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Original article

Impact of a multidisciplinary ECMO-team on the prognosis of patients undergoing veno-arterial extracorporeal membrane oxygenation for refractory cardiogenic shock and cardiac arrest

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ABSTRACT

Objective. We aimed to analyze whether the creation of an Extracorporeal membrane oxygenation Team (ECMO T) has modified the prognosis of patients undergoing veno-arterial ECMO (VA-ECMO) for refractory cardiogenic shock (CS) or cardiac arrest (CA). **Materials and methods.** Observational, single-center, retrospective study that compared the outcomes of VA-ECMO implantation for refractory CS or CA in two consecutive periods: between 2014 and April 2019 (pre-ECMO Team), and between May 2019 and December 2022 (post-ECMO Team). The study assessed in-hospital and ECMO survival, complications, and annual ECMO volume as endpoints. Results. 83 patients were included (36 pre-ECMO T and 47 post-ECMO T). The mean age was 53 +/- 13 years. The most common reason for device indication was different: post-cardiotomy shock (47.2%) pre ECMO T and refractory cardiogenic shock (29.7%) post-ECMO T. The rate of extracorporeal cardiopulmonary resuscitation was 14.5%. The median duration of VA-ECMO was longer after ECMO team implementation: 8 days (interquartile range [IQR]: 5-12.5) vs. five days (IQR: 2-9, p=0.04). Global in-hospital survival was 45.8% (38.9% pre-ECMO T vs. 51.1% post-ECMO T; p=0.37), and the survival rate from VA-ECMO was 60.2% (55.6% pre-ECMO T vs. 63.8% post-ECMO T; p=0.50). The volume of VA-ECMO implantation was significantly higher in the post-ECMO team period (13.2 +/- 3.5 per year vs. 6.5 +/- 3.5 per year, p=0.02). The rate of complications was similar in both groups. **Conclusions.** After the implementation of an ECMO team, there was no statistical difference in the survival rate of patients underwent VA-ECMO. However, a significant increase in the number of patients supported per year was observed after the implementation of this multidisciplinary team. Post-ECMO T, the most common reason for device indication was CS, with longer run times and a higher rate of extracorporeal cardiopulmonary resuscitation.

Keywords: Heart Arrest; Patient Care Team; Extracorporeal Membrane Oxygenation; Shock, Cardiogenic (source: MeSH-NLM).

Introduction

Venoarterial extracorporeal membrane oxygenation (VA-ECMO) is a type of complete continuous flow ventricular support that provides life support to patients with heart failure refractory to conventional support techniques [1]. It is considered a rescue intervention used in patients with cardiogenic shock (CS) or refractory cardiac arrest (CA).

Mortality and complications associated with extracorporeal membrane oxygenation (ECMO) vary among different regions and centers, depending on the infrastructure and experience of each institution [2]. To address this, the Extracorporeal Life Support Organization (ELSO) has developed various clinical guidelines outlining recommendations for conducting this type of assistance in a standardized manner [3]. However, despite international guidelines, advances in ECMO-related technology, increased knowledge, and training of medical teams, in-hospital mortality for adult patients assisted with VA-ECMO, according to the ELSO registry, has remained similar over the past decades, ranging between 50 and 60% [4].

The establishment of multidisciplinary ECMO teams (ECMO T), including physicians from different critical care specialties, nurses, perfusionists, and respiratory therapists, has allowed for the standardization of processes and appropriate patient selection. Considering the complexity of this patient population, ELSO guidelines and multiple consensus recommend an interdisciplinary approach through expert teams [5]. In parallel, there is some evidence that these multidisciplinary groups may be associated with improved outcomes for ECMO patients [6-8]. However, most of these studies were conducted in patients with refractory respiratory failure assisted with venovenous ECMO (VV-ECMO), were not carried out in Latin America, and did not demonstrate a clear benefit in terms of mortality [7-9]. Therefore, it is unknown whether the creation of these multidisciplinary teams has a real impact on the survival and prognosis of patients on VA-ECMO.

The purpose of this study is to analyze whether the establishment of the multidisciplinary ECMO T modifies the prognosis and outcomes of patients undergoing VA-ECMO or the volume of assistance for refractory CS or CA in a specialized cardiovascular center in Argentina.

Materials and Methods

Study design and population

Retrospective, observational, cross-sectional, and single-center study. The institutional database of ventricular assistance, prospectively completed since 2014, was analyzed. Demographic and clinical characteristics, information on the type of ventricular assistance, complications, and relevant clinical events were evaluated. For analysis, the data were divided into two periods defined by the creation of the multidisciplinary ECMO T, which occurred in May 2019.

All consecutive patients aged 18 years or older were eligible for inclusion if they underwent VA-ECMO implantation with central and/or peripheral cannulation, indicated due to refractory CS or CA. Refractory CS was defined as any cardiac shock requiring two or more inotropic drugs at intermediate/high doses (e.g., norepinephrine at 0.5 mcg/kg/min). Refractory CA was defined as witnessed CA of probable cardiac cause (mainly with ventricular tachycardia or ventricular fibrillation as the onset rhythm), extending more than 10 min, even with adequate cardiopulmonary resuscitation from the beginning.

Patients who received VV-ECMO for refractory respiratory failure or any other type of complete ventricular assistance distinct from VA-ECMO, such as Centrimag, were excluded from the study.

Procedures

The ECMO T, although part of the transplant and ventricular assistance clinic, is comprised of specialists from various services: cardiovascular surgeons, critical care cardiologists, heart failure-specialized cardiologists, perfusionists, nurses, respiratory therapists, ultrasound-specialized cardiologists, anesthesiologists, interventional cardiologists, nutritionists, hematologists, and infectious disease specialists. The ECMO T is a component of the Shock team, focusing specifically on VA-ECMO as circulatory support. The key members of the team (cardiovascular surgeons, perfusionists, cardiologists, and nurses) must be available 24 hours a day, 365 days a year, to perform urgent cannulation or address ECMO complications as quickly as possible.

The main objectives of designing an ECMO T were to standardize processes, establish unified inclusion and exclusion criteria for VA-ECMO implantation, and achieve timely ventricular assistance in cases of refractory CS. Following implantation, the team is responsible for daily patient follow-up and monitoring, as well as determining the timing and mode of weaning from assistance. The initial focus was on creating checklists for ECMO assembly, priming, and implantation, as well as establishing team activation protocols. Subsequently, protocols were developed for both percutaneous and surgical implantation, anticoagulation management, ultrasound use (for implantation, monitoring, and weaning), infection prophylaxis, nutrition, and nursing care. After the team matured, efforts were directed towards performing VA-ECMO in in-hospital cardiac arrest and ECMO transport to increase the volume of assistance.

The establishment of the ECMO T, in addition to organizing and standardizing processes, involved theoretical learning and psychophysical skills training. ECMO training courses were conducted, including simulation of emergency scenarios. Subsequently, the institution designed high-fidelity simulation courses for both internal and external personnel, with a minimum frequency of twice a year.

Since the ECMO T was created in May 2019, the study population was divided into two comparable periods: between January 2014 and April 2019 (pre-ECMO T) and a second group assisted between May 2019 and December 2022 (post-ECMO T).

Variables

Within the clinical variables and main complications to be analyzed, the following were included:

- Survival on VA-ECMO. This evaluates survival on ECMO, up to 24 hours after weaning from ventricular assistance. In this case, ECMO disconnection occurs either due to recovery of cardiac function or heart transplantation.
- Survival at discharge. This evaluates survival at hospital discharge, either through discharge to a healthcare facility or transfer to another medical center (e.g., a tertiary rehabilitation center).
- Annual volume of VA-ECMO. Average number of VA-ECMO implants per year in each period.
- Mechanical complications. These are complications specific to assistance that require intervention, such as changing the ECMO system or its components. They include membrane failure, cone failure, tube rupture, circuit change due to air or thrombi, and temperature regulator dysfunction.
- Hemorrhagic complications. Bleeding that requires transfusion of >20 mL/kg/day or >3 units of red blood cells per day.
- Neurological complications. Includes brain death (irreversible loss of consciousness, coupled with irreversible loss of neurovegetative functions, including the ability to breathe) and stroke (acute neurological focus and new ischemic or hemorrhagic changes on brain tomography).
- Infectious complications. Documented infection prior to ECMO implantation or during ECMO, with or without microbiological confirmation, requiring antimicrobial treatment.
- Thromboembolic complications. Presence of thrombosis or emboli confirmed in the patient (either clinically or by imaging) or in the ECMO system.
- Renal complications. Renal failure is defined as a change in creatinine after ECMO implantation (reaching a creatinine level of 1.5 mg/dL or higher) or the need for dialysis.

Statistical analysis

The parametric distribution of quantitative continuous variables was assessed using the Kolmogorov-Smirnov test. Qualitative variables were expressed as proportions, while continuous quantitative variables were presented as means with their respective standard deviations (SD) in the case of parametric distribution, or as medians and interquartile ranges (IQR) for non-parametric variables.

The Student's t-test was used for the analysis of parametrically distributed quantitative variables, and the Mann-Whitney U test was employed for non-parametric variables. The association between qualitative variables was determined through chi-square tests and the Fisher's test. A two-tailed alpha error of 5% was considered statistically significant ($p<0.05$).

Statistical analyses were performed using IBM SPSS Statistics software (version 22, SPSS, IBM Corporation, Armonk, New York).

Ethical aspects

This study complies with all the requirements outlined in the ethical code of the World Health Organization (Declaration of Helsinki) and was approved by the Clinical Research Committee of the Institute and the ethics committee. All patients signed the *habeas data*.

Results

A total of 83 consecutive patients who underwent VA-ECMO implantation due to refractory CS or CA were analyzed. Among them, 36 underwent pre-ECMO T and 47 post-ECMO T. The mean age of the overall population was 53 years (SD: 13.0), with the majority being male (57.8%). Regarding cardiovascular risk factors, 47.0% had dyslipidemia, 34.9% had hypertension, and 20.5% had diabetes. The mean ejection fraction for the population was 28% (SD: 12.8). The primary diagnosis was necrotic ischemic cardiomyopathy (37.3%), followed by significant valvular disease (21.7%). There were no significant differences in population characteristics between the two periods **(Table 1)**.

The main indications for implantation differed for each group: post-cardiotomy pre-ECMO T (47.2%), and refractory CS (mainly due to acute myocardial infarction) post-ECMO T (29.7%), p=0.04. VA-ECMO was performed 14.5% in CA, with a higher frequency post-ECMO T (21.3% *vs.* 5.6%, p=0.04).

The majority of VA-ECMO was indicated in Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs) 1 (78.3%), followed by Intermacs 2 (14.5%). According to the Society for Cardiovascular Angiography and Interventions (SCAI) classification, ECMO was implanted at stage D in 69.9% of cases (n=58), stage E in 18.1% (n=15), and stage C in 12% (n=10). In different periods, pre-ECMO T showed assistance indication at SCAI stage D in 66.7% (n=24), stage E in 27.8% (n=10), and stage C in 5.6% of cases (n=2). After the creation of the multidisciplinary team, the implantation was at SCAI stage D in 78.7% (n=37), stage E in 6.4% (n=3), and stage C in 14.9% (n=7). In this latter period, a higher percentage was observed in stage C, and a lower one in the terminal stage SCAI E. Peripheral cannulation was performed in 84.3% (predominantly femoro-femoral), while central cannulation occurred in only 15.7% of cases, mainly in post-cardiotomy patients.

Ventricular decompression using venting techniques (septostomy, additional afferent cannulation through a transseptal approach with drainage of left cavities, or pulmonary vein drainage) was required in 19.8% of patients, with a higher frequency post-ECMO T (31.9% *vs.* 2.8% pre-ECMO T; p<0.01). Additionally, 85.5% concurrently had an intra-aortic balloon pump to facilitate aortic valve opening. The overall use of a Swan-Ganz catheter was 72.2% pre-ECMO implantation (72.2% pre-ECMO T and 72.3% post-ECMO T) and 48.2% after assistance explantation (41.7% pre-ECMO T and 53.2% post-ECMO T). The median duration of assistance was 6.0 days (IQR: 3-10), significantly longer post-ECMO T (8 days, IQR: 5-12.5 *vs.* 5 days, IQR: 2-9 in pre-ECMO T; p=0.04); **(Table 2).** The longest duration of VA-ECMO support was 26 days.

The overall survival rate at discharge was 45.8%, with a rate of 38.9% before the creation of the ECMO T and 51.1% after ECMO

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Table 1. Baseline characteritics of the included population.

Variables	Global (n=83)	Pre-ECMO T (n=36)	Post-ECMO T (n=47)	p value
Age in years, mean (SD)	53 (13)	55 (13)	51 (13)	0.19
Male, n (%)	48 (57.8)	24 (66.7)	24 (51.1)	0.18
BMI in kg/m^2, mean (SD)	26 (5)	26 (4)	26 (5)	0.96
Hypertension, n (%)	29 (34.9)	11 (30.6)	18 (38.3)	0.49
Diabetes, n (%)	17 (20.5)	8 (22.2)	9 (19.1)	0.98
Dyslipidemia, n (%)	39 (47.0)	20 (55.6)	19 (40.4)	0.27
Current smoking, n (%)	11 (13.3)	3 (8.3)	8 (17.0)	0.33
Previous coronary disease, n (%)	31 (37.3)	12 (33.3)	19 (40.4)	0.63
Moderate-severe valvular disease, n (%)	18 (21.7)	8 (22.2)	10 (21.3)	0.98
Previous cardiac surgery, n (%)	10 (12.1)	6 (16.7)	4 (8.5)	0.33
Stroke/TIA, n (%)	2 (2.4)	2 (5.6)	0 (0.0)	0.19
COPD, n (%)	2 (2.4)	1 (2.8)	1 (2.1)	0.99
CKD, n (%)	17 (20.5)	8 (22.2)	9 (19.1)	0.98
Anemia, n (%)	12 (14.5)	5 (13.9)	7 (14.9)	0.96
Atrial fibrillation, n (%)	15 (18.1)	9 (25.0)	6 (12.8)	0.25
Previous EF <40%, n (%)	40 (48.2)	20 (55.5)	20 (42.6)	0.64

SD: standard deviation, BMI: body mass index, TIA: transient ischemic attack, COPD: chronic obstructive pulmonary disease, CKD: chronic kidney disease, EF: ejection fraction of the left ventricle.

T establishment (p=0.37). The overall survival on VA-ECMO was 60.2%, higher in the post-ECMO T period, but without reaching statistical significance (55.6% pre-ECMO T *vs.* 63.8% post-ECMO T; p=0.50). In contrast, the volume of VA-ECMO was significantly higher in the post-ECMO T period (13.2 cases +/- 3.5 per year *vs.* 6.5 +/- 3.5 per year, p=0.02); **(Table 3)**.

Regarding heart transplant volume, globally in our institution, 48 grafts were performed pre-ECMO T during that period (mean of 9.1 cases per year), and 52 were performed after the team's creation (14.4 cases per year). Of the 36 patients on pre-ECMO T, 15 underwent transplantation (accounting for 41.7% of VA-ECMO patients and 31.2% of the total heart transplants in that period). Conversely, in post-ECMO T, 14 previously assisted VA-ECMO patients underwent transplantation, accounting for 29.8% of VA-ECMO patients and 26.9% of the total transplants in that period. Regarding long-term device implantation, none were performed as they are not available in Argentina.

The main complications during VA-ECMO support were bleeding (59.0%), renal failure (50.6%), infections (48.2%), and thromboembolic events (44.6%), with similar rates in both periods. Most bleeding was medical, mainly from the ECMO implant site. The main vascular complication was peripheral arterial ischemia, which occurred in 20.5% (n=17), with similar rates in both periods (25.0% pre-ECMO T *vs.* 17.0% post-ECMO T, p=0.59); **(Table 3)**. Bleeding from the peripheral cannulation site was observed in 46.9% of cases (50.0% pre-ECMO T *vs.* 44.6% post-ECMO T). Fasciotomy was performed in 6.0% of cases (n=5), with similar rates in both periods (5.5% pre-ECMO T *vs.* 6.4% post-ECMO T). Only two lower limb amputations below the knee were observed, accounting for 2.4% of the total (1 pre and 1 post-ECMO). No mechanical complications associated with ECMO were observed in either period (membrane or cone failure, tube rupture, or temperature regulator dysfunction).

Regarding other complications, the only one significantly different in either period was prolonged mechanical ventilatory support requiring tracheostomy, which was higher post-ECMO T creation (48.9% *vs.* 25.0% pre-ECMO T, p=0.01); **(Table 3)**.

Regarding patients with acute myocardial infarction, none experienced mechanical complications associated with the infarction, and left ventricular decompression with septostomy was required in 35% of cases. Although patients were on dual antiplatelet therapy and anticoagulation, the bleeding rate was 37.5%, which was lower than the overall series.

Discussion

VA-ECMO is a short-term ventricular assistance increasingly developed worldwide, used for the management of CS and refractory CA, even in developing countries, where it is practically the only option available. The development of multidisciplinary teams for decision-making regarding implantation and management of these patients is crucial, and it seems to improve prognosis and clinical outcomes. However, in our study, after the creation of the ECMO T, there was no significant increase in the weaning of VA-ECMO or improvement in survival. Nevertheless,

Table 2. Clinical characteristics related to ventricular assistance.

Variables	Global (n=83)	Pre-ECMO T (n=36)	Post-ECMO T (n=47)	p value
Underlying disease, n (%)				
Idiopathic dilated	6 (7.2)	3 (8.3)	3 (6.4)	
Ischemic necrotic	31 (37.3)	12 (33.3)	19 (40.4)	
Valvular	18 (21.7)	8 (22.2)	10 (21.3)	
HCM	4 (4.8)	3 (8.3)	1 (2.1)	0.63
Myocarditis	5 (6.0)	1 (2.8)	4 (8.5)	
NCM	4 (4.8)	3 (8.3)	1 (2.1)	
Other	11 (13.4)	4 (11.1)	7 (14.9)	
Chagas	4 (4.8)	2 (5.6)	2 (4.3)	
Indications for implant, n (%)				
Post-cardiotomy	28 (33.7)	17 (47.2)	11 (23.4)	
Cardiogenic shock	22 (26.5)	8 (22.2)	14 (29.7)	0.04
Primary graft failure	17 (20.5)	8 (22.2)	9 (19.2)	
CA	12 (14.5)	2 (5.6)	10 (21.3)	
Electronic storm	4 (4.8)	1 (2.8)	3 (6.4)	
ECMO in CA, n (%)	12 (14.5)	2 (5.6)	10 (21.3)	0.04
INTERMACS, n (%)				
1	65 (78.3)	31 (86.1)	34 (72.3)	0.65
2	12 (14.5)	4 (11.1)	8 (17.0)	
3	6 (7.2)	1 (2.8)	5 (10.7)	
Implant strategy, n (%)				
Bridge to transplant	22 (26.5)	10 (27.7)	12 (25.5)	
Bridge to recovery	56 (67.5)	24 (66.7)	32 (68.1)	0.99
Bridge to decision	5 (6.0)	2 (5.6)	3 (6.4)	
Bridge to brigde	0 (0.0)	0 (0.0)	0 (0.0)	
IABP in ECMO, n (%)	71 (85.5)	31 (86.1)	40 (85.1)	0.82
Previous Levitronix® CentriMag, n (%)	2 (2.4)	1 (2.8)	1 (2.1)	0.99
Peripheral cannulation, n (%)	70 (84.3)	31 (86.1)	39 (83.0)	0.77
Ventricular venting, n (%)	16 (19.8)	1 (2.8)	15 (31.9)	<0.01
Duration in days, median (IQR)	6 (3–10)	5 (2-9)	8 (5-12.5)	0.04

IABP: intra-aortic balloon pump, HCM: hypertrophic cardiomyopathy, NCM: non-compact myocardium, CPR: cardiac arrest, ECMO: extracorporeal membrane oxygenation, IQR: interquartile range, CA: cardiac arrest.

a significant increase in the volume of patients assisted per year was observed in the post-ECMO T period **(Figure 1)**.

There are some studies that have assessed the impact of a multidisciplinary team on ECMO patients, but they exhibit certain heterogeneity in design, selected population, and outcomes. The study by Komindr *et al.* included 69 patients, with the vast majority undergoing VA-ECMO (94%), and similar to our experience, there was no variation in mortality in both periods, nor in hospital length of stay. Like in our study, they observed a higher number of ECMO cases (22.7 pre-ECMO T *vs.* 36.3 post-ECMO T) and more extensive data collection [9]. Probably, the non-significant difference in mortality was because the Japanese center had a high volume, with substantial experience from the start of the study (including in the first period), performing more than 20 ECMOs per year, reflected also in the high overall survival (67% compared to 46% described in the ELSO registry) [4].

On the contrary, Dalia *et al.* demonstrated with a larger number of patients (n=279) that after the establishment of the ECMO T, there was a significant increase in in-hospital survival (37.7% *vs.* 52.3%, p=0.02) [6]. However, significantly more VA-ECMO was performed in the first period compared to the second period (76% *vs.* 51%), and less VV-ECMO (19.2% *vs.* 30.8%, respectively). According to the ELSO registry, the mortality of adult patients on VA-ECMO is higher than that of VV-ECMO (54% *vs.* 42%, respectively), so instead of comparing two different time periods, they would be comparing two different types of assistance (cardiac *vs.* respiratory), with different degrees of mortality [4]. In addition, when only the subpopulation receiving VA-ECMO is compared, no difference in terms of survival is observed. Cotza *et al.* conducted a similar study at the San Donato Polyclinic in Italy, including 100 ECMO patients, both VA (67.4%) and VV, adults (52%) and pediatric cases [10]. In this case, the mortality was lower

Table 3. Survival, assistance volumen, and complications associated with VA-ECMO.

Variables	Global (n=83)	Pre-ECMO Team (n=36)	Post-ECMO Team (n=47)	p value
IH survival, n (%)	38 (45.8)	14 (38.9)	24 (51.1)	0.37
ECMO survival, n (%)	50 (60.2): Rec: 38 (45.7) Tx: 12 (14.5)	20 (55.6)	30 (63.8)	0.50
ECMO volume per year, mean (SD)	9.2 (3.2)	6.5 (3.5)	13.2 (3.5)	0.02
ARF, n (%)	42 (50.6)	22 (61.1)	20 (42.6)	0.10
Bleeding, n (%)	49 (59.0)	23 (63.9)	26 (55.3)	0.46
Infection, n (%)	40 (48.2)	19 (52.8)	21 (44.6)	0.82
Thrombosis, n (%)	37 (44.6)	16 (44.4)	21 (44.7)	0.90
Mechanical complication, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	0.99
Ceberal death, n (%)	1 (1.2)	1 (2.8)	0 (0.0)	0.46
Stroke, n (%)	10 (12.0)	6 (16.7)	4 (8.5)	0.50
Dialysis requirement, n (%)	23 (27.7)	10 (27.8)	13 (27.7)	0.99
Tamponade, n (%)	17 (20.5)	6 (16.7)	11 (23.4)	0.42
Prolonged MVA with tracheostomy, n (%)	32 (38.6)	9 (25.0)	23 (48.9)	0.01
Peripheral arterial ischemia, n (%)	17 (20.5)	9 (25.0)	8 (17.0)	0.59

MVA: mechanical ventilatory assistance, ECMO: extracorporeal membrane oxygenation, IH: in-hospital, ARF: acute renal failure, Rec: recovery, Tx: heart transplantation

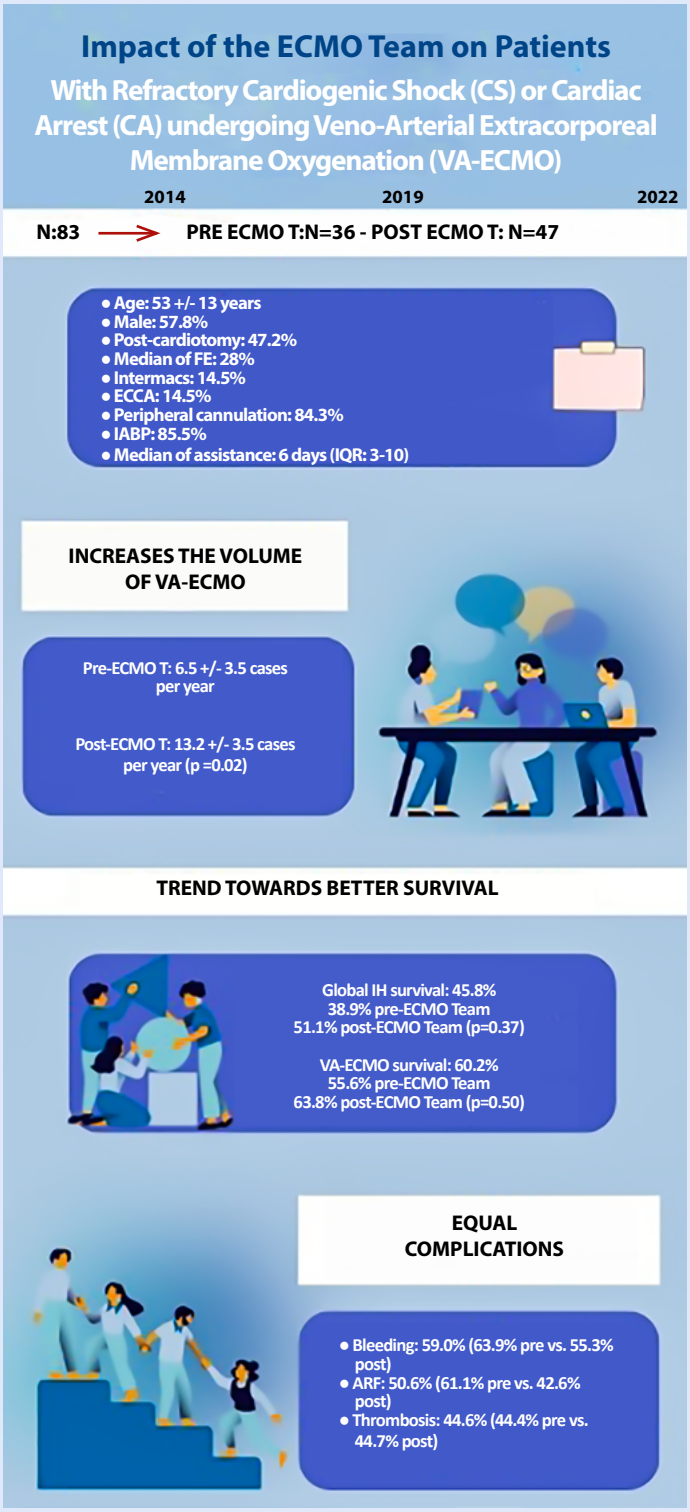
in the post-ECMO T period (44% vs. 62.5%, respectively). However, no statistical tests were performed to determine the significance of this difference in that study, so it is unknown whether this difference is significant.

There are other studies that have demonstrated the survival benefit of the ECMO T, but all of them were conducted in different regions and with patients assisted with VV-ECMO for refractory respiratory failure. Among them is the study by Goh *et al.*, who showed that after the establishment of a multidisciplinary team guided by an intensivist, mortality decreased from 44.4% to 14.8% in patients assisted with VV-ECMO [7]. This was a retrospective study that included 108 patients in a center in Singapore, and the difference remained significant even after adjusting for various confounding variables. It is worth noting that these patients with refractory respiratory failure have lower mortality than those with refractory CS on VA-ECMO. Nevertheless, after the implementation of the ECMO T, extremely low values of in-hospital mortality were achieved, compared to those described by ELSO in adults on VV-ECMO (14.8% vs. 42%, respectively) [4]. In addition, Na *et al.* demonstrated in their cohort of 116 patients assisted with VV-ECMO in South Korea that after the establishment of the ECMO T, there was a significant reduction in in-hospital mortality from 75.7% to 52.2% [8]. However, these values are still high compared to the ELSO registry or the previously mentioned study by Goh *et al.*, making it easier to show improvement when starting from such high mortality rates.

It is likely that the difference in terms of in-hospital mortality reduction after the establishment of the ECMO T between patients assisted with respiratory failure or cardiogenic shock is due to studies exclusively designed with VV-ECMO including a larger number of patients, or it might be easier to standardize processes in less complex patients, such as those with respiratory distress, resulting in rapid improvements.

It is important to highlight that the establishment of the ECMO T in our study has increased the number of patients assisted with VA-ECMO per year. This allows patients in CS or refractory CA to have the possibility of surviving, either as a bridge to recovery or heart transplantation, which would be impossible without this type of assistance [9]. Additionally, there is evidence that a higher volume of ECMO-assisted patients in a center is associated with lower in-hospital mortality. Barbaro *et al.* analyzed data from the ELSO Registry of over 55,000 patients on VV-ECMO and VA-ECMO (39%) and demonstrated that, across all age groups, a high volume of ECMO cases per year significantly reduced in-hospital mortality in those institutions [11]. Adult ECMO patients treated in hospitals with more than 30 cases annually were associated with lower in-hospital mortality compared to those treated in centers with less than 6 cases annually (Odds Ratio: 0.61, 95% confidence interval [CI]: 0.46-0.80). Tchantchaleishvili *et al.* in their institution in Birmingham also demonstrated that transitioning from being a low-volume ECMO center to a high-volume center resulted in improved in-hospital survival [12].

In contrast, Komindr *et al.* could not demonstrate an improvement in survival (even with an increase in ECMO volume) after the creation of the ECMO Team, but this could be because they already started with a high volume of ECMO patients per year. Therefore, they might be comparing two similar periods. In our experience, starting with an average of fewer than seven



IABP: intra-aortic balloon pump, ECMO T: ECMO Team, VA-ECMO: venoarterial extracorporeal membrane oxygenation. ECCA: ECMO in cardiac arrest, EF: Ejection fraction, ARF: Acute renal failure, CPR: cardiopulmonary resuscitation, CS: cardiogenic shock, IH: in-hospital, SV: survival.

Figure 1. Infographic summary of the study.

cases per year (low volume) and reaching a post-multidisciplinary team design average of between 10 and 20 ECMO runs per year (moderate volume), the benefit is likely to be greater. In our study, we observed an improvement in in-hospital survival (from 38.9% to 51.1%) and survival on ECMO (from 55.6% to 63.8%) but without reaching statistical significance. The low number of patients analyzed probably influenced the result. Additionally, in the post-ECMO T period, a higher percentage of patients with ECMO in CA was included, with a known lower survival rate (30% in ECMO in CA vs. 46% in cardiac VA-ECMO), and the reason for assistance was predominantly refractory cardiogenic shock post-heart attack (lower post-cardiotomy rate), probably with a lower rate of reversibility of the cause of shock, reflected in significantly longer assistance durations. Nevertheless, survival rates on ECMO and in-hospital were comparable to the ELSO registry (51.1% in-hospital survival *vs.* 46% in ELSO, and 63.8% survival on ECMO vs. 60% in the international registry) [4].

More broadly, Shock Teams as multidisciplinary approaches to CS have succeeded in reducing mortality, promoting early revascularization in acute myocardial infarction, and indicating early assistance [13-15]. This is probably due to the appropriate patient selection, the type of short-term assistance, and the optimization of timing through a team of critical care experts [16]. In this clinical scenario, Taleb *et al.* compared 123 consecutive patients with refractory CS managed by a Shock Team with 121 patients managed with a standard algorithm and found a 13.1% absolute risk reduction in in-hospital mortality in the former group, with a reduction in all-cause mortality at 30 days with a Hazard Ratio of 0.61 (95% CI: 0.41-0.93) [17].

Regarding the other clinical events analyzed, in our experience, there were no differences in ECMO complications in both periods, except for mechanical ventilation requiring tracheostomy, which was significantly higher post-ECMO T. This is probably due to the fact that in the second period, more complex patients were assisted, with a higher percentage of ECMO in CA and significantly longer assistance. Another cause may be that with the protocolization and standardization of processes, more tracheostomies were performed early. In contrast to our study, Na *et al.* have shown a reduction in the incidence of problems associated with the cannula (32.9% *vs.* 15.2%, p=0.034) and cardiovascular events (88.6% *vs.* 65.2%, p=0.002) in patients assisted with VV-ECMO after the implementation of the ECMO T [8].

The development of a multidisciplinary team for managing ECMO patients is a challenge, even more so in developing countries. It may take at least a year and a half to design and implement an ECMO program in some cases [18]. Subsequently, continuous training is crucial, especially in centers with a low annual assistance volume, where outcomes tend to be unfavorable. In contrast, Nagaoka *et al.* have shown favorable outcomes with the creation of a multidisciplinary team for managing VV-ECMO patients with COVID-19 in a low-volume center in Japan [19]. After assisting only five patients, 80% survived with the ECMO Team's approach. However, this is a very small number of patients to draw a conclusion, and they were assisted for respiratory failure. Meanwhile, Assy et al. have successfully developed an ECMO program in a developing country like Lebanon, with optimal results. From 2015 to 2018, they assisted 12 ECMO patients, mostly venoarterial, with ECMO survival of 75% and discharge survival of 41% [20]. In comparison, in our study, we included 83 VA-ECMO assists for refractory CS and CA, which is a considerable number for a low-income country in Latin America, considering that the median number of assists per center per year in this region is 5 to 6 patients according to the ELSO Registry [4].

In clinical significance, this is the first study conducted in a developing country in South America to compare the experience of VA-ECMO before and after the establishment of a multidisciplinary team. It has been demonstrated that, even in a country with limited resources and access to complex ventricular assist devices, the design and implementation of an ECMO T are feasible and allow for optimal outcomes comparable to international experience, with a non-significant improvement in survival and an increase in the annual volume of assistance. From a conceptual model, the greater volume of ECMO enables the structuring and standardization of care processes (knowledge and training of personnel, development of protocols, and appropriate patient selection), leading to an improvement in the quality of patient care in ECMO, with a consequent reduction in mortality. As a result, the center would likely become a reference at both the local and regional levels, further increasing the annual ECMO caseload, completing a virtuous circle [11]. The presence of an active institutional ECMO T, with regular meetings (initially weekly), review and creation of new protocols, case discussions, and ongoing staff training, will likely ensure the sustained quality of care and optimization of outcomes for VA-ECMO patients over time.

This study has certain limitations that need to be mentioned. Firstly, it is a retrospective observational study, which comes with inherent biases. Secondly, the sample size is small compared to international cohorts. Nevertheless, it is a considerable number of patients compared to the experience of similar centers in Latin America. Another limitation to consider is that it was a single-center study conducted in a high-complexity cardiovascular monovalent center, with an intermediate volume of VA-ECMO assistance, so the results may not be extrapolated to other institutions in the region and may not be representative of the national reality.

In conclusion, following the implementation of the ECMO T, although there was a favorable trend in terms of in-hospital survival and weaning from VA-ECMO in patients assisted for refractory CA or CS, no statistically significant difference was observed. However, after the creation of the multidisciplinary team, there was a significant increase in the volume of patients assisted per year. Post-ECMO T, a significantly higher number of patients were assisted for CS, in CA, and for a longer duration.

Author contributions

Conceptualization: LAS, MD, LB. Data curation: LAS, JFF, LB, RBV. Formal analysis: LB, RBV. Investigation: LAS, LB, JPC, MV, ODRH, MVi, JF. Methodology: LAS, LB, RBV, JPC. Project administration: LAS, MD. Software: LB, RBV. Supervision: LAS, DN, MD. Validation: LAS, LB, JF. Visualization: LAS, JPC, JF, ODRH, MV. Writing – Original Draft: LAS, LB, RBV, JF, JPC, MV, MD, DN, MVi, ODRH. Writing - Review & Editing: LAS, LB, RBV, JF, JPC, MV, MD, DN, MVi, ODRH.

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