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The Journal of Heart and Lung Transplantation
http://www.jhltonline.org

ORIGINAL CLINICAL SCIENCE

# Cardiac transplantation for older patients: Characteristics and outcomes in the septuagenarian population

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**KEYWORDS:**
heart transplantation;
organ donor;
organ recipient;
septuagenarian;
aging

**BACKGROUND:** With increasing age of patients with heart failure, it is important to understand the potential role for orthotopic heart transplant (OHT) in elderly patients. We examined recipient and donor characteristics and long-term outcomes of older recipients of OHT in the United States.

**METHODS:** Using the United Network for Organ Sharing database, we identified OHT recipients from the years 1987–2014 and stratified them by age 18–59 years old, 60–69 years old, and ≥70 years old. We compared baseline characteristics of recipients and donors and assessed outcomes across groups.

**RESULTS:** During this period, 50,432 patients underwent OHT; 71.8% ($n$ = 36,190) were 18–59 years old, 26.8% ($n$ = 13,527) were 60–69 years old, and 1.4% ($n$ = 715) were ≥70 years old. Comparing the ≥70 years old group and 60–69 years old group, older patients had higher rates of ischemic etiology (53.6% vs 44.9%) and baseline renal dysfunction (61.4% vs 56.4%) and at the time of OHT were less likely to be currently hospitalized (45.0% vs 50.9%) or supported with left ventricular assist device therapy (21.0% vs 28.3%). Older recipients received organs from older donors (median age 36 years old vs 30 years old) who were more likely to have diabetes and substance use. After OHT, the median length of stay was similar between groups. At 1 year, of patients alive, patients ≥70 years old had fewer rejection episodes (17.8%) compared with patients 60–69 years old (29.5%). The 5-year mortality was 26.9% for recipients 18–59 years old, 29.3% for recipients 60–69 years old, and 30.8% for recipients ≥70 years old.

**CONCLUSIONS:** Despite advanced age and less ideal donors, OHT recipients in their 70s had similar outcomes to recipients in their 60s. Selected older patients should not routinely be excluded from consideration for OHT.

J Heart Lung Transplant ▮▮▮▮;▮:▮▮▮–▮▮▮



The risk of heart failure increases with age.[1] As the prevalence of older patients with heart failure increases, the potential role for orthotopic heart transplant (OHT) in elderly patients requires further evaluation. Historically, heart transplant was offered only to younger patients without significant comorbidities. Prior guidelines suggested that although patients older than age 50 could be considered for transplantation, the risk of adverse outcomes could be higher with increasing age.[2] Although patients in their 60s

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1053-2498/$ - see front matter 
http://dx.doi.org/10.1016/j.healun.2015.10.028

were routinely evaluated for transplant, septuagenarian patients were considered too old for transplant until recently.

In 2006, the International Society for Heart and Lung Transplant (ISHLT) issued updated guidelines on patient selection for heart transplantation that included consideration of adults in their 70s.[3] In the United States, transplantation of older adults is increasingly performed, but limited contemporary data exist regarding outcomes for elderly patients.[4–8] To evaluate transplantation in older adults, we used data from the United Network for Organ Sharing (UNOS) to analyze the demographics and outcomes of patients ≥70 years old compared with patients 60 to 69 years old and 18 to 59 years old at the time of cardiac transplant.

## Methods

### Data collection and study population

This was a retrospective cohort study using transplant data from the Organ Procurement and Transplant Network Standard Transplant Analysis and Research database provided by the UNOS. This is a comprehensive database that includes information on all patients who underwent cardiac transplantation in the United States and the donors whose organs were received by those patients.[9–11] The study population consisted of adult patients (≥18 years old) who underwent a primary or re-do heart transplantation between January 1, 1987, and March 31, 2014. Patients who underwent combined heart-lung transplant were excluded from this analysis. The Duke University Institutional Review Board approved this study.

### Outcomes

The primary outcome was 5-year mortality. Other outcomes of interest included length of hospital stay after transplant; episodes of graft rejection; hospitalizations in the first post-transplant year; and 1-year and 5-year rates of renal dysfunction, stroke, and lymphoproliferative disease. Graft rejection was defined as an episode of rejection requiring medical treatment.[12] Renal dysfunction was defined as the need for long-term dialysis.

### Statistical analyses

We identified all adult patients who underwent OHT from January 1, 1987, through March 31, 2014, and stratified them into 3 groups based on age at the time of transplant: 18–59 years old, 60–69 years old, and ≥70 years old. These age groups were used in prior analyses and mirror the changes in ISHLT recommendations over time.[2,3,5–9] We calculated the frequency of heart transplants by age group for each year. Baseline characteristics of transplant recipients were described using means and SDs or medians and interquartile ranges for continuous variables and frequencies and percentages for categorical variables. Variables were compared across groups using the Kruskal-Wallis test for continuous variables and Pearson chi-square or Fisher exact test for categorical variables. Donor characteristics were described and compared using similar methods. In addition, 1-year and 5-year outcomes were measured, and differences in groups were calculated using the chi-square rank based group means score statistics. Kaplan-Meier methods were used to estimate survival. Survival was compared across groups using the log-rank test.

Multivariable proportional hazards regression models were used to estimate the association between age groups and 5-year mortality among heart transplant recipients. Outcomes were adjusted for select baseline characteristics of transplant recipient and donor, chosen a priori based on prior studies and clinical relevance.[8–10,13,14] Single imputation was used for missing values. Missing values for continuous variables were imputed to the median, and missing values for categorical variables were imputed to the most frequent category. There were 2 models created—one using the study period 1995–2014 and the other using a more recent study period 2004–2014 to account for variables not collected before 2004, specifically left ventricular assist device (LVAD) use and U.S. Centers for Disease Control and Prevention (CDC) high-risk donor status.

## Results

Based on Organ Procurement and Transplant Network data as of June 6, 2014, from January 1987 through March 2014, 50,432 patients underwent OHT in the United States, of which 71.8% ($n = 36{,}190$) were 18 to 59 years old, 26.8% ($n = 13{,}527$) were 60 to 69 years old, and 1.4% ($n = 715$) were ≥70 years old. The median age of heart transplant recipients in the oldest cohort was 71 years old, and the maximum age was 79 years old. Although the total number of heart transplants performed each year has remained relatively stable over time, the number of heart transplant recipients in their 70s has increased, most notably after 2006 (Figure 1). Table 1 shows the baseline characteristic of heart transplant recipients by age group. Across all ages, most patients were white men. Comparing the ≥70 years old group with the 60–69 years old and 18–59 years old group, the oldest group had the highest rates of type 2 diabetes (16.3% vs 14.9% vs 8.1%) and chronic kidney disease stage ≥3 (61.4% vs 56.4% vs 35.1%). Of recipients in their 70s, 52.4% had a history of coronary artery bypass grafting. At the time of OHT, the oldest patient group was the least likely to be currently hospitalized (45.0% ≥70 years old vs 50.9% 60–69 years old vs 54.5%18–59 years old) or supported with a LVAD (21.0% ≥70 years old vs 28.3% 60–69 years old vs 28.6%18–59 years old).

Table 2 reports characteristics of organ donors. Recipients ≥70 years old received organs from older donors (median donor age 36 [25th, 75th: 23, 48]) compared with recipients 60 to 69 years old (median donor age 30 [25th, 75th: 21, 43]) and recipients 18 to 59 years old (median donor age 28 [25th, 75th: 20, 39]). Recipients ≥70 years old were the most likely to receive organs from donors considered high risk for transmission of disease, as defined by the CDC, as a result of history of hemophilia, high-risk sexual behaviors, intravenous drug use, or incarceration. Furthermore, donors for older recipients were more likely have a history of tobacco, alcohol, and cocaine use. Across all groups, donors most commonly died as a result of head trauma, but donors for the oldest recipients were comparatively more likely to die of stroke vs donors for the 60–69 years old age group and the 18–59 years old age group (30.9% vs 27.5% vs 24.6%).

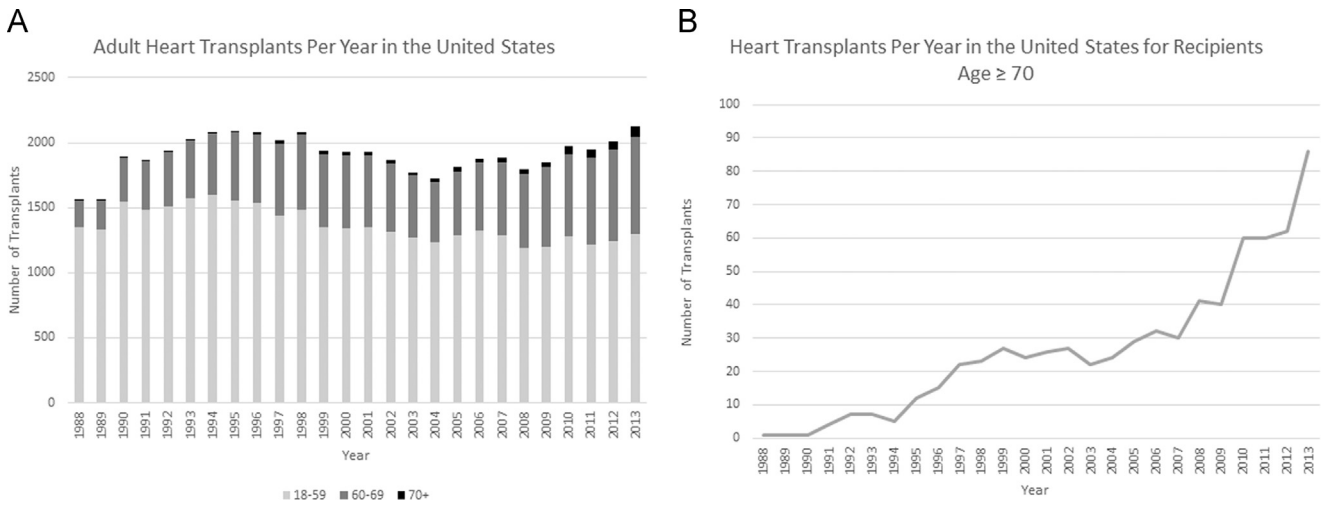


**Figure 1** Frequency of heart transplantation from 1988 to 2013. (A) Frequency of heart transplantation by age group from 1988 to 2013. (B) Frequency of heart transplantation for recipients ≥70 years old from 1988 to 2013.

Donors for older recipients also had longer ischemic times (3.2 hours [25th, 75th: 2.5, 3.9]) than donors for younger recipients (3.0 hours [25th, 75th: 2.3, 3.7] for recipients 60 to 69 years old and 2.9 [25th, 75th: 2.2, 3.6] for recipients 18 to 59 years old).

After OHT, the median length of stay was 15 days (25th, 75th: 10, 23) for the ≥70 years old and 60–69 years old groups and 14 days (25th, 75th: 10, 21) for the 18–59 years old group (Table 3). Of patients alive at 1 year, patients ≥70 years old had lower rates of rejection episodes in the first year (17.8%) compared with patients 60 to 69 years old (29.5%) and patients 18 to 59 years old (38.2%). The oldest age group also had the fewest hospitalizations in the first year. Of patients alive at 5 years, rates of dialysis, stroke, and post-transplant lymphoproliferative disease were similar between groups.

Figure 2 presents 5-year mortality based on age group. The 5-year Kaplan-Meier estimated mortality rates were 30.8% (95% confidence interval [CI] 27.0%–35.0%) in patients ≥70 years old, 29.3% (95% CI 28.5%–30.2%) in patients 60 to 69 years old, and 26.9% (95% CI 26.4%–27.4%) in patients 18 to 59 years old. Overall, these 3 groups had different rates of survival ($p < 0.001$), but survival between the ≥70 years old group and the 60–69 years old group was not significantly different ($p = 0.48$).

Table 4 presents unadjusted and adjusted association between age group and 5-year mortality for heart transplant recipients for the time periods from April 1, 1995, to March 27, 2014, and June 30, 2004, to March 27, 2014. Adjusting for donor, recipient, and transplant procedure characteristics, for both time periods, compared with recipients 18 to 59 years old, recipients 60 to 69 years old and recipients 70 years old at the time of transplant had increased 5-year mortality. In adjusted analysis, for the 1995–2014 time period, patients ≥70 years old had a higher risk of death compared with patients 60–69 years old (hazard ratio 1.2, 95% CI 1.03, 1.41); however, in the more recent time period, there was no difference in risk of mortality between the groups (HR 1.13, 95% CI 0.90, 1.41).

## Discussion

We used data from the UNOS to examine characteristics of heart transplant donors and recipients and post-transplant outcomes, stratified by transplant recipient age. The update of the ISHLT guidelines on heart transplantation ushered in an era of cardiac transplantation of older adults, including patients ≥70 years old. Over time, the frequency of transplantation in older adults has increased, and in 2013 almost 40% of heart transplants occurred in recipients ≥60 years old with >4% of heart transplants occurring in recipients ≥70 years old. Almost 300 septuagenarians have received heart transplants since 2010 when this population was last examined.[6]

Despite their advanced age, transplant recipients in their 70s had few chronic comorbidities with the exception of chronic kidney disease. Moreover, they were less acutely ill at the time of transplantation compared with younger transplant recipients, as they were least likely to be hospitalized before transplantation. Furthermore, fewer patients in the oldest group were supported with LVAD therapy before transplantation. It has been shown that LVAD recipients ≥70 years old have worse short-term and mid-term survival and higher rates of stroke and gastrointestinal bleeding after LVAD implantation.[15] Despite these risks, the rate of use of LVAD as a bridge to transplant is increasing in this older population.[6] Additionally, more recent data suggest that transplant outcomes are worse in patients previously supported with either temporary or durable mechanical circulatory support devices compared with patients supported with inotropes only or with no circulatory support before transplant,[9,13] particularly when device-related complications require emergent transplantation to mitigate the ongoing risk of device support.[16] Our findings highlight that appropriate patient selection is paramount when considering older patients for cardiac transplantation. It appears that current recipient selection strategies at centers that offer transplantation in this population exclude certain high-risk groups, such as patients with a prior LVAD.

**Table 1** Baseline Characteristics of Heart Transplant Recipients

| Variable | *n* | Age 18–59 | *n* | Age 60–69 | *n* | Age ≥70 | *p*-value[a] |
|---|---|---|---|---|---|---|---|
| Characteristic | | | | | | | |
| Sex, male, *n* (%) | 36,190 | 27,030 (74.7) | 13,527 | 11,178 (82.6) | 715 | 644 (90.1) | < 0.001 |
| Race, white, *n* (%) | 36,163 | 26,860 (74.3) | 13,522 | 11,359 (84.0) | 715 | 623 (87.1) | < 0.001 |
| Ischemic etiology, *n* (%) | 36,189 | 8,449 (23.4) | 13,526 | 6,067 (44.9) | 715 | 383 (53.6) | < 0.001 |
| Creatinine (mg/dl), median (25th, 75th)[b] | 24,866 | 1.2 (0.9, 1.5) | 10,682 | 1.3 (1.0, 1.6) | 665 | 1.3 (1.1, 1.6) | < 0.001 |
| eGFR (ml/min/1.73 $m^2$), median (25th, 75th)[b] | 24,864 | 68.4 (52.0, 88.0) | 10,681 | 58.9 (45.0, 72.3) | 665 | 56.9 (45.1, 69.6) | < 0.001 |
| CKD stage ≥3, *n* (%)[b] | 24,864 | 8,714 (35.1) | 10,681 | 6,022 (56.4) | 665 | 408 (61.4) | < 0.001 |
| Condition at time of transplant, *n* (%) | 36,081 | | 13,483 | | 709 | | < 0.001 |
| Not hospitalized | | 16,409 (45.5) | | 6,619 (49.1) | | 390 (55.0) | |
| Hospitalized, not in ICU | | 5,187 (14.4) | | 1,884 (14.0) | | 96 (13.5) | |
| In ICU | | 14,485 (40.2) | | 4,980 (36.9) | | 223 (31.5) | |
| History, *n* (%) | | | | | | | |
| Diabetes[b] | 25,788 | | 11,100 | | 688 | | < 0.001 |
| Type 2 | | 2,085 (8.1) | | 1,650 (14.9) | | 112 (16.3) | |
| Type 1 | | 353 (1.4) | | 190 (1.7) | | 10 (1.5) | |
| Type unknown | | 2,543 (9.9) | | 1,245 (11.2) | | 37 (5.4) | |
| Type other | | 36 (0.1) | | 16 (0.1) | | 0 | |
| Diabetes status unknown | | 335 (1.4) | | 142 (1.3) | | 12 (1.7) | |
| No | | 20,416 (79.2) | | 7,857 (70.8) | | 517 (75.2) | |
| Hypertension[c] | 16,787 | 5,871 (36.2) | 6,502 | 2,729 (43.9) | 279 | 110 (40.7) | < 0.001 |
| Cerebrovascular disease[c] | 16,888 | 609 (3.6) | 6,533 | 279 (4.3) | 282 | 11 (3.9) | 0.02 |
| Peripheral vascular disease[c] | 16,833 | 509 (3.1) | 6,524 | 297 (4.8) | 280 | 11 (4.1) | < 0.001 |
| Chronic obstructive pulmonary disease[c] | 16,913 | 454 (2.8) | 6,548 | 286 (4.6) | 281 | 7 (2.6) | < 0.001 |
| Any prior malignancy[b] | 25,186 | 1,053 (4.2) | 10,859 | 801 (7.4) | 673 | 59 (8.8) | < 0.001 |
| Prior cardiac surgery[d] | 2,606 | | 1,341 | | 105 | | |
| Coronary artery bypass grafting only | | 390 (15.0) | | 447 (33.3) | | 55 (52.4) | < 0.001 |
| Valve replacement/repair only | | 164 (6.3) | | 84 (6.3) | | 5 (4.8) | |
| Other (including multiple surgeries) | | 2,052 (78.7) | | 810 (60.4) | | 45 (42.9) | |
| Life support at time of transplant, *n* (%) | | | | | | | |
| ECMO[e] | 24,301 | 143 (0.6) | 10,592 | 39 (0.4) | 681 | 3 (0.4) | 0.01 |
| Intraaortic balloon pump | 36,190 | 2,087 (5.8) | 13,527 | 757 (5.6) | 715 | 44 (6.2) | 0.57 |
| Prostaglandins[e] | 24,301 | 49 (0.2) | 10,592 | 15 (0.1) | 681 | 0 | 0.14 |
| Intravenous inotropes[b] | 25,832 | 12,093 (46.8) | 11,118 | 5,214 (46.9) | 688 | 304 (44.2) | 0.80 |
| Inhaled nitric oxide | 36,190 | 45 (0.1) | 13,527 | 17 (0.1) | 715 | 0 | 0.83 |
| Ventilator | 36,190 | 1,017 (2.8) | 13,527 | 357 (2.6) | 715 | 22 (3.1) | 0.39 |
| Ventricular assist device at time of transplant[d] | 11,557 | | 5,623 | | 461 | | < 0.001 |
| Left ventricular assist device | | 3,302 (28.6) | | 1,593 (28.3) | | 97 (21.0) | |
| Right ventricular assist device | | 34 (0.3) | | 16 (0.3) | | 1 (0.2) | |
| Left and right ventricular assist devices | | 489 (4.2) | | 109 (1.9) | | 7 (1.5) | |
| Total artificial heart | | 153 (1.3) | | 45 (0.8) | | 1 (0.2) | |
| None | | 7,579 (65.6) | | 3,860 (68.7) | | 355 (77.0) | |

CKD, chronic kidney disease; ECMO, extracorporeal membrane oxygenation; eGFR, estimated glomerular filtration rate; ICU, intensive care unit.

[a] *p*-values are based on chi-square rank-based group means score statistics for all categorical row variables and chi-square 1 *df* rank correlation statistics for all continuous/ordinal row variables.

[b] Excludes patients registered before April 1, 1994.

[c] Excludes patients registered before April 1, 1994, and after January 1, 2007.

[d] Excludes patients registered before June 30, 2004.

[e] Excludes patients registered before April 1, 1995.

To counter ethical concerns over the distribution of limited donor organs to an older population, transplant guidelines propose allocating organs through alternate donor programs. This practice involves use of organs that would traditionally not be accepted for donation or have been turned down by other centers because of donor-related or organ-related factors.[3,17] The criteria used for determining an alternate (or extended criteria) donor varies by transplant center but have been shown to maximize effectively the use of donor organs that otherwise would remain unused and extend the option of transplantation to recipients who otherwise may not have been offered this treatment option.[18–24] Alternate donor use is not captured in the UNOS database, but our results show that older recipients receive organs from donors with older age, more comorbidities, and other high-risk features, such as substance abuse. Furthermore, donors for older recipients had longer ischemic times, suggesting that transplant programs may accept donor organs from a greater distance for these patients.

**Table 2** Characteristics of Organ Donors by Age Group of Transplant Recipients

| Variable | *n* available | Age 18–59 | *n* available | Age 60–69 | *n* available | Age ≥70 | *p*-value[a] |
|---|---|---|---|---|---|---|---|
| Donor characteristic | | | | | | | |
| Sex, male, *n* (%) | 36,190 | 25,647 (70.9) | 13,527 | 9,498 (70.2) | 715 | 479 (67.0) | 0.05 |
| Age (years), median (25th, 75th) | 36,190 | 28 (20, 39) | 13,525 | 30 (21, 43) | 715 | 36 (23, 48) | < 0.001 |
| Age ≥35, *n* (%) | 36,190 | 12,535 (34.6) | 13,525 | 5,607 (41.5) | 715 | 382 (53.4) | < 0.001 |
| Age ≥45, *n* (%) | 36,190 | 5,302 (14.7) | 13,525 | 2,882 (21.3) | 715 | 222 (31.1) | < 0.001 |
| CDC high risk, n (%)[b,c] | 9,294 | 971 (10.5) | 4,750 | 476 (10.0) | 409 | 65 (15.9) | 0.61 |
| Tattoos present, *n* (%)[d] | 9,277 | 3,955 (42.6) | 4,757 | 2,029 (42.7) | 408 | 166 (40.7) | 0.80 |
| Donor history | | | | | | | |
| History of diabetes, *n* (%)[e] | 9,287 | 277 (3.0) | 4,745 | 162 (3.4) | 408 | 27 (6.6) | 0.01 |
| Insulin dependence, *n* (%)[e] | 276 | 117 (42.4) | 162 | 69 (42.6) | 27 | 16 (59.3) | 0.40 |
| History of cigarette use, *n* (%)[e] | 9,233 | 1,280 (13.9) | 4,709 | 760 (16.1) | 407 | 83 (20.4) | < 0.001 |
| Cigarette use in last 6 months, *n* (%)[e] | 1,275 | 1,157 (90.8) | 755 | 689 (91.3) | 83 | 74 (89.2) | 0.89 |
| Heavy alcohol use, *n* (%)[c] | 9,161 | 1,359 (14.8) | 4,696 | 757 (16.1) | 404 | 82 (20.3) | 0.005 |
| History of cocaine use, *n* (%)[d] | 9,117 | 1,302 (14.3) | 4,659 | 698 (15.0) | 402 | 77 (19.2) | 0.05 |
| Cocaine use in last 6 months, *n* (%)[d] | 1,116 | 558 (50.0) | 587 | 284 (48.4) | 69 | 37 (53.6) | 0.75 |
| History of other drug use, *n* (%)[e] | 9,193 | 3,761 (40.9) | 4,690 | 1,995 (42.5) | 405 | 170 (42.0) | 0.07 |
| Other drug use in last 6 months, *n* (%)[e] | 3,316 | 2,354 (71.0) | 1,768 | 1,234 (69.8) | 155 | 114 (73.6) | 0.58 |
| Combined smoking, alcohol, cocaine, other drugs, *n* (%)[c] | 9,304 | 117 (1.3) | 4,764 | 78 (1.6) | 409 | 8 (2.0) | 0.04 |
| Donor transplant variables | | | | | | | |
| Cardiac arrest with downtime, *n* (%)[d] | 9,305 | 611 (6.6) | 4,766 | 319 (6.7) | 409 | 35 (8.6) | 0.42 |
| LVEF (%), median (25th, 75th)[d] | 9,258 | 60 (55, 65) | 4,754 | 60 (55, 65) | 404 | 60 (55, 65) | 0.82 |
| Cause of death, *n* (%) | 36,114 | | 13,500 | | 715 | | < 0.001 |
| Head trauma | | 19,633 (54.4) | | 7,269 (53.8) | | 333 (46.6) | |
| Cerebrovascular/stroke | | 8,875 (24.6) | | 3,718 (27.5) | | 221 (30.9) | |
| Anoxia | | 3,365 (9.3) | | 1,423 (10.5) | | 130 (18.2) | |
| CNS tumor | | 272 (0.8) | | 118 (0.9) | | 8 (1.1) | |
| Other | | 3,969 (11.0) | | 972 (7.2) | | 23 (3.2) | |
| Ischemic time (hours), median (25th, 75th) | 34,458 | 2.9 (2.2, 3.6) | 12,849 | 3.0 (2.3, 3.7) | 675 | 3.2 (2.5, 3.9) | < 0.001 |
| Sex mismatch between donor and recipient, *n* (%) | 36,190 | 10,559 (29.2) | 13,527 | 3,780 (27.9) | 715 | 213 (29.8) | 0.01 |

CDC, U.S. Centers for Disease Control and Prevention; CNS, central nervous system; LVEF, left ventricular ejection fraction.

[a] *p*-values are based on chi-square rank-based group means score statistics for all categorical row variables and chi-square 1 *df* rank correlation statistics for all continuous/ordinal row variables.

[b] High risk defined as history of hemophilia, intravenous drug use, prostitution, high-risk sexual activity, human immunodeficiency virus exposure, or jail sentencing.

[c] Excludes donors admitted before June 30, 2004.

[d] Excludes donors admitted before October 25, 1999.

[e] Excludes donors admitted before April 1, 1994.

**Table 3** Observed Outcomes of Transplant Recipients by Age Group

| Variable | *n* available | Age 18–59 | *n* available | Age 60–69 | *n* available | Age ≥70 |
|---|---|---|---|---|---|---|
| Follow-up outcomes | | | | | | |
| Length of stay transplant to discharge, median (25th, 75th)[a] | 17,229 | 14 (10, 21) | 7,764 | 15 (10, 23) | 555 | 15 (10, 23) |
| Treated for rejection within 1 year, *n* (%) | 16,905 | 6,464 (38.2) | 7,151 | 2,106 (29.5) | 427 | 76 (17.8) |
| Rehospitalizations in the first year, *n* (%)[b] | 14,558 | | 5,869 | | 298 | |
| 2 | | 25 (0.2) | | 14 (0.2) | | 1 (0.3) |
| 1 | | 5,969 (41.0) | | 2,292 (39.1) | | 111 (37.3) |
| 0 | | 8,564 (58.8) | | 3,563 (60.7) | | 186 (62.4) |
| If renal dysfunction, long-term dialysis at 1 year, *n* (%)[b] | 3,149 | 97 (3.1) | 1,501 | 33 (2.2) | 78 | 1 (1.3) |
| If renal dysfunction, chronic dialysis at 5 years, *n* (%)[c] | 2,311 | 182 (7.9) | 939 | 51 (5.4) | 35 | 6 (17.1) |
| Stroke at 1 year, *n* (%)[b] | 9,445 | 95 (1.0) | 3,369 | 38 (1.1) | 124 | 3 (2.4) |
| Stroke at 5 years, *n* (%)[c] | 6,257 | 66 (1.1) | 2,005 | 31 (1.5) | 61 | 0 |
| Post-transplant lymphoproliferative disease at 1 year, *n* (%)[b] | 187 | 33 (17.7) | 211 | 10 (4.7) | 18 | 2 (11.1) |
| Post-transplant lymphoproliferative disease at 5 years, *n* (%)[c] | 355 | 18 (5.1) | 265 | 9 (3.4) | 11 | 0 |

[a]Excludes patients listed before October 25, 1999.
[b]Among patients alive at 1 year.
[c]Among patients alive at 5 years.

Despite receiving organs from older and sicker donors and having longer ischemic times, transplant recipients in their 70s had comparable outcomes after transplant compared with younger recipients. Among patients alive at 1 year, recipients ≥70 years old did not require longer post-transplant hospitalizations and had fewer rejection episodes and rehospitalizations in the first year. Although 5-year survival was lower in the oldest age group, in a contemporary cohort, survival in the ≥70 years old group was not significantly different from survival in the 60–69 years old group. Our study shows comparable outcomes for patients in their 60s and 70s. Given that it is an increasingly common practice for sexagenarians to be considered for transplantation, our data suggest that older patients should not be routinely excluded from transplantation based on age alone. Select patients in their 70s, specifically patients with few comorbidities, may be appropriate candidates for this therapy.

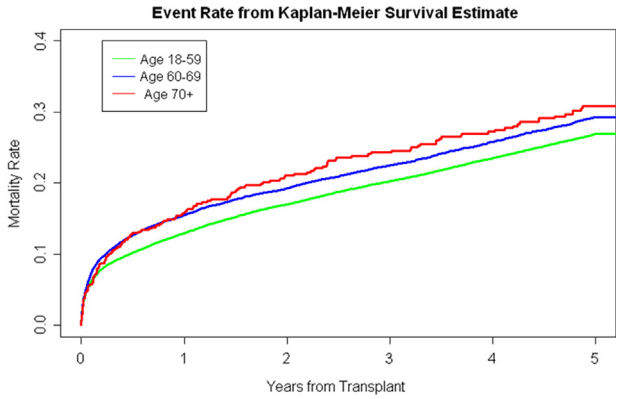


**Figure 2** Mortality rates from Kaplan-Meier estimates of heart transplant recipients by age group.

## Limitations

Our study has several limitations. This was a retrospective cohort study, so there is a possibility of unmeasured confounders. In addition, there was likely a selection bias in the study population that influenced the results, such that sicker older patients may not have been offered heart transplantation. Furthermore, we included only patients who underwent heart transplantation, so we did not assess survival and outcomes of patients on the heart transplant waiting list. In addition, because this study used data collected in a national registry, we were limited by the data available. Certain data elements were not collected for the entire study period, and there is a high degree of missingness for several outcome variables. In addition, we were limited by the quality, accuracy, and completeness of the data entered into the database. Furthermore, our study was unable to account for regional or center-specific variation in the care of patients before and after transplantation.

## Future research

Appropriate patient selection is a key for success in heart transplantation, and this may be especially true in older patients. Future studies should focus on identifying factors associated with favorable outcomes in older patients and ways to select the right patients to be offered this therapy. Furthermore, with the increase in use of LVADs as destination therapy in an older population, identifying which patients would be better suited for transplantation versus LVAD therapy could help inform clinical decision making in the future. In addition, as transplantation of older

**Table 4** Association Between Age Groups and 5-Year Mortality Among Transplant Recipients from April 1, 1995, to March 27, 2014.

| | | Unadjusted | | Adjusted | |
|---|---|---|---|---|---|
| Outcome | Variable | HR (95% CI) | *p*-value | HR (95% CI) | *p*-value |
| April 1, 1995, to March 27, 2014[a] | | | | | |
| 5-year mortality | Age 60–69 vs age 18–59 | 1.12 (1.07, 1.18) | < 0.001 | 1.13 (1.07, 1.18) | < 0.001 |
| | Age ≥70 vs age 18–59 | 1.29 (1.10, 1.51) | 0.001 | 1.35 (1.16, 1.58) | < 0.001 |
| | Age ≥70 vs age 60–69 | 1.15 (0.98, 1.34) | 0.09 | 1.20 (1.03, 1.41) | 0.02 |
| June 30, 2004, to March 27, 2014[b] | | | | | |
| 5-year mortality | Age 60–69 vs age 18–59 | 1.09 (1.02, 1.18) | 0.02 | 1.10 (1.02, 1.19) | 0.02 |
| | Age ≥70 vs age 18–59 | 1.23 (0.99, 1.52) | 0.06 | 1.24 (1.00, 1.54) | 0.05 |
| | Age ≥70 vs age 60–69 | 1.12 (0.90, 1.40) | 0.30 | 1.13 (0.90, 1.41) | 0.28 |

CI, confidence interval; HR, heart rate.

[a]Adjustment variables for period April 1, 1995, to March 27, 2014 for recipient were sex, race, ischemic etiology, creatinine, condition at transplant, mechanical support (extracorporeal membrane oxygenation, intraaortic balloon pump, ventilator, or other), pharmacologic support (prostaglandins, inotropes, or inhaled nitric oxide), and diabetes; for donor were ischemic time, age, diabetes, smoking history, and cause of death (head trauma, stroke, anoxia, other); and sex mismatch and year of transplant.

[b]Adjustment variables for period June 30, 2004, to March 27, 2014, for recipient were ventricular assist device (yes/no), sex, race, ischemic etiology, creatinine, condition at transplant, mechanical support (extracorporeal membrane oxygenation, intraaortic balloon pump, ventilator, or other), pharmacologic support (prostaglandins, inotropes, or inhaled nitric oxide), and diabetes; for donor were Centers for Disease Control and Prevention high risk, ischemic time, age, diabetes, smoking history, and cause of death (head trauma, stroke, anoxia, other); and sex mismatch and year of transplant.

adults becomes more common, future studies should examine longer term outcomes in these patients.

## Conclusions

Patients ≥70 years old selected for OHT were less acutely ill at the time of transplant and tended to receive organs from older donors with high-risk behaviors. Despite advanced age, these patients had comparatively similar outcomes to younger age groups. Select patients in their 70s should not routinely be excluded from consideration for OHT.

## Disclosure statement

L.B.C. received support from the National Institutes of Health Grant No. T32HL069749-11A1.

The data reported here have been supplied by the United Network for Organ Sharing as the contractor for the Organ Procurement and Transplantation Network. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of or interpretation by the Organ Procurement and Transplantation Network, the U.S. Government, or the National Institutes of Health.

None of the authors has a financial relationship with a commercial entity that has an interest in the subject of the presented manuscript or other conflicts of interest to disclose.

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