Prolonged waitlisting is associated with mortality in extracorporeal membrane oxygenation-supported heart transplantation candidates

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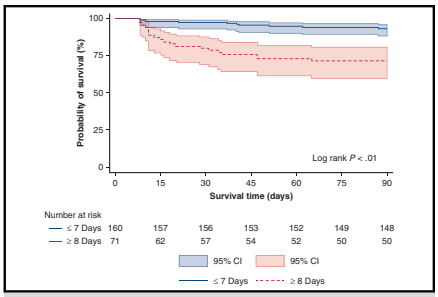
ABSTRACT

Objective: Heart transplantation (HTx) candidates supported with venoarterial extracorporeal membrane oxygenation (ECMO) may be listed at highest status 1 but are at inherent risk for ECMO-related complications. The effect of waitlist time on postlisting survival remains unclear in candidates with ECMO support who are listed using the new allocation system.

Methods: Adult candidates listed with ECMO for a first-time, single-organ HTx from October 18, 2018, to March 21, 2021, in the Scientific Registry of Transplant Recipients database were included and stratified according to waitlist time (≤7 vs ≥8 days). Postlisting outcomes were compared between cohorts.

Results: Among 175 candidates waitlisted for ≤7 days, 162 (92.6%) underwent HTx whereas 13 (7.4%) died/deteriorated compared with 41 (57.8%) and 21 (29.6%) of the 71 candidates waitlisted for ≥8 days, respectively ($P < .01$). Blood type O candidates (odds ratio [OR], 2.94; 95% CI, 1.54-5.61) were more likely to wait ≥8 days whereas candidates with concurrent intra-aortic balloon pump were less likely (OR, 0.30; 95% CI, 0.10-0.89). Obesity was additionally associated among those listed at status 1 (OR, 2.04; 95% CI, 1.00-4.17). Waitlisting for ≥8 days was independently associated with 90-day postlisting mortality conditional on survival to day 8 postlisting (hazard ratio, 5.59; 95% CI, 2.59-12.1). Candidates listed at status 1 showed similar trends (hazard ratio, 5.49; 95% CI, 2.39-12.6). There was no significant difference in 90-day post-HTx survival depending on whether a candidate waited for ≥8 days versus ≤7 days (92.7 vs 92.0%; log rank $P = .87$).

Conclusions: Among ECMO-supported candidates, obtaining HTx within 1 week of listing might improve overall survival. (JTCVS Open 2022;12:234-54)



Prolonged listing is associated with worse 90-day postlisting survival.

CENTRAL MESSAGE

In heart transplant candidates supported with ECMO, undergoing transplant within the first week of listing might improve overall survival.

PERSPECTIVE

The new donor heart allocation system places ECMO-supported candidates at highest status 1. A substantial portion, however, wait for more than 1 week, which predisposes candidates to deconditioning and ECMO-related complications. These candidates face a fivefold increase in hazard of 90-day postlisting mortality. Every effort should be made to obtain a transplant within 1 week of listing.

In October 2018, the Organ Procurement and Transplantation Network updated its donor heart allocation policy to permit candidates in florid biventricular failure, supported with either venoarterial extracorporeal membrane oxygenation (ECMO) or surgical biventricular assist device, uncontended placement atop the waitlist with wider access to donor organs.[1] This change was prompted by data showing disproportionate waitlist mortality in this cohort under the old allocation systems that permitted hemodynamically stable

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Abbreviations and Acronyms

BMI = body mass index
ECMO = extracorporeal membrane oxygenation
HR = hazard ratio
HTx = heart transplantation
IABP = intra-aortic balloon pump
IQR = interquartile range
LVAD = left ventricular assist device
OR = odds ratio
SRTR = Scientific Registry of Transplant Recipients

candidates to be listed at the same status.[2] During discussion of the new donor heart allocation system in 2016, the decision to restrict the initial qualifying period to 7 days for those supported with ECMO sought to balance equitable access to donor organs while ensuring device use in appropriate patients.[1] However, modeling studies showed that approximately 15% of candidates would be supported for ≥8 days, leading to the decision to allow reapproval for status 1 candidacy after application to the regional review board.[1]

As a result of these changes, candidates supported with ECMO have noticed a substantial decrease in waitlist time with an associated increase in survival to heart transplantation (HTx) and have, moreover, noticed an improvement in post-HTx survival.[3,4] Although this improvement is an undoubted step in the right direction, candidates listed at status 1 continue to show waitlist mortality at a substantially higher rate than others,[5] reflecting the tenuous condition of patients supported with ECMO in addition to its significant complication burden.[6]

Previous studies of ECMO under the new allocation system have analyzed waitlist outcomes and post-HTx survival separately, without showing how undergoing HTx affects the postlisting survival course of a patient. In the present study, we aimed to evaluate 1) how waitlisting for ≥8 days affects postlisting survival, and 2) candidate characteristics associated with waitlist time ≥8 days.

METHODS

Data Source

The Scientific Registry of Transplant Recipients (SRTR) database was used in this analysis. The SRTR has prospectively collected data on all solid organ transplant candidates, recipients, and donors in the United States since October 1, 1987. Because the SRTR database is publicly available and deidentified, this study was deemed exempt from institutional review board review.

Inclusion and Exclusion Criteria

Adults (18 years of age or older) listed for a single-organ HTx between October 18, 2018, and March 31, 2021, supported with ECMO at the time of listing were identified. Candidates listed for a redo HTx or multiple organ transplant were excluded.

Study Definitions

Candidates were stratified according to waitlist time (≤7 vs ≥8 days) with comparison of characteristics at the time of listing. The cutoff of 1 week was chosen because candidates supported with ECMO must be reapproved by the regional review board every 7 days to remain at status 1.

The primary end point was composed of death (either post-HTx or waitlist) or waitlist removal because of clinical deterioration, because nearly three-quarters of these patient die within 1 year of delisting.[7] Survival time from listing was calculated as the sum of waitlist time and post-HTx survival time; candidates who did not undergo HTx were assigned a post-HTx survival time of 0.

Statistical Analysis

Continuous variables are presented as median (interquartile range [IQR]) and categorical variables are presented as number (percent). After stratification according to waitlist time, baseline demographic characteristics were compared using the Wilcoxon rank sum test for continuous variables and the χ^2 test or Fisher exact test for categorical variables. The Kaplan–Meier method and log rank tests were used to determine survival differences between groups. Candidates who did not experience the outcome of interest were censored at 90 days postlisting. Variables included in logistic regression and Cox proportional hazards models were selected on the basis of clinical and/or biological relevance. Additionally, collinearity was examined in all models using the variance inflation factor. Results of multivariable analyses are presented as hazard ratio (HR) or odds ratio (OR), where appropriate, with accompanying 95% CI. These analyses included the following:

I) Cox proportional hazards models to examine 90-day postlisting survival conditional on survival to 8 days postlisting, which was performed to determine difference in postlisting outcomes between those who were alive at this point after HTx versus those who were alive at this point on the waitlist;
II) Logistic regression to determine risk factors associated with waitlist time ≥8 days; and
III) A subanalysis of post-HTx survival using Cox proportional hazards models to determine 1) whether differences in postlisting survival were chiefly because of post-HTx or waitlist demise, and 2) if HTx remains a viable exit strategy for candidates waitlisted ≥8 days.

In analysis I, a landmarked analysis was performed to avoid immortal time bias, because, by definition, anyone who survives to ≥8 days of waitlisting has survived the first 7 days. We additionally examined characteristics of candidates who underwent HTx versus died or deteriorated on the waitlist if listed for ≥8 days. All analyses were repeated among candidates listed at status 1 to determine the robustness of observed results. Stata version 17 (StataCorp) was used for all analyses.

RESULTS

Overall Trends

A total of 246 candidates were included with a median waitlist time of 4 days (IQR, 2-9 days; Figure 1, *A*); patients listed as status 1 (n = 210) had a median waitlist time of 4 days (IQR, 2-7 days; Figure 1, *B*). In 2018, 4/11 (36.4%) candidates were waitlisted for ≥8 days compared with 11/30 (36.7%) in 2021 (*P* for trend = .46; Figure 2, *A*). Among status 1 candidates, 22.2% waited for ≥8 days in 2018 compared with 37.0% in 2021 (*P* for trend = .15; Figure 2, *B*).

Baseline Characteristics

Cohorts showed a similar distributions of age, sex, and body mass index (BMI). Candidates who waited for

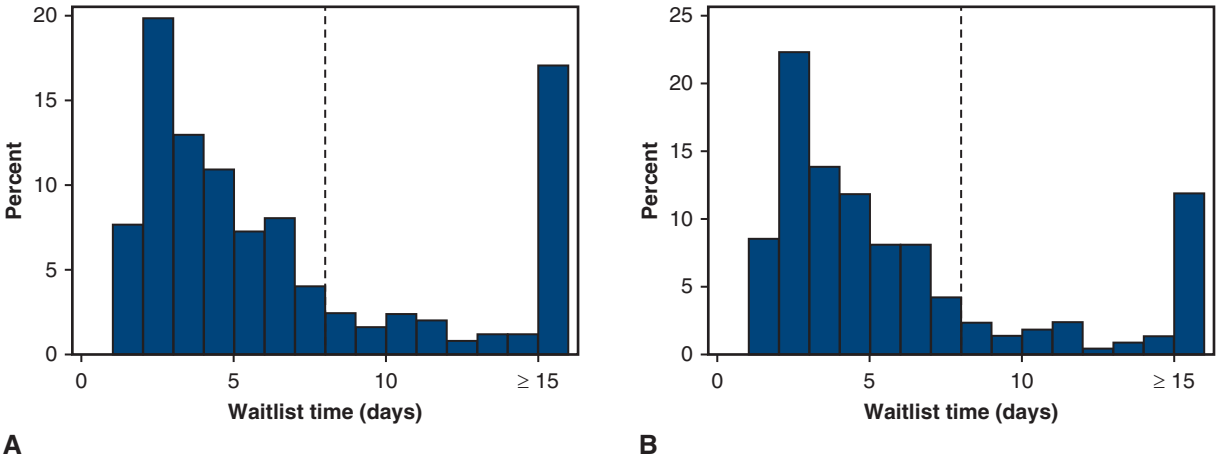


FIGURE 1. Histograms showing the distribution of waitlist time among (A) the entire cohort and (B) status 1 candidates. The *vertical dashed line* represents 7 days.

≥8 days were more likely to be blood type O (56.3% vs 34.9%; $P < .01$) and have elevated creatinine (35.2% vs 22.3%; $P = .04$) whereas they were less likely to be concurrently supported by intra-aortic balloon pump (IABP; 7.0% vs 20.0%; $P = .01$) or listed at status 1 (67.6% vs 92.6%; $P < .01$; Table 1). Similar trends were observed among status 1 candidates, with significantly more blood type O (56.3% vs 36.4%; $P < .01$) and previous smokers (35.4% vs 21.0%; $P = .04$) among those waitlisted for ≥8 days with less with concurrent IABP support (6.4% vs 19.1%; $P = .03$; Table E1).

Multivariable logistic regression showed blood type O (OR, 2.94; 95% CI, 1.54-5.61) to be independently associated with increased likelihood of waitlist time ≥8 days; concurrent IABP support (OR, 0.30; 95% CI, 0.10-0.89) and status 1 listing (OR, 0.12; 95% CI, 0.05-0.30) were associated with decreased likelihood of waitlist time ≥8 days (Table 2). Among status 1 candidates, blood type O (OR, 2.15; 95% CI, 1.08-4.24) and obesity (OR, 2.04; 95% CI, 1.00-4.17) remained independently associated with prolonged waitlisting (Table E2).

Waitlist Outcomes and Postlisting Survival

Among candidates waitlisted for ≥8 days, 57.8% ultimately received a transplant, whereas 29.6% died or deteriorated on the waitlist. However, 92.6% of candidates waitlisted ≤7 days received a transplant whereas only 7.4% died or deteriorated ($P < .01$; Figure 3, *A*). Of status 1 candidates waitlisted for ≤7 days 93.8% received a transplant whereas 6.2% died or deteriorated; 56.3% of those who waited for ≥8 days received a transplant and 29.2% died or deteriorated ($P < .01$; Figure 3, *B*). Overall, 9 (3.7%) candidates were removed because of recovery or other causes; all of these candidates were listed for ≥8 days. The percentage of candidates removed from the waitlist because of HTx was highest when listed for ≤4 days at 97.6% (Figure E1).

Two of 162 (1.2%) candidates who received a transplant within 7 days of listing died shortly after HTx. Ninety-day postlisting survival was estimated to be 70.4% (95% CI, 58.3%-79.6%) if a candidate remained waitlisted at 8 days compared with 93.7% (95% CI, 88.7%-96.6%) if the candidate received a transplant (Figure 4, *A*). Multivariable Cox proportional hazards analysis showed an independent association between waitlisting ≥8 days and 90-day mortality (HR, 5.59; 95% CI, 2.59-12.1; Table 3). These results were replicated on analysis of status 1 candidates alone (HR, 5.49; 95% CI, 2.39-12.6; Table E3; Figure 4, *B*).

Recipient Characteristics

Forty-one recipients underwent HTx after listing for ≥8 days compared with 162 at ≤7 days. Recipients who received a transplant at ≥8 days were younger (44 vs 53 years; $P = .04$) and less likely to be supported with ECMO at HTx (63.4% vs 95.7%; $P < .01$) or mechanically ventilated (7.35% vs 29.0%; $P < .01$) whereas more often blood type O (53.7% vs 35.2%; $P = .03$) and more likely to be supported with durable left ventricular assist device (LVAD; 12.2% vs 0.6%; $P < .01$; Table E4). Donors were similarly likely to be blood type O and otherwise showed similar characteristics. There were no significant differences in ischemic time or distance from recipient to donor. At 90 days post-HTx, 92.0% of recipients listed for ≤7 days were alive compared with 92.7% if listed for ≥8 days (log rank $P = .87$; Figure E2, *A*).

Among those listed at status 1, those who underwent HTx at ≥8 days of listing were younger (39 vs 53 years; $P = .04$) and less likely to be mechanically ventilated (7.4% vs 29.6%; $P = .02$) or supported with ECMO (70.4% vs 96.7%; $P < .01$) but more likely to be supported with

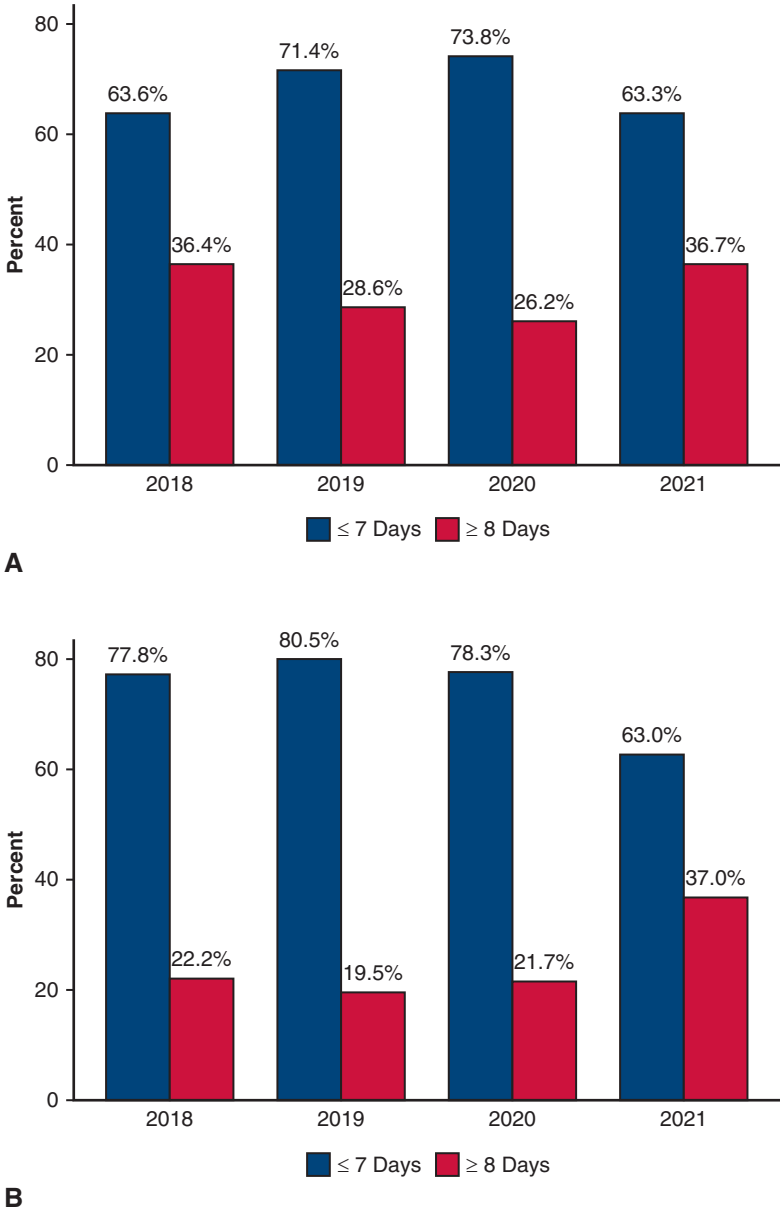


FIGURE 2. Bar charts showing the percentage of candidates who waited for ≥8 days (A) cohortwide and (B) when listed at status 1 according to year of listing.

durable LVAD (7.4% vs 0%; $P = .02$) at the time of transplantation (Table E5). There was no significant difference in donor or operative characteristics. For patients listed as status 1, 90-day post-HTx survival was 92.6% among those who waited for ≥8 days compared with 91.4% among those who waited for ≤7 days (log rank $P = .83$; Figure E2, *B*).

Compared with candidates who were waitlisted for ≥8 days and underwent HTx, those who died or deteriorated were older (58 vs 44 years; $P < .01$) and showed greater atherosclerotic burden, indicted by a greater prevalence of ischemic heart disease (57.1% vs 19.5%; $P < .01$), diabetes (47.6% vs 17.1%; $P = .01$), and cerebrovascular accident (23.8% vs 2.4%; $P = .01$; Table E6). Among those listed at status 1, a larger proportion of those who died showed ischemic heart failure etiology (57.1% vs 25.9%; $P = .049$). The study design and findings are represented in Figure 5.

DISCUSSION

In the present study we examined the relationship between prolonged waitlist time and postlisting survival and had 4 key findings. First, waitlist time >1 week while listed with ECMO support was independently associated with worse postlisting survival. Second, blood type O, a nonmodifiable risk factor, was associated with prolonged waitlist

TABLE 1. Candidate characteristics

	≤7 Days (n = 175)	≥8 Days (n = 71)	*P* value
Age, y	53 (39-60)	51 (32-60)	.42
Female sex	46 (26.3)	22 (31.0)	.46
BMI	27.3 (24.2-31.6)	28.0 (24.6-33.5)	.39
Blood type O	61 (34.9)	40 (56.3)	**<.01**
Ethnicity			.43
White	123 (70.3)	44 (62.0)	
Black	25 (14.3)	12 (16.9)	
Other	27 (15.4)	15 (21.1)	
Region*			**.04**
Northeast	57 (32.6)	14 (19.7)	
Southeast	45 (25.7)	30 (42.3)	
Midwest	40 (22.9)	17 (23.9)	
West	33 (18.9)	10 (14.1)	
Private insurance	103 (58.9)	42 (59.2)	.97
Heart failure etiology			.57
Nonischemic	120 (68.6)	46 (64.8)	
Ischemic	55 (31.4)	25 (35.2)	
Medical history			
Diabetes	34 (19.5)	18 (25.4)	.31
CVA	11 (6.4)	6 (8.5)	.57
ICD	58 (33.1)	26 (36.6)	.60
Smoking	40 (22.9)	24 (33.8)	.08
Previous cardiac surgery	41 (23.4)	19 (26.8)	.58
Inotrope-dependent	96 (54.9)	36 (50.7)	.55
Ventilator-dependent	58 (33.1)	18 (25.4)	.23
Creatinine ≥1.5 mg/dL	39 (22.3)	25 (35.2)	**.04**
Concurrent MCS			
IABP	35 (20.0)	5 (7.0)	**.01**
Microaxial LVAD	25 (14.3)	8 (11.3)	.61
Durable LVAD	3 (1.7)	3 (4.2)	.25
Listing status			**<.01**
1	162 (92.6)	48 (67.6)	
2	9 (5.1)	6 (8.5)	
3	1 (0.6)	4 (5.6)	
4	0	4 (5.6)	
6	1 (0.6)	5 (7.0)	
7	2 (1.1)	4 (5.6)	

Continuous variables are presented as median (interquartile range) and categorical variables are presented as n (%). Statistical significant *P*-values were shown in bold. *BMI*, Body mass index; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

time. Third, waitlist time >1 week did not compromise the efficacy of HTx as an exit strategy. Fourth, after being waitlisted for >1 week, candidates who then die or deteriorate showed characteristics associated with acquired heart disease. Moreover, the relationship between waitlist time and postlisting survival remained present on examination of status 1 candidates alone. Taken together, these data suggest that undergoing prompt HTx is of high importance in candidates listed with ECMO support, although young candidates without a large chronic disease burden who are clinically stable can be maintained on the waitlist if they cannot receive a transplant within the first week.

Using previous allocation systems, it has been noted that inability to acquire a suitable heart for transplantation among ECMO-supported candidates in a timely fashion is associated with poor postlisting survival.[8] Ivey-Miranda and colleagues[8] analyzed 712 candidates supported with ECMO and showed postlisting survival at 1 year to be

TABLE 2. Risk factors for prolonged waitlist time (≥8 days)

	Univariable		Multivariable	
	OR	*P* value	OR	*P* value
Age, y	0.99 (0.97-1.01)	.35	0.98 (0.96-1.00)	.08
Female sex	1.26 (0.69-2.31)	.46	1.46 (0.73-2.92)	.28
Obese	1.45 (0.82-2.56)	.20	1.93 (0.99-3.74)	.052
Blood type O	2.41 (1.37-4.23)	**<.01**	2.94 (1.54-5.61)	**<.01**
White ethnicity	0.69 (0.39-1.23)	.21		
Region*				
Northeast	Ref.	–	Ref.	–
Southeast	2.71 (1.29-5.72)	**<.01**	1.91 (0.82-4.42)	.13
Midwest	1.73 (0.77-3.91)	.19	1.64 (0.68-4.00)	.27
West	1.23 (0.49-3.09)	.65	1.16 (0.43-3.16)	.77
Private insurance	1.01 (0.58-1.77)	.97		
Ischemic HF etiology	1.19 (0.66-2.12)	.57		
Medical history				
Diabetes	1.40 (0.73-2.69)	.31		
CVA	1.35 (0.48-3.81)	.57		
ICD	1.17 (0.65-2.07)	.60		
Smoking	1.72 (0.94-3.16)	.08		
Previous cardiac surgery	1.19 (0.64-2.24)	.58		
Inotrope-dependent	0.85 (0.49-1.47)	.55		
Ventilator-dependent	0.69 (0.37-1.27)	.23		
Creatinine ≥1.5 mg/dL	1.90 (1.04-3.46)	**.04**		
Concurrent MCS				
IABP	0.30 (0.11-0.81)	**.02**	0.30 (0.10-0.89)	**.03**
Microaxial LVAD	0.80 (0.34-1.87)	.61		
Durable LVAD	2.53 (0.50-12.8)	.55		
Listing at status 1	0.17 (0.08-0.36)	**<.01**	0.12 (0.05-0.30)	**<.01**

Statistical significant *P*-values were shown in bold. *OR*, Odds ratio; *HF*, heart failure; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

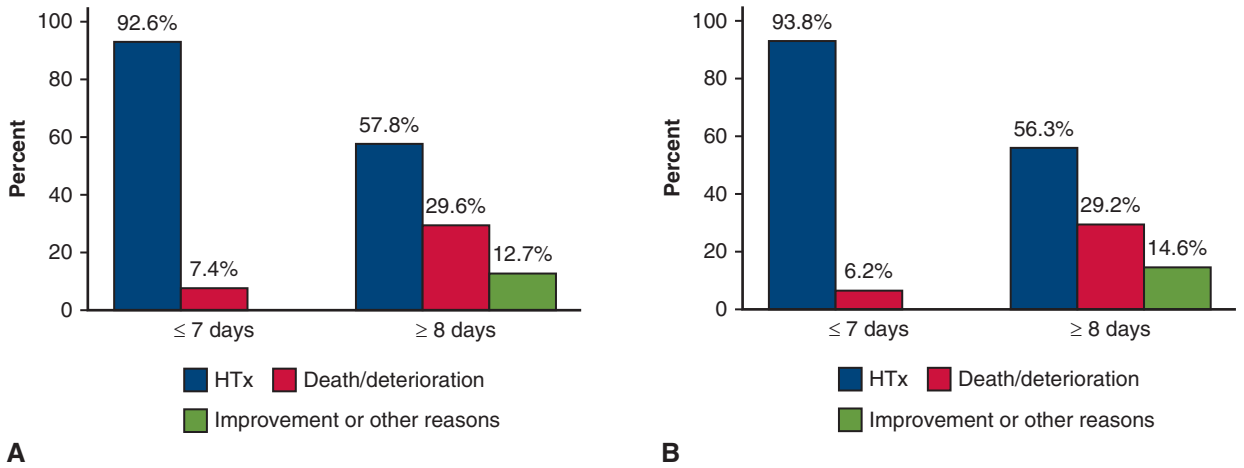


FIGURE 3. Bar charts showing the percentage of candidates removed from the waitlist because of heart transplantation (*HTx*), death/deterioration, or other causes stratified according to waitlist time. A, The entire cohort, and (B) status 1 candidates only. χ^2 *P* is < .01 in both graphs.

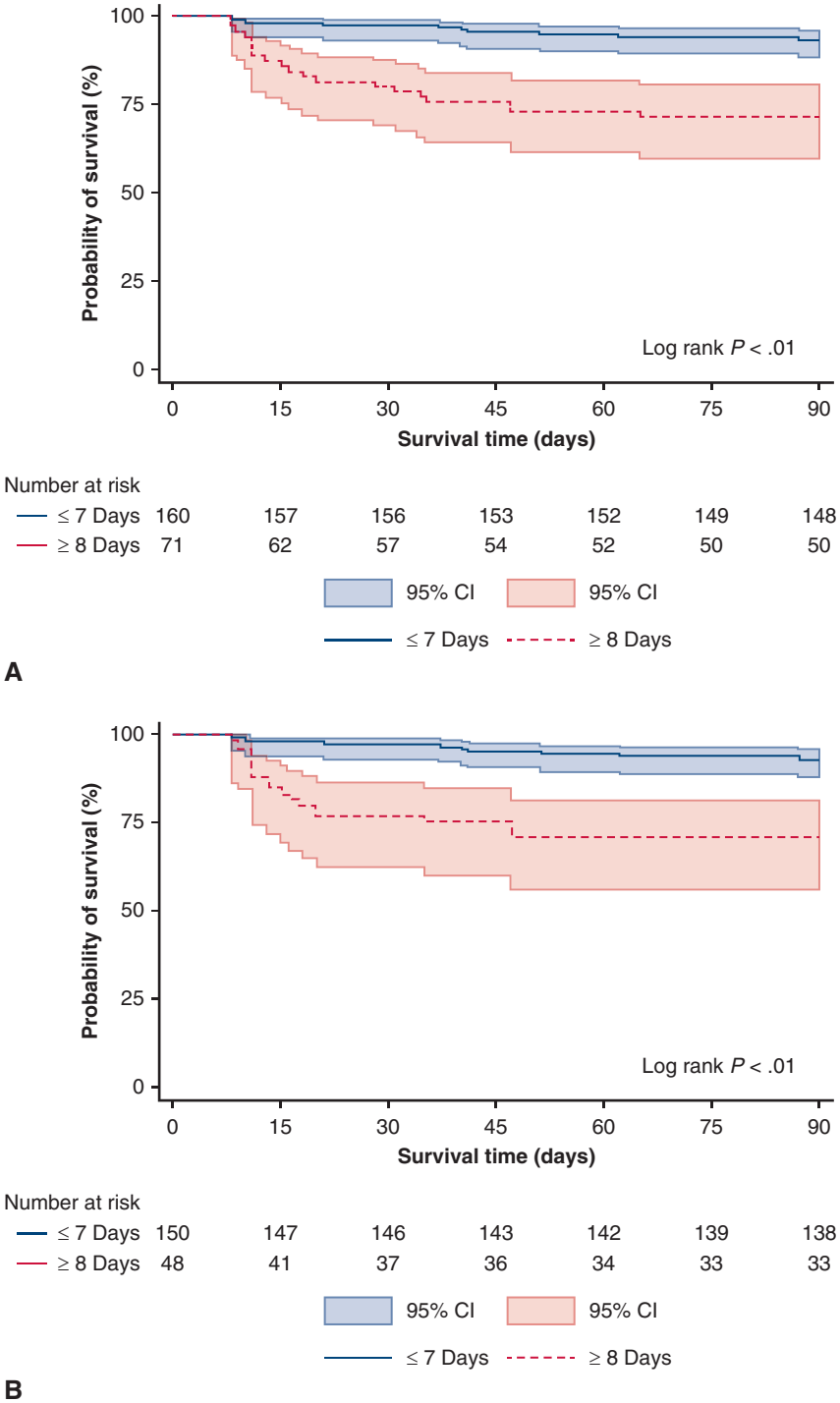


FIGURE 4. Kaplan–Meier curves showing a significant decrease in postlisting survival among candidates who waited for ≥8 days versus ≤7 days. A, The entire cohort, and (B) status 1 candidates only. *CI*, Confidence intervals.

22.5% if the candidate did not undergo HTx compared with 73.4% if they did. In this same analysis, it was shown that longer time on the waitlist is associated with worse post-HTx survival on the order of a 2% increase per day waitlisted. Despite higher rates of post-HTx mortality among ECMO-supported recipeints,[9] Singh and colleagues[10] showed that the survival benefit gained from HTx compared with continued waitlisting increases among sicker candidates. In the present analysis, we were unable to detect a significant difference in post-HTx mortality among recipients

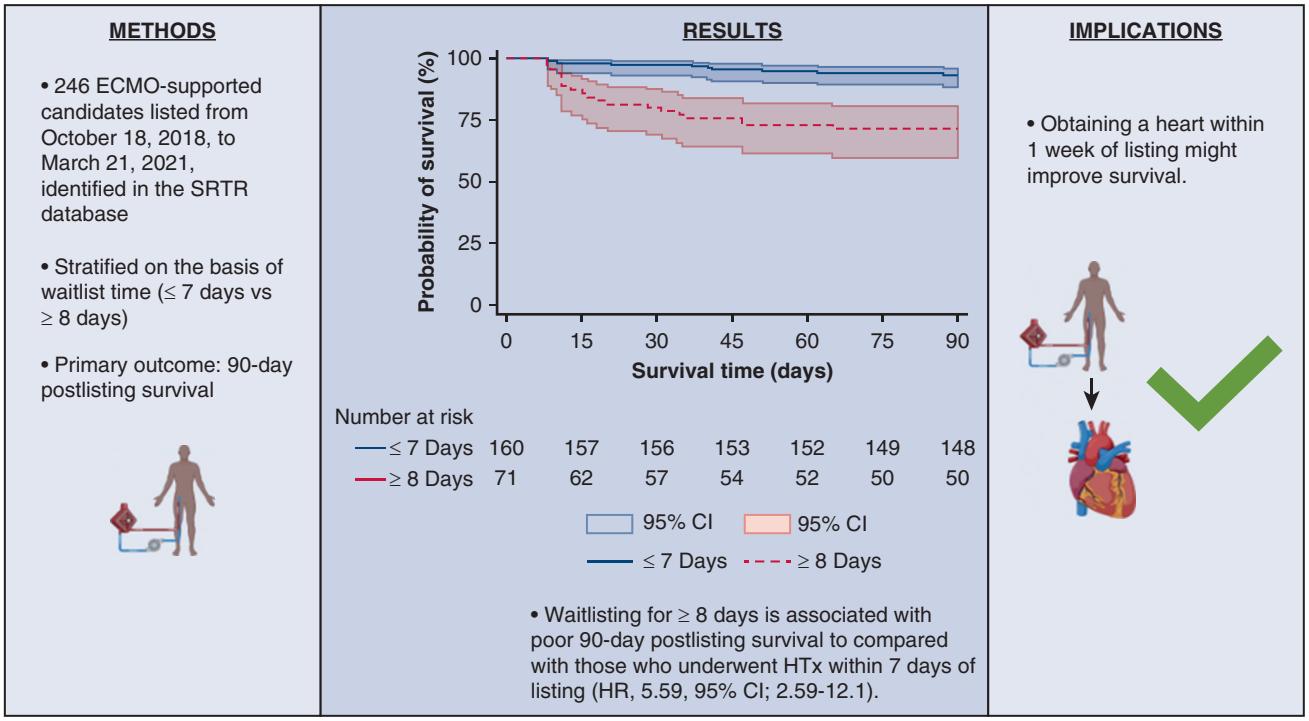


FIGURE 5. A summary of the study's methodology, findings, and implications. *ECMO*, Extracorporeal membrane oxygenation; *SRTR*, Scientific Registry of Transplant Recipients; *CI*, confidence intervals; *HTx*, heart transplant; *HR*, hazard ratio.

with a prolonged waitlist time, with excellent post-HTx survival among those listed for ≤7 days (92.0%) and those listed for ≥8 days (92.7%). When interpreting this information, there is a caveat, however, in that selection bias might be present in considering candidates who survived to HTx after listing for ≥8 days. When examining the clinical characteristics of this population compared with those listed for ≤7 days, we noticed these candidates were less likely to be ECMO-dependent at the time of HTx and more likely to be durable LVAD-dependent, leading one to consider the role of durable LVAD as a feasible bridge from ECMO to HTx.

In a recent analysis of combined SRTR and Interagency Registry for Mechanically Assisted Circulatory Support databases, DeFilippis and colleagues[11] investigated survival among candidates bridged with ECMO to LVAD versus HTx. They showed post-ECMO to HTx survival of 70.7% at 1 year, 66.6% at 2 years, and 61.8% at 5 years compared with 69.2%, 62.6%, and 56.5% at 1, 2, and 5 years, respectively, among those bridged to LVAD. However, this analysis did not separate post-HTx outcomes according to allocation system. Published data demonstrate post-HTx survival rates of approximately 90% in those bridged directly to HTx and might thus obfuscate this equivalency in the current era.[3,4] From this information, the question does then arise of whether temporary support candidates are currently transplanted too fast without consideration of transition to durable support. In a recent analysis of the SRTR database, Topkara and colleagues[12] showed a significant decrease in rate of waitlist recovery using the new system in this population, suggesting an inadequate period for improvement while receiving temporary support. It appears that candidates listed with durable LVAD also have shorter waitlist time using the current allocation system, although their post-HTx outcomes might be suffering.[13] Undoubtedly, further investigation is required in this area.

Among the total cohort, we noticed blood type O to be independently associated with prolonged waitlist time, whereas obesity emerged as an additional predictor among those listed at status 1. Regarding blood type, it has been recognized that type O candidates have longer waitlist time, at least in part because of the biology of donor organs they can accept.[14] This phenomenon is intriguing when considering the population restricted to status 1 candidates, as per United Network for Organ Sharing donor heart allocation policies, type O hearts are first offered to status 1 candidates of a primary blood type match within 500 nautical miles.[15] Interestingly, there was no difference in the proportion of type O donors among those who received a transplant within 7 days versus ≥8 days without a notable difference in donor quality, although a larger proportion of candidates who received a transplant ≥8 days were blood type O. This likely indicates that several type O donor hearts were passed on by type O candidates. First, this could represent a subconscious bias in which type O candidates supported with ECMO tend to be listed earlier in their

TABLE 3. Relationship between waitlist ≥8 days and postlisting death or deterioration, landmarked at 8 days

	Univariable		Multivariable	
	HR (95% CI)	***P* value**	**HR (95% CI)**	***P* value**
Waitlist ≥8 d	5.47 (2.58-11.6)	**<.01**	5.59 (2.59-12.1)	**<.01**
Age, y	1.04 (1.01-1.07)	**.01**	1.04 (1.01-1.08)	**<.01**
Female gender	1.45 (0.69-3.02)	.33		
Obese	2.32 (1.14-4.70)	**.02**	1.83 (0.90-3.74)	.10
Blood type O	2.29 (1.11-4.72)	**.03**		
White ethnicity	0.62 (0.30-1.28)	.20		
Region*				
Northeast	–	Referent		
Southeast	2.55 (0.90-7.23)	.08		
Midwest	2.14 (0.70-6.54)	.18		
West	2.15 (0.66-7.04)	.21		
Private insurance	0.68 (0.34-1.38)	.29		
Ischemic HF etiology	2.19 (1.08-4.44)	**.03**		
Medical history				
Diabetes	2.53 (1.21-5.29)	**.01**		
CVA	3.09 (1.18-8.08)	**.02**		
ICD	1.41 (0.69-2.89)	.34		
Smoking	2.23 (1.09-4.56)	**.03**		
Previous cardiac surgery	1.79 (0.86-3.73)	.12		
Inotrope-dependent	0.83 (0.41-1.68)	.60		
Ventilator-dependent	1.13 (0.53-2.41)	.74	1.18 (0.55-2.52)	.67
Creatinine ≥1.5 mg/dL	1.97 (0.95-4.05)	.07	1.33 (0.64-2.77)	.45
Concurrent MCS				
IABP	0.56 (0.17-1.83)	.34		
Microaxial LVAD	1.78 (0.73-4.35)	.20		
Durable LVAD	-	-		
Listing at status 1	0.67 (0.28-1.64)	.38		

Statistical significant *P*-values were shown in bold. *HR*, Hazard ratio; *CI*, confidence intervals; *HF*, heart failure; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

cardiogenic shock process because of known difficulties obtaining HTx in this population.[14,16] This might also be reflective of true differences in pathophysiology, because type O candidates are less likely to be afflicted by ischemic heart disease.[17] Although listed for HTx, transplant teams might opt to monitor the patient's status closely while still having the option of urgent HTx if needed as opposed to waiting for failure to recover and then listing. Regarding concurrent IABP use, Nishi and colleagues[18] recently examined concurrent IABP use in ECMO in a large Japanese national database and showed significant decreases in post-ECMO mortality. They reported significantly higher rates of concurrent IABP use in large-scale teaching institutions, although in the United States, data documenting the correlation between center volume and advanced ECMO management strategies are sparse.

We additionally noticed an association between obesity and prolonged waitlist time among candidates listed at status 1. In a recently published study, Chouairi and colleagues[19] examined the relationship between obesity and HTx outcomes. In this analysis, they showed a dose-dependent decrease in the hazard of undergoing HTx as BMI increased, from 0.83 (95% CI, 0.81-0.85) among those with BMI from 25 to 29.9 to 0.42 (95% CI, 0.36-0.49) among those with a BMI from 40 to 55. This likely represents difficulty in procuring organs of appropriate size match, because donor BMI was noted to be a mean of 26.9 in 2020. In our analysis, mean donor BMI was 28.2, which points toward difficulty obtaining hearts from adequately sized donors as the likely etiology of the increased waitlist time.

This study has several limitations inherent to its design. First, the study was retrospective in nature. Second, although the United Network for Organ Sharing database contains >500 variables, data are collected primarily at the time of listing and HTx, without update during listing.

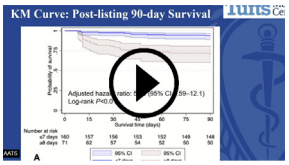
It has been shown that a candidate's risk can change rapidly.[20] Moreover, important variables that might be indicative of a patient's physiologic status, such as lactate, are not available. Third, the database does not contain granular information surrounding the reason to delist a candidate for other reasons or continue additional support, such as IABP, in those listed for a prolonged period, thus limiting conclusions regarding candidates listed for ≥8 days. Additionally, it should be noted that ECMO is primarily a therapy for those in biventricular failure as opposed to left heart failure, and the decision to pursue ECMO in these patients is highly individualized. Fourth, because the timepoints at which data are collected, we were unable to assess the situation surrounding the escalation to ECMO support, such as patients who begin ECMO support in the setting of cardiopulmonary arrest. Fifth, non-status 1 candidates were included to represent the entirety of the candidate pool, with analyses then restricted to status 1 candidates, because of the sample size of the current analysis.

CONCLUSIONS

Although candidates supported with ECMO are listed at status 1 in the new donor heart allocation system, a substantial portion are waitlisted for ≥8 days. Those who do not undergo HTx within the first week after listing are at increased risk of subsequent waitlist demise but show adequate post-HTx survival. Further investigation into optimal bridging strategies of candidates who cannot immediately undergo HTx is warranted.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/1329.



Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: heart transplantation, allocation system, prolonged waitlisting

Discussion

Presenter: Dr Masashi Kawabori

Dr Leora Yarboro *(Charlottseville, Va)*. Thank you very much and congratulations. That was an excellent presentation. I have received honoraria from Abbot and Medtronic, neither of which is related to my discussion today. The heart transplant allocation change in 2018 has dramatically affected how we care for patients awaiting heart transplant. There's been a dramatic shift toward the increased use of temporary circulatory supports such as ECMO in these populations. In your talk today, you demonstrate a decrease in postlisting survival among those patients who were supported for eight days or longer with a high percentage of those patients not progressing to transplant. In this, I have 3 questions for you. The first is, in these data, you showed that a third of the transplant patients—a third of the patients fall into the high-risk category of having to wait more than 8 days from transplant. Do you foresee that this time will get longer as more patients are supported on ECMO pretransplant? And if so, what strategies do you think we can use to mitigate these complications?

Dr Masashi Kawabori *(Boston, Mass)*. Thank you for comments, Dr Yarboro. To answer this question, I think, as shown in the slide, I think there's improvement room for these issues because, number 1, there's more than one-third of patients, a lot of patients, are in the high-risk group. And we know what the issue is, prolonged waitlisting. And now, we know that if we could transplant the patient within 7 days or if we could use balloon pump, which is a protective factor, which will help transplant these patients earlier.

Dr Yarboro. Thank you. The second question is, your finding of increased wait time for those patients with the blood group O is consistent with our previous work showing the same thing, in the durable LVAD population. Given that these patients are less likely to progress to transplant, do you think there needs to be a further change in how we allocate organs, or should we be managing these patients who are at disadvantaged from their blood group differently?

Dr Kawabori. Absolutely. In my research group, we do run multiple UNOS analyses. And then, one of the topics—one of the other topics we have is blood type O transplantation under the new allocation system, which our surgical fellow, Dr Eapen, will present today at rapid-fire oral today. I don't want to steal her thunder. However, long story short, there is—so blood type O recipient could only receive type O donors. However, only 75% of donor O heart are allocated to O recipients. So, there's 25% of patient donor O hearts, which is leaking out to type A, 15%, and type B, 10%. So, if we could potentially make some allocation algorithm changes, that might help save some of the blood type O recipients.

Dr Yarboro. Thank you. And finally, we have found deconditioning to be a significant problem for our patients who are awaiting transplant with mechanical support. And were you able to identify any data that were related to cannulation strategy and success in terms of transitioning them to transplant?

Dr Kawabori. That is one of the limitations of our study, the UNOS database data of granularity. So UNOS data do not have the cannulation strategy. So, I think the ELSO database, those have the cannulation site. So, I think studies using the ELSO database will help understand those clinical questions.

Dr Yarboro. Thank you.

Dr Kawabori. Thank you.

Dr Yarboro. And the follow-up to that is, what is your center-specific approach to cannulation for patients who might be blood type O? Is it used any differently, or do you have any thoughts to that?

Dr Kawabori. In our centers, we basically do femoral cannulations. And if the patient does not look optimized enough for transplant, then either we use [inaudible] 55 or bridge with surgical bypass.

Dr Yarboro. Thank you.

Dr Kawabori. Thank you.

Dr Yarboro. Congratulations.

Dr Kawabori. Thank you.

Dr Scott Silvestry *(Orlando, Fla)*. No disclosures for this. So, the question is—2 questions, short questions. First is, you need to look at whether this is acute ECMO or chronic ECMO. These patients who decompensate and then get transplanted or are these patients who are chronic, who slide into ECMO and ECMO is used, and you can get that by looking at the time from listing to actual ECMO. And the date is in the SRTR, so that you can tell patients who were listed who get ECMO as opposed to patients who were listed with ECMO, which is a very important difference. My question to you is we have these data—and then I'll ask the question. So what? What do you do

differently? What is the actionable item? Is it the patients—the sick patients who don't get transplanted because they're not really ready for transplant or is it the doctors? They're picking and choosing the hearts that they want. They're not willing to take a 50-year-old heart for a 30-year-old who's receiving ECMO. What is the factor? And the reality is, it's probably variable in different places, but we wanted on the committee ECMO 7 days only. And we didn't want to renew because at some point, as Donna Mancini said, "ECMO becomes a chronic choice because there's a game advantage of transplants."

Dr Kawabori. I think that's a very good point. In the UNOS database it doesn't have data on how many days were there on ECMO prior to this date. So, there is acute and also chronic ECMO patients, which cannot be captured from these data. And I understand that the ECMO duration is 1 of the factors, so I totally agree with you that ECMO >7 days might be overused.

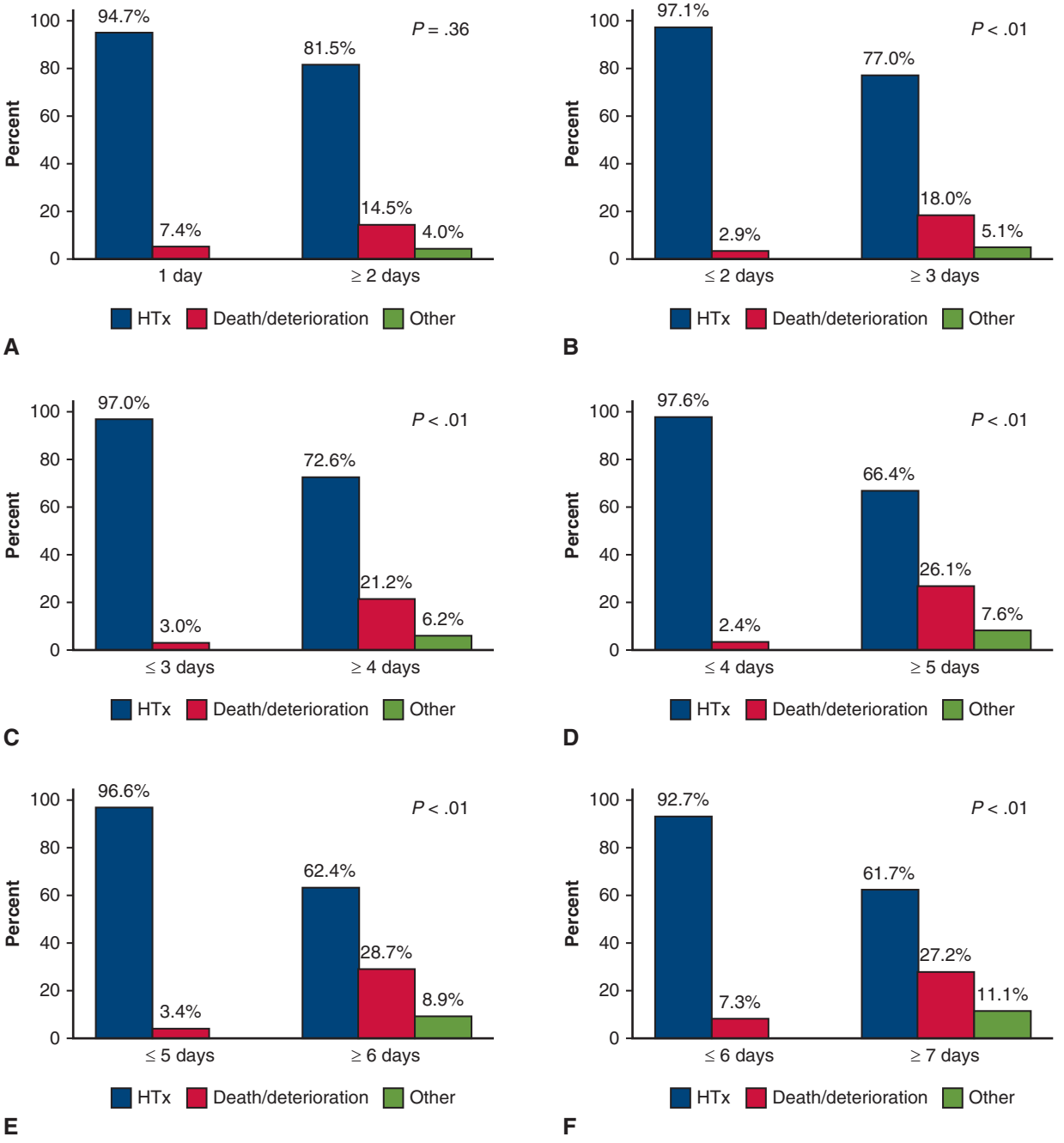

FIGURE E1. Bar charts showing reasons for waitlist removal as days on the waitlist increase. A, One versus ≥2 days; (B) ≤2 versus ≥3 days; (C) ≤3 versus ≥4 days; (D) ≤4 versus ≥5 days; (E) ≤5 versus ≥6 days; and (F) ≤6 versus ≥7 days. *HTx*, Heart transplantation.

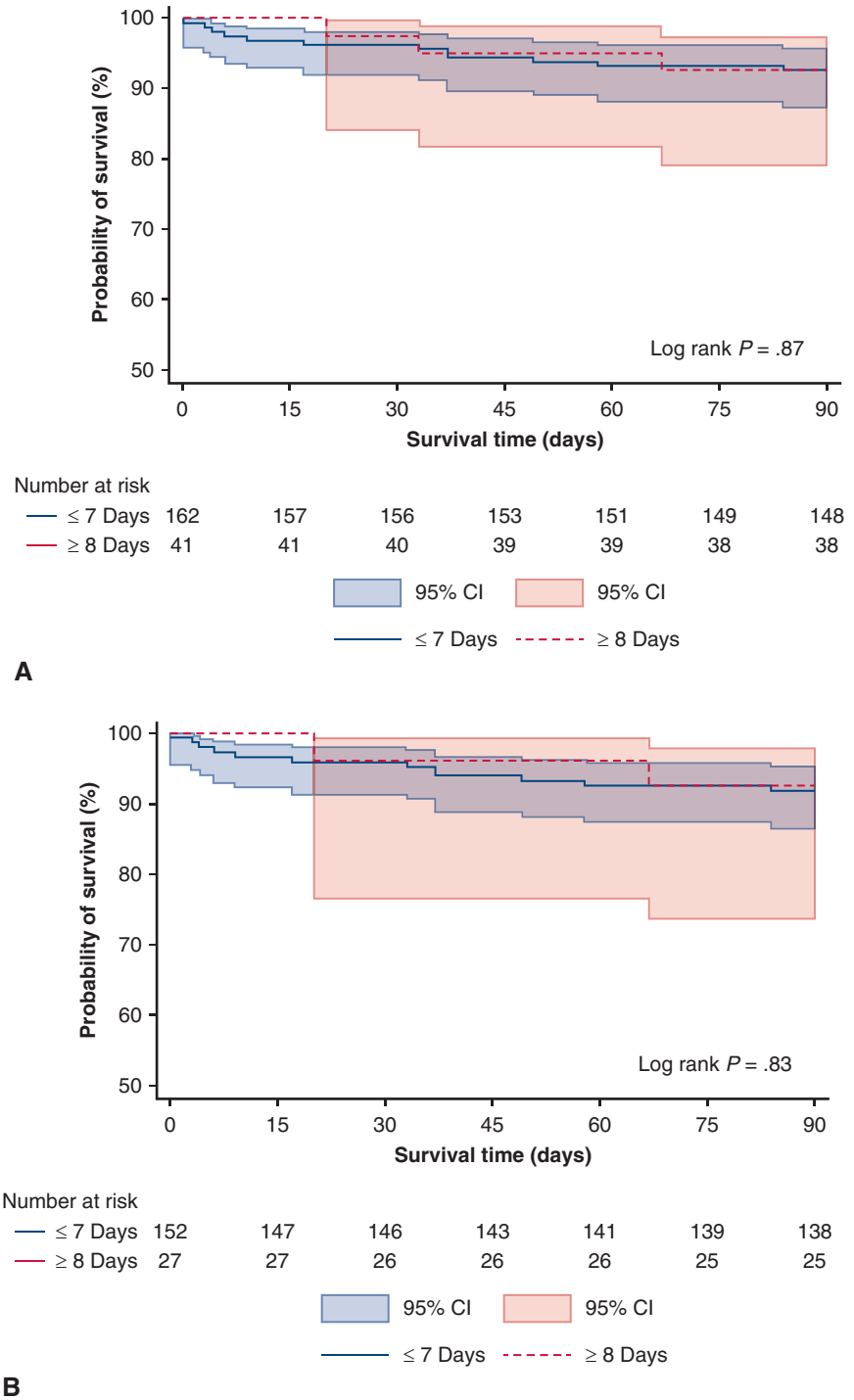

FIGURE E2. Kaplan–Meier curves showing post-HTx survival stratified according to listing time (A) cohortwide (adjusted HR, 1.13; 95% CI, 0.32-4.05) and (B) among candidates listed at status 1 (adjusted HR, 1.08; 95% CI, 0.24-4.87). *CI*, Confidence intervals.

TABLE E1. Candidate characteristics, status 1 only

	≤7 Days (n = 162)		≥8 Days (n = 48)	*P* value
Age, y	53 (38-60)		49 (32-58)	.18
Female sex	44 (27.2)		16 (33.3)	.41
BMI	27.4 (24.1-31.7)		30.0 (24.5-33.3)	.15
Blood type O	59 (36.4)		27 (56.3)	**.01**
Ethnicity				.74
White	117 (72.2)		32 (66.7)	
Black	21 (13.0)		8 (16.7)	
Other	24 (14.8)		8 (16.7)	
Region*				.12
Northeast	54 (33.3)		10 (20.8)	
Southeast	40 (24.7)		17 (35.4)	
Midwest	36 (22.2)		15 (31.3)	
West	32 (19.8)		6 (12.5)	
Private insurance	100 (61.7)		33 (68.8)	.38
Heart failure etiology				.34
Nonischemic	110 (67.9)		29 (60.4)	
Ischemic	52 (32.1)		18 (39.6)	
Medical history				
Diabetes	31 (19.3)	11 (22.9)		.58
CVA	10 (6.3)	4 (8.3)		.62
ICD	53 (32.7)	16 (33.3)		.94
Smoking	34 (21.0)	17 (35.4)		**.04**
Previous cardiac surgery	37 (22.8)	12 (25.0)		.76
Inotrope-dependent	89 (54.9)	24 (50.0)		.55
Ventilator-dependent	55 (34.0)	13 (27.1)		.37
Creatinine ≥1.5 mg/dL	33 (20.4)	16 (33.3)		.06
Concurrent MCS				
IABP	31 (19.1)		3 (6.3)	**.03**
Microaxial LVAD	25 (15.4)		5 (10.4)	.44
Durable LVAD	1 (0.6)		0	1.00

Variables are presented as percent. Statistical significant *P*-values were shown in bold. *BMI*, Body mass index; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

TABLE E2. Risk factors for prolonged waitlist time (≥8 days), status 1 only

	Univariable		Multivariable	
	OR (95% CI)	***P* value**	**OR (95% CI)**	***P* value**
Age, y	0.98 (0.96-1.01)	.16	0.98 (0.95-0.999)	**.049**
Female sex	1.34 (0.67-2.68)	.41	1.51 (0.71-3.22)	.28
Obese	2.02 (1.05-3.89)	**.04**	2.04 (1.00-4.17)	**.049**
Blood type O	2.24 (1.17-4.32)	**.02**	2.42 (1.19-4.90)	**.01**
White ethnicity	0.77 (0.39-1.54)	.46		
Region*				
Northeast	Referent	–	Referent	–
Southeast	2.29 (0.95-5.54)	.07	2.24 (0.87-5.75)	.09
Midwest	2.25 (0.91-5.56)	.08	2.01 (0.76-5.30)	.16
West	1.01 (0.34-3.05)	.98	0.98 (0.31-3.13)	.98
Private insurance	1.36 (0.69-2.71)	.38		
Ischemic HF etiology	1.39 (0.71-2.70)	.34		
Medical history				
Diabetes	1.25 (0.57-2.72)	.58		
CVA	1.35 (0.41-4.53)	.62		
ICD	1.03 (0.52-2.04)	.94		
Smoking	2.06 (1.02-4.17)	**.04**		
Previous cardiac surgery	1.13 (0.53-2.38)	.76		
Inotrope-dependent	0.82 (0.43-1.56)	.55		
Ventilator-dependent	0.72 (0.35-1.48)	.37		
Creatinine ≥1.5 mg/dL	1.95 (0.96-3.98)	.07		
Concurrent MCS				
IABP	0.28 (0.08-0.97)	**.04**	0.37 (0.10-1.32)	.13
Microaxial LVAD	0.65 (0.24-1.81)	.41		
Durable LVAD	–	–		

Statistical significant *P*-values were shown in bold. *OR*, Odds ratio; *CI*, confidence intervals; *HF*, heart failure; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

TABLE E3. Relationship between waitlist ≥8 days and postlisting death or deterioration, landmarked at 8 days, status 1 only

	Univariable		Multivariable	
	HR (95% CI)	***P* value**	**HR (95% CI)**	***P* value**
Waitlist ≥8 d	5.48 (2.46-12.2)	<**.01**	5.49 (2.39-12.6)	<**.01**
Age, y	1.03 (0.99-1.06)	.07	1.04 (1.01-1.07)	**.02**
Female sex	1.15 (0.50-2.66)	.75		
Obese	3.34 (1.48-7.57)	<**.01**	2.41 (1.05-5.52)	**.04**
Blood type O	2.19 (0.99-4.88)	.054		
White ethnicity	0.50 (0.22-1.10)	.09		
Region*				
Northeast	Referent	–		
Southeast	3.68 (1.17-11.6)	**.03**		
Midwest	1.95 (0.55-6.93)	.30		
West	1.79 (0.45-7.15)	.41		
Private insurance	0.67 (0.30-1.47)	.32		
Ischemic HF etiology	1.71 (0.78-3.77)	.18		
Medical history				
Diabetes	2.31 (0.998-5.36)	.051		
CVA	3.34 (1.14-9.77)	**.03**		
ICD	1.37 (0.62-3.06)	.44		
Smoking	2.15 (0.97-4.80)	.06		
Previous cardiac surgery	1.89 (0.84-4.28)	.14		
Inotrope-dependent	0.69 (0.32-1.53)	.37		
Ventilator-dependent	1.28 (0.56-2.89)	.56	1.44 (0.63-3.27)	.39
Creatinine ≥1.5 mg/dL	2.47 (1.11-5.50)	**.03**	1.69 (0.75-3.81)	.21
Concurrent MCS				
IABP	0.44 (0.10-1.87)	.27		
Microaxial LVAD	1.72 (0.65-4.59)	.28		
Durable LVAD	–	–		

Statistical significant *P*-values were shown in bold. *HR*, Hazard ratio; *CI*, confidence intervals; *HF*, heart failure; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

TABLE E4. Characteristics of HTx recipients and donors, and operative characteristics stratified according to waitlist time

	≤7 Days (n = 162)	≥8 Days (n = 41)	*P* value
Recipient			
Age, y	53 (38-60)	44 (31-57)	**.04**
Female sex	44 (27.2)	10 (24.4)	.72
BMI	27.3 (24.2-31.0)	27.3 (22.3-31.3)	.56
Blood type O	57 (35.2)	22 (53.7)	**.03**
Ethnicity			.17
White	119 (73.5)	24 (58.5)	
Black	21 (13.0)	8 (19.5)	
Other	22 (13.6)	9 (22.0)	
Medical history			
Diabetes	27 (16.7)	7 (17.1)	.96
Smoking	36 (22.2)	12 (29.3)	.34
CVA	10 (6.3)	1 (2.4)	.47
Region			.12
Northeast	54 (33.3)	10 (24.4)	
Southeast	39 (24.1)	16 (39.0)	
Midwest	36 (22.2)	11 (26.8)	
West	33 (20.4)	4 (9.8)	
Private insurance	102 (63.0)	25 (61.0)	.81
Ischemic HF etiology	48 (29.6)	8 (19.5)	.20
MCS at time of HTx			
IABP	32 (19.8)	6 (14.6)	.45
ECMO	155 (95.7)	26 (63.4)	**<.01**
Durable LVAD	1 (0.6)	5 (12.2)	**<.01**
Microaxial LVAD	24 (14.8)	6 (14.6)	.98
Creatinine ≥1.5 mg/dL	35 (21.6)	10 (24.4)	.70
Inotrope-dependent	85 (52.5)	21 (51.2)	.89
Ventilator-dependent	47 (29.0)	3 (7.3)	**<.01**
HTx status			**<.01**
1	159 (98.2)	32 (78.1)	
2	3 (1.9)	6 (14.6)	
3	0	3 (7.3)	
4	0	0	
6	0	0	
Donor			
Age, y	32 (25-39)	29 (21-38)	.12
Female sex	29 (17.9)	9 (22.0)	.55
Blood type O	112 (69.1)	27 (65.9)	.69
BMI	26.6 (23.5-31.2)	26.8 (24.6-32.2)	.56
Ethnicity			.85
White	107 (66.1)	29 (70.7)	
Black	27 (16.7)	6 (14.6)	
Other	28 (17.3)	6 (14.6)	
Medical history			
Smoking	18 (11.3)	1 (2.4)	.09
Hypertension	21 (13.0)	7 (17.1)	.51
Cocaine use	45 (28.0)	9 (23.1)	.54
Alcohol use	32 (20.0)	13 (32.5)	.09
HCV-positive	14 (8.6)	2 (2.4)	.18
CMV-positive	85 (52.5)	22 (53.7)	.89
Trauma COD	73 (45.1)	21 (51.2)	.48
Creatinine ≥1.5 mg/dL	49 (30.3)	17 (41.5)	.17
LVEF, %	60 (56-65)	60 (60-65)	.43
Operative characteristics			
Ischemic time ≥4 h	36 (22.4)	8 (19.5)	.69
Distance, nautical miles	256 (91-414)	302 (138-416)	.32

(Continued)

TABLE E4. Continued

Continuous variables are presented as median (interquartile range) and categorical variables are presented as n (%). Statistical significant *P*-values were shown in bold. *BMI*, Body mass index; *CVA*, cerebrovascular accident; *HF*, heart failure; *MCS*, mechanical circulatory support; *HTx*, heart transplant; *IABP*, intra-aortic balloon pump; *ECMO*, extracorporeal membrane oxygenation; *LVAD*, left ventricular assist device; *HCV*, hepatitis C virus; *CMV*, cytomegalovirus; *COD*, cause of death; *LVEF*, left ventricular ejection fraction.

TABLE E5. Characteristics of HTx recipients and donors, and operative characteristics stratified according to waitlist time, status 1 listing only

	≤7 d (n = 152)	≥8 d (n = 27)	*P* value
Recipient			
Age, y	53 (38-60)	39 (28-56)	**.04**
Female sex	43 (28.3)	8 (29.6)	.89
BMI	27.3 (24.2-30.7)	28.0 (20.5-31.3)	.74
Blood type O	55 (36.2)	14 (51.9)	.12
Ethnicity			.41
White	114 (75.0)	17 (63.0)	
Black	17 (11.2)	5 (18.5)	
Other	21 (13.8)	5 (18.5)	
Medical history			
Diabetes	25 (16.6)	5 (18.5)	.80
Smoking	32 (21.1)	8 (29.6)	.32
CVA	9 (6.0)	1 (3.7)	.63
Region			.14
Northeast	52 (34.2)	8 (29.6)	
Southeast	34 (22.4)	6 (22.2)	
Midwest	34 (22.4)	11 (40.7)	
West	32 (21.1)	2 (7.4)	
Private insurance	96 (63.2)	21 (77.8)	.14
Ischemic HF etiology	46 (30.3)	7 (25.9)	.65
MCS at time of HTx			
IABP	31 (20.4)	5 (18.5)	.82
ECMO	147 (96.7)	19 (70.4)	**<.01**
Durable LVAD	0	2 (7.4)	**.02**
Microaxial LVAD	22 (14.5)	2 (7.4)	.32
Creatinine ≥1.5 mg/dL	30 (19.7)	7 (25.9)	.46
Inotrope-dependent	80 (52.6)	15 (55.6)	.78
Ventilator-dependent	45 (29.6)	2 (7.4)	**.02**
HTx status			**<.01**
1	152 (100)	24 (88.9)	
2	0	2 (7.1)	
3	0	1 (3.7)	
4	0	0	
6	0	0	
Donor			
Age, y	32 (26-38)	31 (19-38)	.25
Female sex	28 (18.4)	9 (33.3)	.08
Blood type O	108 (71.1)	18 (66.7)	.65
BMI	26.7 (23.5-31.3)	28.2 (23.8-34.6)	.62
Ethnicity			.92
White	100 (65.8)	18 (66.7)	
Black	25 (16.5)	5 (18.5)	
Other	27 (17.8)	4 (14.8)	
Medical history			
Smoking	18 (12.0)	1 (3.7)	.20
Hypertension	19 (12.6)	6 (22.2)	.18
Cocaine use	43 (28.5)	6 (24.0)	.64
Alcohol use	30 (20.0)	7 (25.9)	.49
HCV-positive	14 (9.2)	1 (3.7)	.34
CMV-positive	79 (52.0)	15 (55.6)	.73
Trauma COD	65 (42.8)	16 (59.3)	.11
Creatinine ≥1.5 mg/dL	47 (30.9)	11 (40.7)	.32
LVEF, %	60 (57-65)	60 (60-65)	.92
Operative characteristics			
Ischemic time ≥4 h	32 (21.1)	5 (18.5)	.76
Distance, nautical miles	251 (95-412)	302 (138-447)	.24

(Continued)

TABLE E5. Continued

Continuous variables are presented as median (interquartile range) and categorical variables are presented as n (%). Statistical significant *P*-values were shown in bold. *BMI*, Body mass index; *CVA*, cerebrovascular accident; *HF*, heart failure; *MCS*, mechanical circulatory support; *HTx*, heart transplant; *IABP*, intra-aortic balloon pump; *ECMO*, extracorporeal membrane oxygenation; *LVAD*, left ventricular assist device; *HCV*, hepatitis C virus; *CMV*, cytomegalovirus; *COD*, cause of death; *LVEF*, left ventricular ejection fraction.

TABLE E6. Demographic characteristics of candidates waitlisted ≥8 days stratified according to waitlist outcome

	HTx (n = 41)	Death/deterioration (n = 21)	*P* value
Age, y	44 (31-57)	58 (49-64)	**<.01**
Female sex	10 (24.4)	8 (38.1)	.26
BMI	27.2 (22.9-32.8)	28.6 (25.8-32.3)	.34
Blood type O	22 (53.7)	14 (66.7)	.33
Ethnicity			.88
White	24 (58.5)	13 (61.9)	
Black	8 (19.5)	3 (14.3)	
Other	9 (22.0)	5 (23.8)	
Region*			.38
Northeast	10 (24.3)	4 (19.1)	
Southeast	16 (39.0)	9 (42.9)	
Midwest	11 (26.8)	3 (14.3)	
West	4 (9.8)	5 (23.8)	
Private insurance	26 (63.4)	10 (47.6)	.23
Heart failure etiology			**<.01**
Nonischemic	33 (80.5)	9 (42.9)	
Ischemic	8 (19.5)	12 (57.1)	
Medical history			
Diabetes	7 (17.1)	10 (47.6)	**.01**
CVA	1 (2.4)	5 (23.8)	**.01**
ICD	16 (39.0)	8 (38.1)	.94
Smoking	12 (29.3)	8 (38.1)	.48
Previous cardiac surgery	9 (22.0)	7 (33.3)	.33
Inotrope-dependent	21 (51.2)	12 (57.1)	.66
Ventilator-dependent	9 (22.0)	6 (28.6)	.57
Creatinine ≥1.5 mg/dL	14 (34.2)	9 (42.9)	.50
Concurrent MCS			
IABP	3 (7.3)	2 (9.5)	.76
Microaxial LVAD	3 (7.3)	4 (19.1)	.17
Durable LVAD	3 (7.3)	0	.20
Listing status			.97
1	27 (65.9)	14 (66.7)	
2	3 (7.3)	2 (9.5)	
3	3 (7.3)	1 (4.8)	
4	2 (4.8)	2 (9.5)	
6	3 (7.3)	1 (4.8)	
7	3 (7.3)	1 (4.8)	

Statistical significant *P*-values were shown in bold. *HTx*, Heart transplant; *BMI*, body mass index; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.

TABLE E7. Demographic characteristics of candidates waitlisted ≥8 days stratified according to waitlist outcome, status 1 only

	HTx (n = 27)	Death/deterioration (n = 14)	*P* value
Age, y	39 (28-56)	54 (39-63)	.18
Female sex	8 (29.6)	5 (35.7)	.69
BMI	28.0 (21.1-32.8)	30 (26.7-33.5)	.15
Blood type O	14 (51.9)	9 (64.3)	.45
Ethnicity			.93
White	17 (63.0)	9 (64.3)	
Black	5 (18.5)	2 (14.3)	
Other	5 (18.5)	3 (21.4)	
Region*			**.03**
Northeast	8 (29.6)	2 (14.3)	
Southeast	6 (22.2)	8 (57.1)	
Midwest	11 (40.7)	1 (7.1)	
West	2 (7.4)	3 (21.4)	
Private insurance	21 (77.8)	8 (57.1)	.17
Heart failure etiology			
Nonischemic	20 (74.1)	6 (42.9)	**.049**
Ischemic	7 (25.9)	8 (57.1)	
Medical history			
Diabetes	5 (18.5)	6 (42.9)	.10
CVA	1 (3.7)	3 (21.4)	.07
ICD	10 (37.0)	5 (35.7)	.93
Smoking	8 (29.6)	5 (35.7)	.69
Previous cardiac surgery	5 (18.5)	5 (35.7)	.22
Inotrope-dependent	14 (51.9)	8 (57.1)	.75
Ventilator-dependent	6 (22.2)	5 (35.7)	.36
Creatinine ≥1.5 mg/dL	8 (29.6)	6 (42.9)	.40
Concurrent MCS			
IABP	2 (7.4)	1 (7.1)	.98
Microaxial LVAD	2 (7.4)	3 (21.4)	.19
Durable LVAD	0	0	–

Statistical significant *P*-values were shown in bold. *HTx*, Heart transplant; *BMI*, body mass index; *CVA*, cerebrovascular accident; *ICD*, implantable cardioverter-defibrillator; *MCS*, mechanical circulatory support; *IABP*, intra-aortic balloon pump; *LVAD*, left ventricular assist device. *Northeast: UNOS regions 1, 2, and 9; Southeast: UNOS regions 3, 4, and 11; Midwest: UNOS regions 7, 8, and 10; and West: UNOS regions 5 and 6.