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Trends and outcomes of patients with adult congenital heart disease and pulmonary hypertension listed for orthotopic heart transplantation in the United States

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KEYWORDS:
adult congenital heart disease;
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outcomes;
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BACKGROUND: Heart transplantation is increasing in patients with adult congenital heart disease (ACHD). In this population, the association of pulmonary hypertension (PH) with post-transplant outcomes is not well-defined.

METHODS: Using data from the United Network for Organ Sharing database (1987 to 2014), we identified ACHD patients listed for heart transplantation, and examined survival between those with and without PH (pre-transplant PH defined as transpulmonary pressure gradient >12 mm Hg).

RESULTS: Among 983 ACHD patients, 216 (22%) had PH. At time of listing, PH patients had a transpulmonary pressure gradient of 17.0 mm Hg vs 6.0 mm Hg ($p < 0.01$) in the no-PH group. Although left ventricular assist device (LVAD) use was infrequent, 3.1% of PH patients were treated with an LVAD versus 6.8% of the no-PH patients. Days from listing to transplant, days from listing to death on the waitlist and length of post-transplant hospitalization were not significantly different between the PH and no-PH groups. However, PH was associated with higher waitlist mortality (HR 1.73, CI 1.25 to 2.41). Pre-transplant PH was not associated with post-transplant mortality at 30 days (HR 0.51, CI 0.23 to 1.13), 1 year (HR 0.68, 95% CI 0.40 to 1.18) or 5 years (HR 0.84, 95% CI 0.55 to 1.29).

CONCLUSIONS: PH is common among ACHD patients listed for transplant and is associated with increased waitlist mortality. Conversely, PH was not associated with worse survival after transplant. Bridge-to-transplant LVAD therapy was uncommon in this ACHD population.

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The prevalence of adult congenital heart disease (ACHD) is increasing due to increased survival of congenital heart disease patients. Nevertheless, ACHD patients may have a progressive decline in cardiac function into and throughout

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adulthood, leaving heart transplantation as one of the only treatment options.[1] Unfortunately, many of these patients also have pulmonary vascular disease secondary to years of elevated systemic ventricular filling pressures. The presence of pulmonary hypertension (PH) is widely recognized in heart transplant candidates, and is associated with post-transplant right ventricular dysfunction and early post-transplant mortality.[2–4] Accordingly, the International Society for Heart and Lung Transplantation (ISHLT) considers the presence of severe pre-transplant PH (defined as pulmonary vascular resistance [PVR] >5 Wood units [WU] or transpulmonary pressure gradient [TPG] >16 to 20 mm Hg) as a relative contraindication for heart transplantation.[2]

Because most studies describing the effects of PH on transplant outcomes either combine multiple indications for heart transplant or exclude congenital heart disease patients from the analysis, the association of pre-transplant PH on post-transplant survival in the ACHD population has not been well studied.[3,5–9] Herein we examine the association of pre-transplant PH and survival after heart transplantation in ACHD patients in a national registry of heart transplant recipients in the USA.

Methods

Data source

Data were obtained from the United Network for Organ Sharing (UNOS)/Organ Procurement and Transplantation Network (OPTN) registry. The data listed in the UNOS registry include pre- and post-transplant variables captured and entered by transplant centers into an online database at the time of listing, transplantation and follow-up.[10] We retrospectively reviewed the UNOS registry data on all adult patients listed for heart transplant in the USA from January 1, 1985 to March 31, 2014 who had a diagnosis of congenital heart disease. The UNOS registry Standard Transplant Analysis and Research files provide de-identified data, which are publicly available. Exemption was obtained for this study by a Duke University institutional review board.

Study participants

This analysis included all adults (≥18 years) with a diagnosis of congenital heart disease listed for heart transplantation. We excluded patients with missing hemodynamic measurements whose PH status was unable to be classified. To minimize the influence of data entry error in our study, patients were also excluded if their cardiac hemodynamics were out of the following ranges: cardiac output <2 liters/min or >12 liters/min; mean pulmonary artery pressure (mPAP) <10 mm Hg or >80 mm Hg; diastolic pulmonary artery pressure <3 mm Hg or >40 mm Hg; and pulmonary capillary wedge pressure (PCWP) <5 mm Hg or >50 mm Hg, consistent with previous studies.[3] A total of 142 patients were excluded for outlying hemodynamic values.

Definitions and outcomes

Patients were classified as PH or no-PH, based on the most recent invasive hemodynamic measurements before heart transplant listing. The PH cohort was defined as having a TPG >12 mm Hg, and the no-PH cohort was defined as having a TPG ≤12 mm Hg.[3,11,12] As noted earlier, the ISHLT considers severe PH (TPG >16 to 20) to be a relative contraindication to cardiac transplant; however, studies have shown no difference in post-transplant outcomes, even with escalating PH severity.[3] As TPG >12 mm Hg has been used to describe PH in earlier studies, it was thought to appropriately represent the hemodynamic status and risk of the PH cohort. In addition, TPG is less affected by alterations in left heart function than other measurements used to define PH, including mPAP and PVR.[13,14] TPG >12 mm Hg has been shown to describe patients with "out-of-proportion" PH, which is PH that is more severe than would be expected given the degree of congestion. Out-of-proportion PH occurs when the pulmonary vasculature responds to long-term pulmonary venous congestion by remodeling, resulting in additional resistance to flow.

The primary outcome of interest was post-transplant all-cause mortality. The secondary outcomes included waitlist mortality or removal from the waitlist due to worsening clinical condition.[15,16]

Statistical analysis

Baseline characteristics of heart transplant recipients were summarized using medians and 25th to 75th percentiles for continuous variables, and frequencies and percentages for categorical variables. Characteristics were compared between the PH and no-PH groups using Pearson's chi-square tests for categorical variables and chi-square rank-based group-means score statistics (equivalent to Wilcoxon's rank sum test) for continuous variables. Similar methods were used to compare mechanical circulatory support (MCS) use, waitlist outcomes and post-transplant outcomes between groups. Kaplan–Meier curves were constructed to assess post-transplant survival of patients in relation to the presence of pre-transplant PH, and survival between groups was compared by log-rank test. Proportional hazard regression analysis was used to assess the association between PH and mortality at 30 days, 1 year and 5 years post-transplant. Both a cause-specific hazard model and Fine–Gray hazard model were used to assess the association between PH and waitlist mortality; both models led to the same conclusion, so only the cause-specific hazard model was reported.[17] Of note, a multivariate analysis was not performed as there were no statistically significant differences between the 2 cohorts with regard to variables that could potentially affect outcomes, such as age, body mass index (BMI), comorbidities, previous sternotomies, etc. Results are presented as hazard ratios (HRs) and 95% confidence intervals (CIs). $p < 0.05$ was considered significant. All analyses were carried out using SAS version 9.4 statistical software (SAS Institute, Inc., Cary, NC).

Results

Demographics and clinical characteristics of the study population are shown in Table 1. Based on OPTN data as of June 6, 2014, among 983 ACHD patients listed for transplantation, 216 (22%) had PH. Age, gender, body mass index and past medical history did not differ significantly between the PH and no-PH groups. At time of listing, median PCWP in the PH group was 20.0 mm Hg and 16.0 mm Hg in the no-PH group ($p < 0.01$); median TPG in the PH group was 17.0 mm Hg and 6.0 mm Hg in the no-PH group.

MCS use in the ACHD cohort is shown in Table 2. Overall MCS use at time of listing was low in both the PH and no-PH groups. Of patients with PH, 3.1% were treated

Table 1 Clinical Characteristics of the Study Population

Variable	*N*	Overall (*N* = 983)	CHD with PH (*N* = 216)	CHD w/out PH (*N* = 767)	*p*-value
Characteristic					
Age (years), median (25th–75th)	983	35.0 (25.0–46.0)	36.0 (28.0–46.0)	34.0 (25.0–45.0)	0.13
Gender, female [*N* (%)]	983	381 (38.8%)	76 (35.2%)	305 (39.8%)	0.22
Weight (kg), median (25th–75th)	978	70.0 (58.8–84.8)	70.7 (60.0–84.8)	70.0 (58.1–84.8)	0.49
BMI (kg/m^2), median (25th–75th)	973	24.2 (20.7–28.5)	24.5 (20.4–28.7)	24.2 (20.8–28.4)	0.99
Prior cardiac surgery [*N* (%)]	582	498 (85.6%)	109 (84.5%)	389 (85.9%)	0.70
Medical history [*N* (%)]					
Diabetes	975	57 (5.9%)	21 (9.8%)	36 (4.7%)	0.01
Drug-treated systemic hypertension	489	110 (22.5%)	18 (17.0%)	92 (24.0%)	0.12
Drug-treated COPD	487	11 (2.3%)	4 (3.8%)	7 (1.8%)	0.24
History of cigarette use	583	133 (22.8%)	33 (25.6%)	100 (22.0%)	0.40
Lab values, median (25th–75th)					
Serum creatinine (mg/dl)	298	1.0 (0.9–1.3)	1.0 (0.8–1.2)	1.0 (0.9–1.3)	0.39
Hemodynamics, median (25th–75th)					
Systolic PAP (mm Hg)	927	38.0 (27.0–50.0)	57.0 (45.0–72.0)	33.0 (25.0–45.0)	<0.01
Mean PAP (mm Hg)	982	25.0 (18.0–34.0)	40.0 (32.0–50.0)	22.0 (17.0–29.0)	<0.01
Mean pulmonary capillary wedge pressure (mm Hg)	982	17.0 (12.0–23.0)	20.0 (13.5–25.5)	16.0 (11.0–22.0)	<0.01
Transpulmonary pressure gradient (mm Hg)	982	7.0 (5.0–12.0)	17.0 (15.0–23.0)	6.0 (4.0–9.0)	<0.01
Diastolic pressure gradient (mm Hg)	881	1.0 (−2.0 to 3.0)	6.0 (3.0–10.0)	0.0 (−3.0 to 2.0)	<0.01
Pulmonary vascular resistance (WU)	768	1.9 (1.1–3.2)	4.3 (3.2–5.5)	1.6 (1.0–2.3)	<0.01
UNOS status at time of transplant [*N* (%)]	982				0.04
Status 1A		221 (22.5%)	52 (24.1%)	169 (22.1%)	
Status 1B		272 (27.7%)	61 (28.2%)	211 (27.6%)	
Status 2		226 (23.0%)	35 (16.2%)	191 (24.9%)	
Other		263 (26.8%)	68 (31.5%)	195 (25.5%)	

BMI, body mass index; CHD, congenital heart disease; COPD, chronic obstructive pulmonary disease; PAP, pulmonary artery pressure; PH, pulmonary hypertension; UNOS, United Network for Organ Sharing; w/out, without; WU, Wood units.

with a left ventricular assist device (LVAD) compared with 6.8% of patients without PH. Overall, extracorporeal membrane oxygenation support was utilized in 1.1% of ACHD patients, and intra-aortic balloon pump therapy was utilized in 1.7% of ACHD patients.

Waitlist and post-transplant outcomes are described in Tables 3a and 3b. Overall, days from listing to transplant, days from listing to death while on the waitlist, and length of hospital stay after transplantation were not significantly different between groups. Waitlist mortality was higher for patients with PH compared with patients without PH (18.5% vs 12.4%). Among those who were transplanted and alive at 1 year post-transplant, rehospitalizations for rejection or other causes within the first year were similar between the PH and no-PH groups.

As shown in Table 4, PH at time of listing was associated with an increased risk of waitlist mortality compared with no-PH at time of listing (HR 1.73, CI 1.25 to 2.41; $p = 0.001$). Pre-transplant PH was not associated with post-transplant mortality at 30 days (HR 0.51, 95% CI 0.23 to

Table 2 Mechanical Circulatory Support Use in the Study Population

Variable	*N*	Overall (*N* = 983)	CHD with PH (*N* = 216)	CHD w/out PH (*N* = 767)	*p*-value
Ventricular assist device [*N* (%)]	328				0.50
LVAD + RVAD		2 (0.6%)	0 (0.0%)	2 (0.8%)	
TAH		2 (0.6%)	1 (1.6%)	1 (0.4%)	
RVAD		2 (0.6%)	0 (0.0%)	2 (0.8%)	
LVAD		20 (6.1%)	2 (3.1%)	18 ((6.8%)	
None		302 (92.1%)	61 (95.3%)	241 (91.3%)	
Extracorporeal membrane oxygenation [*N* (%)]	566	6 (1.1%)	0 (0.0%)	6 (1.3%)	0.24
IABP [*N* (%)]	582	10 (1.7%)	3 (2.7%)	7 (1.5%)	0.38
Intravenous inotropes [*N* (%)]	582	285 (49.0%)	55 (49.6%)	230 (48.8%)	0.89
Prostaglandins [*N* (%)]	566	2 (0.4%)	2 (1.9%)	0 (0.0%)	<0.01
Inhaled nitric oxide [*N* (%)]	582	2 (0.3%)	2 (1.8%)	0 (0.0%)	<0.01

CHD, congenital heart disease; IABP, intra-aortic balloon pump; LVAD, left ventricular assist device; PH, pulmonary hypertension; RVAD, right ventricular assist device; TAH, total artificial heart.

Table 3a Outcomes of Adults With Congenital Heart Disease

Variable	*N*	Overall (*N* = 983)	CHD with PH (*N* = 216)	CHD w/out PH (*N* = 767)	*p*-value
Follow-up outcomes, median (25th–75th percentile)					
Days from listing to transplant, among those who were transplanted	580	134.0 (40.0–321.5)	129.0 (53.0–306.0)	135.0 (38.0–324.0)	0.64
Days from listing to death while on the waitlist, among those who were not transplanted	92	150.5 (43.0–426.0)	153.0 (58.0–477.0)	130.0 (32.0–384.0)	0.39
Length of hospitalization after transplantation, among those who were transplanted	567	15.0 (10.0–27.0)	14.0 (9.0–28.0)	16.0 (11.0–26.0)	0.39

CHD, congenital heart disease; PH, pulmonary hypertension.

1.13), 1 year (HR 0.68, 95% CI 0.40 to 1.18) or 5 years (HR 0.84, 95% CI 0.55 to 1.29). In addition, as shown in Figure 1, overall mortality did not differ significantly between the PH and no-PH groups from time of transplant to 5 years post-transplant ($p = 0.43$). Among those alive at 1 year post-transplant, PH was not significantly associated with long-term survival outcomes ($p = 0.54$; Figure 2).

Discussion

Our analysis highlights several important findings with regard to the association of pre-transplant PH and post-transplant outcomes in the ACHD population. First, ACHD patients who are listed for heart transplant are young and have low rates of comorbidities such as diabetes and hypertension. Second, pre-transplant PH is prevalent among ACHD patients who are listed for heart transplant, but PH at the time of listing is not associated with adverse post-transplant outcomes. Third, ACHD patients with PH have higher waitlist mortality than ACHD patients without PH. Finally, utilization of MCS is limited in the ACHD population.

These findings have important clinical implications for ACHD patients requiring heart transplantation. Our study has shown that ACHD patients are young and have low rates of comorbidities. This may explain the findings from previous studies, which show that, despite the higher operative risk and 1 year post-transplant mortality for ACHD patients, ACHD heart transplant recipients have long-term survival benefit compared with non-ACHD heart transplant recipients if they survive to 1 year post-transplant.[18–21]

Pre-transplant PH was prevalent in our study population, although PH at time of listing was not associated with increased mortality at 30 days, 1 year or 5 years post-transplant. This is not consistent with earlier studies of non-ACHD patients, which show an association between pre-transplant PH and post-transplant mortality.[3,5–9,22] This finding is also different from earlier findings from ACHD patients asserting that pre-transplant PH contributes to higher operative risk and 1-year post-transplant mortality for ACHD heart transplant recipients compared with non-ACHD heart transplant recipients.[1] One possible explanation for this discrepancy is that we used hemodynamic data at the time of listing, whereas other studies performed serial right heart catheterizations while patients were on the waitlist and utilized hemodynamic data closest to the time of transplant.[3,5–8] As a result, in our study, patients with PH at the time of listing may not have had PH at the time of transplant due to optimization of their pre-transplant hemodynamics.

The PH group had a higher rate and risk of waitlist mortality compared with the no-PH group. The increased risk of waitlist mortality seems to indicate that the PH group may have been more critically ill before heart transplant than the no-PH group. Alternatively, there may have been a subset of the PH cohort with persistent PH (i.e., patients with hemodynamic profiles that failed to optimize with medical therapy), which could have contributed to the increased waitlist mortality. It is important to note that the PH cohort also had a higher PCWP compared with the no-PH cohort, suggesting that the PH cohort may have had more advanced left ventricular dysfunction in addition to PH. A greater degree of left ventricular dysfunction could also contribute to waitlist mortality with PH as a secondary marker of elevated left-sided filling pressures.

MCS use at time of listing in the ACHD population was limited, and was not significantly different between the PH

Table 3b Outcomes of Adults With Congenital Heart Disease

Variable	*N*	Overall (*N* = 983)	CHD with PH (*N* = 216)	CHD w/out PH (*N* = 767)
Follow-up outcomes [*N* (%)]				
Died while on waitlist	983	135 (13.7%)	40 (18.5%)	95 (12.4%)
Hospitalized for rejections in the first year among those alive at 1 year post-transplant	210	14 (6.7%)	3 (7.1%)	11 (6.6%)
Rehospitalized in the first year among those alive at 1-year post-transplant	328	69 (21.0%)	14 (19.4%)	55 (21.5%)

CHD, congenital heart disease; PH pulmonary hypertension.

Table 4 Association Between Pulmonary Hypertension at Time of Listing and Survival Outcomes

Variable	HR (95% CI)	*p*-value
Follow-up outcomes		
Waitlist mortality	1.73 (1.25–2.41)	0.001
30-day post-OHT mortality	0.51 (0.23–1.13)	0.098
1-year post-OHT mortality	0.68 (0.40–1.18)	0.175
5-year post-OHT mortality	0.84 (0.55–1.29)	0.428

CI, confidence interval; HR, hazard ratio; OHT, orthotopic heart transplantation.

and no-PH groups. In our study, the no-PH group had higher rates of LVAD utilization, raising the possibility that LVADs were able to reduce pulmonary pressures before listing. In the non-ACHD literature data, it is well established that LVADs are able to reduce pulmonary pressures and possibly reverse PH.[23] Therefore, LVADs may be able to improve post-transplant outcomes by reducing rates of early post-transplant allograft right heart dysfunction and mortality.[24,25] However, the limited use of MCS in the ACHD population makes it difficult to establish an association of LVADs and pre-transplant PH and outcomes.

The results of this investigation should be interpreted in the context of several limitations. First, this was a retrospective study. Modeling techniques do not account entirely for the lack of randomization among cohorts, and the impact of unmeasured confounders is not known. Second, a selection bias may exist, as those with truly severe PH could have died on the waitlist or been denied heart transplantation. Third, certain variables (i.e., MCS use) were only collected after certain dates, so the data included in those particular analyses were limited. Furthermore, because the UNOS database does not collect data on the specific congenital abnormality and corresponding corrective surgery, we cannot ascertain why LVAD use was limited. Fourth, we were unable to account for

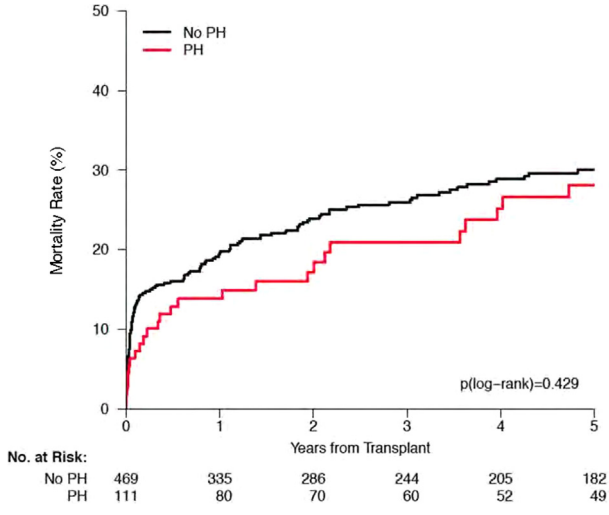

Figure 1 Transplant recipients with congenital heart disease. Kaplan–Meier curve that shows all-cause mortality rates of adult transplant recipients with congenital heart disease stratified by pulmonary hypertension. PH, pulmonary hypertension.

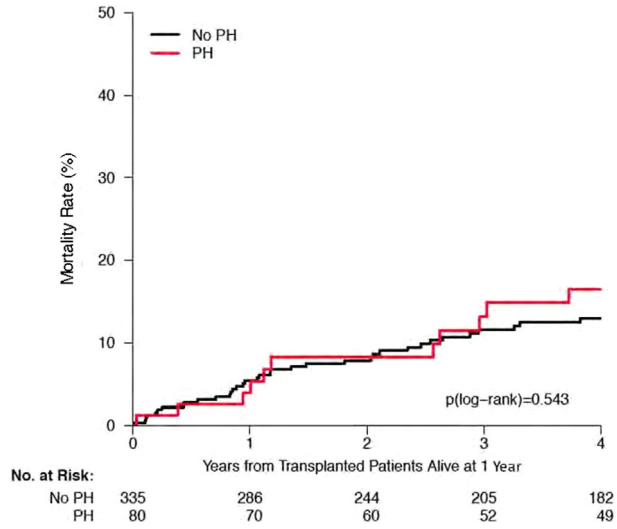

Figure 2 Transplant recipients alive at 1 year with congenital heart disease. Kaplan–Meier curve that shows all-cause mortality rates of adult transplant recipients with congenital heart disease who are alive at 1 year stratified by pulmonary hypertension. PH, pulmonary hypertension.

center-dependent practices that may have impacted waitlist or post-transplant survival. Also, the inclusion time period was long (1987 to 2014), and advancements in pre- and post-transplant management, such as vasodilatory therapy, immunosuppression and MCS, could have affected study outcomes. Finally, because our study was retrospective, the accuracy of the data is dependent on the accuracy of the data reporting; however, we did attempt to minimize the influence of erroneous data entry by utilizing validation ranges for hemodynamic values.

In conclusion, PH is common among ACHD patients listed for transplant and is associated with higher waitlist mortality. Nonetheless, by the time of transplant, PH at time of listing was not significantly associated with post-transplant outcomes. LVAD therapy is uncommon in the ACHD population, but it may emerge as a potential bridge to transplant among patients with ACHD and PH.

Disclosure statement

The authors have no conflicts of interest to disclose. The data reported here have been supplied by the United Network for Organ Sharing as the contractor for the Organ Procurement and Transplantation Network (OPTN). 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 OPTN, the U.S. Government, the National Institutes of Health or the Agency for Healthcare Research and Quality (AHRQ). This study was supported by grants from the National Institutes of Health (T32HL069749-11A1 to L.B.C.) and the AHRQ (U19HS021092 to A.F.H.).

References

1. Patel ND, Weiss ES, Allen JG, et al. Heart transplantation for adults with congenital heart disease: analysis of the United network for organ sharing database. Ann Thorac Surg 2009;88:814-21.

2. Mehra MR, Kobashigawa J, Starling R, et al. Listing criteria for heart transplantation: International Society for Heart and Lung Transplantation guidelines for the care of cardiac transplant candidates—2006. J Heart Lung Transplant 2006;25:1024-42.
3. Vakil K, Duval S, Sharma A, et al. Impact of pre-transplant pulmonary hypertension on survival after heart transplantation: a UNOS registry analysis. Int J Cardiol 2014;176:595-9.
4. Stobierska-Dzierzek B, Awad H, Michler RE. The evolving management of acute right-sided heart failure in cardiac transplant recipients. J Am Coll Cardiol 2001;38:923-31.
5. Goland S, Czer LS, Kass RM, et al. Pre-existing pulmonary hypertension in patients with end-stage heart failure: impact on clinical outcome and hemodynamic follow-up after orthotopic heart transplantation. J Heart Lung Transplant 2007;26:312-8.
6. Chen JM, Levin HR, Michler RE, et al. Reevaluating the significance of pulmonary hypertension before cardiac transplantation: determination of optimal thresholds and quantification of the effect of reversibility on perioperative mortality. J Thorac Cardiovasc Surg 1997;114:627-34.
7. Chang PP, Longenecker JC, Wang NY, et al. Mild vs severe pulmonary hypertension before heart transplantation: different effects on posttransplantation pulmonary hypertension and mortality. J Heart Lung Transplant 2005;24:998-1007.
8. Delgado JF, Gómez-Sánchez MA, Sáenz de la Calzada C, et al. Impact of mild pulmonary hypertension on mortality and pulmonary artery pressure profile after heart transplantation. J Heart Lung Transplant 2001;20:942-8.
9. Klotz S, Wenzelburger F, Stypmann J, et al. Reversible pulmonary hypertension in heart transplant candidates: to transplant or not to transplant. Ann Thorac Surg 2006;82:1770-3.
10. U.S. Department of Health & Human Services. About data. http://optn.transplant.hrsa.gov/converge/data/about/. Accessed June 10, 2015.
11. Buddhe S, Du W, L'Ecuyer T. Impact of pulmonary hypertension on transplant outcomes in pediatric cardiomyopathy patients. Pediatr Transplant 2012;16:367-72.
12. Pons J, Leblanc MH, Bernier M, et al. Effects of chronic sildenafil use on pulmonary hemodynamics and clinical outcomes in heart transplantation. J Heart Lung Transplant 2012;31:1281-7.
13. Tampakakis E, Leary PJ, Selby VN, et al. The diastolic pulmonary gradient does not predict survival in patients with pulmonary hypertension due to left heart disease. JACC Heart Fail 2015;3:9-16.
14. Naeije R, Vachiery JL, Yerly P, et al. The transpulmonary pressure gradient for the diagnosis of pulmonary vascular disease. Eur Respir J 2013;41:217-23.
15. Schulze PC, Kitada S, Clerkin K, et al. Regional differences in recipient waitlist time and pre- and post-transplant mortality after the 2006 United Network for Organ Sharing policy changes in the donor heart allocation algorithm. JACC Heart Fail 2014;2:166-177.
16. Wever-Pinzon O, Drakos SG, Kfoury AG, et al. Morbidity and mortality in heart transplant candidates supported with mechanical circulatory support: is reappraisal of the current United network for organ sharing thoracic organ allocation policy justified? Circulation 2013;127:452-62.
17. Latouche A, Allignol A, Beyersmann J, et al. A competing risks analysis should report results on all cause-specific hazards and cumulative incidence functions. J Clin Epidemiol 2013;66:648-53.
18. Lund LH, Edwards LB, Kucheryavaya AY, et al. Registry of the International Society for Heart and Lung Transplantation: thirty-first official adult heart transplant report—2014. J Heart Lung Transplant 2014;33:996-1008.
19. Lamour JM, Addonizio LJ, Galantowicz ME, et al. Outcome after orthotopic cardiac transplantation in adults with congenital heart disease. Circulation 1999;100:II200-5.
20. Coskun O, Coskun T, El-Arousy M, et al. Heart transplantation in adults with congenital heart disease: experience with 15 patients. ASAIO J 2007;53:103-6.
21. Izquierdo MT, Almenar L, Morales P, et al. Mortality after heart–lung transplantation experience in a reference center. Transplant Proc 2007;39:2360-1.
22. Tsai FC, Marelli D, Bresson J, et al. Recent trends in early outcome of adult patients after heart transplantation: a single-institution review of 251 transplants using standard donor organs. Am J Transplant 2002;2:539-45.
23. Gallagher RC, Kormos RL, Gasior T, et al. Univentricular support results in reduction of pulmonary resistance and improved right ventricular function. ASAIO J 1991;37:M287-8.
24. John R, Liao K, Kamdar F, et al. Effects on pre- and posttransplant pulmonary hemodynamics in patients with continuous-flow left ventricular assist devices. J Thorac Cardiovasc Surg 2010;140:447-52.
25. Zimpfer D, Zrunek P, Roethy W, et al. Left ventricular assist devices decrease fixed pulmonary hypertension in cardiac transplant candidates. J Thorac Cardiovasc Surg 2007;133:689-95.