Published in final edited form as:

Ann Thorac Surg. 2013 April ; 95(4): 1251–1261. doi:10.1016/j.athoracsur.2012.10.089.

Septuagenarians Bridged to Heart Transplantation with a Ventricular Assist Device Have Similar Outcomes as Younger Patients

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Abstract

INTRODUCTION—Although orthotopic heart transplantation (OHT) is increasingly being offered to older patients, few studies have evaluated outcomes in patients over the age of 70 years. We undertook this study to characterize the outcomes of septuagenarians bridged to heart transplantation (BTT) in the modern era.

METHODS—We conducted a retrospective cohort study of all adult OHT in the United Network for Organ Sharing database from 2005–2011. Primary stratification was by age 70 years. Subgroup analysis evaluated BTT patients. The primary outcome was survival as determined by the Kaplan-Meier method.

RESULTS—From 01/2005–12/2011, 12,274 adults underwent OHT, including 3,243 (26.4%) who were BTT. In the entire cohort, 11,996 (97.7%) recipients were ages 18–70, and 277 (2.3%) were 70 years of age. Overall, OHT patients 70 had decreased 90-day (93.6 vs 88.8%, $p<0.01$), 1-year (89.0 vs 81.6%, $p<0.01$), and 2-year (85.4 vs 79.9%, $p<0.01$) survival compared to recipients of other ages. However, in the BTT subgroup, recipients 70 ($n=43$) had similar 90-day (91.2 vs 84.7%, $p=0.2$), 1-year (86.1 vs 81.7%, $p=0.4$), and 2-year (82.8 vs 81.7%, $p=0.6$) survival compared to recipients of other ages ($n=3,200$). After adjusting for multiple recipient and donor factors, age 70 was still not associated with an increased hazard of mortality at 90-days, 1-year, or 2-years. These results were verified by analysis of a propensity-matched cohort.

CONCLUSIONS—Although patients over the age of 70 years undergoing OHT have decreased survival, amongst patients bridged to heart transplantation, septuagenarians have similar outcomes as younger recipients. In carefully selected, LVAD-dependent patients, recipient age 70 should not be viewed as a contraindication to OHT.

Keywords

Transplantation; Heart; Geriatric; Circulatory assist devices

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*Recipient of the 2004 Hawley H. Seiler Resident Award.

Conflicts: The authors have no relevant conflicts of interest.

Presentation The contents of this manuscript have been accepted for oral presentation at the 59th Annual Meeting of the STSA.

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INTRODUCTION

In the next two decades, the proportion of the United States population over the age of 65 years is expected to double.[1] As the population ages, complex cardiac surgery, including orthotopic heart transplantation (OHT), is increasingly being offered to older patients. Although OHT was initially limited to patients under the age of 50, the current Class I guidelines of the International Society for Heart and Lung Transplantation (ISHLT) recommend consideration of patients $\geq$ 70 years of age for transplantation.[2,3] However, 10% of patients over the age of 70 may suffer from congestive heart failure with as many as 150,000 septuagenarians exhibiting class IV symptoms.[4,5]

Although many elderly patients could benefit from OHT, outcomes in this population are mixed, with several studies demonstrating decreased short and long-term survival.[1,6–14] While many of these elderly patients can be treated with a ventricular assist device (VAD), VAD implantation and support in this population may be associated with decreased survival.[15] Moreover, although outcomes continue to improve, patients bridged to transplantation (BTT) with a VAD may have decreased post-OHT survival.[16] As the number of septuagenarians with heart failure continues to increase, clinicians will increasingly be required to consider OHT in this population. Since recent events have raised public awareness of the issues surrounding OHT in the elderly,[17] we undertook this study to further characterize OHT and BTT outcomes in septuagenarians.

MATERIAL AND METHODS

Data Source

For this study, we utilized the United Network for Organ Sharing (UNOS) database from the UNOS registry, an open cohort of all OHT patients in the United States. The Johns Hopkins Medicine Institutional Review Board approved this study.

Study Design

We conducted a retrospective cohort study of all adults (age $\geq$ 18) who underwent OHT from 01/2005–12/2011. Patients undergoing re-transplantation, combined heart-lung transplantation, and multi-organ transplantation were excluded. Primary stratification was according to recipient age at the time of OHT. Elderly patients were defined by recipient age $\geq$ 70 years at the time of transplantation. Secondary stratification compared recipients of age $\geq$ 70 to recipients of ages 60–70. Subgroup analysis focused on BTT patients.

Variables Examined and Outcomes Measured

We examined pertinent covariates in the database, including: recipient demographics and co-morbidities; recipient hemodynamics, measures of acuity, and need for support; donor demographics and co-morbidities; and transplant variables. Annual center volume was calculated and stratified into 4 quartiles each consisting of an equal number of OHT patients. The primary end-points were 90-day, 1-year, and 2-year survival.

Statistical Analysis

We compared baseline characteristics using the Student's t-test (continuous parametric variables), the Wilcoxon rank-sum test (continuous non-parametric variables), and the chi-square or Fisher's exact test (categorical variables) as appropriate.

Survival was estimated using the Kaplan-Meier method and survival functions were compared using the log-rank test. Multivariable Cox proportional hazards regression models were constructed to estimate mortality with censoring for death and loss to follow-up. To

construct our multivariable models, independent covariates were tested in univariate fashion. Variables associated with mortality on exploratory analysis ($p < 0.20$), those with previous literature support, and those with biological plausibility were incorporated in a forward and backward stepwise fashion into the multivariable model. The likelihood ratio test and Akaike's information criterion were utilized in a nested model approach to identify the parsimonious model with the greatest explanatory power.

The impact of age was further evaluated with propensity matching. To construct our propensity score, a multivariable logistic regression model was constructed as discussed above. Patients under the age of 70 were then matched to patients over the age of 70 in 2:1 fashion using nearest-neighbor matching. The propensity-matched cohort was then analyzed using univariate and multivariable analysis.

For all analyses, $p < 0.05$ (two-tailed) was considered statistically significant. Mean values are displayed with their standard deviations and median values are displayed with their interquartile ranges. Hazard ratios are presented with their 95% confidence intervals. Statistical analysis was performed with STATA 12.0 (StataCorp LP, College Station, TX).

RESULTS

Cohort Statistics

From 2005–2011, 15,557 patients underwent OHT. After excluding pediatric patients ($n=2,411$), redo-OHT ($n=465$), and multi-organ transplants ($n=407$), our final cohort comprised 12,274 patients. The mean age of the cohort was 52 (± 13) years, 277 (2.3%) patients were over the age of 70, 3,846 (31.6%) patients were between 60 and 70, and 8,069 (66.2%) patients were younger than 60. 3,243 (26.4%) patients were bridged to transplantation with mechanical circulatory support, including 1,830 (14.9%) patients bridged with a Heartmate II device (Thoratec Corporation, Pleasanton, CA).

In the BTT subgroup, the mean age was 51 (± 13) years, 43 (1.3%) patients were over the age of 70, 891 (27.6%) patients were between 60 and 70, and 2,290 (71.0%) patients were younger than 60. An examination of volume over time suggests that both the total and the elderly annual volumes of BTT patients are increasing (Figure 1).

Baseline Characteristics

Amongst all patients undergoing OHT, there were some notable differences in baseline characteristics (Table 1). Patients over the age of 70 were more likely to be male, of white ethnicity, and to have higher creatinine levels. They were also more likely to be supported by an older generation VAD, less likely to be hospitalized, and more likely to undergo their OHT at a higher volume center. Older patients were also more likely to receive hearts from older donors of the same ethnicity.

In the BTT cohort, patients over the age of 70 were well-matched to the younger cohort (Table 2). However, older patients were more likely to receive organs from older donors and were more likely to undergo their OHT at higher volume centers.

OHT Outcomes

On unadjusted analysis, recipient age ≥ 70 was associated with decreased survival at 90-days (93.6% vs. 88.9%, $p=0.003$), 1-year (89.1% vs. 81.9%, $p<0.001$), and 2-years (85.4% vs. 79.6%, $p=0.003$; Figure 2a) compared to younger recipients. The difference in survival appears to be driven by perioperative mortality. In patients who survive to 90 days, 1-year survival still favored the younger cohort ($p=0.04$), but was similar by 2-years ($p=0.2$; Figure

2b). Compared to patients in their 60s, recipients in their 70s still tended to have decreased survival at 90-days (93.6% vs. 88.9%, $p=0.059$), 1-year (89.1% vs. 81.9%, $p=0.02$), and 2-years (85.4% vs. 79.6%, $p=0.054$; Figure 2c).

The differences in mortality between recipients over the age of 70 and younger patients persisted on multivariable analysis at 90-days (HR: 1.86 [1.26–7.75], $p=0.002$), 1-year (HR: 1.73 [1.26–2.37], $p=0.001$; Table 3), and 2-years (HR: 1.56 [1.15–2.11], $p=0.004$). After adjustment, recipients over the age of 70 did not have an increased hazard of mortality compared to recipients in their 60s at 90-days (HR: 1.47 [0.98–2.22], $p=0.1$), 1-year (HR: 1.38 [0.99–1.92], $p=0.1$), and 2-years (HR: 1.30 [0.95–1.78], $p=0.1$).

BTT Outcomes

In the BTT subgroup, recipient age ≥ 70 was not associated with decreased survival at 90-days (91.3% vs. 85.0%, $p=0.2$), 1-year (86.3% vs. 81.8%, $p=0.4$), or 2-years (82.8% vs. 81.8%, $p=0.6$; Figure 3a). Although the numbers are small, amongst patients bridged to transplantation with the modern, continuous flow Heartmate II device, recipients over the age of 70 had decreased survival at 90-days (93.5% vs. 79.7%, $p=0.004$) but similar survival at 1-year (88.2% vs. 79.7%, $p=0.1$) and 2-years (85.2% vs. 79.7%, $p=0.1$; Figure 3b). When compared to BTT patients in their 60s, recipients in their 70s had similar survival at 90-days (88.2% vs. 85.0%, $p=0.6$), 1-year (81.9% vs. 81.8%, $p=0.9$) and 2-years (78.5% vs. 81.8%, $p=0.8$; Figure 3c). On adjusted analysis, recipients over the age of 70 did not have an increased hazard of mortality compared to younger patients at 90-days (HR: 1.58 [0.64–3.88], $p=0.3$), 1-year (HR: 1.30 [0.58–2.95], $p=0.5$; Table 4), or 2-years (HR: 1.14 [0.51–2.57], $p=0.8$).

With propensity score matching, 42 elderly BTT patients were matched 2:1 with younger BTT patients to yield a propensity matched cohort of 126 patients. In the final propensity score, patients were matched based on recipient gender, creatinine, diagnosis, ICU status, donor age, need for donor inotropic support, recipient-donor gender matching, organ ischemic time, and annual center volume. The average age in the younger cohort was 53 (± 11) while in the elderly cohort it was 71 (± 1) years. After propensity matching, all other baseline characteristics were similar between the groups. On univariate analysis, age ≥ 70 years was not associated with increased mortality at 90 days (92.8 vs. 87.3%, $p=0.3$), 1-year (89.0 vs. 83.9%, $p=0.5$), or 2-years (81.9 vs. 83.9%, $p=0.9$; Figure 4). Elderly patients bridged with Heartmate II devices also did not have increased mortality at any time point ($p=NS$). On multivariable analysis, age ≥ 70 was not associated with an increased hazard of mortality at any time point ($p=NS$).

COMMENT

In this study, OHT recipients over the age 70 had decreased short and long-term survival compared to younger patients. These survival differences appear to be mediated by early mortality. Additionally, on adjusted analysis, recipients in their 70s had similar outcomes as recipients in their 60s. Moreover, amongst BTT patients, septuagenarians had similar survival compared to younger patients on both univariate and multivariable analysis. These findings were confirmed by analysis of a propensity-matched cohort.

OHT Outcomes

Although OHT is the gold-standard of therapy for patients with end-stage heart failure, its use is limited by the supply of donor hearts.[18–20] Contemporaneous with these organ shortages is the increasingly elderly population of the United States. Congestive heart failure is common in the elderly population which is expected to double over the next two decades. [1,4,5] Thus, clinicians involved in OHT are increasingly forced to consider transplanting

these elderly patients. Therefore, appropriate assessment of the risk associated with increasing recipient age is essential to optimize OHT outcomes.

The outcomes of elderly patients undergoing OHT are mixed, in part due to various definitions of “elderly.” Although several studies have suggested that elderly OHT patients have similar outcomes as younger patients,[7–9,13,14] the majority of larger studies have found increasing age to be associated with poorer short and long-term survival.[1,6,10–12,19] In the most recent ISHLT registry report, increasing recipient age was strongly associated with decreased short and long-term survival.[18] Given these mixed outcomes, the current ISHLT guidelines suggest that recipients ≥ 70 should be considered for OHT(Class I) and that carefully selected patients > 70 may be considered for OHT(Class IIb).[3]

Despite these recommendations, the number of elderly recipients being transplanted appears to be increasing. However, the paucity of available organs and the prominent and recent transplantation of our 71 year-old former Vice President have led many academicians and pundits alike to question whether OHT in septuagenarians optimizes the outcomes associated with these scarce resources.[17]

In this study, septuagenarians undergoing OHT demonstrated 90-day, 1-year, and 2-year survivals of 89%, 82%, and 80%, respectively. Although these survival figures are lower than in younger patients, a 1-year survival of 82% is acceptable, particularly considering the low expected survival of these patients without a transplant. Additionally, on adjusted analysis, we found that patients over 70 did not have an increased hazard of mortality compared to patients in their 60s. Although a type II error is possible, these results suggest that at worst, septuagenarians are at only marginally increased risk of short-term mortality compared to sexagenarians. Therefore, while our current and previously published data suggest that elderly patients appear to suffer from marginally increased post-OHT mortality, there is no compelling reason why the increased risk associated with patients over 60 should be tolerated while the increased risk associated with patients over 70 should not.[12,21] These data suggest that septuagenarians should not be excluded from OHT on the basis of their age alone.

BTT Outcomes

An increasing number of patients are being either temporarily or permanently supported with mechanical circulatory support, particularly since the FDA approval of the Heartmate II device in 2008. Although VAD implantation carries significant risk, short and long-term outcomes continue to improve in all age groups making this a viable solution for patients with advanced heart failure.[22] Recently, Adamson et al. reported excellent VAD implantation results in septuagenarians, with patients over 70 demonstrating similar short-term survival, functional status, and quality of life compared to younger patients.[4] Because of these excellent VAD outcomes, an increasing number of patients, including septuagenarians, are being bridged to transplantation with VAD support.[15]

Whether BTT patients are at increased risk of post-OHT mortality is unclear. Although early reports suggested that BTT patients had worse post-OHT survival than non-VAD dependent recipients, more recent data suggest that MCS, particularly intracorporeal VADs, are not associated with an increased risk of mortality.[16,23,24] Regardless, there is little doubt that this operation is associated with increased complexity. Theoretically, elderly patients may have less physiologic reserve to tolerate the more difficult operation. However, despite the more complex operation, in our BTT subgroup, septuagenarians had similar short-term survival compared to younger recipients. Notably, in patients over 70, 1-year survival was 82%, again reflecting acceptable outcomes.

In the subgroup of BTT patients supported with the modern Heartmate II device, despite septuagenarians having slightly increased 90-day mortality, 1 and 2-year mortality were similar compared to younger patients. Moreover, septuagenarians bridged with Heartmate II devices had virtually identical outcomes compared to sexagenarians. Although the sample size of BTT septuagenarians is relatively small, and thus our results are prone to a type II error, these data suggest that even if a difference does exist, its magnitude is relatively small.

Implications

Overall, these data suggest that both VAD-dependent and VAD-independent septuagenarians have similar and acceptable OHT outcomes compared to younger patients. Although these data are encouraging, they should not be interpreted as supporting indiscriminate transplantation in the elderly. Rather, these data suggest that in carefully selected patients, an absolute age cutoff for OHT recipients is an outdated concept. Advanced age alone should not be an absolute contraindication to transplantation. Rather chronological age should be considered in combination with other recipient co-morbidities and overall health status to determine recipient risk.

Since we focused on modern OHT outcomes, we could not evaluate long-term survival. While it is unclear whether elderly patients have decreased long-term survival, we suspect that this is one of the primary assumptions in limiting OHT in the elderly. However, in addition to absolute survival, it is important to consider recipient quality of life. Although this database analysis cannot assess quality of life, we believe elderly patients may be more likely to achieve their potentially more modest family, lifestyle, and career goals. These types of quality of life factors should be considered.

Limitations

First, although the UNOS database represents the largest national sample of OHT recipients available, the number of septuagenarians, particularly BTT patients, undergoing OHT is limited. Thus, a type II error may exist. Further national experience transplanting patients in this age group is necessary to validate these findings.

Second, in an effort to examine a modern cohort of OHT patients with contemporary VADs, we limited our analysis to OHT since 2005. Thus we were unable to examine long-term survival which may be different in the elderly.

Finally, although our results suggest that septuagenarians bridged to heart transplantation have similar results as younger patients, the database does not contain data on outcomes of septuagenarians after VAD implantation while awaiting heart transplantation. These data may affect the overall decision to bridge a 70 year old patient to OHT.

Conclusions

In conclusion, septuagenarians undergoing OHT have decreased but acceptable outcomes compared to younger patients. Amongst BTT patients, septuagenarians have similar outcomes compared to younger patients. In carefully selected patients, recipient age 70 should not be viewed as an absolute contraindication to OHT.

Acknowledgments

This research was supported by grant T32 2T32DK007713-12 from the National Institutes of Health (Dr. George). Dr. George is the Hugh R. Sharp Cardiac Surgery Research Fellow. Dr. Beaty is the Irene Piccinini Investigators in Cardiac Surgery.

ABBREVIATIONS AND ACRONYMS

BMI	Body mass index
BTT	Bridge to transplantation
CI	Confidence interval
HR	Hazard ratio
IABP	Intra-aortic balloon pump
ICU	Intensive care unit
LVAD	Left ventricular assist device
MCS	Mechanical circulatory support
OHT	Orthotopic heart transplantation
PA	Pulmonary artery
UNOS	United Network for Organ Sharing
VAD	Ventricular assist device

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Figure 1.
Bar graph depicting the number of patients bridged to transplantation each year stratified by recipient age.

Number at risk

Age 18-70	11,951	10,550	9,995	9,286	8,620	7,432	7,303	7,135	6,700
Age ≥ 70	276	219	200	184	168	128	128	128	125

Number at risk

Age 18-70	9,995	9,286	8,620	7,432	7,303	7,135	6,700
Age ≥ 70	200	184	168	128	128	128	125

Figure 2. 2-Year Kaplan-Meier survival curves stratified by recipient age for (A) all OHT recipients and (B) for all OHT recipients conditional on 90-day survival. (C) 2-Year Kaplan-Meier survival curves comparing OHT patients in their 60s to patients in their 70s. P-values determined by the log-rank test.

Figure 3.

2-Year Kaplan-Meier survival curves stratified by recipient age for (A) all BTT patients and (B) for patients bridged to transplantation with a Heartmate II device. (C) 2-Year Kaplan-Meier survival curves comparing BTT patients in their 60s to patients in their 70s. P-values determined by the log-rank test.

Figure 4.
2-Year Kaplan-Meier curve of the propensity-matched BTT cohort stratified by age. P-values determined by the log-rank test.

Table 1

Baseline Characteristics of all OHT recipients Stratified by Age

Variable	Age 18–70 (n=11,996)	Age 70 (n=277)	P-value*
Demographics and Co-morbidities			
Age (years)	52 (±12)	72 (±2)	<0.001
Male gender, n (%)	9,065 (75.6%)	243 (87.7%)	<0.001
White ethnicity, n (%)	8,339 (69.5%)	235 (84.8%)	
Black ethnicity, n (%)	2,275 (19.0%)	25 (9.0%)	
Hispanic ethnicity, n (%)	449 (3.7%)	6 (2.2%)	<0.001
Creatinine (mg/dL)	1.3 (±0.6)	1.4 (±0.5)	0.01
Total bilirubin (mg/dL)	0.8 [IQR: 0.5–1.3]	0.8 [IQR: 0.6–1.3]	0.9
Acuity, Hemodynamics, and Need for Support			
Cardiac index (L/min/m ²)	1.5 (±0.5)	1.4 (±.5)	0.3
Mean PA pressure (mmHg)	29 (±10)	28 (±9)	0.7
Inotropic support, n (%)	4,828 (40.3%)	105 (37.9%)	0.4
IABP support, n (%)	596 (5.0%)	17 (6.1%)	0.4
No MCS, n (%)	8,796 (73.3%)	234 (84.5%)	
Extracorporeal/Temporary MCS ^a , n (%)	160 (1.3%)	1 (0.4%)	
Pulsatile LVAD ^b , n (%)	1,155 (9.6%)	9 (3.3%)	
Continuous flow LVAD(excluding HM2) ^c , n (%)	87 (0.7%)	1 (0.4%)	
Heartmate II LVAD, n (%)	1,798 (15.0%)	32 (11.6%)	<0.001
Hospitalized, n (%)	5278/11954 (44.2%)	104/276 (37.7%)	0.03
ICU support, n (%)	3365/11954 (28.2%)	67/276 (24.3%)	0.2
Ventilator support, n (%)	298 (2.5%)	11 (4.0%)	0.1
Donor Variables			
Age (years)	31 (±12)	36 (±13)	<0.001
Male gender, n (%)	8,703 (72.6%)	186 (67.2%)	0.047
Transplant Variables			
Ischemic time (hours)	3.3 (±1.1)	3.3 (±1.1)	0.6
Same gender match, n (%)	8,828 (73.6%)	194 (70.0%)	0.2
Same race match, n (%)	6,419 (53.5%)	176 (63.5%)	0.001
Waitlist time (days)	75 [IQR: 22–210]	48 [IQR: 16–155]	<0.001
Annual Center Volume			
1–13 OHT/year	3,077 (25.7%)	42 (15.2%)	14–21
OHT/year	3,227 (26.9%)	55 (19.9%)	24–37
OHT/year	2,835 (23.6%)	69 (24.9%)	38–93
OHT/year	2,857 (23.8%)	111 (40.1%)	<0.001

* P-value based on t-test, Wilcoxon rank-sum test, or chi-square test as appropriate.

^a Includes extracorporeal membrane oxygenation support, Abiomed BVS 5000 (Abiomed Inc., Danvers, MA), Biomedicus (Medtronic Inc., Eden Prairie, MN), Centrimag (Levitronix, Waltham, MA), and TandemHeart (Cardiac Assist Inc., Pittsburg, PA)

^bIncludes Abiomed AB5000, Toyobo (Toyobo, Osaka, Japan), Novacor (World Heart Inc., Oakland, CA), Heartmate I/VE/XVE, Thoratec IVAD (Thoratec, Corp., Pleasanton, CA), Lionheart (Arrow International Inc., Reading, PA), and Medos (Medos, Stolberg, Germany).

^cJarvik (Jarvik Heart Inc., New York, NY), DeBakey (Micromed Technology, Inc., Houston, TX), and VentrAssist (Ventracor, Sydney, Australia).

Table 2

Baseline Characteristics of BTT patients Stratified by Age

Variable	Age 18–70 (n=3,200)	Age 70 (n=43)	P-value*
Demographics and Co-morbidities			
Age (years)	51 (±12)	71 (±1)	<0.001
Male gender, n (%)	2,620 (81.9%)	38 (88.4%)	0.3
White ethnicity, n (%)	2,179 (68.1%)	34 (79.1%)	0.1
Black ethnicity, n (%)	692 (21.6%)	8 (18.6%)	0.6
Hispanic ethnicity, n (%)	210 (6.6%)	1 (2.3%)	0.4
Creatinine (mg/dL)	1.3 (±0.7)	1.4 (±0.6)	0.2
Total bilirubin (mg/dL)	0.8 [IQR: 0.5–1.2]	0.8 [IQR: 0.6–1.2]	0.6
Acuity, Hemodynamics, and Need for Support			
Cardiac index (L/min/m ²)	1.5 (±0.5)	1.5 (±0.5)	0.4
Mean PA pressure (mmHg)	28 (±11)	31 (±10)	0.1
Inotropic support, n (%)	488 (15.3%)	7 (16.3%)	0.8
IABP support, n (%)	117 (3.7%)	1 (2.3%)	1.0
Extracorporeal/Temporary MCS, n (%)	160 (5.0%)	1 (2.3%)	
Pulsatile LVAD, n (%)	1,155 (36.1%)	9 (20.9%)	
Continuous flow LVAD(excluding HM2), n (%)	87 (2.7%)	1 (2.3%)	
Heartmate II LVAD, n (%)	1,798 (56.2%)	32 (74.4%)	0.1
Hospitalized, n (%)	1,220 (38.1%)	13 (30.2%)	0.3
ICU support, n (%)	614 (19.2%)	4 (9.3%)	0.1
Ventilator support, n (%)	109 (3.4%)	1 (2.3%)	0.7
Donor Variables			
Age (years)	31 (±11)	36 (±14)	0.01
Male gender, n (%)	2,471 (77.2%)	29 (67.4%)	0.1
Transplant Variables			
Ischemic time (hours)	3.3 (±1.1)	3.3 (±1.0)	0.9
Same gender match, n (%)	2,451 (76.6%)	28 (65.1%)	0.1
Same race match, n (%)	1,679 (52.5%)	27 (62.8%)	0.2
Waitlist time (days)	124 [IQR: 44–282]	143 [IQR:46–293]	0.8
Annual Center Volume			
1–13 OHT/year	920 (28.8%)	9 (20.9%)	
14–21 OHT/year	861 (26.9%)	5 (11.6%)	
24–37 OHT/year	745 (23.3%)	12 (27.9%)	
38–93 OHT/year	674 (21.1%)	17 (39.5%)	0.01

* P-value based on t-test, Wilcoxon rank-sum test, or chi-square test as appropriate.

Table 3

Multivariable Cox Proportional Hazards Regression Model for 1-Year Mortality in OHT Recipients

Variable	HR	95% CI	P-value
Recipient Demographics and Co-Morbidities			
Age 70	1.73	1.26–2.37	0.001
White ethnicity	1 (Reference)		
Black ethnicity	1.48	1.28–1.72	<0.001
Hispanic ethnicity	1.18	0.95–1.47	0.1
Creatinine, per mg/dL	1.20	1.15–1.25	<0.001
Bilirubin, per mg/dL	1.04	1.03–1.06	<0.001
BMI, per kg/m ²	1.01	0.99–1.02	0.1
Dilated etiology	1 (Reference)		
Ischemic etiology	1.36	1.19–1.56	<0.001
Congenital etiology	2.27	1.68–3.07	<0.001
Acuity and Need for Support			
Hospitalized	1.22	1.03–1.44	0.02
ICU	1.14	0.95–1.36	0.2
Inotropic support	0.89	0.78–1.02	0.1
Ventilator support	2.01	1.55–2.63	<0.001
No MCS	1 (Reference)		
Extracorporeal/Temporary MCS	3.18	2.32–4.34	<0.001
Pulsatile LVAD	1.32	1.10–1.60	0.003
Continuous flow LVAD(excluding HM2)	1.36	0.74–2.47	0.3
Heartmate II LVAD	1.31	1.10–1.55	0.002
Donor age (per 10 years)	1.16	1.11–1.22	<0.001
Same gender match	0.83	0.73–0.94	0.003
Ischemic time, per hour	1.17	1.12–1.24	<0.001
Annual Volume (By Quartiles)			
1–13 OHT/year	1 (Reference)		
14–21 OHT/year	0.88	0.75–1.03	0.1
22–37 OHT/year	0.83	0.71–0.98	0.03
38–93 OHT/year	0.80	0.68–0.95	0.008

Table 4

Multivariable Cox Proportional Hazards Regression Model for 1-Year Mortality in BTT Patients

Variable	HR	95% CI	P-value
Recipient Demographics and Co-Morbidities			
Age 70	1.30	0.58–2.95	0.5
White ethnicity	1 (Reference)		
Black ethnicity	1.56	1.22–2.00	<0.001
Hispanic ethnicity	1.28	0.86–1.93	0.2
Creatinine, per mg/dL	1.23	1.14–1.31	<0.001
Bilirubin, per mg/dL	1.05	1.03–1.08	<0.001
BMI, per kg/m ²	1.02	1.01–1.04	0.03
Dilated etiology	1 (Reference)		
Ischemic etiology	1.44	1.15–1.80	0.002
Congenital etiology	1.28	0.50–3.23	0.6
Acuity and Need for Support			
Hospitalized	1.26	0.95–1.65	0.1
ICU	1.32	0.97–1.80	0.08
Inotropic support	1.15	0.87–1.53	0.3
Ventilator support	2.54	1.71–3.77	<0.001
Donor and Transplant Variables			
Donor age (per 10 years)	1.21	1.11–1.31	<0.001
Same gender match	0.74	0.59–0.92	0.007
Ischemic time, per hour	1.12	1.03–1.21	0.008
Annual Volume (By Quartiles)			
1–13 OHT/year	1 (Reference)		
14–21 OHT/year	0.92	0.70–1.21	0.6
22–37 OHT/year	0.76	0.58–1.01	0.06
38–93 OHT/year	0.63	0.47–0.85	0.003