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Heart Transplantation in Patients from Socioeconomically Distressed Communities

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Abstract

Background: Studies examining heart transplantation disparities have focused on individual factors such as race or insurance status. We characterized the impact of a composite community socioeconomic disadvantage index on heart transplantation outcomes.

Methods: From the Scientific Registry of Transplant Recipients, we identified 49,340 primary, isolated adult heart transplant candidates and 32,494 recipients (2005-2020). Zip code-level socioeconomic disadvantage was characterized using Distressed Community Index (DCI: 0-most prosperous, 100-most distressed) based on education, poverty, unemployment, housing vacancies, median income, and business growth. Patients from distressed communities (DCI ≥80) were compared to all others.

Results: Patients from distressed communities were more often non-White, less educated, and had public insurance (all p<0.01). Distressed patients were more likely to require ventricular assist devices at listing (29.4 vs. 27.1%) and before transplant (44.8 vs. 42.0%, both p<0.001), and they underwent transplants at lower-volume centers (23 vs. 26 cases/year, p<0.01). Distressed patients had higher 1-year waitlist mortality or deterioration (12.3% [95% CI 11.6-13.0] vs. 10.9% [95% CI 10.5-11.3]) and inferior 5-year survival (75.3% [95% CI 74.0-76.5] vs. 79.5% [95% CI 79.0-80.0]) (both p<0.001). After adjustment, living in a distressed community was independently associated with an increased risk of waitlist mortality or deterioration (HR 1.10, 95% CI 1.02-1.18) and post-transplant mortality (HR 1.13, 95% CI 1.06-1.20).

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AUTHOR CONTRIBUTIONS

QC, JM and MB were involved in the study conceptualization and design. QC, JM, and MB conducted the data analysis and drafted the manuscript. All other authors were involved in data interpretation, manuscript review, critical revisions, and final approval of the manuscript.

Conclusions: Patients from socioeconomically distressed communities have worse waitlist and post-transplant mortality. These findings should not be used to limit access to heart transplantation, but rather highlight the need for further studies to elucidate mechanisms underlying the impact of community-level socioeconomic disparity.

INTRODUCTION

Heart transplantation remains the only definitive therapy for end-stage heart failure.[1] However, disparities continue to exist in heart transplant outcomes, with previous studies demonstrating inferior post-transplant survival in non-White patients,[2,3] patients with a lower level of education,[4] and patients with public insurance.[5] These prior studies focused primarily on singular metrics of individual socioeconomic status, and few studies have evaluated composite measures of community socioeconomic environment among heart transplant patients, especially on a population level. The distressed community index (DCI) characterizes zip-code-level socioeconomic disadvantage based on education level, poverty, unemployment, housing vacancies, median income, and business growth.[6] This composite measure was found to be associated with coronary bypass artery grafting outcomes,[7,8] failure to rescue after cardiac surgeries,[9] and adverse clinical outcomes in patients with heart failure.[10] Therefore, we sought to characterize the impact of the DCI on waitlist and post-transplant outcomes using data from a national transplant registry.

METHODS

Data source

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donor, wait-listed candidates, and transplant recipients in the US, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors. Between 2005 and 2020, we identified 36,619 adult heart transplant recipients. Exclusion criteria included heart retransplants (n=1,296), multiorgan transplants (n=1,869), and missing or non-US zip codes (n=960), leaving a final cohort of 32,494 heart transplant recipients. During the same period, 52,944 waitlisted adult heart transplant candidates were identified (listed between 1/1/2005 and 12/31/2020). After excluding candidates with prior heart transplants or multiorgan listings (n=2,227) and those with missing or non-US zip codes (n=1,377), 49,340 candidates remained.

Community-level socioeconomic distress was determined using the DCI, developed by the Economic Innovation Group using the U.S. Census Bureau's business patterns and American Community Survey data. This is a composite score based on the following 7 metrics at each 5-digit zip code area: no high school degree, poverty rate, housing vacancy rate, unemployment rate, median household income ratio, change in employment, and change in business establishments. Each zip code area is first ranked on each measure. Next, their seven rankings are averaged and weighted equally to generate a preliminary score, which is then normalized into a final score ranging from 0 (most prosperous) to 100 (most distressed). This score is then linked to patient-level data using the zip code at the time of listing (for waitlisted candidates) or transplant (for recipients). The DCI captures more than 99% of the U.S. population and 26,000-plus zip codes with at least 500 residents. It is sorted into five quintiles of economic well-being: prosperous, comfortable, mid-tier, at risk, and distressed.[11] Patients from distressed communities (quintile 5, DCI ≥80) were compared with all others (quintile 1-4, DCI<80).

Recipient/donor characteristics and patient outcomes were defined according to the standard SRTR definitions (https://www.srtr.org/requesting-srtr-data/saf-data-dictionary/). Those with status 1A before the 2018 allocation policy change and status 1, 2, or 3 afterward were considered to have urgent status at transplant. Donor to recipient predicated heart mass ratio was calculated with a previously developed formula using recipient age, sex, height, and weight.[12] It was used as a surrogate for donor-recipient size match. Recipient's functional status was classified using the Karnofsky Performance Scale Index. Annual center volume is defined as the total number of all heart transplants performed at a center during each calendar year. This study was approved by the Institutional Review Board at Cedars-Sinai Medical Center, with a waiver of informed consent (IRB protocol ID: STUDY00001188, approval date 2/19/2021). The study also complies with the International Society for Heart and Lung Transplantation ethics statement.

Primary and secondary outcomes

The primary outcomes included waitlist mortality or deterioration with subsequent waitlist removal and survival after heart transplantation. Secondary outcomes included the likelihood of transplantation while waitlisted, post-transplant in-hospital complications (dialysis, permanent pacemaker implant, stroke, treated acute rejection), length of stay, 30-day mortality, and 90-day mortality. The median post-transplant follow-up was 5.0 (interquartile range [IQR] 2.1-9.1) years. Among patients who survived at least 1 year after transplant with available follow-up, we also evaluated any rejections, cardiac allograft vasculopathy, and hospital readmissions within 1-year follow-up.

Statistical analysis

Baseline patient characteristics were reported as either mean ± standard deviation or median with IQR for continuous variables depending on overall distribution and proportions for categorical variables. Between-group comparisons were performed using Student’s t-test or Wilcoxon rank-sum test for continuous variables depending on the variable distribution. Pearson’s χ^2-test was performed for categorical variables. Post-transplant survival was analyzed using the Kaplan-Meier method and compared between strata using the log-rank test. Waitlist mortality or clinical deterioration with subsequent removal from the waitlist was evaluated with competing risk analysis, with transplantation or other removals from the waitlist treated as a competing risk event. The likelihood of transplantation while on the waitlist was also assessed, with waitlist death or waitlist removals treated as a competing risk. Right censoring was performed at 12 months for waitlist outcomes and 5 years for post-transplant survival, and patients who did not reach these follow-up times were censored on the last follow-up date. Of the variables included, most had <1% missing data. This was addressed using simple imputation, where missing values were imputed to the most common category for categorical variables and the median for continuous variables (Supplemental Table 1).

A multivariable Fine-Gray sub-distribution hazard model was constructed to evaluate the independent effect of DCI on waitlist outcomes (waitlist mortality/deterioration and transplantation rate). Variables included for adjustment were determined *a priori* based on clinical relevance. They included baseline characteristics at listing such as candidate age, sex, race, body mass index (BMI), diabetes, cerebrovascular disease, dialysis, creatinine, listing status, primary diagnosis, previous cardiac surgery, mechanical circulatory support (MCS), intravenous inotropes, mechanical ventilation use, functional status, geographic region, the annual center volume of all heart transplants, and listing year. The DCI was first incorporated as a binary variable (distressed: DCI ≥80; not distressed: DCI<80). Next, we examined the effect of DCI as a continuous variable by modeling it using restricted cubic splines with five knots placed at the 5th, 27.5th, 50th, 72.5th, and 95th percentiles of DCI, and a DCI of 0 (most prosperous) was set as the reference value for comparison. Sensitivity analyses using cause-specific hazard modeling were also performed.

We also constructed multivariable Cox models to evaluate the independent effect of DCI on post-transplant mortality. Similarly, the DCI was first incorporated as a binary variable and then a continuous variable using restricted cubic splines. Variables included in the Cox model for adjustment were also determined *a priori* based on clinical relevance. They included recipient characteristics (age, gender, race, BMI, diabetes, previous cardiac surgery, primary diagnosis, listing status, total bilirubin, creatinine, dialysis after listing, pre-transplant MCS, intravenous inotropes, mechanical ventilation, functional status, transplant year, and annual center volume) and donor characteristics (age, gender, left ventricular ejection fraction, gender mismatch, size mismatch, total ischemic time). The clustering of patients within each transplant center was accounted for using a robust variance estimator. The proportional hazard assumption was also checked with martingale residuals and was not violated.

To explore the intersectionality between race and DCI, separate models for both waitlist mortality or deterioration and post-transplant mortality were constructed by including the interaction term between recipient race (white vs. non-white) and community distress (distressed [DCI ≥80] vs. non-distressed [DCI<80]). All tests were two-tailed with an alpha level of 0.05. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina).

RESULTS

Waitlisted candidates and outcomes

From 1/1/2005 to 12/31/2020, 49,340 waitlisted candidates were included. Compared to candidates from non-distressed communities (n=41,234), those from distressed communities (n=8,106) were younger (56 vs. 54 years), more frequently female (28.8 vs. 24.9%) and Black (45.6 vs. 18.4%), with a higher prevalence of public insurance (60.0 vs. 45.1%) and a lower level of education (all p<0.001). They were also more likely to be supported with a ventricular assist device/total artificial heart (29.4 vs. 27.1%, p<0.001) or require intravenous inotropic support (33.8 vs. 31.9%, p<0.001) at the time of listing. Other candidate characteristics at listing are outlined in Table 1.

One-year cumulative incidence of waitlist mortality or deterioration was 12.3% (95% CI 11.6-13.0) for candidates from distressed communities and 10.9% (95% CI 10.5-11.3) for others (Figure 1A, unadjusted subdistribution HR 1.13, 95% CI 1.06-1.21, p=0.004). After adjustment, this difference persisted (adjusted subdistribution HR 1.10, 95% CI 1.02-1.18, p<0.001). The relationship between DCI as a continuous variable and the risk of waitlist mortality or deterioration is shown in Figure 2. When the interaction between race (white vs. non-white) and community distress level was considered, living in a distressed community was associated with an increased risk of waitlist mortality or deterioration for both white patients and non-white patients ($P_{interaction}$=0.46). One-year cumulative incidence of transplantation was 54.8% (95% CI 53.7-55.9) for candidates from distressed communities and 58.8% (95% CI 58.3-59.3) for others (p<0.001, Figure 1B). Results from the sensitivity analyses using cause-specific hazard modeling are shown in Supplemental Table 2.

Transplant recipients

Compared to recipients from non-distressed communities (n=27,451), those from distressed communities (n=5,043) were younger (54 vs. 56 years) and more often Black (43.3 vs. 17.0%), less educated (39.4 vs. 54.4% with a college degree), with a higher proportion having public insurance (62.1 vs. 47.2%, all p<0.01). Additionally, they more frequently were diabetic (29.5 vs. 26.9%, p<0.001), required dialysis after listing (2.1 vs. 1.7%, p=0.05), and received pre-transplant VAD/TAH support (44.8 vs. 42.0%, p<0.001). They also underwent transplantation at lower-volume centers (23 [IQR 15-38] vs. 26 [IQR 16-43] cases/year) and lived further away from their transplant centers (48 [IQR 9-107] vs. 30 [IQR 13-81] miles, both p<0.01). Other recipient characteristics are reported in Table 2. Recipients from distressed and non-distressed communities received similar donors (Table 2).

Post-transplant outcomes

After heart transplantation, recipients from distressed communities had more acute rejection episodes before initial discharge (12.7 vs. 10.4%, p<0.001). Other in-hospital outcomes and short-term mortality are similar (Table 3). Among 90% of recipients who survived at least 1 year after the transplant with available follow-up (29,112/3,2494), those from distressed communities had more hospital readmissions within 1 year (40.5 vs. 38.5%, p=0.01) but similar rates of rejections and coronary artery disease (Supplemental Table 3). Post-transplant survival at 1, 3, and 5 years was 89.6% (95% CI 88.7-90.4), 82.0% (95% CI 80.9-83.1), and 75.3% (95% CI 74.0-76.5) for distressed recipients and 90.7% (95% CI 90.4-91.0), 84.8% (95% CI 84.4-85.2), and 79.5% (95% CI 79.0-80.0) for non-distressed recipients (Figure 3, p<0.001). Among patients who died within 5 years of transplant, distressed patients were more likely to die from graft failure (17.9 vs. 14.0%) and cardiovascular causes (4.3 vs. 2.5%), and less likely to die from infections, malignancy, or multiorgan failure (all p<0.01, Figure 4). The 5-year cumulative incidence of any acute rejections was higher in patients from distressed communities (unadjusted HR 1.08, 95% CI 1.02-1.13, p=0.007, Supplemental Figure 1). However, after adjusting for recipient age, sex, race, ischemic cardiomyopathy diagnosis, transplant era, and annual center volume, this difference was no longer observed (HR 1.00, 95% CI 0.95-1.06), and both annual center volume (HR 0.85, 95% CI 0.81-0.88) and recipient race (HR for black recipients [as compared to white]: 1.14, 95% CI 1.09-1.20) were significantly associated with the risk of rejection.

Compared to non-distressed recipients, those from distressed communities had an increased risk of post-transplant mortality (unadjusted HR 1.22, 95% CI 1.15-1.30, p<0.001), and this difference persisted after multivariable adjustment (adjusted HR 1.13, 95% CI 1.06-1.20, p<0.001). The relationship between DCI as a continuous variable and post-transplant mortality risk is shown in Figure 2. When the interaction between recipient race (white vs. non-white) and community distress level was considered, living in a distressed community was associated with an increased risk of post-transplant mortality for both white patients and non-white patients ($P_{interaction}$=0.29).

DISCUSSION

This analysis of the national SRTR database has several important findings. First, living in a distressed community, as reflected by the DCI, correlated with increasing comorbidities before transplant. Second, higher DCI was associated with an increased risk of mortality among both waitlisted candidates and heart transplantation recipients. Those from distressed communities had a 13% higher risk of waitlist mortality or deterioration and a 22% higher risk of post-transplant mortality. After adjusting for baseline risk factors, DCI remained independently associated with both waitlist and post-transplant mortality. Lastly, in the analysis exploring the intersectionality between race and DCI, these associations between DCI and mortality were observed irrespective of patient race.

While previous studies have examined the effect of individual race,[2,3] insurance status,[13] and level of education on heart transplantation outcomes,[5] few have studied the effect of composite measures of community socioeconomic disadvantage using population-level data. A 2017 study utilizing national United Network for Organ Sharing (UNOS) data showed that county-level socioeconomic disadvantage failed to predict mortality after heart transplantation.[14] However, this study relied on matching patient zip codes to counties, which may have misclassified some patients' counties of residence and masked the true effect of community socioeconomic disadvantage. An analysis of the UNOS registry using a zip code-based community socioeconomic index found that heart transplant recipients (1994-2014) living in more disadvantaged areas had 22% higher odds of death or re-transplantation.[4] This was similarly observed in a United Kingdom-based national registry analysis.[15] Our study confirmed these findings in a more contemporary national cohort. Unlike previous studies, we also treated socioeconomic disadvantage as a continuous, non-linear variable in addition to arbitrarily defined categories. This allowed us to assess its effect more accurately across communities with varying degrees of socioeconomic deprivation.

The mechanisms underlying the association between community socioeconomic disadvantage and heart transplant outcomes may be multifactorial. This is difficult to ascertain based on the present study due to unmeasured confounders and the complex causal pathways between different factors. However, our data may provide some possible explanations. First, living in a distressed community was correlated with increasing pre-transplant comorbidities. For example, we observed a higher incidence of diabetes and an increased need for pre-transplant dialysis and MCS among patients from distressed communities. Second, differences in referral trajectory and access to high-quality care may play a role, as distressed patients in our study more frequently underwent transplantation at a lower volume center and lived further away from their transplant center. Third, we observed that in-hospital and short-term outcomes were mainly similar irrespective of community socioeconomic disadvantage, and distressed patients were more likely to be readmitted after discharge. These findings suggest that longitudinal post-transplant care, rather than perioperative care, may be the most sensitive to community socioeconomic disparity. Fourth, distressed patients were more likely to die from graft failure or cardiovascular causes within 5 years of transplantation. The 5-year crude incidence of any acute rejections was also significantly higher in distressed patients. However, this difference was no longer significant after adjusting for risk factors including recipient race, highlighting the potential role of genetic polymorphism and race-based differences in immune responsiveness [16,17] and the complex interplay between race and socioeconomic disparity.

The current SRTR risk-adjustment models for survival after heart transplantation contains patient-level socioeconomic data on race, insurance status, and the highest level of education.[18] Our findings, along with the large body of evidence demonstrating a strong association between community socioeconomic environment and outcomes of cardiovascular interventions,[7-9,19,20] suggest it may be beneficial to consider incorporating composite measures of community socioeconomic disadvantage into risk-adjustment models. This may better account for variations in the social deprivation of patient populations treated at different centers and help improve performance monitoring and quality comparisons. At the same time, it’s essential to recognize that our findings should not be used to limit or deter heart transplantation among those living in disadvantaged communities. Instead, future efforts should be focused on broadening access and developing targeted interventions to address the unique needs of these patients. This may involve providing improved access to transportation to medical appointments, additional support for optimizing insurance coverage to maintain equal access and delivery of post-transplant care, and connecting patients to social support networks. Further research is needed to better uncover the mechanisms underlying the impact of community-level socioeconomic disparity on outcomes in the heart transplant population and test the effectiveness of various specific targeted interventions.

Limitations

Despite using population-based data to evaluate the association between community-level socioeconomic distress and outcomes among heart transplant patients, our approach is subject to several limitations. First, each DCI is calculated at the 5-digit zip code level. This may lack sufficient granularity due to the considerable heterogeneity in education, income, housing, and employment status within a single zip code region. More granular measures of socioeconomic disadvantage at the neighborhood or block level often require a 9-digit zip code for linkage with patient-level data, which was unavailable in the SRTR database. Second, the DCI scores used in this analysis were calculated using census data from 2016-2020. This may not reflect the community socioeconomic condition of patients during the early study periods, especially as we included patients who were transplanted or listed since 2005. Third, because SRTR only collected patient zip codes at the time of listing or transplant, we could not account for subsequent patient relocation. Fourth, no information was available regarding patients evaluated for transplantation but turned down for listing. Similarly, for waitlisted patients, detailed information regarding access to durable MCS bridging was not available, and future investigations into access to durable MCS bridging based on socioeconomic status are needed. Fifth, in the competing risk analysis of waitlist mortality or clinical deterioration, it's possible that those removed from the waitlist for clinical deterioration could receive a durable mechanical support device and be transplanted later. However, there was insufficient information in the SRTR database to account for this. Lastly, one-year outcomes presented in this study should be interpreted with caution, as they were derived from patients who were alive at 1-year after transplantation with available follow-up without considering the competing risk of death. We also attempted to perform time-to-event competing risk analyses to estimate the cumulative incidence of acute rejections. However, there were no event dates for these outcomes in the SRTR database, and we had to use the post-transplant follow-up date where these events were first documented, which may lead to inaccurate estimations. Other longitudinal outcomes such as hospital readmissions, cardiac allograft vasculopathy, and patient non-adherence are largely incomplete in SRTR and not included.

CONCLUSION

Community-level socioeconomic distress was associated with both waitlist outcomes and post-transplant outcomes. Patients living in distressed communities experienced higher rates of waitlist mortality or deterioration and post-transplant mortality, and the deleterious effect of socioeconomic distress exists for both White and non-White patients. These results should not be used to limit access to transplantation. Further prospective studies are needed to fully understand the mechanisms underlying the impact of community-level socioeconomic disparity on outcomes in the heart transplant population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

DCI	Distressed Community Index
HR	Hazard Ratio
IQR	Interquartile Range
OPTN	Organ Procurement and Transplantation Network
SRTR	Scientific Registry of Transplant Recipients
UNOS	United Network for Organ Sharing

REFERENCES

1. Metra M, Ponikowski P, Dickstein K, et al. Advanced chronic heart failure: A position statement from the Study Group on Advanced Heart Failure of the Heart Failure Association of the European Society of Cardiology. Eur J Heart Fail. 2007;9(6-7):684–694. doi:10.1016/j.ejheart.2007.04.003 [PubMed: 17481947]
2. Chouairi F, Fuery M, Clark KA, et al. Evaluation of Racial and Ethnic Disparities in Cardiac Transplantation. J Am Heart Assoc. 2021;10(17):e021067. doi:10.1161/JAHA.120.021067 [PubMed: 34431324]
3. Morris AA, Kransdorf EP, Coleman BL, Colvin M. Racial and ethnic disparities in outcomes after heart transplantation: A systematic review of contributing factors and future directions to close the outcomes gap. J Heart Lung Transplant. 2016;35(8):953–961. doi:10.1016/j.healun.2016.01.1231 [PubMed: 27080415]
4. Wayda B, Clemons A, Givens RC, et al. Socioeconomic Disparities in Adherence and Outcomes After Heart Transplant: A UNOS (United Network for Organ Sharing) Registry Analysis. Circ Heart Fail. 2018;11(3):e004173. doi:10.1161/CIRCHEARTFAILURE.117.004173 [PubMed: 29664403]
5. Allen JG, Weiss ES, Arnaoutakis GJ, et al. Insurance and education predict long-term survival after orthotopic heart transplantation in the United States. J Heart Lung Transplant. 2012;31(1):52–60. doi:10.1016/j.healun.2011.07.019 [PubMed: 21959122]
6. Kesler P. Distressed Communities. Economic Innovation Group. Accessed December 28, 2022. https://eig.org/distressed-communities/
7. Mehaffey JH, Hawkins RB, Charles EJ, et al. Distressed communities are associated with worse outcomes after coronary artery bypass surgery. J Thorac Cardiovasc Surg. 2020;160(2):425–432.e9. doi:10.1016/j.jtcvs.2019.06.104 [PubMed: 31543309]
8. Charles EJ, Mehaffey JH, Hawkins RB, et al. Socioeconomic 'Distressed Communities Index' Predicts Risk-Adjusted Mortality After Cardiac Surgery. Ann Thorac Surg. 2019;107(6):1706–1712. doi:10.1016/j.athoracsur.2018.12.022 [PubMed: 30682354]
9. Strobel RJ, Kaplan EF, Young AM, et al. Socioeconomic distress is associated with failure to rescue in cardiac surgery. J Thorac Cardiovasc Surg. Published online July 20, 2022:S0022-5223(22)00798-X. doi:10.1016/j.jtcvs.2022.07.013
10. Mentias A, Desai MY, Vaughan-Sarrazin MS, et al. Community-Level Economic Distress, Race, and Risk of Adverse Outcomes After Heart Failure Hospitalization Among Medicare Beneficiaries. Circulation. 2022;145(2):110–121. doi:10.1161/CIRCULATIONAHA.121.057756 [PubMed: 34743555]
11. Kesler P. 2022 DCI Methodology. Economic Innovation Group. Accessed December 28, 2022. https://eig.org/distressed-communities/2022-dci-methodology/
12. Kransdorf EP, Kittleson MM, Benck LR, et al. Predicted heart mass is the optimal metric for size match in heart transplantation. J Heart Lung Transplant. 2019;38(2):156–165. doi:10.1016/j.healun.2018.09.017 [PubMed: 30528987]

13. Tumin D, Foraker RE, Smith S, Tobias JD, Hayes D. Health Insurance Trajectories and Long-Term Survival After Heart Transplantation. Circ Cardiovasc Qual Outcomes. 2016;9(5):576–584. doi:10.1161/CIRCOUTCOMES.116.003067 [PubMed: 27625403]
14. Tumin D, Horan J, Shrider EA, et al. County socioeconomic characteristics and heart transplant outcomes in the United States. Am Heart J. 2017;190:104–112. doi:10.1016/j.ahj.2017.05.013 [PubMed: 28760203]
15. Evans JDW, Kaptoge S, Caleyachetty R, et al. Socioeconomic Deprivation and Survival After Heart Transplantation in England: An Analysis of the United Kingdom Transplant Registry. Circ Cardiovasc Qual Outcomes. 2016;9(6):695–703. doi:10.1161/CIRCOUTCOMES.116.002652 [PubMed: 27803093]
16. Hutchings A, Purcell WM, Benfield MR. Peripheral blood antigen-presenting cells from African-Americans exhibit increased CD80 and CD86 expression. Clin Exp Immunol. 1999;118(2):247–252. doi:10.1046/j.1365-2249.1999.01051.x [PubMed: 10540186]
17. Girnita DM, Ohmann EL, Brooks MM, et al. Gene polymorphisms impact the risk of rejection with hemodynamic compromise: a multicenter study. Transplantation. 2011;91(12):1326–1332. doi:10.1097/TP.0b013e31821c1e10 [PubMed: 21659963]
18. Snyder JJ, Salkowski N, Kim SJ, et al. Developing Statistical Models to Assess Transplant Outcomes Using National Registries: The Process in the United States. Transplantation. 2016;100(2):288–294. doi:10.1097/TP.0000000000000891 [PubMed: 26814440]
19. Strobel RJ, Mehaffey JH, Hawkins RB, et al. Socioeconomic Distress Associated With Increased Use of Percutaneous Coronary Intervention Over Coronary Artery Bypass Grafting. Ann Thorac Surg. Published online July 19, 2022:S0003-4975(22)00969-9. doi:10.1016/j.athoracsur.2022.06.040
20. Kabbani LS, Wasilenko S, Nypaver TJ, et al. Socioeconomic disparities affect survival after aortic dissection. J Vasc Surg. 2016;64(5):1239–1245. doi:10.1016/j.jvs.2016.03.469 [PubMed: 27374067]

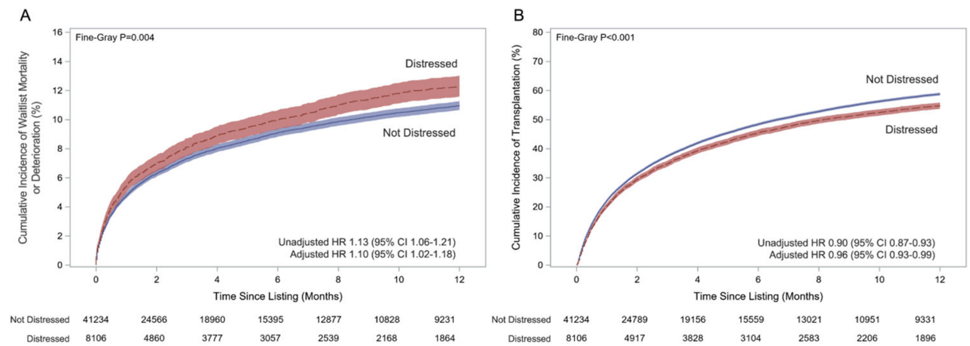

Figure 1. Cumulative incidence of waitlist mortality or clinical deterioration (A) and transplantation (B), stratified by community socioeconomic distress

Patients were stratified based on the distressed community index (DCI) into those from distressed communities (DCI ≥80) and not distressed communities (DCI<80). Waitlist mortality/deterioration and transplantation rate were evaluated with competing risk analysis. Variables included for adjustment are outlined in statistical methods. Sub-distributional hazard ratios are presented.

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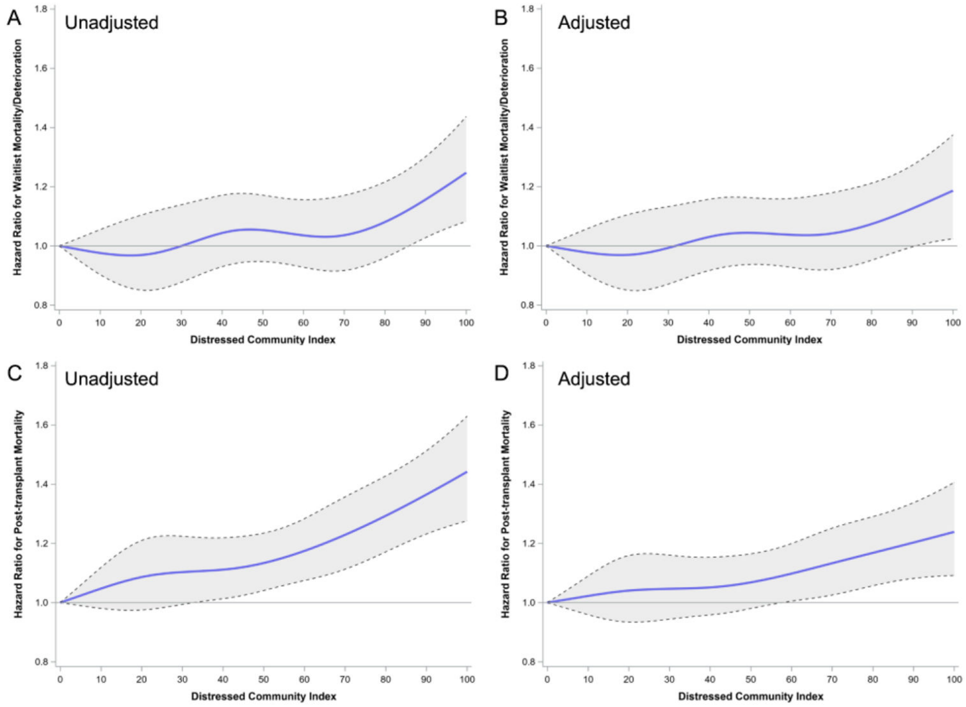

Figure 2. Relationship between distressed community index and risk of waitlist mortality within 1-year of listing (A,B) and post-transplant mortality within 5-year follow-up (C,D)

Restricted cubic spline curves with 5 knots at 5th, 27.5th, 50th, 72.5th, and 95th percentiles are shown. A higher distress community index (DCI) value suggests increasing socioeconomic disadvantage. Hazard ratios and 95% confidence intervals are calculated using DCI=0 (most prosperous) as the reference point. The variables included for adjustment are outlined in the statistical methods.

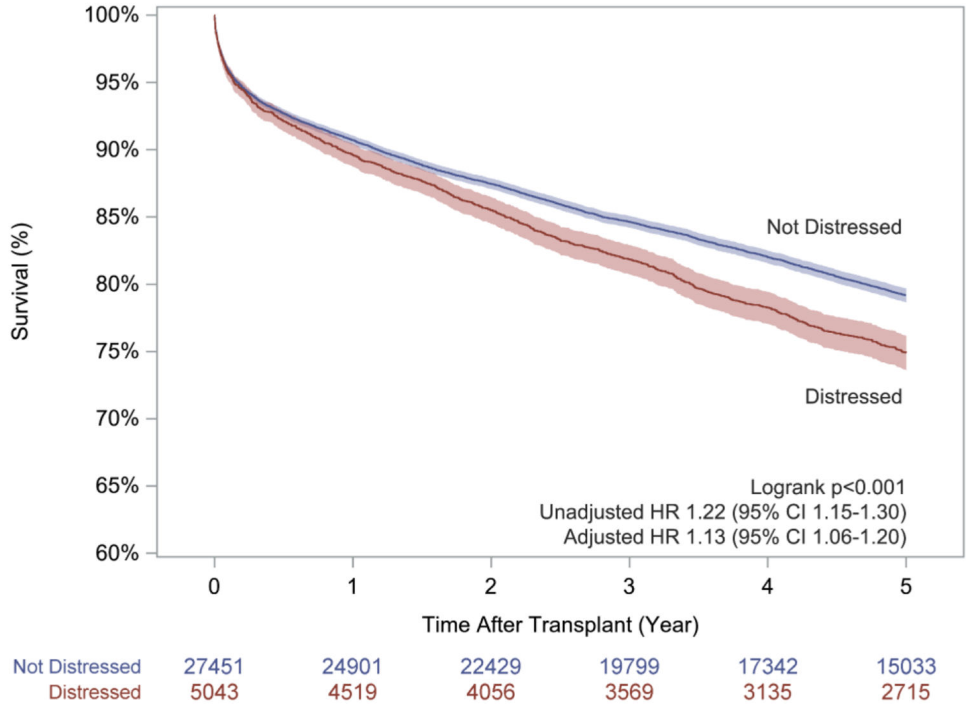

Figure 3. Post-transplant survival stratified by community socioeconomic distress

Patients were stratified based on the distressed community index (DCI) into those from distressed communities (DCI ≥80) and not distressed communities (DCI<80). Variables included for adjustment are outlined in statistical methods.

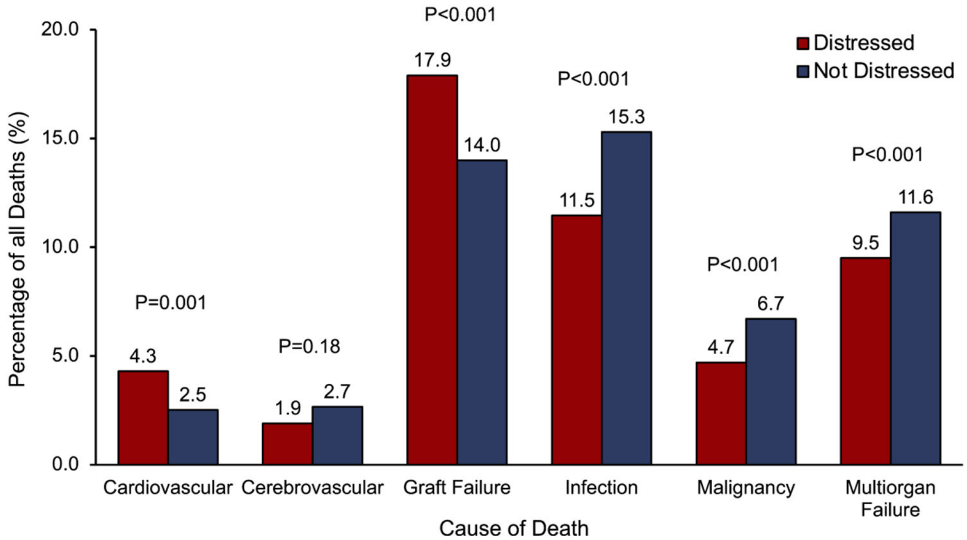

Figure 4. Recipient primary causes of death after heart transplantation

Only recipients who died within 5-year follow-up are included. Patients were stratified based on the distressed community index (DCI) into those from distressed (DCI ≥80) and not distressed communities (DCI<80). Deaths from other causes (49.3% in distressed and 46.4% in non-distressed recipients, p=0.10) are not shown

Table 1.

Baseline characteristics of waitlisted heart transplant candidates

Variables	Distressed (n=8106)	Not distressed (n=41234)	P value
Age (years)	54 (43-61)	56 (46-63)	<0.001
Body mass index (kg/m^2)	28 (24-32)	27 (24-31)	<0.001
Male sex	71.2 (5768)	75.1 (30963)	<0.001
Race			<0.001
White	52.3 (4236)	77.0 (31752)	
Black	45.6 (3695)	18.4 (7600)	
Asian	0.9 (75)	3.5 (1428)	
Pacific islander	0.1 (7)	0.4 (157)	
Native American	0.8 (62)	0.2 (106)	
Multiracial	0.4 (31)	0.5 (191)	
Ethnicity			<0.001
Hispanic	10.4 (842)	7.6 (3128)	
Non-Hispanic or unknown	89.6 (7264)	92.4 (38106)	
Public insurance	60.0 (4861)	45.1 (18574)	<0.001
Highest level of education			<0.001
College degree or more	39.7 (3218)	54.1 (22290)	
High school degree or less	60.3 (4888)	45.9 (18944)	
Working for income	8.0 (647)	15.2 (6268)	<0.001
Cerebrovascular disease	6.2 (499)	5.7 (2344)	0.10
Diabetes	31.7 (2568)	29.0 (11965)	<0.001
Type O blood	46.4 (3764)	43.3 (17872)	<0.001
Dialysis	3.1 (254)	2.9 (1187)	0.21
Creatinine (mg/dL)	1.20 (1.00-1.50)	1.20 (0.97-1.50)	0.004
Smoking history	50.0 (4053)	47.0 (19369)	<0.001
Mechanical ventilation	2.1 (168)	2.2 (895)	0.58
MCS at listing			
VAD/TAH	29.4 (2385)	27.1 (11192)	<0.001
ECMO	1.1 (86)	1.4 (592)	0.08
IABP	6.8 (552)	6.3 (2598)	0.09
Intravenous inotropic support	33.8 (2742)	31.9 (13174)	0.001
Status 1A, 1, 2, or 3	23.0 (1861)	23.9 (9837)	0.09
Functional status			0.08
Mild limitation	12.3 (999)	13.4 (5527)	
Moderate limitation	41.2 (3339)	40.2 (16565)	
Severe limitation	43.2 (3500)	43.4 (17894)	
Unknown	3.3 (268)	3.0 (1248)	

Values are expressed in % (n) or median (interquartile range)

ECMO: extracorporeal membrane oxygenation; IABP: Intra-aortic balloon pump; TAH: total artificial heart; VAD: ventricular assist devices

Table 2.

Baseline heart transplant recipient and donor characteristics

Variables	Distressed (n=5043)	Not Distressed (n=27451)	P value
Recipient characteristics			
Age (years)	54 (44-61)	56 (47-63)	<0.001
Male sex	72.0 (3629)	74.5 (20458)	<0.001
Body mass index (kg/m^2)	28 (21-31)	27 (24-31)	<0.001
Race			<0.001
White	54.7 (2760)	78.3 (21480)	
Black	43.3 (2185)	17.0 (4665)	
Asian	0.9 (46)	3.7 (1011)	
Pacific islander	0.1 (5)	0.4 (97)	
Native American	0.6 (29)	0.3 (69)	
Multiracial	0.4 (18)	0.5 (129)	
Ethnicity			<0.001
Hispanic	10.9 (549)	7.6 (2081)	
Non-Hispanic or unknown	89.1 (4494)	92.4 (25370)	
Insurance type			<0.001
Public	62.1 (3131)	47.2 (12955)	
Private	37.2 (1876)	52.2 (14320)	
Others	0.7 (36)	0.6 (176)	
Highest level of education			<0.001
College or more	39.3 (1984)	54.4 (14932)	
High school or less	60.7 (3059)	45.6 (12519)	
Working for income	5.5 (277)	9.9 (2726)	<0.001
Diabetes	29.5 (1485)	27.0 (7402)	<0.001
Cerebrovascular disease	6.0 (303)	5.6 (1537)	0.25
Previous cardiac surgery	23.8 (1198)	23.7 (6515)	0.97
Dialysis after listing	2.1 (105)	1.7 (465)	0.05
Transfusion after listing	21.6 (1088)	20.6 (5647)	0.11
Type O blood	40.3 (2033)	38.9 (10664)	0.05
Congenital heart disease	2.6 (132)	3.7 (1005)	<0.001
Ischemic cardiomyopathy	33.7 (1697)	36.7 (10077)	<0.001
Pre-transplant MCS			
ECMO	1.0 (50)	1.5 (411)	0.06
VAD or TAH	44.8 (2258)	42.0 (11540)	<0.001
IABP	9.7 (489)	10.0 (2748)	0.49
Mechanical ventilation	1.6 (82)	1.6 (446)	0.99
Intravenous inotropic support	38.5 (1943)	38.3 (10503)	0.72
Status 1A, 1, 2, or 3 at transplant	56.6 (2854)	56.7 (15566)	0.88
Time on waitlist (days)	81 (23-244)	81 (21-251)	0.44

Variables	Distressed (n=5043)	Not Distressed (n=27451)	P value
Creatinine (mg/dL)	1.20 (0.96-1.50)	1.18 (0.92-1.42)	<0.001
Bilirubin (mg/dL)	0.70 (0.50-1.10)	0.70 (0.50-1.10)	0.50
Pre-transplant location			0.18
Hospitalized, intensive care unit	32.6 (1646)	32.5 (8931)	
Hospitalized, non-intensive care unit	14.4 (727)	15.4 (4229)	
Not hospitalized	52.9 (2670)	52.1 (14291)	
Functional limitation			0.60
Mild	14.3 (721)	14.4 (3949)	
Moderate	31.1 (1569)	31.9 (8756)	
Severe	50.2 (2533)	49.6 (13619)	
Unknown	4.4 (220)	4.1 (1127)	
Donor characteristics			
Age (years)	30 (22-41)	30 (22-40)	0.71
Male gender	71.1 (3586)	71.2 (19542)	0.91
Race			<0.001
White	64.9 (3274)	64.6 (17726)	
Black	18.6 (936)	16.0 (4397)	
Hispanic	14.5 (732)	16.6 (4545)	
Asian	1.2 (61)	1.7 (479)	
Others	0.8 (40)	1.1 (304)	
Diabetes	4.1 (206)	4.0 (1099)	0.79
Hypertension	16.2 (816)	15.5 (4265)	0.25
Cocaine use	18.7 (944)	19.3 (5299)	0.33
Smoking history (>20 pack years)	14.5 (729)	13.5 (3713)	0.08
Left ventricular rejection fraction <50%	2.0 (99)	1.7 (457)	0.13
Female donor to male recipient	12.8 (647)	13.8 (3780)	0.08
Size mismatch (donor/recipient predicted heart mass ratio<0.86)	14.1 (710)	13.8 (3787)	0.59
Hepatitis C positivity*	2.6 (129)	3.0 (820)	0.10
Ischemic time (hours)	3.2 (2.5-3.8)	3.2 (2.5-3.9)	0.30

Values are expressed in % (n) or median (interquartile range)

ECMO: extracorporeal membrane oxygenation; IABP: Intra-aortic balloon pump; TAH: total artificial heart; VAD: ventricular assist devices

*Hepatitis C positivity was defined as having a positive antibody to the hepatitis C virus or a positive nucleic acid amplification test

Table 3.

Short-term outcomes after heart transplantation

Variables	Distressed (n=5043)	Not Distressed (n=27451)	P value
In-hospital outcomes			
Treated acute rejection episodes	12.7 (640)	10.4 (2849)	<0.001
Permanent pacemaker	2.7 (136)	3.0 (824)	0.24
Stroke	2.4 (122)	2.9 (781)	0.10
Dialysis requirement	10.9 (548)	10.9 (2981)	0.99
Post-transplant length of stay (days)	15 (11-24)	15 (11-22)	0.40
Short-term mortality			
30-day mortality	3.9 (195)	3.7 (1027)	0.67
90-day mortality	6.0 (302)	5.7 (1572)	0.46

Values are expressed in % (n) or median (interquartile range)