nurse, often referred to as the on-table cooperative catheterization nurse, handled preoperative preparations for both equipment and patients, ensuring sterilization of the surgical area, and cooperating throughout the

catheterization process. The nurse leader, acting as the deputy team leader, oversaw the overall situation, coordinated personnel and materials, monitored activated clotting time (ACT), and ensured the safe transportation of patients.

2.2.6. *Quality control*

After performing ECPR, the status of each patient was carefully assessed and documented following the procedure. The team leader and deputy leader served as quality control for the 24-h ECLS team. Within 48 h of the procedure, they coordinated team members to analyze and summarize the patient's condition while reviewing video footage of the ECPR procedure. The primary objective was to consistently enhance the quality of medical care and nursing during ECPR procedures. To facilitate communication, a WeChat group was established for team members to promptly report any issues encountered during practice, fostering discussion, mutual learning, and resolution of uncertainties or challenges.

Following the weaning of each patient from the ECPR machine and extubation, a retrospective case discussion took place, and an ECPR case report form was filled out. Team members meticulously documented the patient's journey from the moment they entered the resuscitation room to ECPR weaning, continuously gathering insights and refining the ECPR treatment process.

2.3. *Evaluation indexes*

We examined various facets of ECPR administration and operation in the 29 patients. The ECPR circuit, low blood perfusion time, ECPR establishment time, rates of attaining ROSC, and the occurrence of problems during the procedure were among the factors analyzed.

Low blood perfusion time was defined as the period between the start of CPR and the start of ECPR. The ECPR establishment time, on the other hand, was described as the period beginning from the approval of ECPR mechanical start-up after verifying the patient's eligibility and continuing until the ECPR machine was operated successfully.

A mean arterial pressure of greater than 60 mmHg (1 mmHg equals 0.133 kPa) or a systolic blood pressure surpassing 80 mmHg for a continuous duration of more than 20 min were two criteria used to determine ROSC [8]. Weaning meant that the patient's condition has improved to the point where ECMO support was no longer necessary.

2.4. *Statistical methods*

SPSS 21.0 software was used for statistical analysis. The measurement data conforming to normal distribution are expressed as mean ± standard deviation and tested using the Student's *t*-test. The enumeration data are represented as cases (rates) and compared using the chi-squared test or Fisher's exact probability method, and $P < 0.05$ was considered statistically significant.

3. Effect

3.1. *Basic patient information*

A total of 29 patients treated with ECPR were included in this analysis, including 24 men and 5 women with an average age of 55.17 ± 12.13. The control group consisted of 10 patients: 9 men and 1 woman with an average age of 51.90 ± 12.99 years, including 6 patients (60.0 %) with acute myocardial infarction. The ECLS team group consisted of 19 patients: 15 men and 4 women with an average age of 56.89 ± 11.65 years, including 15 patients (78.4 %) with acute myocardial infarction. There was no statistical difference in the baseline data between the two groups of patients, as shown in Table 1.

Table 1
Comparison between Control Group and Extracorporeal life support Team Group in Terms of Relevant Data.

Items	Total (n = 29)	Control group (n = 10)	Extracorporeal life support Team group (n = 19)	P
Gender (male n,%)	24 (82.8)	9 (90.0)	15 (78.9)	0.454
Age, years, mean ± standard deviation	55.17 ± 12.13	51.90 ± 12.99	56.89 ± 11.65	0.300
Cause of cardiac arrest				
Acute myocardial infarction (MI) (n, %)	21 (72.4)	6 (60.0)	15 (78.4)	0.278
Pulmonary embolism (n, %)	2 (6.9)	1 (10.0)	1 (5.3)	0.632
Diluent poisoning (n, %)	1 (3.4)	1 (10.0)	0	0.161
Electrical injury (n, %)	1 (3.4)	1 (10.0)	0	0.161
Drowning (n, %)	1 (3.4)	0	1 (5.3)	0.460
Aortic dissection (n, %)	1 (3.4)	0	1 (5.3)	0.460
Malignant arrhythmia	1 (3.4)	1 (10.0)	0	0.161
Other (etiology unknown)	1 (3.4)	0	1 (5.3)	0.460
Initial shockable heart rate (n, %)	4 (13.8)	1 (10.0)	3 (15.8)	0.667
Witnesses at onset (n, %)	28 (96.6)	9 (90.0)	19 (100.0)	0.632
History of coronary heart (CHD)disease(n, %)	10 (34.5)	3 (30.0)	7 (36.8)	0.713

3.2. Comparison between the two groups of patients in terms of ECPR startup

In the control group, 10 patients underwent ECPR treatment, while in the ECLS team group, 19 patients received the same treatment. Table 2 displays a comparison of the operational efficiency between these two groups. The results indicate that the ECLS team group experienced significant reductions in both item preparation and ECPR circuit times when compared to the control group, and the difference was statistically significant ($P < 0.01$).

3.3. Comparison between the two groups of patients in terms of the ECPR establishment time, ROSC recovery, and weaning status

Cannulation failure results in the inability to complete subsequent operations. Therefore, in this statistical analysis, the focus was placed on the final count of individuals who successfully initiated the procedure. In the control group, out of the 10 patients who underwent ECPR treatment, 1 had femoral arteriovenous and internal jugular vein cannulation in the veno-arterio-venous (VAV) mode, while the remaining 9 had femoral artery and vein cannulation in the VA mode. Two patients with unsuccessful catheterization were excluded from the control group count (final count = 8). In contrast, all 19 patients in the ECLS team group had femoral artery and vein cannulation in the VA mode, except for 1 patient with unsuccessful catheterization who wasn't included in the group count (final count = 18).

When comparing the two groups, the use of ECPR on critically ill patients allowed their hearts to rest, facilitating partial or complete recovery. This approach also reduced the overall time of hypoxia, ensured proper cerebral circulation with ECPR blood flow, and ultimately resulted in neurological improvement. Moreover, the establishment time in the ECLS team group was significantly shorter, with a statistically significant difference ($P < 0.01$). Although the rates of ROSC recovery and weaning were higher in the ECLS team group than in the control group, the difference was not statistically significant ($P > 0.05$) (Table 3).

3.4. Comparison of the location of cardiac arrest and related prognosis between the two groups

In the control group, one out of eight patients with out-of-hospital cardiac arrest (OHCA) survived. Meanwhile, in the ECLS team group, six out of 16 OHCA patients survived. We compared the survival rates of these two groups: among OHCA patients, the survival rate was significantly higher in the ECLS team group compared to the control group, although the difference was not statistically significant ($P > 0.01$).

For patients with in-hospital cardiac arrest (IHCA), one out of two patients survived in the ECLS team group, and one out of three patients survived in the control group. The survival rate in the ECLS team group was slightly lower than that in the control group, but this difference did not reach statistical significance ($P > 0.01$) (See Table 4).

3.5. Complications and prognosis of ECPR patients in the two groups

In the group of 29 patients who received ECPR, the utilization rates of mechanical ventilation, IABP, and CRRT were 100 %, 55.1 %, and 37.9 %, respectively. Among the 10 patients in the control group who underwent ECPR, 1 experienced an electrical injury, while 2 developed coagulopathy due to prolonged cardiac arrest and significant gastrointestinal bleeding during catheterization. Additionally, 3 patients with acute myocardial infarction encountered massive gastrointestinal bleeding due to systemic heparin anticoagulation following catheterization. Timely supplementation of blood products effectively managed gastrointestinal bleeding in 2 of these patients. Furthermore, 3 patients experienced pulmonary hemorrhage following catheterization and mechanical ventilation. Several complications were observed among the 19 patients in the ECLS team group. Specifically, 2 patients experienced cardiac ruptures and aortic dissections due to inadequate preoperative evaluation, resulting in a lack of blood flow and the inability to relocate the machine following successful ECPR catheterization. Additionally, there were 1 case of catheter puncture failure due to the catheter material, and 1 case of unfortunate cerebral hemorrhage during the ECPR procedure, leaving the patient in a vegetative state. Another patient developed compartment syndrome within 48 h of catheterization, requiring distal perfusion catheterization to address limb ischemia. Subsequently, the patient's condition improved, but gangrene developed between the third to fifth toenail bed on their left foot.

It is worth noting that the incidence of massive gastrointestinal bleeding and pulmonary hemorrhage in the ECLS team group, as related to ECPR complications, was significantly lower than that observed in the control group. This difference was statistically significant ($P < 0.05$), as shown in Table 5. In the control group, 2 patients successfully transitioned from life support, with 1 of them recovering to a normal nervous system state and being discharged. The other patient regained spontaneous respiratory circulation but did not regain consciousness, ultimately leading to organ donation.

In the ECLS team group, 7 patients achieved successful weaning. Among them, 3 patients had their nervous systems return to

Table 2
Comparison between two groups of patients in terms of ECPR Startup.

Group	N	Item preparation time (min)	Pipeline priming time (min)
Control group	10	16.42 ± 9.78	35.27 ± 10.34
Extracorporeal life support Team group	19	3.19 ± 1.49	13.46 ± 5.32
T		5.687	7.463
P		<0.01	<0.01

Table 3
Comparison between two groups of patients in terms of ECPR establishment Time, ROSC recovery rate and weaning rate.

Group	N	Low blood perfusion time (min)	ECPR establishment time (min)	ROSC recovery rate	Weaning rate
Control group	8	91.63 ± 29.63	62.35 ± 29.61	3/8 (37.50 %)	2/8 (25.00 %)
Extracorporeal life support Team group	18	98.39 ± 69.91	30.98 ± 13.41	14/18 (77.78 %)	7/18 (38.89 %)
T		−0.261	3.983		
P		0.796	<0.01	0.078	0.667

Table 4
Comparison of cardiac arrest locations and related outcomes between the two groups.

Location of cardiac arrest	Total (n = 29)	Control group (n = 10)	Extracorporeal Life Support Group (n = 19)	P value
The number of OHCA survivors	7	1/8	6/16	0.325
Number of IHCA survivors	2	1/2	1/3	0.7
P value		0.378	0.704	

Table 5
Complications and Prognosis of ECPR Patients in two Groups.

Related complications	Total(n = 29)	Control group(n = 10)	Extracorporeal life support Team group(n = 19)	P
Bleeding at the puncture site	1 (3.4)	1 (10.0)	0	0.161
Massive gastrointestinal bleeding	9 (31.0)	6 (60.0)	3 (15.8)	0.014*
Pneumorrhagia	3 (10.3)	3 (30.0)	0	0.012*
Compartment syndrome	1 (3.4)	0	1 (5.26)	0.460
Cerebral hemorrhage	1 (3.4)	0	1 (5.26)	0.460
Renal insufficiency	11 (37.9)	3 (30.0)	8 (42.1)	0.523
South-north syndrome	1 (3.4)	1 (10.0)	0	0.161
CRRT/case	11 (37.9)	3 (30.0)	8 (42.1)	0.523
IABP/case	16 (55.1)	4 (40.0)	12 (63.2)	0.233
Survivor/case	9 (31.0)	2 (20.0)	7 (36.8)	0.351

Note: * indicates P < 0.05.

normal. Two of these patients were discharged, while a 79-year-old patient with renal failure was transferred to the nephrology department for further treatment. One patient recovered spontaneous respiratory circulation but did not regain consciousness, resulting in organ donation. Additionally, 2 patients in this group remained in a vegetative state after successful weaning. The family of 1 patient chose to discontinue treatment as there was no hope of restoring the patient's nervous system function, ultimately leading to the patient's demise.

4. Discussion

4.1. Establishment of the 24-h ECLS team to help improve the timeliness of emergency treatment

In 2018, the American Heart Association guidelines regarding CPR suggested that in cases where CPR for cardiac arrest patients was ineffective, ECPR could be employed as an alternative to rescue critically ill individuals [9]. The prompt and swift initiation of ECPR is crucial for saving the lives of critical patients and significantly enhancing their chances of survival [10]. Research studies have demonstrated that for cardiac arrest patients, shorter ECPR initiation times correlate with reduced blood perfusion, ischemia, and hypoxia in vital organs, leading to higher patient recovery rates [11–14].

After analyzing 29 cases of ECPR treatment within our department, it became apparent that despite the control group's medical personnel arriving at the scene and commencing ECPR promptly, the ECLS team group consistently displayed significantly shorter preparation times, faster setup of ECPR circuits, and quicker establishment of ECPR. As an emergency procedure conducted at the patient's bedside, the successful early execution of emergency ECPR in the emergency department demands a deep understanding of the procedure and seamless teamwork. This necessitates swift mobility, effective bed coordination, and an optimal operating environment. Additionally, the numerous components involved in ECPR, including various pipelines and monitoring instruments, require the medical staff to respond rapidly and accurately during the connection process. The entire catheterization procedure should be standardized and coordinated.

Furthermore, the effectiveness of ECPR exhibits a direct relationship with quantity—more patients treated corresponds to a higher degree of precision in team coordination, increased expertise in managing critical patients, and improved patient outcomes [15]. When ECPR is implemented by the ECLS team, the active participation of all team members throughout the treatment process facilitates the accumulation of treatment experience and practical skills. Increased patient participation results in a more substantial pool of experience in terms of teamwork and rescue procedures, enhancing the prospects for patient care and improving the treatment outcomes.

Given that ECPR may be initiated at any time, 24 h a day, ensuring the personal safety and attendance of team members during nighttime hours, our department's 24-h ECLS team comprises fixed personnel, primarily consisting of male medical staff. Female medical staff can join the 24-h ECLS team if accompanied by family members during nighttime shifts. By implementing ECPR in critically ill patients, it induces a state of cardiac rest, facilitating partial or complete recovery. Timely and effective application of ECPR therapy ensures a consistent supply of oxygen and stable circulation of blood to patients experiencing CA. This facilitates the rapid restoration of blood and oxygen flow to vital organs like the heart and brain, promoting early spontaneous circulation recovery [16]. The findings of this study revealed that, following the establishment of a 24-h ECLS team, the ECLS team group had a significantly shorter time for ECPR initiation compared to the control group. Although the increase in the rate of ROSC was not statistically significant and requires further data, clinical observations suggest that this approach could potentially enhance the clinical outcomes of ECPR-treated patients, consistent with another report [17]. Additionally, there was a negative correlation between the duration of mechanical ventilation during ECPR and the rate of ROSC within 45 min. In other words, shorter mechanical ventilation times were associated with higher patient survival rates and an increased likelihood of nervous system recovery. Based on the findings from a related study [17], the weaning success rate for patients who underwent ECPR treatment ranged from 35 % to 40 %. In our department, the weaning rate for patients treated with ECPR by the ECLS team was 38.89 % (7 out of 18 cases), aligning with the findings of this report. There is no statistically significant difference in weaning rates between these two groups, which may be due to the various factors affecting patient weaning in clinical practice, as highlighted in a study [17]. It is worth noting that the support and financial contributions from family members also played a crucial role in determining treatment outcomes.

Out of the 29 patients who received ECPR treatment in our department, 9 (31.03 %) were successfully weaned. Additionally, through communication, two families consented to organ donation, potentially saving more lives. Furthermore, four patients with initially shockable heart rhythms saw their nervous systems return to normal, a result consistent with the research conducted by Kandori et al. [18,19] Their studies emphasized that patients with pulseless ventricular tachycardia or ventricular fibrillation can experience substantial benefits from ECPR, leading to improved survival rates and positive long-term prognosis.

4.2. Establishment of the 24-h ECLS team can effectively reduce complications during ECPR implementation and operation

Our department handled 29 ECPR cases following the recommended guidelines from the 2018 *Expert Consensus on Adult Extracorporeal Membrane Oxygenation Cycle Assistance* [20]. These cases involved maintaining the specified target temperature, administering anticoagulation, managing blood flow, and assessing for complications and readiness for weaning.

In a study conducted in Japan, data from 1644 out-of-hospital cardiac arrest patients who underwent ECPR revealed that only 14.1 % of them had a favorable nervous system prognosis upon discharge. The survival rate at discharge stood at 27.2 %, with 32.7 % of patients experiencing complications during ECPR. Among these complications, bleeding was the most common, occurring at the catheterization site in 16.4 % of cases and in other forms at a rate of 8.5 % [21].

In our department, 4 out of 29 patients (13.79 %) treated with ECPR had a favorable nervous system prognosis at discharge, which aligns with the findings of the aforementioned study. Additionally, patients in the ECLS team group experienced bleeding complications during the ECPR procedure, but these were effectively managed through the administration of blood products. In the control group, three patients suffered from pulmonary hemorrhage following catheterization, which resulted in a decrease in flow rate and difficulties in its maintenance. The primary factors contributing to pulmonary edema and pulmonary hemorrhage were examined as follows: ① The oxygenated blood flow direction in the ECMO arterial pipeline was opposite to the direction of left ventricular ejection in patients. This led to an increase in left ventricular afterload, restricted the opening of the aortic valve, caused left ventricular dilation, raised left atrial pressure, and ultimately triggered pulmonary edema or pulmonary hemorrhage [22,23]. ② There was a possibility of lung injury due to mechanical chest compression.

In contrast, the ECLS team group employed a combined IABP therapy for these patients. An IABP was inserted into the contralateral femoral artery to alleviate left ventricular afterload. Additionally, the patients received high positive end-expiratory pressure and closed suction catheter simultaneously. This approach was carried out to support treatment, maintain airways in a closed and high-pressure state, keep the alveoli reasonably open, thus mitigating pulmonary edema and pulmonary hemorrhage, stabilizing effective circulating blood volume, and ensuring a steady ECPR operating flow rate.

Regarding the complications of gastrointestinal bleeding caused by systemic heparinization in the control group (administered as an intravenous loading dose of heparin at 50–100 U/kg during ECMO catheterization, arterial and venous catheterization, and before transfer), bedside ACT (Medtronic ACT PlusTM) monitoring technology was utilized for the ECLS team group, to continuously assess the coagulation status of patients in real-time. Subsequently, an appropriate anticoagulant dose (12,500 units of heparin sodium injection diluted in 50 ml of 0.9 % sodium chloride injection) was administered to maintain the ACT between 160 and 180 s. If the ACT fell below 160 s, continuous heparin infusion was initiated, and platelets and fibrinogen were supplemented based on the patient's condition to address bleeding and enhance systemic coagulation status. This approach effectively reduced the risk of bleeding.

To enhance the success rate of catheterization and reduce the risk of bleeding at the puncture site, ultrasound-guided puncture catheterization was adopted in the ECLS team group. One patient in the ECLS team group experienced compartment syndrome within 48 h of catheterization. The condition was effectively treated with the placement of a distal perfusion catheter and CRRT, leading to improvements in both compartment syndrome and distal limb ischemia. Upon investigation, it was determined that the femoral artery catheter had been inserted too high, causing compression of the deep femoral artery and a decrease in the effective blood circulation to the limb. Limb ischemia is a known complication in patients undergoing veno-arterial extracorporeal cardiopulmonary resuscitation (VAECPR), with reported incidence rates ranging from 11 % to 52 %. The placement of a distal perfusion catheter has been shown to reduce the occurrence of such complications [24]. However, in patients undergoing ECPR, which typically lasts 3–5 days, a 15 FR arterial catheter is commonly used, making the risk of distal limb ischemia relatively low. Consequently, only 4 out of 24 patients in our department who underwent VAECPR for more than 6 h had a distal perfusion catheter in place. By examining and assessing the pertinent data concerning complications in both groups, the 24-h ECLS team actively engaged in preoperative assessment, ultrasound-guided catheter placement, flow control, anticoagulation supervision, temperature regulation, and the evaluation of complications, as well as compiled a summary of their experiences with each patient undergoing ECPR treatment. Furthermore, the team successfully built valuable expertise in real-world ECPR treatment, leading to a significant decrease in complications during the execution and operation of ECPR procedures.

5. Conclusion

Due to the complex nature and challenging management of ECPR, establishing a 24-h ECLS team serves as a valuable model for achieving early success with ECPR in emergency departments. This approach effectively reduces the duration of ECPR mechanical start-up, enhances initial response efficiency, and lowers the occurrence of complications during ECPR implementation and operation. It is important to note that this study is retrospective, involving a limited number of ECPR-treated patients and conducted at a single center, which introduces some potential bias. Nevertheless, the ECPR-treated patients in our department exhibited favorable survival and organ donation rates, and all participants were individuals who did not achieve ROSC during CPR. Timely implementation of ECPR is crucial to mitigate the higher risk of mortality faced by patients, and we hope that this study can serve as a valuable resource for emergency department team members looking to independently initiate ECPR at an early stage.

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Ethics approval

This study was conducted with approval from the Ethics Committee of Aerospace Center Hospital (2021-ASCH-014). This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from all participants.

Additional information

No additional information is available for this paper.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Zhan-Xiao Liu: Writing - original draft, Funding acquisition, Formal analysis, Conceptualization. **Ya Yang:** Writing - original draft, Formal analysis, Data curation, Conceptualization. **Huan-Huan Song:** Writing - original draft, Formal analysis. **Wei Liu:** Writing - review & editing, Conceptualization. **Peng Sun:** Funding acquisition, Formal analysis, Data curation. **Cai-Wei Lin:** Writing - review & editing, Funding acquisition, Conceptualization.

Declaration of competing interest

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

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Abbreviation

ECPR	extracorporeal cardiopulmonary resuscitation
CA	cardiac arrest
CCPR	conventional cardiopulmonary resuscitation
ECMO	extracorporeal membrane oxygenation
ROSC	return of spontaneous circulation
OHCA	out-of-hospital cardiac arrest

IHCA	in-hospital arrest arrest
IABP	intra-aortic balloon pump
CRRT	continuous renal replacement therapy
VAV	venous-arterial-venous
VA	venous-arterial
VAECPR	venous-arterial extracorporeal cardiopulmonary resuscitation
PEEP	positive end-expiratory pressure

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