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Extracorporeal cardiopulmonary resuscitation in-hospital cardiac arrest due to acute coronary syndrome

Akut koroner sendroma bağlı gelişen hastane içi kardiyak arrestte ekstrakorporeal kardiyopulmoner resüsitasyon

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ABSTRACT

Background: The aim of this study was to analyze the effect of extracorporeal cardiopulmonary resuscitation on survival and neurological outcomes in in-hospital cardiac arrest patients.

Methods: Between January 2018 and December 2020, a total of 22 patients (17 males, 5 females; mean age: 52.8±9.0 years; range, 32 to 70 years) treated with extracorporeal cardiopulmonary resuscitation using veno-arterial extracorporeal membrane oxygenation support for in-hospital cardiac arrest after acute coronary syndrome were retrospectively analyzed. The patients were divided into two groups as those weaned (n=13) and non-weaned (n=9) from the veno-arterial extracorporeal membrane oxygenation. Demographic data of the patients, heart rhythms at the beginning of conventional cardiopulmonary resuscitation, the angiographic and interventional results, survival and neurological outcomes of the patients before and after extracorporeal cardiopulmonary resuscitation were recorded.

Results: There was no significant difference between the groups in terms of comorbidity and baseline laboratory test values. The underlying rhythm was ventricular fibrillation in 92% of the patients in the weaned group and there was no cardiac rhythm in 67% of the patients in the non-weaned group (p=0.125). The recovery in the mean left ventricular ejection fraction was significantly evident in the weaned group (36.5±12.7% *vs.* 21.1±7.4%, respectively; p=0.004). The overall wean rate from veno-arterial extracorporeal membrane oxygenation was 59.1%; however, the discharge rate from hospital of survivors without any neurological sequelae was 36.4%.

Conclusion: In-hospital cardiac arrest is a critical emergency situation requiring instantly life-saving interventions through conventional cardiopulmonary resuscitation. If it fails, extracorporeal cardiopulmonary resuscitation should be initiated, regardless the underlying etiology or rhythm disturbances. An effective conventional cardiopulmonary resuscitation is mandatory to prevent brain and body hypoperfusion.

Keywords: Acute coronary syndrome, conventional cardiopulmonary resuscitation, extracorporeal cardiopulmonary resuscitation, extracorporeal membrane oxygenation, ventricular fibrillation.

ÖZ

Amaç: Bu çalışmada hastane içi kardiyak arrest görülen hastalarda ekstrakorporeal kardiyopulmoner resüsitasyonun sağkalım ve nörolojik sonuçlar üzerindeki etkisi araştırıldı.

Çalışma planı: Ocak 2018 - Aralık 2020 tarihleri arasında akut koroner sendrom sonrası hastane içi kardiyak arrest nedeniyle veno-arteriyel ekstrakorporeal membran oksijenasyon desteği kullanılarak ekstrakorporeal kardiyopulmoner resüsitasyon ile tedavi edilen toplam 22 hasta (17 erkek, 5 kadın; ort. yaş: 52.8±9.0 yıl; dağılım, 32-70 yıl) retrospektif olarak incelendi. Hastalar veno-arteriyel ekstrakorporeal membran oksijenasyonundan ayrılan (n=13) ve ayrılmayanlar (n=9) olmak üzere iki grupta ele alındı. Hastaların demografik verileri, konvansiyonel kardiyopulmoner resüsitasyon başlangıcındaki kalp ritimleri, anjiyografik ve girişimsel sonuçları, sağkalım ve ekstrakorporeal kardiyopulmoner resüsitasyon öncesi ve sonrasında nörolojik sonuçları kaydedildi.

Bulgular: Eşlik eden hastalıklar ve başlangıç laboratuvar test değerleri açısından her iki grup arasında anlamlı bir fark yoktu. Ayrılan gruptaki hastaların %92'sinde altta yatan ritim ventriküler fibrilasyon iken, ayrılmayan gruptaki hastaların %67'sinde kardiyak ritim yoktu (p=0.125). Ortalama sol ventrikül ejeksiyon fraksiyonundaki düzelme ayrılan grupta anlamlı düzeyde daha belirgindi (sırasıyla, %36.5±12.7'e kıyasla %21.1±7.4; p=0.004). Tüm hastalarda veno-arteriyel ekstrakorporeal membran oksijenasyonundan ayrılma oranı %59.1 olmakla birlikte, nörolojik sekel olmayan sağ kalanların hastaneden taburcu edilme oranı %36.4 idi.

Sonuç: Hastane içi kardiyak arrest, konvansiyonel kardiyopulmoner resüsitasyon yoluyla anında hayat kurtarıcı müdahale gerektiren önemli ve acil bir durumdur. Başarısız olunursa, altta yatan etiyoloji veya ritim bozukluklarından bağımsız olarak, ekstrakorporeal kardiyopulmoner resüsitasyon başlatılmalıdır. Etkili konvansiyonel kardiyopulmoner resüsitasyon, beyin ve vücut hipoperfüzyonu önlemek için zorunludur.

Anahtar sözcükler: Akut koroner sendrom, konvansiyonel kardiyopulmoner resüsitasyon, ekstrakorporeal kardiyopulmoner resüsitasyon, ekstrakorporeal membran oksijenasyonu, ventriküler fibrilasyon.

Severe fatal complications of acute myocardial infarction (AMI) such as malignant ventricular arrhythmia or acute heart failure constitute the most common cause of in-hospital cardiac arrest (IHCA). Despite all the aggressive medical treatment and conventional cardiopulmonary resuscitation (c-CPR), more than one half of patients die from delayed resuscitation or persistent hemodynamic instability.[1] On the contrary, the most serious problem in survived patients is neurological damage due to the ineffective and/or delayed c-CPR resulting in intractable hemodynamic insufficiency, as well as the low tissue perfusion during the post-CPR re-establishing the native circulation. The main determinant of successful resuscitation should be the availability adequate circulation that ensures sufficient end-organ perfusion.

Extracorporeal CPR (e-CPR) is the advanced method of c-CPR using veno-arterial extracorporeal membrane oxygenation (va-ECMO), which provides circulatory and respiratory support in patients with cardiac arrest, when it is resistant to c-CPR.[2] Although the heart has little or no intrinsic activity, e-CPR can be also applied to ensure adequate circulation in IHCA patients.[3] Early implementation of e-CPR increases the survival rate over 50% through adequate tissue perfusion of vital organs by providing circulatory and pulmonary support that would help to maintain native adequate perfusion after e-CPR.[4] This preferred strategy supports patient's life and patients can be taken to the catheter laboratory for emergency percutaneous interventions to diagnose and/or treat the underlying coronary pathology.

Despite very limited number of nationally published studies on e-CPR in pediatric age groups,[5,6] there is no published study on the effectiveness of e-CPR in adult population with IHCA in the national literature. In the present study, we aimed to analyze the effect of e-CPR on survival and neurological outcomes in IHCA patients.

PATIENTS AND METHODS

This single-center, retrospective study was conducted by ECMO team of Koşuyolu High Specialization Education and Research Hospital between January 2018 and December 2020. A total of 22 patients (17 males, 5 females; mean age: 52.8±9.0 years; range, 32 to 70 years) treated with e-CPR using from va-ECMO support for IHCA after acute coronary syndrome (ACS) were included. Patients with a history of terminal disease or acute aortic dissection were excluded from the study, as well as patients with out-of-hospital cardiac arrest. A written informed consent was obtained from each patient. The study protocol was approved by the Koşuyolu High Specialization Education and Research Hospital Ethics Committee (date/no: 08.12.2020; 2020/13/391). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The standard biochemical analysis including alanine aminotransferase (ALT), aspartate aminotransferase (AST), troponin, creatinine, creatine kinase (CK), and lactate dehydrogenase (LDH) were examined immediately after the patients were admitted to the hospital before IHCA occurred, while several arterial blood gas samples were taken during c-CPR, e-CPR and within the first 4 h after va-ECMO implantation. As soon as the patients were stabilized, all anesthetic agents were discontinued, and the presence of consciousness and full orientation of all patients were expected. The neurological status of the patients was monitored with the Cerebral Performance Category (CPC) scale performed on Days 5 and 10 after IHCA (Table 1), where the CPC score 1-2 or a Glasgow Outcome Scale (GOS) score of 4-5 was defined favorable.

Initially, the heart rhythm at the beginning of c-CPR, angiographic and interventional imaging were evaluated from the hospital records, while all the information of the patients were obtained from the hospital database. Then, the ability of weaning

Table 1. Cerebral performance category scale

Category status	Clinical	Clinical condition
Category 1	Conscious and cooperative, without disability	Positive
Category 2	Conscious and non-orientality, with moderate disability	Positive/negative
Category 3	Conscious and confused, with severe disability	Negative/positive
Category 4	Comatose or vegetative state	Negative/death
Category 5	Death	Death

from va-ECMO, neurological complications, rate of discharge from hospital, neurological conditions during discharge, and the causes of mortality were evaluated. The patients were divided into two groups according to success of weaning from va-ECMO (n=13) or not (n=9) to evaluate the negative impact of risk factors on early outcome and discharge.

The definition of IHCA was documented as irreversible loss of pulse and breathing after sudden circulatory collapse and cardiac arrest in patients admitted or hospitalized, despite multiple doses of epinephrine injections, defibrillation, and chest compressions. The indications for e-CPR were young age (<70 years), the presence of pulselessness during c-CPR (i.e., ventricular fibrillation or asystole on electrocardiograph), shorter interval (<20 min) between IHCA and c-CPR, and also shorter (<10 min) no-answer phenomenon to c-CPR and defibrillated electroshock.

e-CPR application and ECMO weaning

If hemodynamic stability cannot be ensured despite effective c-CPR, va-ECMO support is provided percutaneously with a return cannula (outlet cannula) through the left common femoral artery and a longer, multi-hole drainage cannula (inlet cannula) through the right femoral vein, after systemic heparinization. It is essential to place a 7-Fr distal perfusion cannula distally through the left superficial femoral artery to ensure distal limb blood supply and perfusion to avoid leg ischemia. After hemodynamic stabilization in the intensive care unit (ICU), the patient is immediately taken into the catheter laboratory to perform diagnostic coronary angiography through the right femoral artery, and percutaneous revascularization is performed for all culprit lesions. On the contrary, if the patient is hemodynamically instable, pharmacological support is initiated through inotropic and vasopressor therapy to maintain a mean arterial pressure (MAP) of >65 mmHg for adequate tissue perfusion. In addition, an intra-aortic balloon pump (IABP) should be placed from the right femoral artery, after the initial percutaneous intervention in stable patient or directly in instable patient to ensure aortic blood flow pulsatility, and thus to provide better left ventricular unloading and to prevent left ventricular distention. Moreover, the patient must be sedated at least 24 h after va-ECMO implementation to reduce cardiac metabolism and myocardial oxygen consumption and also to prevent brain damage. Heparin or bivalirudin infusion is started for anticoagulation and monitored with the activated coagulation time (ACT). Daily laboratory tests and imaging should be made. The right radial artery should be cannulated to monitor hemodynamics and blood gas analyses with the aim to avoid potential Harlequin syndrome in the presence of pulmonary hypoxemia due to pulmonary edema or ECMO-related acute respiratory distress syndrome.

After hemodynamic stabilization with or without percutaneous revascularization, the general procedure is to follow the patient for at least three to five days and, then, the decision can be made to wean from va-ECMO. Once circulatory and pulmonary functions are sufficiently restored, va-ECMO support would be discontinued to prevent possible ECMO-related complications. Arterial blood gas values are monitored to define the necessity or continuity of an artificial gas-exchange support. The first step is to temporarily decrease the ECMO flow rate while monitoring circulatory functions echocardiographically, and keep the MAP hemodynamically above 65 mmHg. If the cardiac functions are sufficient, ECMO support is discontinued and the cannulas are removed, and the patient is kept under close observation for at least 12 h against possible complications. Stabilization of the patient with mechanical ventilation, IABP and inotropic support is sustained with daily echocardiographic controls of cardiac functions, and according to the stable course, the patient would be weaned from all supportive treatments step by step (decreasing inotropic support, extubation, and removal of counter-pulsation).

Statistical analysis

Analyzes were performed using SPSS Statistics version 15.0 software (SPSS Inc., Chicago, IL, USA). Categorical variables are expressed as percentages and analyzed using the Chi-square or Fisher's exact test. Continuous parameters are presented as mean ± standard deviation, if non-normal distributed given as median and interquartile range (IQR), and groups were comparing using Student's t-test or Mann Whitney U test. $P < 0.05$ was considered statistically significant.

RESULTS

Demographic, clinical, and laboratory characteristics of the patients are summarized in Table 2. There was no significant difference between the groups in terms of comorbidity and baseline laboratory test values. However, significant biochemical deterioration, indicating multi-organ failure due to severe cardiogenic shock, was observed in all patients, indicating that all patients developed multi-organ failure prior to eCPR. As multi-organ failure was more severe in the non-weaned group due to failure of cardiocirculatory recovery despite e-CPR and

Table 2. Demographic, clinical, and laboratory data

	Total (n=22)			No wean (n=9)			Wean (n=13)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	p
Age (year)			52.8±9.0			54.0±6.5			52.0±10.4	0.616
Sex										0.279
Female	5	23		1	11		4	31		
Male	17	77		8	89		9	69		
Hypertension	13	59		5	55		8	62		0.779
Diabetes mellitus	6	27		2	22.2		4	31		0.658
Previous CAD	3	16.6		1	11.1		2	22.2		0.527
Troponin (ng/dL)			6.2±3.9			8.1±3.1			4.8±3.9	0.051
Creatinine (mg/dL)			1.6±0.7			2.0±0.6			1.3±0.7	0.025
AST (U/L)			652.7±733.5			992.7±937.0			417.3±457.7	0.117
ALT (U/L)			571.3±1403.1			1,066.8±2,151.2			228.3±219.5	0.277
LDH (U/L)			1,386.9±810.9			1,715.8±862.0			1,159.2±719.7	0.132
CK (µg/L)			3,025.6±3,055.6			4,229.8±3,189.1			2,192.1±2,778.2	0.141

SD: Standard deviation; CAD: Coronary artery disease; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; LDH: Lactate dehydrogenase; CK: Creatine kinase.

Table 3. Demographic, clinical, and laboratory data

	Total (n=22)		No wean (n=9)		Wean (n=13)		
	n	%	n	%	n	%	p
Acute coronary syndrome							
ST-elevated myocardial infarction	16	72.7	6	66.7	10	76.9	0.595
Non-ST-elevated myocardial infarction	6	27.3	3	33.3	3	23.1	
Rhythm							
Asystole	4	18.2	3	33.3	1	7.7	0.125
Ventricular fibrillation	18	81.8	6	66.7	12	92.3	
Coronary lesion							
Single vessel	10	45.4	3	33.3	7	53.8	
Double vessels	8	36.3	3	33.3	5	38.4	0.135
Multiple vessels	4	18.1	3	33.3	1	7.6	

Table 4. Comparison of arterial blood gas analyses

	Total (n=22)	No wean (n=9)	Wean (n=13)	
	Mean±SD	Mean±SD	Mean±SD	p
pre-ECMO pH	7.1±0.2	7.1±0.2	7.1±0.2	0.870
on-ECMO pH	7.3±0.2	7.1±0.1	7.4±0.1	0.001
pre-ECMO lactate (mmol/L)	12.7±6.4	15.4±7.3	10.8±5.1	0.127
on-ECMO lactate (mmol/L)	10.1±7.0	15.1±5.9	6.7±5.5	0.001
pre-ECMO p_aCO_2 (mmHg)	48.9±13.7	44.5±13.9	51.9±13.2	0.223
on-ECMO p_aCO_2 (mmHg)	35.7±8.3	40.3±9.1	32.6±6.3	0.074
pre-ECMO p_aO_2 (mmHg)	67.6±15.3	70.7±13.7	65.5±16.6	0.443
on-ECMO p_aO_2 (mmHg)	182.9±54.2	179.2±48.2	185.5±59.3	0.798

SD: Standard deviation; ECMO: Extracorporeal membrane oxygenation; pCO$_2$: Partial arterial carbon dioxide pressure; pO$_2$: Partial arterial oxygen pressure.

Table 5. Outcome data

	Total (n=22)					No-wean (n=9)					Wean (n=13)					p
	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	
Ejection fraction (%)			30.2±13.1					21.1±7.4					36.5±12.7			**0.004**
Days on-ECMO				3.5	1-9				3	1-7				4	2-9	0.314
Days in ICU				7	1-20				3	1-7				13.5	6-20	
Days in Hospital				13	1-34				-	-				17.5	12-34	
Mortality rates																
Hospital mortality	13	59.1				9	100				4	30.7				
On-ECMO	9	40.1				9	100				0	0				
Between wean and discharge	4	18.2				0	0				4	30.7				
Cerebral performance category																
CPC-1	6	27.3				-	-				6	-				
CPC-2	3	13.6				-	-				3	-				
CPC-3	3	13.6				-	-				3	-				
CPC-4	6	27.3				5	-				1	-				
CPC-5	4	18.2				4	-				-	-				
Cause of death																
Severe neurologic events	6	27.3				3					3					0.545
Multiorgan failure	4	18.2				4					0					**0.008**
Sepsis	3	13.6				2					1					0.358
Limb ischemia	2	9.1				1					1					0.662
Renal insufficiency	6	27.3				4					2					0.155

SD: Standard deviation; ECMO: Extracorporeal membranous oxygenation; ICU: Intensive care unit; CPC: Cerebral performance category.

va-ECMO support, their biochemical markers were more severely impaired.

Baseline e-CPR rate of detected ST-elevated AMI and ventricular fibrillation was 72.7% and 81.8% in IHCA patients, respectively. Coronary angiography was performed in all patients and single-vessel disease was detected in approximately half of the patients (Table 3). While ECMO wean could be provided mostly in patients with single-vessel disease, three-quarters of the patients with multi-vessel disease could not be weaned from ECMO.

There was no significant difference in arterial blood gas results obtained before effective e-CPR between the groups (Table 4). Rapidly recovered arterial pH and lactate values on ECMO indicated that adequately managed tissue perfusion through e-CPR improved the clinical status and facilitated weaning from va-ECMO. However, the patients with uncorrected body hypoperfusion despite successful e-CPR did not recover at the same level and died on va-ECMO.

Outcomes of the patients are summarized in Table 5. In our study, the mean e-CPR onset time was 29.8±13.2 min in the patients weaned from va-ECMO and 33.6±13.9 min in non-survivors, indicating no statistically significant difference. The support period of va-ECMO ranged between 1 to 9 days, without any significant difference between the groups. Four (30.7%) patients in the surviving group died within four to eight days after weaning from ECMO, without being discharged, while nine surviving patients (40.1%) were discharged from the hospital within 12 to 34 days following the discontinuation of ECMO. The reason for hospital-mortality in four patients was intracranial hemorrhage in two cases with CPC-3, ischemic encephalopathy in one with CPC-4, and sepsis in another one with CPC-2.

The most common associated morbidity was acute renal failure that developed in six (27.2%) of all patients, and continuous kidney replacement therapy was initiated. Distal limb ischemia despite distal perfusion cannula was observed in two patients, and the return cannula was surgically changed to the axillary.

Cerebral performance categories after e-CPR could be monitored only in survived patients on Days 4 and 10 after ECMO wean, and six patients with CPC-1 and two patients with CPC-2 were discharged to home, and one patient with CPC-3 was referred to an external center due to the need for palliative intensive care.

DISCUSSION

The main finding of this study is that effective c-CPR is mandatory to prevent brain ischemia during the arrest period, which is the main predictor of in-hospital mortality. Second, c-CPR support through ECMO to maintain adequate body perfusion may be life-saving with more than 50% weaning rate. Third, every effort should be made to prevent or to treat acute kidney injury and also distal limb ischemia, both of which may increase hospital morbidity and mortality. Fourth, even if chaotical or malignant, the underlying shockable heart rhythm is associated with a higher survival rate due to its reversibility in the sinus rhythm, which is essential to ensure native systemic circulation with sustained adequate systemic blood pressure, rather than delayed asystole.

Extracorporeal CPR has been used successfully in adult patients with IHCA for different etiologies, particularly for cardiovascular pathologies, and has shown promising results in terms of survival and hospital discharge.[7,8] The purpose of e-CPR support is to assist patients with cardiac arrest to provide time for recovery, diagnosis, and treatment of potentially reversible causes. According to the 2020 Extracorporeal Life Support Organization (ELSO) report, survival rates after e-CPR reach to be around 30% in all patient groups.[9] Several meta-analyses indicate the efficacy of e-CPR over c-CPR with better survival rates and this is approximately >30% in patients rescued with the e-CPR protocol supported by va-ECMO versus approximately 15% in patients intervened with the c-CPR protocol.[10-12] The higher mean age may be a negative determinant for survival and neurological outcomes, and older patients are not often selected for e-CPR probably due to the wrong beliefs and fears of clinicians. Unlike out-of-hospital cardiac arrest, IHCA occurs mostly in cardiac patients without any neurological complications and, therefore, effective c-CPR followed by e-CPR is mandatory. Additionally, one-year survival after IHCA is higher in cardiac patients compared to non-cardiac patients, while comorbid diseases worsen survival.

The second favorable common result is better neurological outcomes in IHCA patients treated with e-CPR.[13] Since neurological sequelae can be life-threatening and also quality of life-lowering complications during follow-up in surviving IHCA patients, an immediate and effective rescue intervention with e-CPR would prevent cerebral hypoxemia and, thus, neurological complications with or without permanent neurological sequelae. The CPC scoring system is the most used assessment to predict the

neurological outcomes of IHCA patients for hospital mortality or permanent deficits during a post-CPR follow-up period. Surviving patients by e-CPR have lower scores indicating better neurological outcomes; for instance, CPC-1 or -2 patients' incidence can be more than 85% in 1-year survivors.[13-15]

In our study, the rate of va-ECMO wean was 59.1%; however, the discharge from hospital was 40.9%, where eight patients (36.4%) were discharged to home without any sequel and one patient with CPC-3 was referred to another center due to neurological sequelae such as hemiparesis requiring palliative ICU. Unless a vital response is available within 10 min following c-CRP, we prefer rapid va-ECMO administration due to our more effective results compared to the published literature.[16,17] We are aware of that only a minority (<5%) of cardiac arrest patients undergoing c-CPR get a favorable neurological outcome beyond the first 10 to 15 min despite sufficient c-CPR. Second, as the most important reason for in-hospital mortality is probably ineffective c-CPR intervention due to insufficient heart massage or incorrect thorax compression, which leads to inadequate supportive systemic perfusion problems during c-CPR, or directly fatal complications through adverse events in the central nervous system such as thromboembolic events, faster va-ECMO implementation seems to be more neuroprotective approach than prolonged ineffective c-CPR or delayed implementation of va-ECMO. All non-survivors except one in septic shock died from major neurological events (e.g., ischemic encephalopathy, intracranial hemorrhage) in the hospital setting. This finding suggests that, during the c-CPR and/or e-CPR process, not only the cardiopulmonary system should be intervened, but probably and more importantly, that adequate cerebral perfusion is indispensable and a higher level of sensitivity and attention should be paid to brain protection.

Pre-resuscitation cardiac rhythm is important for prognosis in IHCA patients with ACS, such as ST-elevated myocardial infarction (STEMI) or non-STEMI, or without ACS, such as myocarditis or end-stage heart failure. A shockable rhythm during c-CPR is associated with better outcomes; however, if the chaotic heart rhythm does not return to its normal ejecting rhythm with at least three defibrillation attempts within 10 min, which is considered to be shock-refractory IHCA, persistent ventricular fibrillation would be associated with a fatal outcome due to permanent myocardial and/or neurological damage.[18] Essential properties of effective c-CPR with efficiency ability for more successful vital and neurological outcomes in IHCA patients have been published by several studies as follows: shockable initial rhythm (<3 times defibrillation within 10 min), shorter low-flow period (<10 min), lower total conversion-time form c-CPR to e-CPR (<30 to 40 min), non-increased blood lactate levels before e-CPR (<7 to 8 mmol/L), lower Sequential Organ Failure Assessment (SOFA) score and normal creatinine levels in the first 24 h after ICU admission (<1 mg/dL).[19-22] These factors could also benefit to identify which IHCA patients would benefit most from e-CPR. Although the etiology of all e-CPR patients performed in our clinic was IHCA due to ACS, we could not find any adverse effect of STEMI or non-STEMI on the prognosis, weaning from va-ECMO and discharge of the patients. In our study, the mean interval between the initiation of e-CPR and IHCA was approximately 1.5 h without a statistically significant difference between both groups. Since these times are acceptable in patients treated under effective c-CPR, it is thought that the main problem is the irreversibility of the cardiac rhythm and possibly the inadequate cerebral perfusion.

The presence of ventricular fibrillation as the underlying cardiac dysrhythmia positively affected ECMO wean and discharge rates, compared to patients presenting with asystole or no rhythm. These differences suggest that restoring the cardiac rhythm, which is the most effective factor in preventing neurological complications, should be prioritized, as the conversion of ventricular fibrillation or other abnormal rhythms to normal sinus rhythm by electroshock is the cornerstone of e-CPR to establish adequate venous drainage and normal systemic return of ECMO. Although the difference in other survival markers of the patients is striking, the restoration of the cardiac rhythm during e-CPR is also found to be one of the important factors for better survival in the literature.[18,23-26]

The success of e-CPR application can be also affected by the time between e-CPR and percutaneous coronary intervention in the catheterization laboratory. It is well known that the shorter the conversion time from c-CPR to e-CPR via va-ECMO, the more favorable outcomes would be obtained, including better survival and less neurological complications. The same argument should not be ignored for coronary revascularization in IHCA patients suffering from ACS and, therefore, saving time through e-CPR to intervene in coronary arteries percutaneously is also important on myocardial salvage and survival rate.[27] As done in emergency in ACS-related IHCA, e-CPR opens new areas in various elective or non-elective percutaneous interventions with favorable

effectiveness and life-saving potential (i.e., most severe coronary interventions, transcatheter aortic valve implantation, and invasive electrophysiological procedures) under life-threatening situations, such as refractory cardiac arrest or advanced cardiogenic shock, particularly in the absence of more advanced temporary left ventricular assist devices, such as Impella® and TandemHeart®.[28-30]

Nonetheless, there are several limitations to this study. First, e-CPR-related complications such as bleeding and inflammatory response might have affected the survival and neurological outcome; however, they were unable to be evaluated in this study. Second, our sample size is limited, as we could not perform e-CPR in all IHCA patients due to not available device in time, longer no-flow time in some patients, and suspicious efficacy of c-CPR. Third, our ECMO-team is newly established and working principles and rules have been arranged by the hospital management and, thus, we believe our case series would increase over time, as well as our success with e-CPR.

In conclusion, our early result indicates that extracorporeal cardiopulmonary resuscitation may improve in-hospital mortality rate and neurological outcomes, compared to the best current standard of salvage treatment approaches in in-hospital cardiac arrest patients. With the widespread use of this approach to out-of-hospital cardiac arrest patients or to apply patients at external centers suffering from pandemic-related respiratory failure, we believe that more patients would be saved. Finally, more chaotic situations can be overcome by applying prophylactic extracorporeal cardiopulmonary resuscitation in the catch lab, particularly in patients with unstable condition and instability due to severe coronary lesions such as left main coronary artery disease, aortic stenosis undergoing percutaneous intervention, severe pulmonary thrombolysis due to acute thromboembolism, or electrophysiological disturbances.

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