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Venous-arterial extracorporeal membrane oxygenation for refractory cardiac arrest: a clinical challenge

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Abstract

Guidelines stated that extracorporeal membrane oxygenation (ECMO) may improve outcomes after refractory cardiac arrest (CA) in cases of cardiogenic shock and witnessed arrest, where there is an underlying circulatory disease amenable to immediate corrective intervention. Due to the lack of randomized trials, available data are supported by small series and observational studies, being therefore characterized by heterogeneity and controversial results. In clinical practice, using ECMO involves quite a challenging medical decision in a setting where the patient is extremely vulnerable and completely dependent on the medical team's judgment. The present review focuses on examining existing evidence concerning inclusion and exclusion criteria, and outcomes (in-hospital and long-term mortality rates and neurological recovery) in studies performed in patients with refractory CA treated with ECMO. Discrepancies can be related to heterogeneity in study population, to differences in local health system organization in respect of the management of patients with CA, as well as to the fact that most investigations are retrospective. In the real world, patient selection occurs individually within each center based on their previous experience and expertise with a specific patient population and disease spectrum. Available evidence strongly suggests that in CA patients, ECMO is a highly costly intervention and optimal utilization requires a dedicated local health-care organization and expertise in the field (both for the technical implementation of the device and for the intensive care management of these patients). A careful selection of patients guarantees optimal utilization of resources and a better outcome.

Keywords

Refractory cardiac arrest, extracorporeal membrane oxygenation, prognosis, in-hospital cardiac arrest, out-of-hospital cardiac arrest

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Introduction

Extracorporeal membrane oxygenation (ECMO) is an aggressive and invasive method for extra-corporeal cardiopulmonary resuscitation (CPR) that has been suggested for refractory cardiac arrest (CA), with the goal of supporting the body's circulation in the absence of an adequately functioning cardiac pump.[1] ECMO has been used in CA since 1976,[2] after the introduction of battery-powered portable cardiopulmonary bypass machines. However, the use of this technique remained restricted for many years to particular subsets of patients, such as those presenting CA following an open heart surgery[3] and to those undergoing accidental hypothermia[4] and massive drug overdose.[5]

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Recent developments in cardiopulmonary by-pass technology, such as miniaturized extra-corporeal devices, heparin-coated circuits and percutaneous cannulation techniques,[6–8] allowed a wider use of this support in different clinical situations.[9] Recent studies have also highlighted the capability, with the early application of ECMO, to improve the prognosis of prolonged CA occurring both in in-hospital CA (IHCA) [10] and out-of-hospital CA (OHCA) settings.[11,12]

The international consensus of 2005 on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations by the International Liaison Committee on Resuscitation stated that ECMO may improve outcomes after CA, when compared with standard CPR, in cases of cardiogenic shock and witnessed arrest, where there is an underlying circulatory disease amenable to immediate corrective intervention.[13] The American Heart Association (AHA) proposed that ECPR (ECMO-cardiopulmonary resuscitation) should be considered for in-hospital patients in CA when the duration of the no-flow arrest is brief and the condition leading to the CA is reversible (e.g. hypothermia or drug intoxication) or amenable to heart transplantation or revascularization.[1,14]

Due to the lack of randomized trials, available data are supported by small series and observational studies, being therefore characterized by heterogeneity and controversial results. On the other hand, in clinical practice, using ECMO involves quite a challenging medical decision in a setting where the patient is extremely vulnerable and completely dependent on the medical team's judgment .

The present review focuses on examining existing evidence concerning inclusion and exclusion criteria, and outcomes (in-hospital and long-term mortality rates and neurological recovery) in previous studies performed in patients with refractory CA treated with ECMO. Case reports, investigations enrolling patients with postcardiotomy shock, refractory cardiogenic shock and CA following hypothermia and drug intoxication were not considered.

Inclusion criteria

Age

When examining inclusion criteria, age was one of them. Despite most papers considering age as an inclusion criteria, it may be strictly viewed as an exclusion criteria since patients not within the age-range are not included. While in the 1990s, Raithel et al.[15] and Reedy et al.[16] enrolled patients ranging in age from 19–78 years and from 10–78 years, respectively, the latest studies included only patients younger that 75 years.[9,17–21] In the meta-analysis by Cardarelli et al.,[10] the median age for the group of patients treated with ECMO was 56 years (range 18–83). Compared with the youngest group (17–41 years), the odds ratio (OR) for mortality was higher for the age group of 41–56 years (OR 2.9 95% confidence interval (CI), 1.6–8.2)) and those older than 67 years (OR 3.4%; 95% CI, 1.2–9.7).

Despite the clinical importance of age, many investigations did not mention it as an inclusion criteria.[5,22,23] On the other hand, age range was an arbitrary criteria in several papers. In the small series reported by Sakamoto et al.,[22] mean age was 72±12 years. Le Guen et al.[12] excluded patients older than 70 years of age 'because of the poor expected neurological recovery' while Shin et al.[24] included only patients <80 years. Chen et al.[19] stated that the age criterion varied through the years and that from 2001, in their center it was extended to 80 years because of the increased number of older patients and the satisfactory survival rate of the initial ECPR patients. Age was reported as an independent predictor of in-hospital[18,19,25] mortality in 607 adults who received ECMO as a mechanical circulatory support.[26]

Duration of cardiopulmonary resuscitation (CPR)

Within inclusion criteria, duration of CPR varies among investigations. The absence of a return of spontaneous circulation (ROSC) after 30 min of CPR was considered by Le Guen et al.[12] and Avalli et al.[17] CPR >10 min without return of spontaneous circulation was reported by Chen et al.[19,20,25] and Shin et al.[24] Kagawa et al.[9] included patients who showed ROSC not achievable within 20 min of conventional CPR.

Rhythm of presentation

Concerning rhythm of presentation, discrepancies exist among studies. While a shockable rhythm was considered as an inclusion criteria by Avalli et al.[12] and Kagawa et al.,[9] other papers included patients regardless of rhythm.[22]

Several factors may account for so many discrepancies in inclusion criteria: (a) heterogeneity in study population: especially in the first reports,[15,16,27] patients included in the studies showed CA from different etiologies (ACS: acute coronary syndrome (ACS), post-cardiotomy surgery, myocarditis); (b) most investigations were retrospective, so that inclusion criteria were somewhat 'related' to the study population; (c) differences in local health system organization in respect to the management of patients with CA. In the real world, patient selection occurs individually within each center based on their previous experience and expertise with a specific patient population and disease spectrum. There is growing recognition of the importance of developing universal guidelines for patient selection to facilitate outcome comparisons between centers and identify factors affecting those outcomes. Moreover, some selection criteria are thought to affect prognosis, such as CPR duration.[9,11,12,18,19,22,24]

Exclusion criteria

The exclusion criteria more frequently reported were as follows: previous severe neurologic damage, current intracranial hemorrhage, malignancy in the terminal stage, arrest of traumatic origin with uncontrolled bleeding, arrest of septic origin, irreversible organ failure leading to CA when no physiological benefit could be expected despite maximal therapy (hepatic failure, late stage of adult respiratory distress syndrome, etc), aortic dissection, severe peripheral arterial disease and patients who previously signed 'do-not-resuscitate' orders.[9,12,18–20,24]

Outcomes

In order to better assess the clinical impact of Venous-arterial extracorporeal membrane oxygenation (VA-ECMO) in CA patients, we considered as outcomes, survival rate (both at hospital discharge and at long-term) and neurological recovery.[5,9,11,12,17–25,27–34]

In-hospital survival rate

Table 1 shows the study design, the number of patients weaned from ECMO, in-hospital and 30-day survival rates, together with neurological recovery after discharge (as indicated by cerebral performance categories (CPC)) in each study included in the present review.

The in-hospital survival rate showed a great variability, ranging from 6–59%. Several factors can account for these findings. Differences in population selection: a higher in-hospital survival rate is reported in investigations including ACS patients (when submitted to revascularization) and/or post pericardiotomy patients. A better weaning and survival rate was observed by Chen et al.[28] in the postcardiotomy subgroup, probably thanks to a earlier detection of CA and to the fact that the possible detrimental factors or underlying anatomic factors had been corrected before ECMO.

Several studies investigated the relation between CPR duration and survival, though with controversial results. In a multi-institutional experience, Hill and colleagues[35] reported that the time from witnessed arrest to portable cardiopulmonary bypass had moderate predictive value for mortality and had not been a major consideration for withholding extracorporeal life support (ECLS) if evidence of neurologic function persisted. This contrasts with the experience of Hartz and colleagues,[36] who suggested 30 min as a cut-off for bypass initiation. Chen et al.[18] evaluated the relation between CPR duration and survival and observed that a shorter CPR duration correlated with shorter weaning and better survival. In particular 100% of those whose CPR duration was 30 min were weaned from ECPR and survived: in those receiving CPR <60 min, the survival rate was acceptable (48.39%), and the incidence of weaning was high (80.65%). A detailed analysis of the relation between CPR duration and survival was performed by Chen et al.[18] who, in a series of 135 patients, documented that the probability of survival in the ECPR setting was approximately 0.5, 0.3, and 0.1 when CPR was 30, 60, and 90 min, respectively. According to their results, the authors concluded that with assisted circulation, CPR duration could be extended to 60 min with acceptable survival and the incidence of major neurologic deficits was relatively low at hospital discharge.

Comparison between OHCA and IHCA and in-hospital survival rate

Patients with OHCA treated with ECLS support have been reported to experience a worse prognosis in respect to IHCA patients treated with ECLS, in part because of a longer treatment delay.[32] Kagawa et al.[9] compared IH and OH refractory CA treated with ECLS and reported a lower survival rate in OHCA (10% vs 26%). In selected OHCAs, ECLS may be lifesaving, provided that the patient has not sustained hypoxic cerebral damage. Consistently, Chen et al.[19] hesitated to recommend ECLS for out-of hospital CPR because of the uncertain duration of arrest. However, they recognized that ECLS may offer an acceptable survival rate in prolonged CPR up to 60 min with 30% probability of survival. In the study by Megarbane et al.[23] duration of cardiac massage until ECLS implementation (155 min (120–180)) was longer than in others. With a 105±44 min duration, three patients survived in Massetti et al.'s study[21] despite irreversible cardiac dysfunction, while bridged to a ventricular-assist device (n=2) and cardiac transplantation (n=1). However, the majority of Massetti et al.'s CAs occurred and were treated within the hospital in charge, with a shorter time to cannulation. In the in-depth review by Morimura et al.[11] on OHCA including 139 cases, the mean time from collapse and ECLS was 52.0 (33.3–70) min. Le Guen et al.[12] reported a minimum delay to start ECLS of 75 min. Part of this delay is unavoidable but it may be shortened by earlier alerting of the system before reaching the 30-minute delay point until diagnosis of refractory CA.[37] According to the French guidelines, the role of the delay until initiation of advanced CPR may be far less important while other important factors should be considered, particularly the quality of CPR during ground transportation.

Biochemical factors and risk stratification

Among biochemical factors which may help in deciding whether to decide for an earlier interruption of futile ECLS in OHCA patients, a greater lactate clearance[12] was associated with survival while SpvO2 ≤8% predicted the development of early multiple organ failure with a specificity of 1 and, similarly, lactate concentration ≥21 mmol/l, fibrinogen ≤0.8 g/l and prothrombin index ≤11% suggested ECLS futility.[23]

TABLE 1.

(Section I)

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Raithel et al[15] (1989)		29 patients	CA during catheterization (10 pts), shock secondary to AMI (10 pts), high risk PTCA (4 pts), postcardiotomy failure (4 pts), hypothermia (1 ptt).	6 /29 (20.6%)	6 /29 (20.6%)		
Reedy et al[16] (1990)	prospective	38 pts; 35 pts successfully implanted	AMI (12 pts), ischemic disease (15 pts), end-stage cardiomyopathy (7 pts), congenital heart disease (3 pts), or postoperative cardiac transplant graft rejection (1 pt)	24 pts (24/38, 63.1%)	9 pts (24%)		
Younger et al[27] (1994)		25 patients (2 children) in 4 pts failure to cannulate	drowing (3 pts), AMI (9 pts), viral cardiomyopathy (2 pts) procedure complications (1 pt), pulmonary emobolism (9), aortic endocarditis (1 pt)	9/25 (36%)			
Chen et al[28] (2003)	retrospective	57 pts	post cardiotomy (14 pts), pumonary embolism (2 pt), AMI (3 pts), cardiomyopathy (14)	38/57 (66.7%)	18/57 (31.6%)	16/57 (28%)	15/57 (26%)
Schwarz et al[29] (2003)		46 pts 4 cannulation failure 1 ECMO failure	CS (25 ptsi) CA (21 pts)	28/46 (61%)	13/46 (28.2%)	01/12/46	

(Section II)

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Massetti et al[21] (2005)		40 pts	AMI (16 pts), pulmonary embolism (3 pts) postcardiotomy (4 pts), cardiomypathy (4 pts), myocardial intoxication (4 pts) myocarditis (2 pts) arrhythmias (4 pts)	6 pts (15%) 9 bridge to VAD 2 bridge to transplantation	8 (8/40, 20%)	8 (8/40, 20%)	8 (8/40, 20%)
Chen et al[25] (2006)	retrospective	36 patients	AMI	Weaned 25 pts Withdrawn 6 wean-but-die 13 pts	12 pts (33 %)		
Megarbane et al[5] (2007)	prospective cohort study	17 patients 3 ECMO failure	toxic cardiac arrest (12 pts) non toxic cardiac arrest (5 pts)	4 (4/17, 25%)	4 (4/17, 25%)	3 (3/17, 18%)	3 (3/17, 18%)

TABLE 1. (Continued)

(Section II)

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Chen et al[18] (2008)	observational cohort study	135 IHCA	ACS (66 pts), post cardiotomy (23 pts) cardiomyopathy (22 pts) myocarditis (12 pts) pulmonary embolism (5 pts), others (7 pts)	79 (79/132) 58.5%	46 (46/135, 34.1%)		
Chen et al[19] (2008)	3-year prospective study	59 IHCA	ACS (37 pts), congestive heart failure (6 pts), myocarditis (5 pts) post-cardiotomy (7 pts), pulmonary embolism (1 pt), unspecified causes (3 pts)	29 (29/59, 49%)	17 (17/9, 28%)		9 (15.3%)

(Section III)

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Thiagarajan et al[30] (2009)	prospective (ELSO registry)	297 pts	cardiac origin (221 pts), non cardiac origin (76 pts)		81 (81/297, 27%)		
Nagao et al (2010)[31]	prospective	171	ACS (131 pts), cardiomypathy (8 pts), others (32 pts)		33 (33/171, 19%)		1-year 20 (11.7%)
Kagawa et al[9] (2010)	retrospective	77 patients	38 IHCA 39 OHCA	IHCA:23 pts OHCA: 14 pts	NA	IHCA: 13 (34%) OHCA: 5 (13%)	IHCA: 10/38 (26%) OHCA:4/39 (10%)
Jaski et al[32] (2010)	prospective registry	150 patients (127 for cardiac arrest, 23 refractory shock)	CA (127 pts) cardiogenic shock (23 pts)	61 patients		39 (26%)	
Liu et al[20] (2011)	retrospective chart-review	11 patients	AMI	7 pts (63.6%)	4 pts (36.4%)	NA	NA
Megarbane et al (2011)[23]	prospective cohort study	66 pts 1 cannulation failure	IHCA: 47 pts (71%) OHCA:19 pts (29%)		4 (4/66, 6%)	NA	NA
Le guen et al[12] (2011)		51 OHCA patients *8 ECMO failure* *1 cannulation failure* 42 ECMO pts	cardiac origin (44 pts), trauma (3 pts), drug overdose (2 pts), respiratory (1 pt), elettrocaution (1%).		5 (5/42, 12%)	2 pts (4%)	2 pts (4%)
Morimura et al[11] (2011)	meta-analysis -indepth review	139 OHCA		59 pts (58.4%)			
Shin et al[24] (2011)	retrospective	85 IHCA 3 cannulation failure 2 ECMO failure	cardiac origin (79 pts), non cardiac origin (6 pts)		29 pts (34%)	24 (28%)	24 (28%)

TABLE 1. (Continued)

Section IV

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Avalli et al[17] (2012)	retrospective	42 patients (24 pts IHCA; 18 pts OHCA)		IHCA: 14 (14/42, 33%) OHCA: 3 (7%)	NA	IHCA: 10 OHCA: 1	IHCA:9 (37.5%) OHCA: 1 (5.5%)
Kim et al[33] (2012)	retrospective	27 pts	cardiogenic shock (27 pts); CA in 21 pts (77.8%)	22 (81.5%)	16 (59.3%)	13 (48%)	13 (48%)
Sakamoto et al[22] (2012)	single-center, retrospective study cohort	98 patients	ACS: cardiogenic shock (28 pts, 28.6%), cardiac arrest (36, 36.7%)	54 pts (55.1%)	32 (32.7%)	NA	NA
Kagawa et al[34] (2012)	multicenter cohort study	86 pts	ACS IHCA: 44 (51.1%) OHCA: 42 (48.9%)	53 pt (50%)		25 (25/88, 29%)	21 (21/88, 24%)

ECMO: extracorporeal mebrane oxygenation; ACS: acute coronary syndrome; AMI: acute myocardial infarction; CA: cardiac arrest; IHCA: in-hospital cardiac arrest; OHCA: out-of-hospital cardiac arrest; CPC: cerebral performance categories.

Concerning the prognostic role of renal dysfunction (quite common in ECMO patients), it was reported in 102 patients supported with ECMO (most of them because of cardiogenic shock), acute kidney injury score assessed at 48 h represented an independent risk factor for in-hospital mortality.[38] Similar results were reported by Lan et al.[26] who observed that the need of dialysis during ECMO is one of the independent predictors of early mortality. More recently in a retrospective analysis of 200 patients treated with ECMO, the survival of patients with acute kidney injury requiring renal replacement was 17%, while patients without renal replacement therapy (RRT) showed a three-month survival of 53% (p=0.001).[39]

Long-term survival

Extracorporeal CPR showed a survival benefit over conventional CPR in a prospective observational investigation on witnessed in-hospital patients suffering CA of cardiac origin and subjected to CPR for more than 10 min. In that population, survival to hospital discharge, together with survival to 30 days and one year, significantly favored ECMO treatment compared to conventional CPR.[19]

Comparison between OHCA and IHCA and long-term survival rate

A different long-term prognosis has been reported in IHCA patients with respect to OHCA patients treated with ECMO. More than 40% of patients resuscitated from refractory IHCA with the aid of ECMO treatment achieved six-month survival with minimal neurological impairment, compared to only 5% of the OHCA patients.[12] Similarly, Kagawa et al.[9] demonstrated improved survival after ECMO in the IHCA group compared to the OHCA, 34% versus 13%, and supposed that the shorter time of low flow in the IHCA patients may account for the difference in outcome.

The underlying pathology causing CA is another important determinant for survival and neurological recovery. Medical intoxication[38] and severe accidental hypothermia[4] are two widely accepted indications for ECMO support in patients with refractory CA since they are associated with good long-term survival and neurological recovery. Schwartz et al.[29] observed that long-term survival rates after emergency percutaneous cardiopulmonary bypass are encouraging in patients with an underlying cardiocirculatory disease amenable to immediate corrective intervention (angioplasty, surgery, transplantation). In this context, compared with conventional CPR, ECMO might provide a chance to perform definitive treatment (percutaneous coronary intervention, open heart surgery, etc) through successful resuscitation and temporary stabilization. Similar results were reported by Megarbane et al.[5] Kagawa et al.[34] observed (though in a retrospective study) a 29% 30-day survival and 24% favorable neurological outcome with rapid-response ECMO, PCI and/or hypothermia in CA patients who were unresponsive to conventional CPR and who were generally thought to have an unfavorable prognosis. In particular, rapid-response ECMO plus intra-arrest PCI was associated with a higher survival rate in these patients.

In recent years, mild hypothermia has been considered as an adjunctive therapy in CA patients.[13,14] In the study by Nagao et al.,[31] it was reported that early attainment of mild hypothermia (a core temperature of 34°C) during extracorporeal CPR with PCI has neurological benefits for patients with OHCA who fail to respond to conventional CPR.

Similarly results were reported by the same group in 23 patients submitted to ECLS and mild hypothermia who showed a good neurological outcome (12/23, 52%) and survival at hospital discharge (15/23, 65.2%). In Kagawa et al.,[9] mild hypothermia was performed in the 32% of the study population and, in the recent paper,[34] in 37% of the study population. However, in this study, hypothermia was not associated with 30-day survival (probably because of the small sample size).

General comments

In clinical practice, in a setting where the patient is extremely vulnerable, the decision on whether an ECMO should be implanted in a single patient, is still a clinical challenge, since it is based on clinical data and on the clinical judgment and experience of the ECMO team and it has to be taken in quite a short time. AS a matter of fact, available literature data are heterogeneous and somewhat controversial, due to heterogeneity in study populations, differences in local health system for the management of CA patients, and outcomes.

According to the revised data, the following taken-home messages can be put forward:

- In patients with refractory CA, ECMO is a highly costly intervention and optimal utilization requires a dedicated local health-care organization and expertise in the field (both for the technical implementation of the device and for the intensive care management of these patients). The health-care pathways of patients suffering from CA (both IHCA and OHCA) should be locally organized in detail in order to avoid wasting of time and to guarantee the optimal resource utilization. An ECMO center can be implemented only where a cardiac surgery unit is available and an ECMO team (including an intensivist trained in acute cardiac patient care, a cardiac surgeon, a cardiopulmonary technician) has to be available 24 h/7 d.
- Outcomes (survival and neurological function) of CA patients treated with ECMO are strictly dependent on two factors: (a) expertise of the ECMO team (in technical skills for implantation and, especially, in intensive care); (b) a careful selection of patients. That is why the impact of ECMO implantation in CA patients can be considered a clinical challenge, since it is strictly linked to the 'clinical selection of patients', and not only to technically skills. Though in this emergency setting it is quite difficult to gain information concerning historical data of the patient, inclusion and exclusion criteria are of paramount importance. The following exclusion criteria should be considered: previous severe neurologic damage, current intracranial hemorrhage, malignancy in the terminal stage, irreversible organ failure leading to CA when no physiological benefit could be expected despite maximal therapy (i.e. hepatic failure), aortic dissection, severe peripheral arterial disease, and patients who previously signed 'do-not-resuscitate' orders. Inclusion criteria should be as follows: (a) age <75 years; (b) estimated interval of ≤15 min from the time of collapse to CPR with or without witnessed CA, independently of rhythm of presentation; (c) failure to achieve ROSC within 20 min of conventional CPR administered by medical personnel. Written informed consent for ECPR was obtained from family members, to justify that they have been properly informed. In the real world, according to our experience, and in order not to waste time, while the ECMO team leader is gaining information and talking with the relatives, the other members of the ECMO team are preparing for ECMO implantation.
- The most important target to be pursed in CA patients treated with ECMO is to identify the 'reversible cause' (i.e. drowning, drug intoxication, hypothermia, Takotsubo Syndrome, myocarditis, acute coronary syndrome) of CA since it has to be treated in due time and the ECMO device gives us the opportunity (time) to do it. In other terms, i.e. in a patient with CA treated with ECMO if acute coronary syndrome is suspected, coronary angiography and eventually mechanical revascularization can be performed after ECMO implantation and initiation of hypothermia.
- When the 'reversible cause' of CA is identified and treated, management of ECMO patients mainly consists of organ support therapies (i.e. renal replacement therapy) and, most importantly, serial neurological assessments (by means of electroencephalogram (EEG) and somato-sensory evoked potentials). Neurological evaluations, since the first 12–24 h, play a pivotal role in the risk assessment of these patients. For example, the identification of EEG patters of brain death raises serious doubts for continuing on ECMO support.
- ECMO futility. Due to the lack of recommendations and guidelines, the decision not to implant ECMO is a hard decision which, in the real world, has to be taken in quite a short time. Taking into account available data and our experience, ECMO is not to be implanted in the presence of even one exclusion criteria or whenever the ECMO team is not alerted in due time. On the other hand, two factors may trigger the decision to stop ECMO: (a) the evidence of brain death; (b) the fact that, in lack of recovery, the patient is not considered eligible for transplantation.

Despite the paucity of literature data so far, in the real world the ECMO implementation in patients with refractory CA

is not only a promising tool but the only opportunity to improve survival and neurological outcome in these patients (or at least in a subset of these patients, those who meet the inclusion criteria). Further research should be performed by means of local or national ECMO registries since several aspects of the management of ECMO patients are still to be clarified such as the weaning techniques.

Conflict of interest

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