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ORIGINAL ARTICLE

Predictive factors of mortality with short-term ventricular assist devices for heart transplantation

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KEYWORDS
Heart failure;
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Devices;
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Mortality

Abstract
Introduction and objectives: The shortage of donor hearts has led to an increased use of temporary mechanical circulatory support as a bridge to urgent heart transplantation (HT). This study aimed to identify predictors of in-hospital mortality in patients supported with short-term ventricular assist devices (VADs), specifically CentriMag and Impella, as a bridge to HT, used either as direct implantation or following prior extracorporeal membrane oxygenation support (ECMO).
Methods: Retrospective, single-center, observational study conducted at a tertiary care center, including all patients receiving short-term VADs, specifically CentriMag and Impella, as a bridge to HT between 2016 and 2024.
Results: A total of 73 patients were included: 22 received VAD following prior ECMO support (27.3% underwent transplantation; 50% in-hospital mortality post-transplant), and 51 underwent direct VAD implantation (80.4% underwent transplantation; 9.8% in-hospital mortality post-transplant). Independent predictors of in-hospital mortality included: use of CentriMag as left-sided VAD, acute coronary syndrome (ACS), VAD implantation following prior ECMO support, infection, and female sex. After adjustment for confounding variables, prior ECMO support before VAD implantation remained significantly associated with increased in-hospital mortality.

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Conclusions: The complex nature of patients requiring short-term VADs and the physiological impact of different devices must be addressed early and individually, based on the etiology of the shock and urgency status. In-hospital mortality was significantly higher among patients previously supported with ECMO, which highlights the importance of timely and optimized management to mitigate complications and enhance outcomes.
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PALAVRAS-CHAVE
Insuficiência cardíaca;
Transplante cardíaco;
Dispositivos;
Oxigenação por membrana extracorporal;
Fatores prognósticos;
Mortalidade

Fatores preditivos de mortalidade com dispositivos de assistência ventricular de curta duração para transplante cardíaco

Resumo
Introdução e objetivos: A escassez de corações de dadores tem impulsionado a utilização de suporte circulatório mecânico temporário como ponte para transplante cardíaco (TC) urgente. Este estudo teve como objetivo identificar preditores de mortalidade intra-hospitalar em doentes submetidos a dispositivos de assistência ventricular (DAV) de curta duração, nomeadamente CentriMag e Impella, implantados diretamente ou após suporte com oxigenação por membrana extracorporal (ECMO).
Métodos: Estudo observacional, retrospetivo e unicêntrico, realizado num centro terciário, incluindo todos os doentes submetidos a DAV de curta duração entre 2016 e 2024.
Resultados: Foram incluídos 73 doentes: 22 receberam DAV após suporte prévio com ECMO (27,3% foram transplantados; 50% de mortalidade intra-hospitalar após o transplante), enquanto 51 foram submetidos à implantação direta de DAV (80,4% transplantados; 9,8% de mortalidade). Os preditores independentes de mortalidade intra-hospitalar foram: utilização de CentriMag como DAV esquerda, síndrome coronária aguda, implantação de DAV após suporte com ECMO, infeção e sexo feminino. Após ajuste para variáveis de confusão, a utilização prévia de ECMO manteve associação significativa com mortalidade aumentada.
Conclusões: A gravidade clínica dos doentes e o impacto fisiológico dos DAV requerem avaliação precoce e individualizada, com base na etiologia do choque e na urgência. A mortalidade intra-hospitalar foi mais elevada nos doentes previamente suportados com ECMO, reforçando a importância de uma abordagem oportuna e otimizada para melhorar os desfechos clínicos.
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Introduction

Despite significant advances in ventricular assist devices (VADs), heart transplantation (HT) remains the gold standard for end-stage heart failure (HF).[1,2] Nevertheless, access is limited by donor scarcity and patient-specific contraindications that may preclude eligibility. In cardiogenic shock, characterized by rapid onset and frequent biventricular involvement, extracorporeal membrane oxygenation (ECMO) is frequently employed as an initial stabilizing strategy. In some patients, ECMO serves as a bridge to VAD implantation. However, the management of these critically ill patients remains highly complex and is associated with substantial risk.[2–6]

In Spain, a relatively high organ donation rate and unique healthcare system factors have led to the widespread use of ECMO and short-term VADs as bridges to urgent transplantation, depending on the patient's functional status and the presence of uni- or biventricular involvement. Nonetheless, these temporary support strategies carry significant risks that may increase morbidity and mortality.[4,7–9] Despite growing clinical use, there is limited literature on ECMO followed by short-term VAD as a bridge-to-bridge strategy to HT.

Objectives

This study aimed to identify independent predictors of in-hospital mortality among patients who received short-term VADs, specifically CentriMag (Abbott, Chicago, IL) and Impella (Abiomed, Danvers, MA), as a bridge to HT, either via direct VAD implantation or following prior ECMO support.

Methods

Study design

This was a single-center, retrospective, observational and analytical study conducted at a tertiary care center between

January 2016 and June 2024. We included all patients listed for HT under urgent status or Code 0 designation (national priority for the first available donor heart) who received short-term VADs, specifically CentriMag and Impella. Patients were divided into those who received direct VAD implantation and those who received prior support with venoarterial ECMO (ECMO-bridge-to-VAD). Exclusion criteria included lack of ECMO weaning prior to HT (i.e., VAD used solely for ventricular unloading), including those with ECPELLA configurations (combined ECMO and Impella for left ventricular unloading). Additionally, patients were excluded who had received other types of devices, such as long-term implantable left VADs or total artificial hearts (e.g. SynCardia; Syncardia Systems, Tucson, AZ), as a bridge to HT, as well as those who received short-term VADs as a bridge to long-term VAD implantation. Patients undergoing combined organ transplantation (e.g. heart-kidney transplantation) were also excluded.

The study was approved by the institutional ethics committee. Informed consent was not required as this was a retrospective, non-interventional study and no identifiable patient data were used.

The following variables were analyzed: age, sex, weight, height, and body mass index (BMI); comorbidities including diabetes, dyslipidemia, hypertension, and chronic obstructive pulmonary disease (COPD); underlying etiology or indication for device implantation (ACS vs. chronic dilated cardiomyopathy, either idiopathic or ischemic); type of VAD (CentriMag or Impella); INTERMACS (Interagency-Registry-for-Mechanically Assisted-Circulatory-Support) profile; peri-implant cardiac arrest; duration of support (with ECMO and VAD or VAD alone in the direct VAD to HT group); laboratory parameters including lactate, creatinine, and bilirubin measured at device implantation and at 48 hours post-implantation. Complications were also recorded, including ischemic or hemorrhagic ones, major infectious complications (pneumonia, bacteremia, or sepsis), a need for hemodialysis, and neurological complications (intracranial hemorrhage, ischemic stroke, seizures, or hypoxic–ischemic brain injury).

Surgical technique

Initially, left-sided CentriMag VADs were implanted via median sternotomy, with an apical left ventricular inflow cannula and arterial outflow in the ascending aorta. Biventricular support involved additional right atrial drainage and pulmonary artery return cannula. The approach later evolved to left thoracotomy for inflow left ventricular cannula and subclavicular access to the axillary artery for outflow. For right ventricular support, a percutaneous approach using femoral vein to right atrial inflow and jugular vein to pulmonary artery outflow was adopted. More recently, left-sided support with axillary Impella was combined with right-sided CentriMag via dual-lumen ProtekDuo cannula (LivaNova, PLC, UK) inserted through the right internal jugular vein.[10]

Statistical analysis

Quantitative variables were expressed as mean and standard deviation or as median and interquartile range, depending on distribution. Categorical variables were expressed as frequencies and percentage. Bivariate comparisons used Student's t-test or Mann–Whitney U test for continuous variables and Chi-square test or Fisher's exact test for categorical variables. A binary logistic regression analysis was used to identify independent predictors of in-hospital mortality. Variables with $p<0.05$ in the bivariate analysis with clinical relevance were included using the forward stepwise selection method to obtain a parsimonious model and minimize overfitting. Forward selection offers the advantage of incorporating only statistically significant variables, halting the inclusion process when no additional variables meet the predefined entry criteria. However, it presents the limitation of not accounting for all potential interactions among variables. Statistical significance was assessed using the likelihood ratio test.

To evaluate the adjusted effect of direct VAD versus ECMO-bridge-to-VAD, a full model including the exposure and theoretically relevant cofounders was constructed. Variables were retained if exclusion altered the odds ratio (OR) of the main exposure >10%.

For handling missing data, the listwise deletion strategy was employed, as Little's test confirmed that the missing data mechanism was missing completely at random, with a non-significant Chi-squared statistic. All analyses were performed using IBM SPSS Statistics v.27 (IBM Corp., Armonk, NY). A p-value <0.05 was considered statistically significant.

Results

Between January 2016 and June 2024, 73 patients were analyzed: 22 underwent ECMO-bridge-to-VAD (18 CentriMag, 4 Impella), and 51 received direct VAD (37 CentriMag, 14 Impella). Isolated left-sided VAD support was used in 58 patients; 14 required biventricular support, and 1 received isolated right-sided VAD support. In the ECMO-bridge-to-VAD group, 6 out of 22 underwent HT (27.3%). The in-hospital mortality among these transplanted patients was 50% (3 survivors), and overall in-hospital mortality in this group was 86.4%. In the direct VAD group, 41 of 51 patients reached transplantation (80.4%). In-hospital mortality among these transplanted patients was 9.8% (37 survivors), with an overall in-hospital mortality of 27.5% in the group (Figure 1).

Bivariate analysis

Table 1 presents the comparison between the ECMO-bridge-to-VAD and direct VAD groups. Hypertension was more prevalent in the direct VAD group. ECMO-bridge-to-VAD patients had higher rates of peri-implant cardiac arrest (31.8% vs. 5.9%; p=0.003), were all INTERMACS class 1, and had higher arterial lactate and plasma creatinine levels. This group also had a higher incidence of complications, including infection, limb ischemia, local bleeding, and need for hemodialysis. Median support duration was significantly longer (33.5 vs. 9 days; p<0.001).

Table 2 compared patients with in-hospital mortality (HM) to survivors (No-HM). A lower proportion of male patients was found in the HM group (72.7% vs. 92.5%; p=0.023). In-hospital mortality was associated with ACS, peri-implant cardiac arrest, ECMO-bridge-to-VAD strategy, and use of

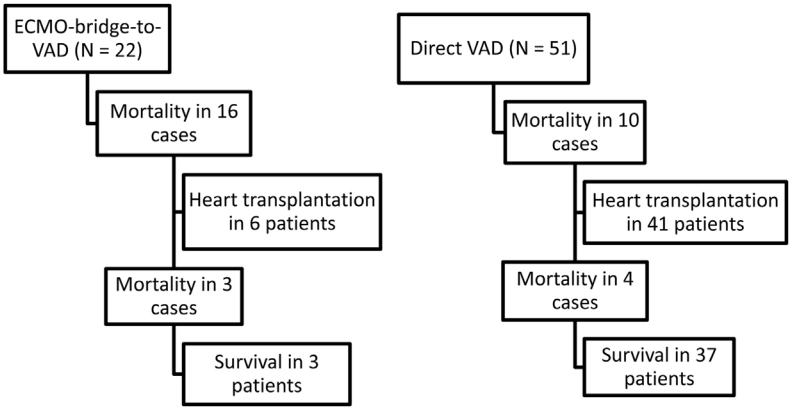

Figure 1 Flowchart of patients listed for urgent heart transplantation under short-term ventricular assist device (VAD) support: extracorporeal membrane oxygenation (ECMO) as a bridge to VAD versus direct VAD implantation.

Table 1 Bivariate analysis of differences between patients with ECMO-bridge-to-VAD and patients with direct VAD.

	Total (n=73)	ECMO-bridge-to-VAD (n=22)	Direct VAD (n=51)	p-Value
Age (years), median (IQR)	54.5(15.5)	51.5(15.5)	55.5(19.8)	0.342
Male sex	83.6%	77.3%	86.3%	0.341
BMI (kg/m^2), mean (SD)	24.6(4.7)	22.8(5.1)	25.1(4.5)	0.111
Obesity (BMI >30 kg/m^2)	12.3%	4.5%	15.7%	0.386
Diabetes	27.4%	18.2%	31.4%	0.246
Dyslipidemia	37%	22.7%	43.1%	0.097
Hypertension	60.3%	36.4%	70.6%	0.006
COPD	12.3%	13.6%	11.8%	0.823
Peri-implant cardiac arrest	13.7%	31.8%	5.9%	0.003
INTERMACS 1	34.2%	100%	5.9%	<0.001
INTERMACS 2	17.8%	0%	25.5%	
INTERMACS 3	47.9%	0%	68.6%	
Pre-implant lactate (mmol/L), median (IQR)	1(1.2)	2.8(2.2)	0.8(0.5)	<0.001
Lactate at 48 h (mmol/L), median (IQR)	1(0.9)	1.7(1.1)	0.9(0.5)	<0.001
Pre-implant creatinine (mg/dL), median (IQR)	0.99(0.8)	1.81(1.5)	0.93(0.5)	<0.001
Creatinine at 48 h (mg/dL), median (IQR)	0.92(0.7)	1.27(1.3)	0.85(0.6)	0.011
Pre-implant bilirubin (mg/dL), median (IQR)	1.25(1.2)	1.48(1.16)	0.9(1.1)	0.084
Bilirubin at 48 h (mg/dL), median (IQR)	1.38(1.5)	1.6(1.6)	1.2(1.5)	0.331
Hemodialysis	23.3%	54.5%	9.8%	<0.001
Infection	32.9%	63.7%	19.6%	<0.001
Ischemia of cannulated limb	6.8%	18.2%	2%	0.012
Local hemorrhage	20.5%	36.4%	13.7%	0.028
Neurological complications	16.4%	22.7%	13.7%	0.341
Total assistance time (days), median (IQR)	12(15)	33.5(34)	9(9)	<0.001

BMI: body mass index; COPD: chronic obstructive pulmonary disease; ECMO: extracorporeal membrane oxygenation; INTERMACS: Interagency-Registry-for-Mechanically-Assisted-Circulatory-Support; IQR: interquartile range; SD: standard deviation; VAD: ventricular assist device.

CentriMag for left-sided support. INTERMACS class 1 was also strongly associated with mortality. The HM group had significantly higher lactate at implantation and at 48 hours, and more frequent complications: infections (57.6% vs. 12.5%; p<0.001), hemodialysis (36.4% vs. 12.5%; p=0.016), and neurological complications (27.3% vs. 7.5%; p=0.023). Median support duration was longer in the HM group (20 vs. 9 days; p<0.001).

In the patients who underwent a HT, those in the ECMO-bridge-to-VAD group showed higher mortality (42.9% vs. 7.5%; p=0.035). Infection was more frequent among those who died (57.1% vs. 12.5%; p=0.018). Although the absence of invasive mechanical ventilation (IMV) at the time of transplantation did not differ between groups, the duration of IMV was longer in patients who died (6 vs. 1 day; p=0.009). Organ ischemia time (202 vs. 187 minutes; p=0.636) and donor

Table 2 Bivariate analysis of predictors of in-hospital mortality.

	Total (n=73)	In-hospital mortality (HM) (n=33)	No in-hospital mortality (No-HM) (n=40)	p-Value
Age (years), median (IQR)	54.5(15.5)	56.5(15.5)	52(19.8)	0.39
Male sex	83.6%	72.7%	92.5%	0.023
BMI (kg/m^2), mean (SD)	24.6(4.7)	24.9(5.7)	24.4(4.1)	0.73
Obesity (BMI >30 kg/m^2)	12.3%	12.1%	12.5%	0.713
Diabetes	27.4%	7%	13%	0.282
Dyslipidemia	37%	37%	27%	0.264
Hypertension	60.3%	57.6%	62.5%	0.669
COPD	12.3%	9.1%	15%	0.445
Acute coronary syndrome	23.3%	45.5%	5%	<0.001
Peri-implant cardiac arrest	13.7%	24.2%	5%	0.017
ECMO-bridge-to-VAD	30.1%	57.6%	7.5%	<0.001
Isolated left VAD	79.5%	75.8%	82.5%	0.42
Isolated right VAD	1.4%	0%	2.5%	
Biventricular VAD	19.2%	24.2%	15%	
CentriMag as left VAD	74%	87.9%	64.1%	0.02
INTERMACS 1	34.2%	63.6%	10%	<0.001
INTERMACS 2	17.8%	18.2%	17.5%	
INTERMACS 3	47.9%	18.2%	72.5%	
Pre-implant lactate (mmol/L), median (IQR)	1(1.2)	1.4(3.2)	0.9(1.6)	0.002
Lactate at 48 h (mmol/L), median (IQR)	1(0.9)	1.2(1)	1(0.5)	0.02
Pre-implant creatinine (mg/dL), median (IQR)	0.99(0.8)	1.36(1.3)	0.94(0.5)	0.034
Creatinine at 48 h (mg/dL), median (IQR)	0.92(0.7)	1.06(1.1)	0.86(0.6)	0.096
Pre-implant bilirubin (mg/dL), median (IQR)	1.25(1.2)	1.25(1.36)	1.24(1.01)	0.881
Bilirubin at 48 h (mg/dL), median (IQR)	1.38(1.5)	1.5(1.7)	1.15(1.25)	0.458
Hemodialysis	23.3%	36.4%	12.5%	0.016
Infection	32.9%	57.6%	12.5%	<0.001
Ischemia of cannulated limb	6.8%	12.1%	2.5%	0.169
Local hemorrhage	20.5%	24.2%	17.5%	0.478
Neurological complications	16.4%	27.3%	7.5%	0.023
Total assistance time (days), median (IQR)	12(15)	20(31)	9(9)	<0.001

BMI: body mass index; COPD: chronic obstructive pulmonary disease; ECMO: extracorporeal membrane oxygenation; INTERMACS: Interagency-Registry-for-Mechanically-Assisted-Circulatory-Support; IQR: interquartile range; SD: standard deviation; VAD: ventricular assist device.

characteristics showed no significant differences. A multivariate analysis of this subgroup of transplanted patients could not be performed due to the limited number of events and the imbalance observed in predictor variables. Hospital mortality was mainly due to major infection, multiorgan failure, or neurological complications before HT, and predominantly to multiorgan failure after transplantation.

Multivariate analysis

To address the objective of the study, the following variables were included in the multivariate model: sex (male as reference), ACS (with chronic dilated cardiomyopathy, idiopathic or ischemic, as reference), ECMO-bridge-to-VAD (with direct VAD as the reference), use of CentriMag as left-sided VAD (versus Impella), lactate and creatinine levels at implantation, hemodialysis, infection, neurological complication, and duration of support. INTERMACS class 1 (vs. classes 2 and 3) was excluded from the model due to high collinearity with the type of support. All ECMO-bridge-to-VAD patients were INTERMACS class 1. When both variables were analyzed together in the first step of the backward stepwise method, they exhibited exceptionally large standard errors, with p=1). The following were identified as independent predictors of in-hospital mortality (Table 3): use of CentriMag as left-sided VAD (OR 810.13; p<0.001), ACS etiology (OR 134.715; p=0.001), ECMO-bridge-to-VAD (OR 79.315; p<0.001), infection (OR 26.743; p<0.001) and female sex (OR 21.169; p=0.014). Statistical significance was assessed using the likelihood ratio test.

If these significant predictors were used to build a predictive model for in-hospital mortality, which is beyond the scope of this study, the model would explain data variability with a Nagelkerke R^2 of 0.802. The model demonstrated a correct classification rate of 91.2%, with a non-significant Hosmer–Lemeshow test (p=0.992). The overall model was statistically significant (p<0.001 in likelihood ratio test), explaining a substantial proportion of variability in the outcome. The area under the curve was 0.964 (95%CI 0.925–1), with sensitivity 93.8% and specificity 88.9% (Figure 2).

To assess the adjusted effect of direct VAD versus ECMO-bridge-to-VAD, a full model was constructed including the

Table 3 Multivariate analysis of predictors of in-hospital mortality.

	OR	95%CI OR	p-Value
CentriMag as left VAD	810.13	3.914–167,672.564	<0.001
Acute coronary syndrome	134.715	1.677–10,823.667	0.001
ECMO-bridge-to-VAD	79.315	5.778–1,088.736	<0.001
Infection	26.743	3.008–237.738	<0.001
Female sex	21.169	1.432–312.916	0.014

ECMO: extracorporeal membrane oxygenation; OR: odds ratio; VAD: ventricular assist device; 95%CI: 95% confidence interval.

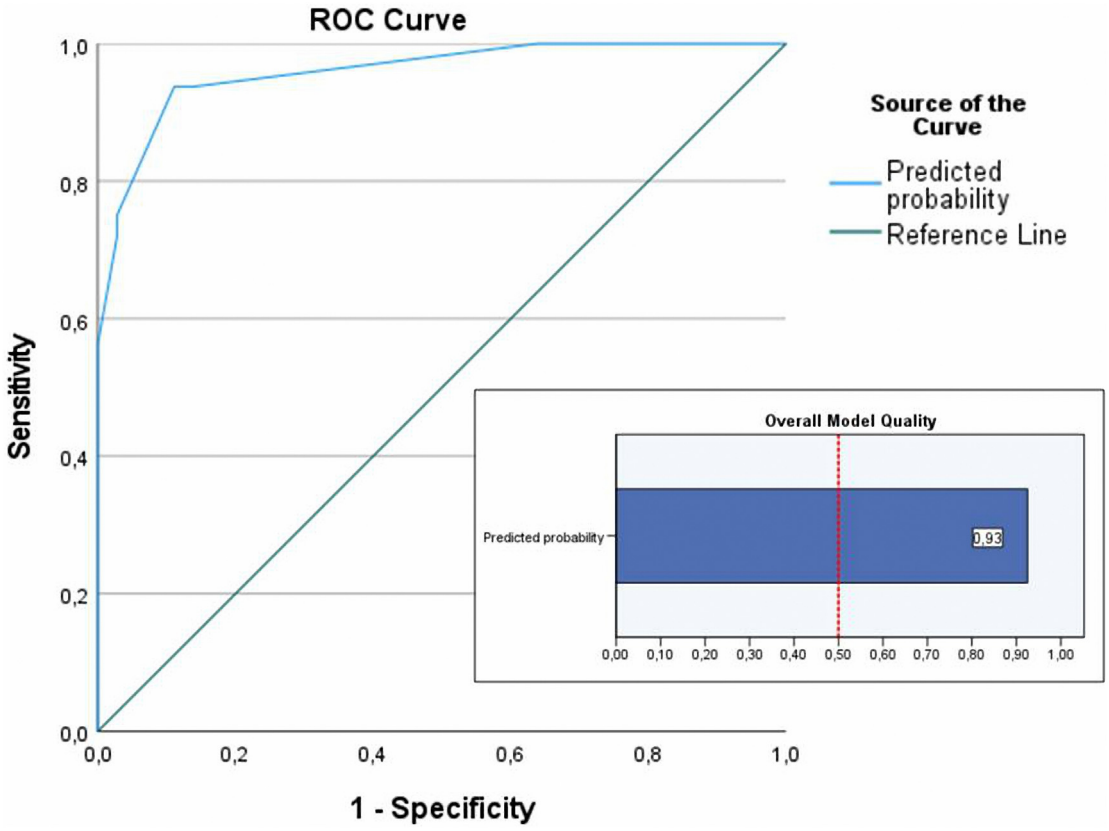

Figure 2 Area under the curve of the predictive model 0.964 (95%CI 0.925–1) and overall model quality 0.93.

Table 4 Adjusted analysis of the effect of direct VAD versus ECMO-bridge-to-VAD.

	OR	95%CI OR	p-Value
CentriMag as left VAD	810.13	3.914–167,672.564	0.014
Acute coronary syndrome	134.715	1.677–10,823.667	0.028
ECMO-bridge-to-VAD	79.315	5.778–1,088.736	0.001
Infection	26.743	3.008–237.738	0.003
Female sex	21.169	1.432–312.916	0.001

ECMO: extracorporeal membrane oxygenation; OR: odds ratio; VAD: ventricular assist device; 95%CI: 95% confidence interval.

exposure variable (ECMO-bridge-to-VAD) and the following control variables: female sex, CentriMag as left-sided VAD, ACS etiology, and infection. Results of this model are presented in Table 4. This model was selected as the optimal one for adjustment, as the exposure effect estimate varied by less than 10% and yielded the narrowest confidence

interval. In this final adjusted model, ECMO-bridge-to-VAD remained a statistically significant risk factor for in-hospital mortality, with an OR of 79.315 (95%CI 5.778–1088.736; p=0.001).

Discussion

The scarcity of donor organs has extended waiting times for HT, thereby increasing the use of VADs as a bridge to urgent HT. In cardiogenic shock, ECMO is commonly used to provide biventricular and respiratory support. However, short-term VADs, such as CentriMag and Impella, have emerged as effective alternatives for bridging to HT, either directly or following initial ECMO support.[4,7,11] In our cohort of 73 patients, in-hospital mortality was higher among patients supported with prior ECMO (86.4%) compared to those directly supported with VAD (27.5%). These findings suggest that patients supported by ECMO have a more severe risk profile associated with the deleterious effects of ECMO, which may increase the likelihood of clinical deterioration prior to transplantation.

Despite increasing clinical use, data on ECMO followed by short-term VAD as a bridge-to-bridge strategy to HT remain limited. Internationally, long-term VADs are more commonly employed in this context, showing comparable mortality to ECMO-to-HT strategies, but with potentially higher complication rates.[12–14] In Spain, high organ donation rates shorten waiting times for HT, influencing mechanical support strategies.[15] ECMO and short-term VADs are commonly used as direct bridges to HT, shaped by the logistics of the national transplant program. In our center, the use of direct ECMO support as a bridge to HT has shown excellent outcomes, as previously reported: 90.9% of patients supported with ECMO successfully underwent HT, with a 75% survival rate among those who reached HT.[16] The need for a bridge-to-bridge approach does not necessarily imply ECMO failure. In 2017, Spanish prioritization criteria for HT were modified to limit ECMO support under Urgency 0 status to 7–10 days, mandating transition to other strategies and necessitating consideration of VAD use as an additional bridge. No improvement in mortality was observed. In 2023, this time limit was removed, with strict criteria applied to avoid ECMO-related complications.[17]

The CentriMag system is a paracorporeal centrifugal pump device capable of providing prolonged support in various configurations.[18–20] Mohite et al.[19] analyzed 46 patients supported with CentriMag for over 30 days: 21 recovered, 8 bridged to long-term VAD, and only 5 bridged to HT (100% one-year survival), with the remainder deceased. Conversely, Takayama et al.[20] described 143 patients with shorter support durations. 18% were transplanted, with 49% one-year survival. Most were INTERMACS class 1. The Spanish multicenter registry[21] with 358 patients reported 84.6% transplantation rate and 77.6% one-year survival. The most frequent complications were bleeding, infections, and stroke.[20,22]

Whereas the Impella device is a transaortic axial-flow pump that unloads the left ventricle, enhancing systemic and myocardial perfusion. Its less invasive surgical approach enables early withdrawal of mechanical ventilation and active rehabilitation. Various models exist: CP, 5.0, and 5.5 for left ventricular support (our series included 6, 2, and 10 patients with each type, respectively), and RP for right ventricular support (not used at our center).[10,11,23] Haddad et al.[11] reported 16 patients supported with Impella reaching HT with 100% one-year survival. Funamoto et al.[24] found that 10 of 25 patients supported with ECMO prior to Impella were transplanted and experienced fewer complications compared to CentriMag-supported patients.[11,24] Gill et al.[25] described 221 patients, 105 of whom received Impella as a bridge to HT, with 81% 90-day survival and 49% were INTERMACS class 1, and 14% had prior ECMO.

Our multivariate analysis identified use of CentriMag as left-sided VAD, ACS, ECMO-bridge-to-VAD, infection, and female sex as independent predictors of in-hospital mortality. After adjusting for confounders, ECMO use remained associated with increased mortality, suggesting that factors beyond baseline severity contribute to poor outcomes. The literature emphasizes the importance of early hemodynamic optimization, as delays may disrupt micro- and macrocirculation coherence. Invasive monitoring and timely intervention are essential.[26,27] In ACS, although ECMO has shown limited benefit, early use of Impella improved survival in the Danger Shock Trial.[28,29] Underlying etiology, ventricular involvement, device selection, and timing are critical.[30] Patients without compensatory adaptations of chronic HF benefit from early circulatory support and ventricular unloading to enhance myocardial perfusion and reduce congestion.

Of the 73 patients in our cohort, 58 received isolated left-sided VAD support, 14 required biventricular support, and 1 received isolated right-sided support. Mortality did not differ between uni- and biventricular support. However, right ventricular failure after long-term left VAD implantation has been reported in 30–40% of cases, with 10–40% mortality, which underscores the importance of careful patient selection.[31,32] Impella RP was not used in our cohort: its femoral venous access limits mobilization during prolonged support. This may be overcome using CentriMag with a dual-lumen ProtekDuo cannula via the jugular vein.[10] Percutaneous biventricular VAD combining Impella and ProtekDuo offers advantages over sternotomy-based strategies, including reduced transfusion requirements, earlier weaning from mechanical ventilation, and faster recovery. It outperforms other minimally invasive techniques.[33,34]

The main limitation of this study is the limited sample size and number of events, which may reduce statistical power to estimate parameters accurately. The single-center design provides homogeneity but limits external validity. Overfitting due to sample size and the limited number of available events may also compromise external validity, potentially leading to an overestimation of the model's area under the curve, which could not be corrected through cross-validation. This is reflected in the wide confidence intervals of the predictors and poses a challenge to the generalizability of the results. The optimal approach would have been to use a propensity score; however, in our study, the technique employed predominantly depends on the patient's condition. Thus, a multivariable logistic regression was performed for the analysis of predictor factors. Additionally, listwise deletion to handle missing data reduced statistical power. Variability in device types and transplantation indications may also have influenced results. Moreover, local

factors related to the Spanish transplant program logistics may influence outcomes, and differences in transplant program organization should be considered when extrapolating these findings. We describe clinically relevant trends that require confirmation in larger studies. Independent of unmeasured confounders, assignment to the ECMO-bridge-to-VAD group was significantly associated with an increased risk of in-hospital mortality risk.

A likely predictor excluded from the model due to collinearity was INTERMACS class 1, which is associated with a higher risk of mortality and should be taken into account when interpreting the model. Patients supported with ECMO who show early signs of right ventricular failure, as well as those classified as INTERMACS 1, likely represent the most critically ill subgroup and may have the highest risk of mortality. The objective of our study was to analyze the impact of the type of strategy employed. However, because of high collinearity, the INTERMACS profile was excluded from the multivariate analysis. However, being in the ECMO-bridge-to-VAD group is essentially equivalent to being classified as INTERMACS class 1, as both convey the same information in the analysis due to their high collinearity. Moreover, this suggests that some of the effects and complications associated with this type of assistance are due not only to the specific clinical condition but also to the inherent risks of the technique itself.

Conclusions

In conclusion, the use of CentriMag as a left ventricular assist device, ACS etiology, ECMO-bridge-to-VAD, infection, and female sex were identified as predictors of in-hospital mortality. After adjustment for confounding factors, ECMO-bridge-to-VAD compared to direct VAD implantation also showed significant differences in mortality. In-hospital mortality remains high in patients with prior ECMO support, which highlights the importance of early and appropriate management aimed at preventing complications and improving outcomes. We describe clinically relevant trends that require confirmation in larger studies.

Ethical considerations

Approved by the Ethics Committee of the University and Polytechnic Hospital La Fe of Valencia (Spain). Informed consent was not required as this was a retrospective, non-interventional study and no identifiable patient data were used.

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Conflict of interests

Manuel Pérez-Guillén reports a relationship with Palex Medical SA that includes speaking and lecture fees. All other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Mancini D, Colombo PC. Left ventricular assist devices. A rapidly evolving alternative to transplant. J Am Coll Cardiol. 2015;65:2542–55.
2. Poptsov V, Spirina E, Dogonasheva A, et al. Five years' experience with a peripheral veno-arterial ECMO for mechanical bridge to heart transplantation. J Thorac Dis. 2019;11:S889–901.
3. Kormos RL, Cowger J, Pagani FD, et al. The Society of Thoracic Surgeons Intermacs Database Annual Report: evolving indications, outcomes, and scientific partnerships. Ann Thorac Surg. 2019;107:341–53.
4. Barge-Caballero E, Almenar-Bonet L, González-Vilchez F, et al. Clinical outcomes of temporary mechanical circulatory support as a direct bridge to heart transplantation: a nationwide Spanish registry. Eur J Heart Fail. 2018;20:178–86.
5. DeFilippis EM, Clerkin K, Truby LK, et al. ECMO as a bridge to left ventricular assist device or heart transplantation. JACC Heart Fail. 2021;9:281–9.
6. Hébert M, Noly PE, Lamarche Y, et al. Early and long-term outcomes after direct bridge-to-transplantation with extracorporeal membrane oxygenation. Heart Surg Forum. 2021;24:E1033–42.
7. Domínguez-Massa C, Pérez-Guillén M, Sirgo-González J, et al. Resultados del uso de dispositivos de asistencia ventricular de corta-media duración como puente al trasplante cardiaco. Cir Cardiov. 2022;29:319–22.
8. McDonagh TA, Metra M, Adamo M, et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J. 2021;42:3599–726.
9. López-Vilella R, Pérez Guillén M, Guerrero Cervera B, et al. Comparative temporal analysis of morbidity and early mortality in heart transplantation with Extracorporeal Membrane Oxygenation support: exploring trends over time. Biomedicines. 2024;12, 2109.
10. Pérez-Guillén M, Domínguez-Massa C, Heredia-Cambra T, et al. Percutaneous biventricular mechanical assistance as a bridge to heart transplant. Rev Esp Cardiol (Engl Ed). 2024;77:101–3.
11. Haddad O, Sareyyupoglu B, Goswami RM, et al. Short-term outcomes of heart transplant patients bridged with Impella 5.5 ventricular assist device. ESC Heart Fail. 2023;10:2298–306.
12. Zhoul AL, Etchill EW, Shou BL, et al. Outcomes after heart transplantation in patients who have undergone a bridge-to-bridge strategy. JTCVS Open. 2022;12:255–68.
13. Tokunaga C, Iguchi A, Nakajima H, et al. Surgical outcomes of bridge-to-bridge therapy with extracorporeal left ventricular assist devices for acute myocardial infarction in cardiogenic shock. BMC Cardiovasc Disord. 2022;22:54.
14. Tonai K, Fukushima S, Tadokoro N, et al. Bridge from central extracorporeal life support is a risk factor of cerebrovasacular accidents after durable left ventricular assist device implantation. J Artif Organs. 2022;25:214–22.
15. National Transplant Organization (ONT). Activity report 2024 of the ONT; 2024. Retrieved from: https://www.ont.es. [Accessed 26 February 2025].
16. Domínguez-Massa C, Pérez-Guillén M, Zarragoikoetxea-Jauregui I, et al. Predictive factors of mortality in Extracorporeal Membrane Oxygenation assisted patients as a bridge to heart transplantation. J Cardiothorac Vasc Anesth. 2025;39:2111–20.
17. González-Costello J, Pérez-Blanco A, Delgado-Jiménez J, et al. Review of the allocation criteria for heart transplant in Spain in 2023 SEC-Heart Failure Association/ONT/SECCE consensus document. Rev Esp Cardiol (Engl Ed). 2024;77:69–78.

18. Sef D, Mohite P, De Robertis F, et al. Bridge to heart transplantation using the Levitronix Centrimag short-term ventricular assist device. Artif Organs. 2020;44:1006–8.
19. Mohite PN, Zych B, Popov AF, et al. CentriMag short-term ventricular assist as a bridge to solution in patients with advanced heart failure: use beyond 30 days. Eur J Cardiothorac Surg. 2013;44:e310–5.
20. Takayama H, Soni L, Kalesan B, et al. Bridge-to-decision therapy with a continuous-flow external ventricular assist device in refractory cardiogenic shock of various causes. Circ Heart Fail. 2014;7:799–806.
21. Cabezón-Villalba G, Barge-Caballero E, González-Vílchez F, et al. Use of a surgically implanted, nondischargeable, extracorporeal continuous flow circulatory support system as a bridge to heart transplant. Rev Esp Cardiol (Engl Ed). 2024;77:39–49.
22. Borisenko O, Wylie G, Payne J, et al. Thoratec CentriMag for temporary treatment of refractory cardiogenic shock or severe cardiopulmonary insufficiency: a systematic review and meta-analysis of observational studies. ASAIO J. 2014;60:487–97.
23. Aguirre-Ramón CM, Domínguez-Massa C, Pérez-Guillén M, et al. Uso de bypass extraanatómico para el manejo de complicaciones con ECPELLA. Arch Cardiol Mex. 2023;93:112–4.
24. Funamoto M, Kunavarapu C, Kwan MD, et al. Single center experience and early outcomes of Impella 5.5. Front Cardiovasc Med. 2023;10, 1018203.
25. Gill G, Rowe G, Chen Q, et al. Bridging with surgically placed microaxial left ventricular assist devices: a high-volume centre experience. Eur J Cardiothorac Surg. 2023;63, ezad116.
26. Merdji H, Levy B, Jung C, et al. Microcirculatory dysfunction in cardiogenic shock. Ann Intensive Care. 2023;13:38.
27. Osman M, Syed M, Patel B, et al. Invasive hemodynamic monitoring in cardiogenic shock is associated with lower in-hospital mortality. J Am Heart Assoc. 2021;10, e021808.
28. Thiele H, Zeymer U, Akin I, et al. Extracorporeal life support in infarct-related cardiogenic shock. N Engl J Med. 2023;389:1286–97.
29. Møller JE, Engstrøm T, Jensen LO, et al. Microaxial flow pump or standard care in infarct-related cardiogenic shock. N Engl J Med. 2024;390:1382–93.
30. Schrage B, Sundermeyer J, Blankenberg S, et al. Timing of active left ventricular unloading in patients on venoarterial Extracorporeal Membrane Oxygenation therapy. JACC Heart Fail. 2023;11:321–30.
31. Takayama H, Naka Y, Kodali SK, et al. A novel approach to percutaneous right-ventricular mechanical support. Eur J Cardiothorac Surg. 2012;41:423–6.
32. Coromilas EJ, Takeda K, Ando M, et al. Comparison of percutaneous and surgical right ventricular assist device support after durable left ventricular assist device insertion. J Card Fail. 2019;25:105–13.
33. Patel NJ, Verma DR, Gopalan R, et al. Percutaneous biventricular mechanical circulatory support with Impella CP and Protek Duo Plus TandemHeart. J Invasive Cardiol. 2019;31:E46.
34. Iglesias-Gil C, Estévez-Cid F, González-Barbeito M, et al. Minimally invasive approach for biventricular assist device with centrifugal pump: first experience in Spain. Rev Esp Cardiol (Engl Ed). 2020;73:512–3.