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Research Article

Duration of Bridge-to-Transplant Extracorporeal Membrane Oxygenation and Heart Transplant Survival

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Background. The 2018 Organ Procurement and Transplantation Network (OPTN) heart allocation policy change prioritizes patients bridged to transplant with mechanical circulatory support (MCS) devices, including extracorporeal membrane oxygenation (ECMO). As a result, the use of ECMO has significantly increased. *Methods*. We reviewed the OPTN database for adult patients undergoing heart transplant after bridge with ECMO between January 1st 2000 and October 18th 2018. We excluded patients with ≥180 days of ECMO duration, prior transplants, and those using additional MCS devices. Survival and morbidity outcomes of patients with ≥7 days of pre-transplant ECMO were compared to those of patients with <7 days. *Results*. Of 362 eligible transplant recipients, 163 (45%) utilized <7 days of pre-transplant ECMO and 199 (55%) utilized ≥7 days. Those with ≥7 days were younger (median age: 43 [28–54] vs. 50 [36–57] years, $p = 0.006$) and more likely to have temporary waitlist inactivity (18% vs. 7%, $p = 0.003$) with significantly longer duration of ECMO use (median: 14 [9–24] vs. 4 [2–5] days, $p < 0.001$). Patients with ≥7 days of ECMO had comparable survival to those with <7 days at one year (81.1% vs. 79.4%, $p = 0.64$) and five years (61.1% vs. 49.3%, $p = 0.27$). After adjustment for clinically relevant variables, duration of ECMO ≥7 days did not increase mortality at five years (HR = 0.90, $p = 0.59$). *Conclusions*. Longer duration of ECMO (≥7 days vs. <7 days) among patients successfully bridged to transplant is not associated with increased mortality or selected adverse outcome, including graft failure or rejection, at up to five years.

1. Introduction

In October of 2018, the Organ Procurement and Transplantation Network (OPTN) implemented an updated heart allocation policy with the goal of increasing waitlist stratification and improving access to transplant for the most medically urgent candidates. Prior to this policy change, Status 1A received top priority and included stable patients with durable mechanical circulatory support devices for a period of time, encompassing groups with significantly heterogeneous waitlist mortality risk [1, 2]. After the policy change, patients previously assigned to Status 1A were redistributed into Statuses 1–3 within the new, six-tier allocation system. As a result, patients with extracorporeal membrane oxygenation (ECMO) are prioritized by assignment to Status 1 during the first week following implantation and to Status 3 after seven days of ECMO only if durable mechanical circulatory support is no longer contraindicated and if specific hemodynamic qualifications are no longer met [1, 2]. Early evidence has suggested that the policy change has accomplished several of its intended goals, including improved waitlist patient stratification and increased rates of transplantation for medically urgent groups while causing minimal impact to waitlist mortality and post-transplant outcomes [3]. Despite some evidence that waitlist duration, waitlist mortality, and rates of transplantation have been improved by the policy change, there remains a lack of consensus as to whether post-transplant mortality is unchanged or increased in the postpolicy change era [3–9].

In response to the policy change, several groups raised concerns that the prioritization of patients bridged to transplant with ECMO would increase the incidence of this high-acuity intervention, leading to increased transplantation of critically ill patients at the expense of recipient survival [10, 11]. Several reports have confirmed that the use of mechanical circulatory support, including ECMO, has increased following the policy change [5, 7, 9, 12, 13]. This is concerning for two reasons: ECMO may not only result in adverse vascular events, infection, renal complications, and neurologic impairment during use but also increase the incidence of adverse outcomes following transplant, including prolonged length of stay, sepsis, bleeding, reoperation, and acute renal, hepatic, or respiratory failure [14–17]. A recent review of the OPTN database found that recipients bridged with ECMO survived an average of 16.6 fewer months than non-ECMO bridged counterparts [18]. We also raise the concern that increased use of ECMO as a bridge to transplant may eventually result in longer durations of ECMO use in this critically ill subset of patients, further worsening post-transplant outcomes. The relationship between pre-transplant ECMO duration and post-transplant outcomes has not yet been characterized. We therefore sought to determine whether longer duration of pre-transplant ECMO use was associated with increased post-transplant mortality at short-term (one year) and long-term (five years) follow-up prior to the 2018 policy change. Among patients with longer durations of ECMO, we also compared those who underwent transplant to those who died on the waitlist. Should the duration of pre-transplant ECMO use rise in the postpolicy change era, these findings will provide insight into the mortality and morbidity risks faced by ECMO-bridged patients on the waitlist and after transplant. If no change to ECMO duration occurs, these data may still inform clinical decision making regarding the use of prolonged ECMO prior to transplant.

2. Materials and Methods

2.1. Study Population. The Organ Procurement and Transplantation Network (OPTN) database was queried for adult (≥18 years) patients undergoing heart transplant after bridge with ECMO between January 1st 2000 and the OPTN heart allocation policy change on October 18th2018. Patients with multiple temporary mechanical circulatory support (tMCS) devices, no tMCS devices, prior transplants, or ECMO duration longer than 180 days were excluded.

Patients were sorted into two groups of approximately equal size to compare the upper 50th percentile of pre-transplant ECMO duration to the lower 50th percentile, resulting in two groups: <7 days (short duration) and ≥7 days (long duration). Pearson's chi-squared test and Fisher's exact test were used to measure differences in categorical demographic and clinical characteristics between these two groups. Analysis of variance (ANOVA) was used to assess differences in variables with normal distributions between the groups, while the Kruskal–Wallis H test was used to assess differences in continuous variables with nonnormal distributions.

2.2. Survival Analysis. Kaplan–Meier survival functions of short-duration and long-duration ECMO patients were compared at one year, five years, and ten years using log-rank tests. The risk of mortality associated with short-duration ECMO at each post-transplant time point was calculated using univariate Cox proportional hazards regression. In this and subsequent survival analyses, patients were censored at time of retransplant or loss to follow-up after transplant. Survival time was calculated as the time between transplant and death or censorship event.

Log-rank tests and univariate Cox proportional hazards regression were subsequently used to determine the association between other clinically relevant continuous and categorical variables, respectively, with post-transplant survival at five years. Variables with $p \leq 0.20$ were included in a multivariable Cox proportional hazards regression model. Three clinically relevant variables with $p > 0.20$, including organ ischemic time, donor age, and recipient gender, were also included in this model. Ten variables were included in the multivariable model, and the association between pre-transplant ECMO duration and post-transplant survival at one year, five years, and ten years was calculated with adjustment for other variables. The proportionality of hazards assumption was satisfied in our multivariable Cox model.

Logistic regression was used to assess the incidence of secondary outcomes in each group, including graft failure, acute rejection, treatment for rejection in the first year after transplant, hospitalization for rejection at any time, post-transplant stroke, or new post-transplant dialysis requirement. Other OPTN adverse outcomes, such as post-transplant coronary artery disease, new pacemaker requirement, or hospitalization for infection, could not be analyzed due to missing data or low incidence.

Finally, the incidence of waitlist outcomes (death or transplantation) was compared between short-duration and long-duration ECMO groups. Among patients with long-duration ECMO, we further compared the demographics and clinical characteristics of patients who received transplant vs. those who died on the waitlist. ANOVA and the Kruskal–Wallis H test were used to assess differences in continuous variables based on normality of distribution, as above.

All statistical analyses were performed using Stata 15/SE[22] with a p value of <0.05 considered statistically significant. Institutional review board approval was obtained for analysis of the OPTN database in a prognostic study of survival following heart transplant, with no requirement to obtain informed consent. Our study was compliant with the ISHLT Ethics statement.

3. Results

3.1. Demographics. A total of 801 adult patients were on ECMO while on the waitlist for heart transplantation between January 1st 2000 and October 18th 2018 (Figure 1). Of

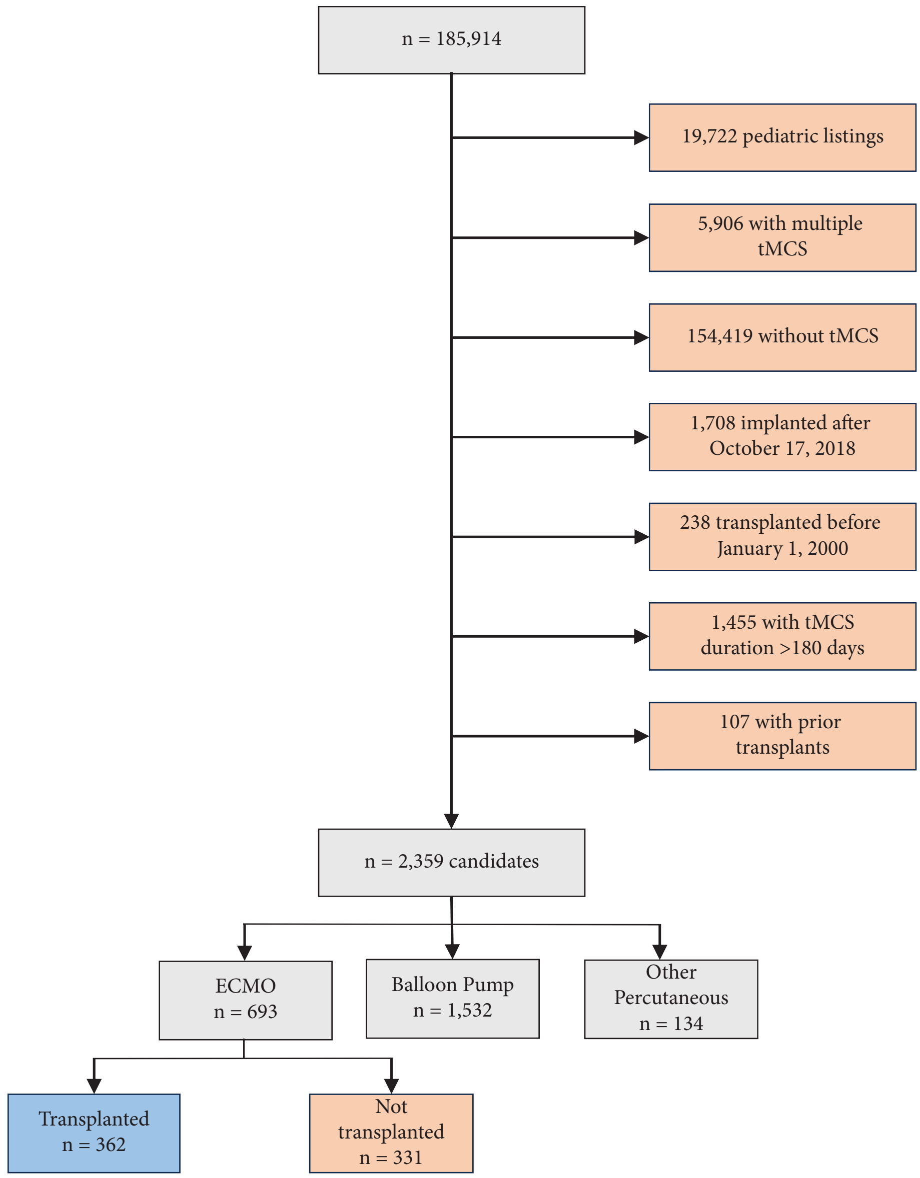

FIGURE 1: Exclusion criteria and types of temporary mechanical circulatory support used to bridge patients to heart transplantation, with number of transplants and removal/deaths from the waitlist among patients bridged with ECMO. tMCS, temporary mechanical circulatory support; ECMO, extracorporeal membrane oxygenation.

this number, 362 (45.2%) received a transplant and were eligible for inclusion in this study. Of these 362 patients, 163 (45%) were bridged with <7 days (short-duration group) of ECMO and 199 (55%) were bridged with ≥7 days (long-duration group).

Long-duration ECMO patients were younger than their short-duration counterparts (median age: 43 [28–54] vs. 50 [36–57] years, $p = 0.006$) but were similar with regard to race and gender (Table 1). Long-duration ECMO patients spent a greater median number of days on the waitlist (16 [10–28] vs. 4 [2–5], $p < 0.001$) and utilized ECMO for a significantly longer duration (14 [9–24] vs. 4 [2–5] days, $p < 0.001$). These patients were more likely than their short-duration counterparts to have a Karnofsky functional status of 4–6 (disabilities requiring occasional, considerable, or ongoing assistance) but equally likely to have a functional status of 1–4 (severely disabled to moribund) or 7–10 (able to care for self to no disability). Long-duration patients were also more likely to require blood transfusion while on ECMO (68% vs. 46%, $p < 0.001$) and more likely to have a history of dialysis use (23% vs. 11%, $p = 0.04$), although incidence of diabetes was similar between groups. Lastly, long-duration patients were more likely to experience periods of temporary waitlist inactivity due to illness with subsequent return to the waitlist (18% vs. 7%, $p = 0.003$). Other recipient clinical characteristics, including hemodynamic factors such as inotrope use, cardiac output, and pulmonary capillary wedge pressure, were similar across the two groups at listing and time of transplant. All donor

Table 1: Demographic, clinical, hemodynamic, and organ donor characteristics for patients bridged to heart transplant with ECMO, by duration of recipient pre-transplant use.

	ECMO <7 days $N = 163$	ECMO ≥7 days $N = 199$	p
Recipient demographics			
Male gender	108 (66%)	122 (61%)	0.33
Recipient age	50 (36–57)	43 (28–54)	0.006
Race/ethnicity			
White	125 (77%)	144 (72%)	
Black	14 (9%)	26 (13%)	0.17
Hispanic	17 (10%)	18 (9%)	0.81
Asian	5 (3%)	8 (4%)	0.57
American Indian/Alaskan Native	2 (1%)	0 (0%)	0.13
Pacific Islander	0 (0%)	1 (1%)	0.35
Recipient clinical characteristics			
ECMO when listed	152 (93%)	181 (91%)	0.42
ECMO duration	4 (2–5)	14 (9–24)	<0.001
Days on waiting list	4 (2–5)	16 (10–28)	<0.001
Waitlist inactivity after listing	12 (7%)	36 (18%)	0.003
Prior cardiac surgery	18 (11%)	30 (15%)	0.25
Multiorgan transplant	2 (1%)	9 (5%)	0.07
Recipient BMI (kg/m^2)	25.5 (21.7–29.1)	24.8 (21.0–28.8)	0.38
History of diabetes	55 (34%)	60 (30%)	0.48
History of dialysis use	9 (11%)	23 (23%)	0.04
History of cigarette use	64 (39%)	62 (31%)	0.12
Prior malignancy	15 (9%)	10 (5%)	0.12
Prior cerebrovascular disease	0 (0%)	2 (6%)	0.19
Serum creatinine at Tx (mg/dL)	1.0 (1.0)	0.8 (0.7)	0.04
Required transfusion after listing	73 (46%)	130 (68%)	<0.001
Functional status 1–3	148 (93%)	174 (88%)	0.19
Functional status 4–6	5 (3%)	18 (9%)	0.02
Functional status 7–10	6 (4%)	2 (1%)	0.08
Recipient hemodynamic characteristics			
Inotrope use at listing	13 (8%)	9 (5%)	0.17
Inotrope use at Tx	16 (10%)	11 (6%)	0.12
Cardiac output at listing (L/min)	5.5 (2.0)	5.4 (2.2)	0.59
Cardiac output at Tx (L/min)	5.6 (2.1)	5.4 (2.5)	0.61
PCW pressure at listing (mmHg)	13.8 (9.1)	13.7 (8.7)	0.89
PCW pressure at Tx (mmHg)	12.8 (8.5)	13.8 (8.3)	0.35
Donor clinical characteristics			
Organ ischemic time (hours)	5.4 (4.3–6.4)	5.1 (3.8–6.4)	0.18
Donor heart ejection fraction (%)	60 (55–65)	60 (55–65)	0.30
Donor age	33 (22–46)	33 (23–46)	0.97
Female donor for male recipient	35 (21%)	37 (19%)	0.49
Donor BMI (kg/m^2)	25.8 (22.8–29.7)	25.8 (22.3–29.5)	0.83
Donor history of diabetes	13 (8%)	11 (6%)	0.37
Donor history of hypertension	32 (20%)	40 (20%)	0.92
Donor history of cancer	4 (2%)	2 (1%)	0.28
ABO mismatch (%)	18 (11%)	19 (10%)	0.72
HLA mismatch level (1–6)	5 (4–5)	5 (4–5)	0.29

ECMO, extracorporeal membrane oxygenation; BMI, body mass index; Tx, transplant; PCW, pulmonary capillary wedge.

characteristics were similar across the two groups, including frequency of ABO mismatch (available for 100% of patients) and HLA mismatch (available for 91% of patients).

3.2. Survival Analysis. In unadjusted Kaplan–Meier analyses, estimated survival functions of long-duration ECMO patients were comparable to those of short-duration ECMO patients at one year (81.1% vs. 79.4%, $p = 0.64$), five years (61.1% vs. 49.3%, $p = 0.27$), and ten years (44.8% vs. 37.4%, $p = 0.30$) (Table 2). Although long-duration ECMO patients demonstrated a trend of reduced mortality compared to their short-duration counterparts, survival was comparable at all time points (Figure 2).

Ten clinically relevant variables, including seven associated with five-year survival in univariate Cox regression, were included in a multivariable Cox regression model: transplant year, recipient gender, recipient age, recipient

Table 2: Kaplan–Meier survival estimates at one year, five years, and ten years for patients receiving <7 or ≥7 days of pre-transplant ECMO.

Posttransplant survival functions by time point			
	ECMO <7 days (%)	ECMO ≥7 days (%)	p
One year	79.4	81.1	0.64
Five years	49.3	61.1	0.27
Ten years	37.4	44.8	0.30

ECMO, extracorporeal membrane oxygenation.

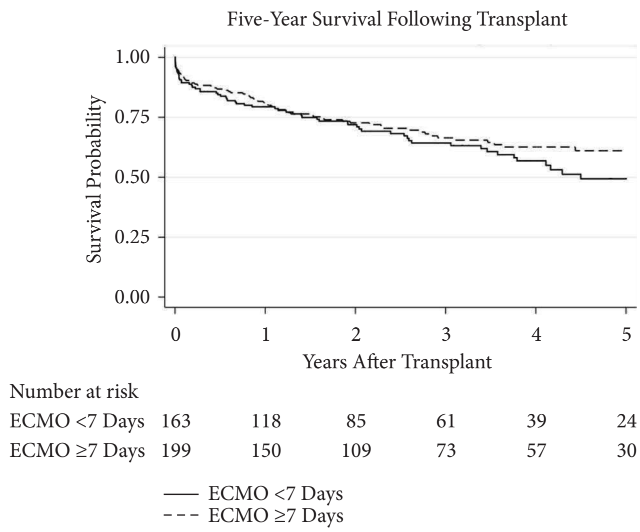

Figure 2: Kaplan–Meier survival curves of patient survival following heart transplant bridged with <7 days (solid line) or ≥7 days (dashed line) of ECMO. Morbidity outcomes are comparable at five years ($p = 0.27$) and at ten years ($p = 0.30$, not shown). ECMO, extracorporeal membrane oxygenation.

body mass index, recipient history of cigarette use, recipient inotrope use at transplant, duration of ECMO use, organ ischemic time, gender mismatch (female donor to male recipient), and donor age (Table 3). In this multivariable model, later transplant year was associated with decreased mortality (HR: 0.93 [0.88–0.98] per year after 2000, $p = 0.01$) and recipient body mass index was associated with increased mortality (HR = 1.04 [1.00–1.08] per kg/m^2, $p = 0.04$). Pre-transplant ECMO duration of ≥7 days was not associated with mortality at the primary endpoint of five years (HR = 0.90 [0.63–1.31], $p = 0.59$). In addition, ECMO duration of ≥7 days was not associated with other outcomes such as post-transplant graft failure ($p = 0.16$), acute rejection ($p = 0.45$), treatment for rejection within one year ($p = 0.55$), post-transplant stroke ($p = 0.92$), or new post-transplant dialysis requirement ($p = 0.76$).

Table 3: Multivariable Cox proportional hazards model for five-year mortality following transplant.

Five-year mortality				
	HR	95% confidence interval		p
Recipient characteristics				
Transplant year (per year)	0.93	0.88	0.98	0.01
Male gender	1.12	0.73	1.70	0.60
Recipient age (per year)	1.01	<1.00	1.03	0.08
Body Mass index (per kg/m^2)	1.04	>1.00	1.08	0.04
Prior cigarette use	0.99	0.66	1.47	0.95
Inotrope use at Tx	1.53	0.76	3.07	0.23
Organ ischemic time (per minute)	1.08	0.98	1.18	0.12
ECMO ≥7 days	0.90	0.63	1.31	0.59
Donor characteristics				
Female donor for male recipient	1.21	0.75	1.96	0.43
Donor age (per year)	1.01	0.99	1.02	0.39

ECMO, extracorporeal membrane oxygenation; Tx, transplant.

3.3. Waitlist Outcomes. Among patients awaiting transplant while on ECMO, those with <7 days of device use were more likely to receive a transplant compared to those with ≥7 days (58% vs. 48%, $p = 0.009$), without any adjustment for other factors. Among listed patients with ≥7 days of ECMO, those who received a transplant were younger than those who did not (43 [28–54] vs. 48 [33–59] years, $p = 0.03$), more likely to be male (61% vs. 51%, $p = 0.04$), and more likely to be listed with ECMO (91% vs. 82%, $p = 0.01$) (Table 4). Long-duration patients who did not receive a transplant either died on the waitlist or were removed due to clinical decompensation resulting in transplant ineligibility. Long-duration ECMO patients who received a transplant were also less likely to have any periods of waitlist inactivity (18% vs. 58%, $p < 0.001$) and spent fewer days on the waitlist (16 [10–28] vs. 23 [13–53], $p < 0.001$) and on ECMO (14 [9–24] vs. 19 [11–37], $p < 0.001$). Finally, transplanted patients had

Table 4: Comparison of patients with ≥7 days of ECMO who either underwent transplant or did not, either due to death or removal from the waitlist.

	Transplanted vs. nontransplanted patients with ≥7 days of ECMO		
	Not transplanted $N = 214$	Transplanted $N = 199$	
Demographics			
Male gender	110 (51%)	122 (61%)	0.04
Age	48 (33–59)	43 (28–54)	0.03
Race/ethnicity			
White	159 (74%)	144 (72%)	
Black	28 (13%)	26 (13%)	0.93
Hispanic	18 (8%)	18 (9%)	0.78
Asian	5 (2%)	8 (4%)	0.32
Amer. Indian/Alaskan Native	1 (~0%)	0 (0%)	0.34
Pacific Islander	3 (1%)	1 (1%)	0.37
Clinical characteristics			
ECMO when listed	176 (82%)	181 (91%)	0.01
Days on waiting list	23 (13–53)	16 (10–28)	<0.001
ECMO duration	19 (11–37)	14 (9–24)	<0.001
Waitlist inactivity after listing	125 (58%)	36 (18%)	<0.001
Multiorgan transplant	0 (0%)	9 (5%)	0.002
Body mass index (kg/m^2)	26.5 (23.0–30.0)	24.9 (21.3–28.3)	0.002
History of diabetes	54 (25%)	60 (30%)	0.26
History of cigarette use	62 (32%)	62 (31%)	0.83
Prior cerebrovascular disease	9 (7%)	2 (6%)	0.85
Functional status 1–3	147 (74%)	174 (88%)	<0.001
Functional status 4–6	19 (10%)	18 (9%)	0.90
Functional status 7–10	7 (4%)	2 (1%)	0.10
Hemodynamic characteristics			
Inotrope use at listing	63 (29%)	9 (5%)	<0.001
Cardiac output at listing (L/min)	4.5 (1.6)	5.4 (2.2)	<0.001
PCW pressure (mmHg)	17.0 (10.4)	13.7 (8.7)	0.006

ECMO, extracorporeal membrane oxygenation; PCW, pulmonary capillary wedge pressure.

a lower median BMI (24.9 [21.3–28.3] vs. 26.5 [23.0–30.0] kg/m^2, $p = 0.002$), higher cardiac output (5.4 ± 2.2 vs. 4.5 ± 1.6, $p < 0.001$), lower pulmonary capillary wedge pressure (13.7 ± 8.7 vs. 17.0 ± 10.4, $p = 0.006$), and lower incidence of inotrope use (5% vs. 29%, $p < 0.001$) compared to nontransplanted counterparts at time of listing.

4. Conclusion

In our analysis of patients bridged to heart transplant with ECMO, roughly half of the study population utilized ECMO for <7 days (short duration) and half for ≥7 days (long duration). Long-duration ECMO patients were younger, spent more time on the waitlist and on ECMO, and were more likely to experience periods of waitlist inactivity. Long-duration patients were also more likely to have used dialysis in the past but were otherwise similar with regard to hemodynamic and clinical characteristics. After adjustment for relevant clinical variables in a multivariable model, long-duration ECMO patients had comparable survival to short-duration patients at one year, five years, and ten years. ECMO duration was similarly not associated with incidence of post-transplant complications such as graft failure, rejection, and stroke.

Prolonged duration of ECMO has been associated with increasing risks of morbidity and mortality in nontransplant patient populations, and ECMO duration ≥7 days may now result in a lower priority waitlist status for transplant patients who are eligible for durable mechanical circulatory support and do not meet specific hemodynamic qualifications [1, 2, 18–20]. However, it remains unclear whether longer durations of ECMO as a bridge to transplant are also associated with adverse post-transplant outcomes. In our analyses of the OPTN database, we found that patients with ≥7 days of pre-transplant ECMO did not experience increased risk of post-transplant mortality or morbidity compared to their counterparts with <7 days. Despite a nearly 4-fold increase in median waitlist time and ECMO duration, patients in the long-duration ECMO group experienced a trend towards improved survival resulting in >10% improved Kaplan–Meier survival estimate at five years, but this did not reach statistical significance. At first glance, this similarity might be attributed to more rigorous patient selection: patients with ≥7 days of ECMO were less likely to receive a transplant, but those who did were largely similar to their <7 day counterparts in most demographic, clinical, and hemodynamic respects. However, patients transplanted after ≥7 days of ECMO were more likely to have experienced waitlist inactivity, which may contribute to longer waitlist periods and ECMO duration despite similar clinical characteristics. With adjustment for other clinically relevant factors, survival of ECMO-bridged patients remained independent of ECMO duration at up to five years. Although the survival of patients bridged to transplant with ECMO is worse than that of patients without an MCS requirement, recent studies suggest that this decrement is relatively modest. In one recent study, survival at 30 days and 16 years was 89.3% and 47.4% for ECMO-bridged patients compared to 96.2% and 54.8% for non-MCS patients, suggesting that bridge-to-transplant with ECMO offers comparable long-term survival and a viable approach for sickest patients requiring heart transplant [18].

Within the long-duration ECMO group, we also compared patients who underwent transplant to those who died or were removed from the waitlist. Here, clinical differences were more substantial: patients who did not undergo transplant had even longer ECMO duration and more frequent waitlist inactivity as well as greater BMI, lower cardiac output, higher pulmonary capillary wedge pressure, and greater frequency of inotrope use at listing. These differences likely represent both a difference in clinical condition at listing and progressive decompensation with prolonged ECMO use. These observations likely suggest that while duration of ECMO support lends itself to increasing morbidity, those who are spared from complications on ECMO may experience similar or short- and long-term outcomes after transplant. Further study is needed to validate this concept.

Our study was subject to several limitations, including those associated with any retrospective analysis of a large, national database. One such limitation was the inability to confirm whether very long durations of ECMO (e.g., >180 days) were the result of outlier clinical courses or inaccurate device implant/explant dates. As a result, we excluded four ECMO-bridged transplant patients with the rationale that, even if the reported device duration was accurate, outcomes for these patients would not accurately represent those of a group whose median ECMO use was 14 days. It is further limited by missing data, in particular for the variables of cardiac output and pulmonary capillary wedge pressure, where data were missing for 30–34% of the cohort. A related limitation is that the OPTN does not always specify how data are collected. For example, it is not specified how cardiac output, specifically, is measured for each patient. Next, our study focused on post-transplant outcomes up to five years and so did not include patients transplanted after the 2018 policy change. However, ECMO-bridged patients following the policy change are similar to or clinically healthier than their prepolicy change counterparts, suggesting that survival among the patients bridged to transplant with ≥7 days of ECMO may be similarly independent of ECMO duration [21, 22]. In addition, although ECMO duration ≥7 days was not associated with post-transplant mortality among patients who were transplanted, this analysis only included patients who were not removed from the waitlist due to illness or death and thus does not represent potential outcomes of any patient with longer duration of ECMO use. Finally, it should be noted that five-year mortality described in this study was worse than expected based on OPTN reports for 2019 [23]. We expect that this difference is due, in part, to improving outcomes over the course of our 2001–2018 study period and worse outcomes for ECMO-bridged patients in general related to critical illness requiring this high-acuity intervention.

Increased utilization of ECMO in the post-policy change era raises two major concerns. First, that ECMO will be inappropriately used as mechanical circulatory support to increase the likelihood of organ allocation. Although some studies show improving clinical characteristics among patients bridged to transplant after the policy change, suggesting possible use of this high-acuity intervention in a new population, waitlist mortality and survival to transplant have both improved for these patients, reducing concerns that it might be used unnecessarily [21, 22]. The second concern is more complex: patients bridged with ECMO have experienced improved waitlist and post-transplant outcomes since the 2018 policy change. It has been suggested that this is the result of shorter waiting times and fewer ECMO-related complications [4, 21, 22]. Increased use of ECMO and an expanding population of Status 1 patients may undermine this novel waitlist mobility, producing a higher number of patients at risk for ECMO-related complications without relief by rapid organ allocation and transplant. Our study provides reassurance that patients bridged to transplant with ECMO, although at increasing risk for adverse outcomes while receiving mechanical circulatory support, do not experience increased mortality or morbidity in the short- or long-term periods following transplant. Prolonged ECMO use among waitlisted patients without clinical deterioration should not raise concerns for worsening post-transplant outcomes in the post-policy change era.

Data Availability

All data utilized in this study are available through the OPTN database.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors contributed to the conception and design of this study. Matthew McGoldrick, Iulia Barbur, Eric Etchill, Katherine Giuliano, and Chun Woo Choi contributed to statistical analysis of this study. Matthew McGoldrick completed the majority of writing and figure design. All authors contributed to review of the completed statistical analysis, figures, and manuscript.

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