ORIGINAL RESEARCH

Trends and Outcomes of Cardiac Transplantation in the Lowest Urgency Candidates

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BACKGROUND: Because of discrepancies between donor supply and recipient demand, the cardiac transplantation process aims to prioritize the most medically urgent patients. It remains unknown how recipients with the lowest medical urgency compare to others in the allocation process. We aimed to examine differences in clinical characteristics, organ allocation patterns, and outcomes between cardiac transplantation candidates with the lowest and highest medical urgency.

METHODS AND RESULTS: We performed a retrospective analysis of the United Network for Organ Sharing database. Patients listed for cardiac transplantation between January 2011 and May 2020 were stratified according to status at time of transplantation. Baseline recipient and donor characteristics, waitlist survival, and posttransplantation outcomes were compared in the years before and after the 2018 allocation system change. Lower urgency patients in the old system were older (58.5 versus 56 years) and more likely female (54.4% versus 23.8%) compared with the highest urgency patients, and these trends persisted in the new system ($P<0.001$, all). Donors for the lowest urgency patients were more likely older, female, or have a history of cytomegalovirus, hepatitis C, or diabetes ($P<0.01$, all). The lowest urgency patients had longer waitlist times and under the new allocation system received organs from shorter distances with decreased ischemic times (178 miles versus 269 miles, 3.1 versus 3.5 hours; $P<0.001$, all). There was no difference in posttransplantation survival ($P<0.01$, all).

CONCLUSIONS: Patients transplanted as lower urgency receive hearts from donors with additional comorbidities compared with higher urgency patients, but outcomes are similar at 1 year.

Key Words: advanced heart failure ■ heart transplantation ■ outcomes research ■ UNOS

Cardiac transplantation presents the challenge of allocating a resource with limited supply to a population with growing demand. The allocation system generally aims to prioritize the most medically urgent patients for transplantation, and in recent years, the system has been refined to consider geography and ischemic times to ensure equitable access to organs and optimal outcomes.[1] In October 2018, the Organ Procurement and Transplantation Network (OPTN) implemented a new donor allocation system for cardiac transplantation that replaced a 3-tiered system (Statuses 1A, 1B, and 2) with a new 6-tier system (Statuses 1–6).[2,3] The purpose of the allocation system change was to increase organ availability for patients with higher levels of urgency, reduce waitlist mortality and time, and address disparities in organ availability

CLINICAL PERSPECTIVE

What Is New?
- Over the past decade, cardiac transplantation candidates at the lowest urgency receive hearts from donors with additional comorbidities compared with the highest urgency patients but outcomes are similar at 1 year.

What Are the Clinical Implications?
- Our results may support the utility of early listing and less stringent thresholds for organ acceptance to increase access to cardiac transplantation.

Nonstandard Abbreviations and Acronyms

HU	highest urgency
LU	lowest urgency
OPTN	Organ Procurement and Transplantation Network

due to prior geographic sharing.[2,3] Status 6 represents the lowest priority listing in the new allocation system and replaces Status 2 in the prior system. The Status 6 category consists of all active cardiac transplant candidates who do not fall into Statuses 1 to 5 and therefore, are neither supported by a device or inotropes, awaiting a retransplant, listed for combined organ transplant, nor diagnosed with congenital heart disease, ischemic heart disease with intractable angina, hypertrophic cardiomyopathy, restrictive cardiomyopathy, or amyloidosis.

Despite the criteria set forth by OPTN, there is meaningful clinician and center-level variation on whether to accept organs for individual patients. In the absence of any clear data on outcomes among patients transplanted at the lowest end of urgency status—those transplanted as Status 6 under the current system and Status 2 during the prior one—evidence-based guidance around decision making for these patients is unknown. To add clarity around this important clinical question, we sought to compare the donor/recipient characteristics, outcomes, and allocation trends for these lowest urgency candidates under both the former and new allocation systems.

METHODS

Anonymized data and materials are available through request from the OPTN.

Data and Study Population

We used the UNOS (United Network for Organ Sharing) registry to identify all adult heart transplantations in patients transplanted as Status 1, 2, or 6 in the new allocation system between October 12, 2018 and May 12, 2020 and patients transplanted as 1A or 2 in the old allocation system between January 1, 2011 and October 11, 2018. The UNOS registry is a prospectively maintained database consisting of every organ transplant performed in the United States each year.[2] This study was deemed exempt by the Yale Institutional Review Board. Patient informed consent was waived given that the UNOS registry is publicly available and patient data are de-identified. Patients with dual organ transplantation were excluded and patients under the age of 18 were excluded. Patients were stratified into 2 cohorts based on status at time of transplantation: highest urgency and lowest urgency candidates. Highest urgency (HU) patients were defined as Status 1A in the former allocation system or Status 1 or 2 in the new allocation system. Lowest urgency (LU) patients were defined as Status 2 patients in the former allocation system or Status 6 patients in the new allocation system. Patients with <30 days of follow-up were excluded.

Statistical Analysis

Patient and donor sociodemographic characteristics, comorbidities, and outcomes were compared between cohorts using chi-square analysis for categorical variables and Mann-Whitney U tests for continuous variables. Kaplan-Meier survival analysis was used to examine post-transplantation mortality. Volumes of transplantation were then plotted in bar graphs and stratified by OPTN region. Trends in LU and HU transplantations were assessed by plotting annual rates of transplantation in each cohort over time. In supplemental analyses, the initial listing status for patients transplanted as HU were also compared under the former and revised allocation system. The threshold for statistical significance was 2-sided with a type I error rate of 0.05. All analyses were performed using SPSS version 26 (IBM, Armonk, NY).

RESULTS

During the time period studied under the old allocation system, there were 11 455 HU (UNOS Status 1) and 570 LU (UNOS Status 2) patients transplanted. LU patients tended to be older (58.5 years versus 56 years, $P<0.001$) and were more likely to be female (54.4% versus 23.8%, $P<0.001$; Table 1). They were also less likely to be Black (11.6% versus 22.8%, $P<0.001$). Donors for LU recipients before the new allocation system tended to be older (mean age 34 years versus 30, $P<0.001$)

Table 1.   Listing Characteristics of Patients by Status at Time of Transplant

	Old allocation system			New allocation system		
Variables	Status 1a (n=11 455)	Status 2 (n=570)	P value	Status 1–2 (n=2614)	Status 6 (n=181)	P value
Age, y [Q1, Q3]	56.0 [46.0, 62.0]	58.5 [50.0, 65.0]	<0.001*	55.0 [45.0, 62.0]	59.0 [52.0, 63.5]	<0.001*
Female sex (%)	23.8	54.4	<0.001*	23.9	47.0	<0.001*
Body mass index [Q1, Q3]	27.1 [23.7, 30.8]	26.4 [23.1, 30.4]	0.01*	27.4 [24.0, 31.6]	28.1 [24.5, 31.8]	0.48
Race or ethnicity, %			<0.001*			0.31
White	64.0	68.8		60.9	67.4	
Black	22.8	11.6		25.4	18.2	
Hispanic	8.5	11.8		8.9	8.8	
Asian	3.5	6.0		3.6	4.4	
Other†	1.2	1.8		1.2	1.2	
Primary payer, %			0.54			0.06
Private	51.4	53.3		42.5	49.7	
Public	47.7	46.1		45.2	47.0	
Other‡	0.9	0.6		12.3	3.3	
Cardiac diagnosis, %			0.41			<0.001*
Dilated cardiomyopathy	54.2	42.1		57.2	55.8	
Restrictive cardiomyopathy	2.7	6.3		4.6	1.1	
Ischemic cardiomyopathy	32.5	31.9		25.1	37.0	
Congenital cardiomyopathy	2.5	5.8		3.5	0.0	
Hypertrophic cardiomyopathy	2.1	4.6		3.1	2.2	
Valvular cardiomyopathy	1.1	1.0		1.3	0.6	
Other	4.9	8.3		5.2	3.3	
Cardiac support at time of listing, %						
Ventilator	1.7	0.0	0.002*	3.3	0.0	0.01*
Inotropes	34.5	0.7	<0.001*	40.3	8.3	<0.001*
LVAD	31.4	0.2	<0.001*	16.0	0.0	<0.001*
Right ventricular assist device +/– LVAD or mechanical circulatory support unspecified	2.0	0.0	0.001*	2.6	0.0	0.03*
Total artificial heart	0.9	0.0	0.02*	0.8	0.0	0.23
Extracorporeal membrane oxygenation	1.3	0.0	0.01*	5.1	0.0	0.002*
Intra-aortic balloon pump	6.5	0.2	<0.001*	24.8	0.0	<0.001*
Comorbidities, %						
Diabetes	29.4	25.1	0.03*	26.9	27.1	0.97
Tobacco user	45.9	34.6	<0.001*	39.6	45.3	0.13
Malignancy	8.7	11.2	0.03*	8.8	9.4	0.77
Prior cerebrovascular accident	6.3	6.7	0.75	5.9	7.7	0.30
End-stage renal disease	2.7	2.6	0.89	3.5	0.0	0.01*
Implanted cardioverter-defibrillator	75.2	76.1	0.60	67.8	82.9	<0.001*
Prior cardiac surgery	42.0	35.6	0.002*	30.6	23.8	0.05
Outcomes						
Waitlist time [Q1, Q3]	78.0 [24.0, 229.0]	102.5 [37.0, 246.3]	<0.001*	19.0 [7.0, 89.0]	58.0 [21.0, 190.0]	<0.001*

Continuous variables are reported as median [Q1, Q3]. LVAD indicates left ventricular assist device.
*Indicates the statistical measure has met the threshold for statistical significance of P<0.05.
†"Other" race or ethnicity is defined as American Indian/Alaska Native, Native/Hawaiian/other Pacific Islander, Multiracial, or undefined.
‡"Other" primary payer is defined as self-pay, fee care/donation, or unknown insurance status.

and female (52.6% versus 26.5%, *P*<0.001; Table 2). Donors for LU patients were also more likely to have hepatitis C (2.8% versus 1.0%, *P*<0.001) and have a history of diabetes (6.3% versus 3.5%, *P*<0.001). In terms of waitlist outcomes, the LU patients had longer waitlist times (102.5 days versus 78 days, *P*<0.001), longer ischemic times (3.4 hours versus 3.1 hours, *P*<0.001), and longer distances travelled for organ procurement (189.5 miles versus 84.0 miles, *P*<0.001).

Under the new allocation system, there were 2614 HU patients (UNOS Status 1 or 2) and 181 LU patients (UNOS Status 6) transplanted over the study period. LU patients were older (59 years versus 55 years, *P*<0.001) and more likely female (47.0% versus 23.9%, *P*<0.001). These patients were more likely to suffer from ischemic cardiomyopathy (*P*<0.001) (Table 1; Table S1). Donors for the lowest risk patients tended to

be older (mean age 36 years versus 30, *P*<0.001) and more likely female (54.1% versus 19.5%, *P*<0.001). They were also more likely to be a high-risk donor (42.0% versus 34.0%, *P*=0.029), have hepatitis C (9.9% versus 5.4%, *P*=0.011), and have a prior history of malignancy (2.8% versus 0.7%, *P*=0.002) and diabetes (7.2% versus 2.2%, *P*<0.001). Lower urgency patients had longer waitlist times (58 days versus 19 days, *P*<0.001), shorter ischemic times (3.1 hours versus 3.5 hours, p<0.001), and shorter distances travelled (178 miles versus 269 miles, *P*<0.001) (Table 2).

Under the former allocation system, there were 570 patients transplanted as Status 2 (3.3%) out of 17 309 total transplants (Figure 1). The vast majority of patients were transplanted as Status 1A (66%). Under the revised allocation system, 181 patients (3.7%) of the total 4847 transplants performed were Status 6

Table 2. Donor Characteristics

Variables	Old allocation system			New allocation system		
	Status 1A (n=11 455)	Status 2 (n=570)	*P* value	Status 1–2 (n=2614)	Status 6 (n=181)	*P* value
Age, y [Q1, Q3]	30.0 [23.0, 40.0]	34.0 [3.0, 48.0]	<0.001*	30.0 [23.0, 38.0]	36.0 [29.0, 45.5]	<0.001*
Female sex, %	26.5	52.6	<0.001*	19.5	54.1	<0.001*
Body mass index [Q1, Q3]	27 [23.7, 30.8]	26.4 [23.3, 30.3]	0.01*	26.7 [23.7–30.8]	27.1 [23.3–31.1]	0.75
High-risk donor, %	24.4	22.6	0.35	34.0	42.0	0.03*
Race or ethnicity, %			<0.001*			0.70
White	63.2	59.8		62.1	61.3	
Black	16.7	11.9		16.9	18.2	
Hispanic	17.2	18.9		18.1	17.7	
Asian	1.6	5.1		1.6	0.0	
Other†	1.3	4.3		1.3	2.8	
Substance use, %						
Alcohol use	16.8	14.6	0.16	16.7	16.6	0.98
Tobacco user	10.0	10.0	0.99	9.8	13.8	0.08
Cocaine use	10.3	10.0	0.83	14.8	16.6	0.51
Other drug user	38.8	32.6	0.003*	47.7	47.5	0.96
Comorbidities, %						
Hypertension	32.6	29.8	0.17	33.7	29.8	0.28
Malignancy	1.4	2.3	0.08	0.7	2.8	0.002*
Diabetes	3.5	6.3	<0.001*	2.2	7.2	<0.001*
Infections, %						
Pneumonia	69.3	66.8	0.22	71.3	72.9	0.63
Urinary tract infection	11.3	19.5	<0.001*	8.7	21.0	<0.001*
Hepatitis C virus	1.0	2.8	<0.001*	5.4	9.9	0.01*
Cytomegalovirus	60.4	65.8	0.01*	61.7	63.5	0.62
Transplant outcomes						
Ischemic time [Q1, Q3]	3.1 [2.4, 3.8]	3.4 [2.6, 4.1]	<0.001*	3.5 [3.0, 4.0]	3.1 [2.4, 3.9]	<0.001*
Distance traveled [Q1, Q3]	84.0 [13.0, 269.0]	189.5 [24.0, 405.0]	<0.001*	269.0 [121.0, 408.0]	178.0 [31.5, 445.0]	0.001*

Continuous variables are reported as median [Q1, Q3].

*Indicates the statistical measure has met the threshold for statistical significance of *P*<0.05.

†"Other" race or ethnicity is defined as American Indian/Alaska Native, Native/Hawaiian/other Pacific Islander, Multiracial, or undefined.

patients. The proportion of LU candidates transplanted remained around 3% to 5% of overall transplants both before and after the allocation system change, whereas the proportion of HU candidates transplanted remained around 60% (Figure 2). There were no meaningful trends in the proportion of patients at the highest and lowest status over time (Figure 2). The highest proportion of LU transplants both before and after the allocation system change occurred in OPTN region 5 (Figure 3), which includes California, Nevada, Utah, Arizona, and New Mexico. Region 11 (Virginia, West Virginia, North Carolina, South Carolina) performed the second highest percentage of LU transplants, whereas Region 10 (Michigan, Ohio, Indiana) performed the lowest percentage (Figure S1). Under the former allocation system, 2234 (19.8%) of the 11 264 patients transplanted as Status 1A were initially listed as low urgency (Status 2) (Figure S2A). Under the revised allocation

system, 328 (12.7%) of the 2583 transplanted as high urgency (Status 1 or 2) were initially listed as low urgency (Status 6) (Figure S2B). There was no difference in 1-year posttransplantation survival between HU and LU urgency patients in either the former or revised allocation systems (Figure 4).

DISCUSSION

The organ allocation process intends to balance the organ supply and recipient urgency. The primary driver of prioritizing a listed recipient has been the severity of their heart failure, the granularity of which was increased during the 2018 allocation system change. As a result, the majority of transplants occur among those listed at the HU status with a small percentage occurring among patients who are at the LU status; however, there was significant geographical variation in patterns
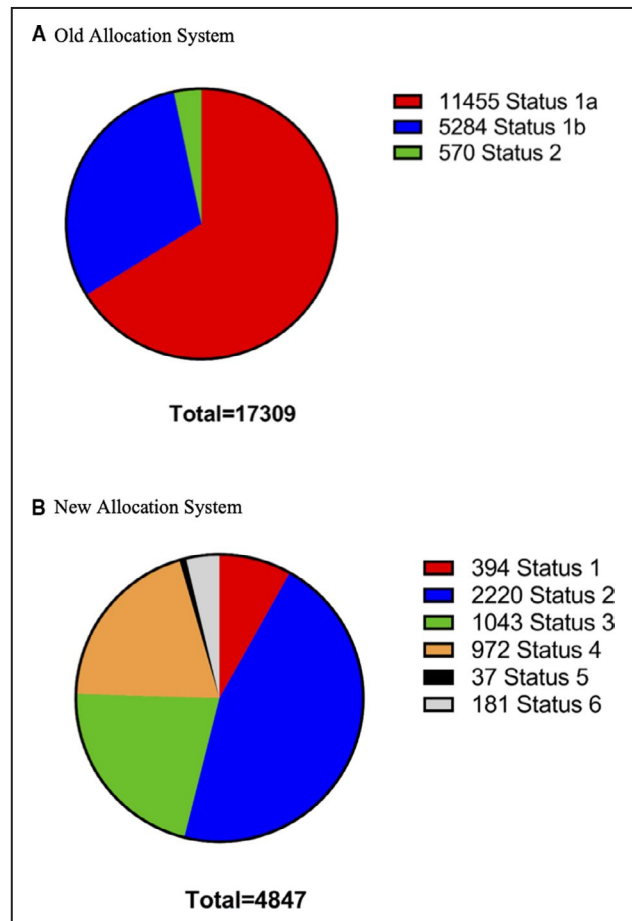

Figure 1.   UNOS status at time of transplantation during old and new allocation system.
In the old allocation system (**A**), the lowest urgency patients made up 3.3% of total transplants and the highest urgency patients made up 66%. In the new allocation system (**B**), Status 6 patients represented 3.7% of total transplants, whereas the highest urgency patients (Status 1 or 2) made up 54% of all transplants. UNOS indicates United Network for Organ Sharing.
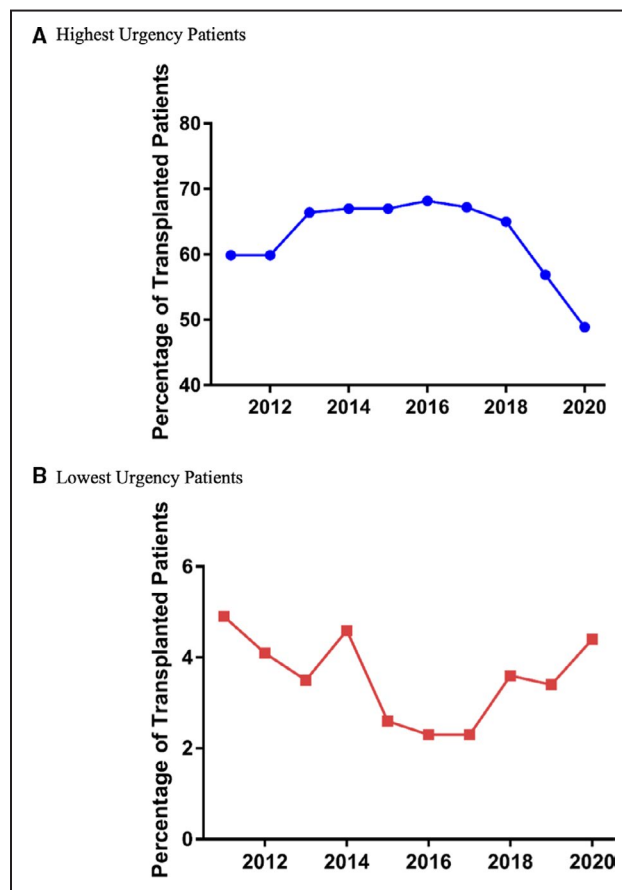
Figure 2.   Trends in transplantation stratified by status in the old and new allocation systems.
A, Depicts the highest priority patients (Status 1A in the old system and Status 1 or 2 in the new system), and (**B**) shows trends in Status 2 patients in the old system and Status 6 patients in the new system. For lower urgency candidates, 3% to 5% of transplants were performed annually and this remained consistent across the allocation system change in October 2018. UNOS indicates United Network for Organ Sharing.
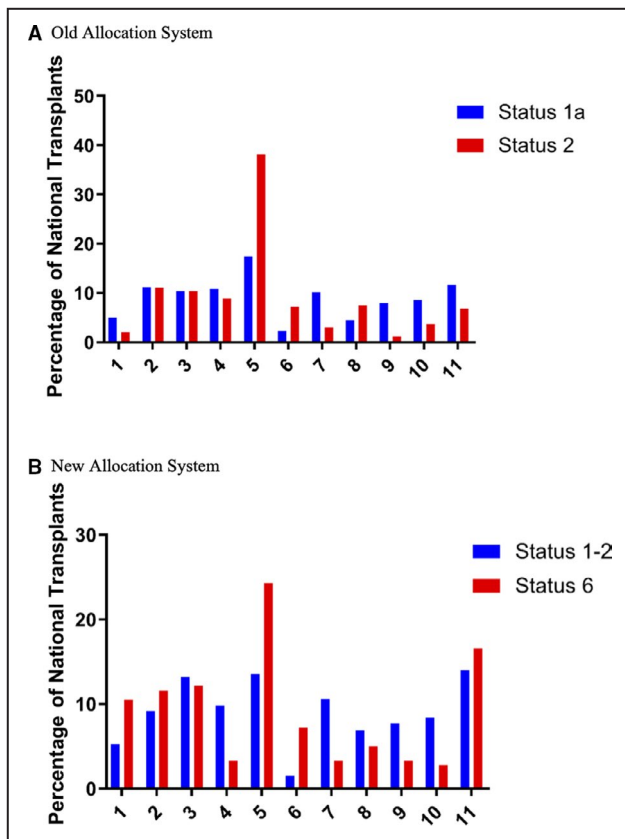
Figure 3. Cardiac transplantation for lower medical urgency patients stratified by region under the former (A) and revised (B) allocation systems.
Region 5 performed the largest proportion of lower urgency transplants (Status 2 in former system; Status 6 in new system) and also the largest proportion of transplants overall.
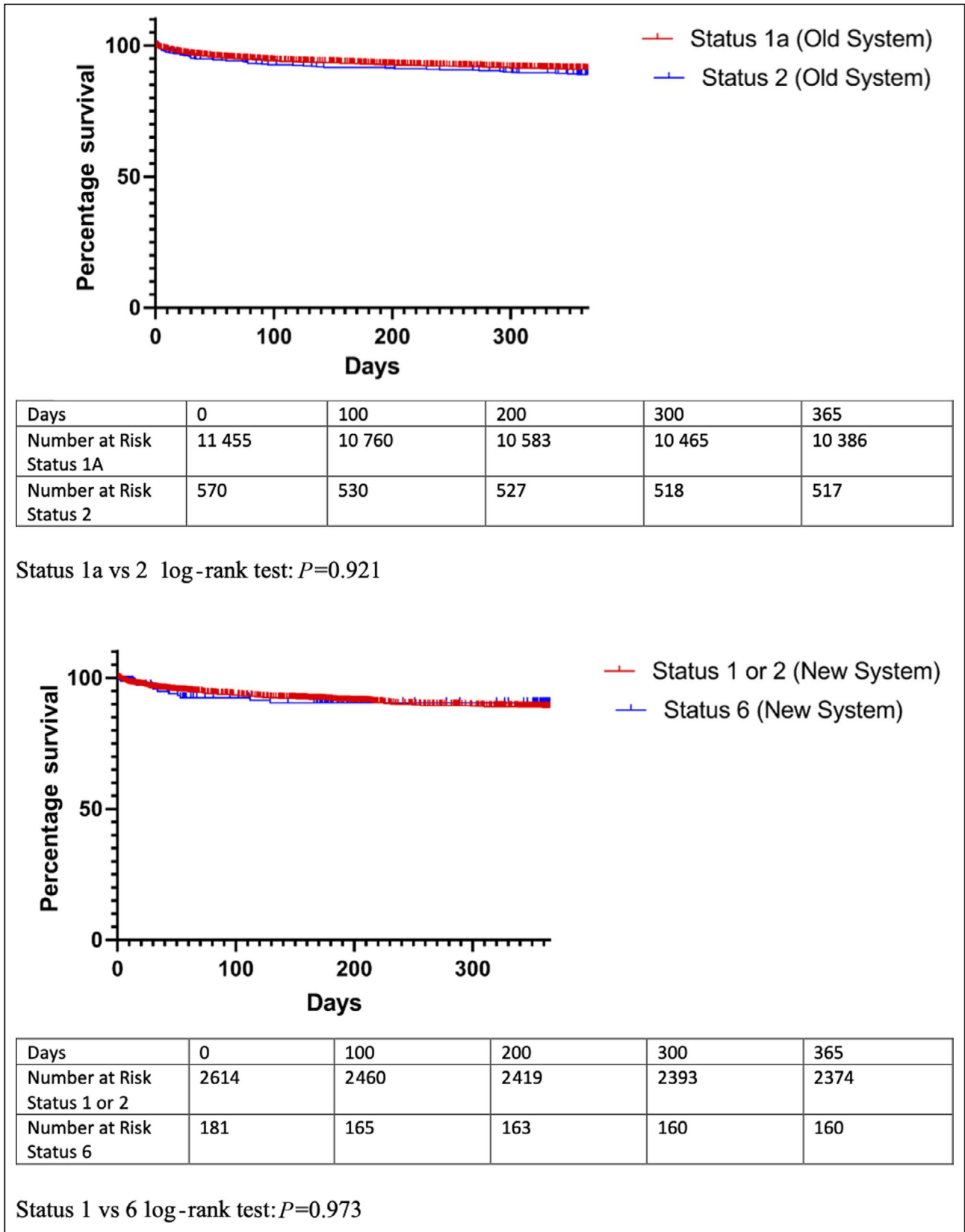
of transplantation. We found that patients who were transplanted at the lowest urgency status tended to be female and were transplanted with donor hearts that might have been considered of lower quality with greater risk factors. The allocation system changes significantly reduced the number of patients with congenital, restrictive, and hypertrophic cardiomyopathies at the LU status as defined by the new policy. It also dramatically reduced the waitlist times for both the HU and LU status patients. Finally, we noted no differences in short-term mortality between either cohort. Overall, these data suggest that expansion of the donor pool could allow for successful transplantation among recipients who do not meet strict criteria for a higher urgency status but yet meet criteria for end-stage heart failure.

Transplant center variability exists within both the patient listing and organ allocation processes. Despite the listing criteria set forth by OTPN, transplant centers determine the appropriate timing of listing. For example, a patient could be listed early as a lower medical priority patient or after progression of

disease when additional support in the form of inotropes or mechanical support is required. We demonstrate that LU recipients received organs from older donors with additional comorbidities such as hepatitis C virus (HCV) infection, malignancy, and diabetes. Despite receiving organs that might otherwise be discarded, there was no difference in posttransplant outcomes at 1-year compared with the HU patients. Our findings suggest that a broadened organ acceptance strategy may benefit patients, particularly those listed at LU.

Transplant center is associated with survival benefit of transplant in both the former and revised allocation system.[4,5] Acceptance of hearts from older donors with additional comorbidities that were declined by other centers has been shown to increase transplant volume, decrease ischemic time, and not change survival at 180 days compared with a more stringent acceptance strategy in an institutional study.[6] These findings have been corroborated in larger registry analyses, which have shown that first-rank offer had a similar survival to a lower-rank offer.[7] The organ acceptance policies of individual centers may be influenced by Medicare's reimbursement requirements to maintain a certain survival rate, which may encourage smaller centers to take a conservative approach to donor heart selection or risk probation or program termination.[8] Despite these considerations, there is growing evidence that a more liberal strategy of organ acceptance produces equivalent outcomes and increases access to life-saving therapy.[9]

Given the limited supply of organs relative to the number of recipients, there has recently been interest in expanding the donor pool by accepting organs according to extended donor criteria.[10,11] It has been noted that about 30% to 35% of donor hearts are transplanted annually, and the most common reasons for decline are older donor age, female donor, and donor comorbidity.[12] Extended criteria cardiac transplant programs more often use hearts from older donors, with longer ischemic time and higher sequence number, and showed comparable outcomes with standard criteria transplantation.[13] The development of direct-acting antiviral therapies has led to curative options for HCV and an addressable opportunity to expand the donor supply. In a prospective cohort trial using HCV positive donors, there was no significant difference in survival between recipients who developed donor-derived HCV, recipients without infection, or patients who received transplants from hepatitis C negative donors.[14] Despite the safety of transplant with HCV organs, only about 5% of HCV positive donor organs were accepted for transplantation between 2014 and 2017.[15] We would hypothesize that lower urgency patients would have better outcomes given less advanced heart failure; however, outcomes were similar

Days	0	100	200	300	365
Number at Risk Status 1A	11 455	10 760	10 583	10 465	10 386
Number at Risk Status 2	570	530	527	518	517

Status 1a vs 2 log-rank test: P=0.921

Days	0	100	200	300	365
Number at Risk Status 1 or 2	2614	2460	2419	2393	2374
Number at Risk Status 6	181	165	163	160	160

Status 1 vs 6 log-rank test: P=0.973

Figure 4. Posttransplantation survival of patients stratified by listing urgency under each allocation system.
Unadjusted Kaplan-Meier curves for posttransplantation survival in patients Statuses 1 and 2 under the old allocation system and Statuses 1 and 6 under the revised allocation system. There were no differences in survival between the groups under the former system (Status 1a vs 2; log-rank test: P=0.921) or the new system (Status 1 vs 6; log-rank test: P=0.973). UNOS indicates United Network for Organ Sharing.

between high and low urgency candidates. We suspect that the additional donor comorbidities negated the benefit in recipient outcomes we would expect for lower urgency candidates but acknowledge that this requires further evaluation in future studies.

Second, the trends in lower urgency listings are also noteworthy. We demonstrate that ≈3% to 5% of transplanted patients are lower urgency patients, and these proportions have remained stable over the past decade. Our results highlight the need to develop best practices surrounding LU patients, and future studies should characterize whether these patients are best served by transplant, left ventricular assist device, or chronic inotropes. UNOS Region 5 (California, Nevada, Arizona, New Mexico, Utah) performed the highest percentage of lower listing patients, which may be a result of this region performing the most transplants of all regions.[3] The increased ischemic time and distance travelled for donor organs under the 2018 allocation system change in both LU and HU patients reflects the intended geographic expansion of organ availability of the new policy.

Our analysis also highlights sex differences in organ allocation. Sex differences in advanced heart failure therapies have been described previously.[16,17] Notably, under the previous allocation system women were less likely than men to be on mechanical circulatory support and more likely to be on inotropic support as a bridge to transplantation.[17,18] In addition, women are less frequently transplanted than men (OPTN), and women are less likely to be transplanted as the HU status (Status 1A) compared with men under the former allocation system.[17] Our analysis demonstrates that women are still less likely to be transplanted as high urgency status (Status 1 or 2) and more likely to be transplanted as low urgency (Status 6). The persistent trends of women being transplanted at lower urgency status may reflect nontraditional presentations of women with advanced heart failure that make it more difficult to list women at a higher priority under the current criteria. Future studies might characterize the clinical characteristics of women transplanted under the revised allocation system and develop new ways to risk stratify this population.

Limitations

This analysis is limited by several important factors. Though the UNOS registry is prospectively maintained, these analyses are both observational and retrospective and are subject to common limitations of such analyses. Second, our follow-up data are limited to posttransplant mortality at 1-year, which may not reflect longer-term complications. Data from quality of life or rehospitalization are unavailable in the UNOS data set. The UNOS registry also does not include the donor organ sequence number, which limits our ability to analyze the number of acceptances or rejections for each organ. Finally, we acknowledge that the allocation system policy has been in effect for just over 2 years (of which only 19 months are included in our analysis) and that the heart transplantation community practices are continuing to evolve under the new system.

CONCLUSIONS

Cardiac transplantation for lower urgency patients has not been well characterized. Over the past decade, low urgency patients received hearts from older donors with additional comorbidities compared with higher urgency patients but had similar posttransplantation survival. Our results may support the utility of early listing and less stringent thresholds for organ quality to better increase access to cardiac transplantation.

REFERENCES

1. Taylor LJ, Fiedler AG. Balancing supply and demand: review of the 2018 donor heart allocation policy. *J Card Surg*. 2020;35:1583–1588. doi: 10.1111/jocs.14609
2. Goff RR, Uccellini K, Lindblad K, Hall S, Davies R, Farr M, Silvestry S, Rogers JG. A change of heart: preliminary results of the US 2018 adult heart allocation revision. *Am J Transplant*. 2020;20:2781–2790. doi: 10.1111/ajt.16010
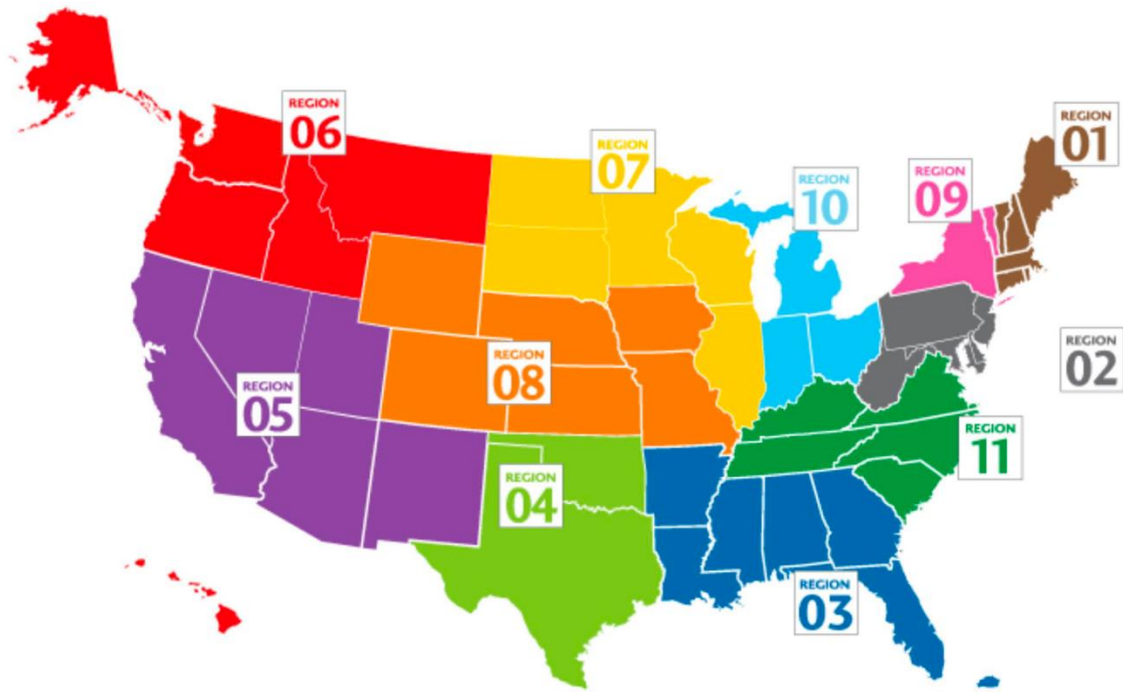
3. OPTN. Adult heart allocation criteria for medical urgency status. Available at: https://optn.transplant.hrsa.gov/media/2414/adult_heart_infographic.pdf. Accessed April 2, 2021.

4. Parker WF, Anderson AS, Gibbons RD, Garrity ER Jr, Ross LF, Huang ES, Churpek MM. Association of transplant center with survival benefit among adults undergoing heart transplant in the United States. *JAMA*. 2019;322:1789–1798. doi: 10.1001/jama.2019.15686

5. Suarez-Pierre A, Lui C, Zhou X, Fraser CD III, Crawford TC, Choi CW, Whitman GJ, Higgins RS, Kilic A. Discrepancies in access and institutional risk tolerance in heart transplantation: a national open cohort study. *J Card Surg*. 2019;34:994–1003. doi: 10.1111/jocs.14179

6. Mori M, Wilson L, Ali A, Ahmad T, Anwer M, Jacoby D, Geirsson A, Krumholz HM. Evaluation of case volumes of a heart transplant program and short-term outcomes after changes in the United Network for Organ Sharing Donor Heart Allocation System. *JAMA Netw Open*. 2020;3:e2017513. doi: 10.1001/jamanetworkopen.2020.17513

7. Choi AY, Mulvihill MS, Lee HJ, Zhao C, Kuchibhatla M, Schroder JN, Patel CB, Granger CB, Hartwig MG. Transplant center variability in organ offer acceptance and mortality among US patients on the heart transplant waitlist. *JAMA Cardiol*. 2020;5:660–668. doi: 10.1001/jamacardio.2020.0659

8. Centers for Medicare & Medicaid Services Decision memo for TRANSPLANT centers: re-evaluation of criteria for Medicare approval (CAG-00061N). Published July 26, 2000. Available at: https://www.cms.gov/medicare-coverage-database/details/nca-decision-memo.aspx?NCAId=75&NcaName=Transplant+Centers*3a%24+Re-Evaluation+of+Criteria+for+Medicare+Approval&CoverageSelection=National&KeyWord=transplant&KeyWordLookUp=Title&KeyWordSearchType=And&bc=gAAAABAAEAAA&. Accessed May 4, 2021.

9. Khush KK, Menza R, Nguyen J, Zaroff JG, Goldstein BA. Donor predictors of allograft use and recipient outcomes after heart transplantation. *Circ Heart Fail*. 2013;6:300–309. doi: 10.1161/CIRCHEARTFAILURE.112.000165

10. Tong CKW, Khush KK. New approaches to donor selection and preparation in heart transplantation. *Curr Treat Options Cardiovasc Med*. 2021;23:28. doi: 10.1007/s11936-021-00906-5

11. Sandhu AT, Woo YJ, Khush KK. Optimizing the use of heart transplant in the United States. *JAMA*. 2019;322:1772–1774. doi: 10.1001/jama.2019.16002

12. Khush KK, Zaroff JG, Nguyen J, Menza R, Goldstein BA. National decline in donor heart utilization with regional variability: 1995–2010. *Am J Transplant*. 2015;15:642–649. doi: 10.1111/ajt.13055

13. Samsky MD, Patel CB, Owen A, Schulte PJ, Jentzer J, Rosenberg PB, Felker GM, Milano CM, Hernandez AF, Rogers JG. Ten-year experience with extended criteria cardiac transplantation. *Circ Heart Fail*. 2013;6:1230–1238. doi: 10.1161/CIRCHEARTFAILURE.113.000296

14. Schlendorf KH, Zalawadiya S, Shah AS, Perri R, Wigger M, Brinkley DM, Danter MR, Menachem JN, Punnoose LR, Balsara K, et al. Expanding heart transplant in the era of direct-acting antiviral therapy for hepatitis C. *JAMA Cardiol*. 2020;5:167–174. doi: 10.1001/jamacardio.2019.4748

15. Moayedi Y, Fan CPS, Gulamhusein AF, Manlhiot C, Ross HJ, Teuteberg JJ, Khush KK. Current use of hearts from hepatitis C viremic donors. *Circ Heart Fail*. 2018;11:e005276. doi: 10.1161/CIRCHEARTFAILURE.118.005276

16. Hsich EM. Sex differences in advanced heart failure therapies. *Circulation*. 2019;139:1080–1093. doi: 10.1161/CIRCULATIONAHA.118.037369

17. Hsich EM, Blackstone EH, Thuita L, McNamara DM, Rogers JG, Ishwaran H, Schold JD. Sex differences in mortality based on United Network for Organ Sharing status while awaiting heart transplantation. *Circ Heart Fail*. 2017;10:e003635. doi: 10.1161/CIRCHEARTFAILURE.116.003635

18. Morris AA, Cole RT, Laskar SR, Kalogeropoulos A, Vega JD, Smith A, Butler J. Improved outcomes for women on the heart transplant wait list in the modern era. *J Card Fail*. 2015;21:555–560. doi: 10.1016/j.cardfail.2015.03.009

19. OPTN. About OPTN Regions. Available at: https://optn.transplant.hrsa.gov/members/regions/. Accessed April 2, 2021.

SUPPLEMENTAL MATERIAL

Table S1. Medical Urgency Status under the 2018 Revised Allocation System (3).

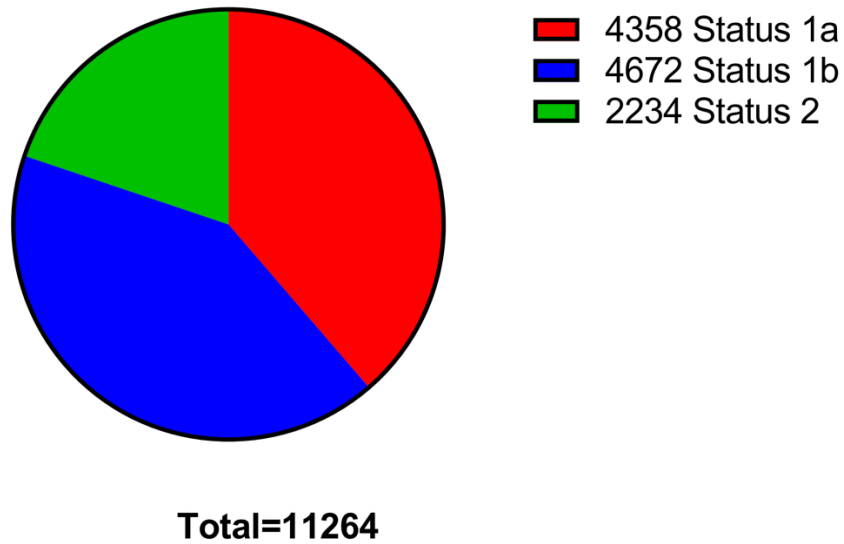|	
1	VA-ECMO; Nondischargeable, surgically implanted, nonendovascular biventricular support device; MCS with life-threatening ventricular arrhythmia
2	Nondischargeable, surgically implanted, nonendovascular LVAD; IABP; Ventricular tachycardia/ventricular fibrillation; MCS with device malfunction/mechanical failure; TAH, BiVAS, RVAD or VAD for single-ventricle patients; Percutaneous endovascular MCS
3	Dischargeable LVAD for up to 30 days; Multiple inotropes or single high-dose inotrope with continuous hemodynamic monitoring; VA-ECMO after 7 days; percutaneous endovascular circulatory support device or IABP after 14 days; Nondischargeable, surgically implanted, nonendovascular LVAD after 14 days MCS with 1 of the following: Device infection, Hemolysis, Pump thrombosis, Right-heart failure, Mucosal bleeding, Aortic insufficiency
4	Dischargeable LVAD without discretionary 30 days; Inotropes without hemodynamic monitoring; Retransplant; Diagnosis of 1 of the following: Congenital heart disease, Ischemic heart disease with intractable angina, Hypertrophic cardiomyopathy or restrictive cardiomyopathy, Cardiac amyloidosis
5	Combined organ transplants
6	All remaining active candidates

Figure S1. OPTN Regions (19).

OPTN region 5 performed the most transplants for lower urgency patients and the most transplants overall. Region 5 includes California, Nevada, Utah, Arizona, and New Mexico.
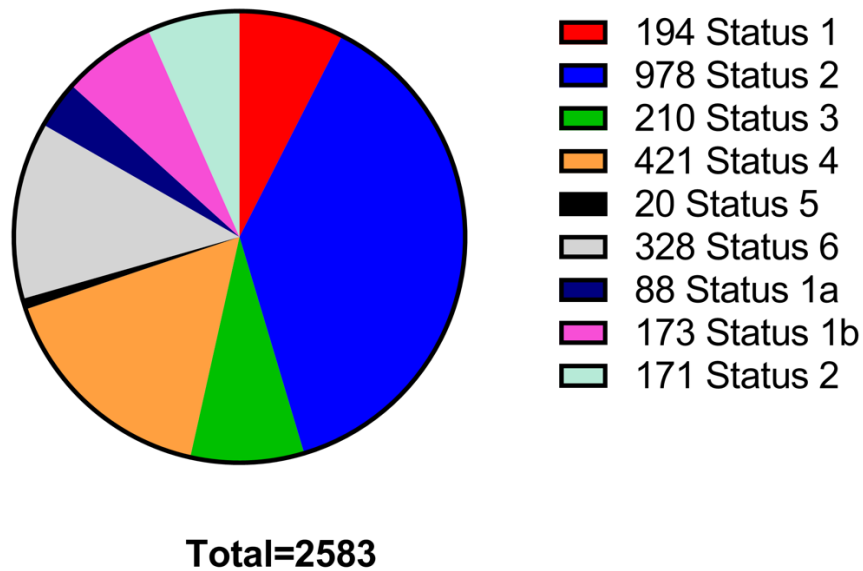
Obtained from (https://optn.transplant.hrsa.gov/members/regions/)

Figure S2. Initial Listing for Highest Urgency Transplant Recipients.

(A) Initial Status for Patients Transplanted as Status 1A under the Former Allocation System

4358 Status 1a
4672 Status 1b
2234 Status 2

Total=11264

(B) Initial Status for Patients Transplanted as Status 1 or 2 under the Revised Allocation System

194 Status 1
978 Status 2
210 Status 3
421 Status 4
20 Status 5
328 Status 6
88 Status 1a
173 Status 1b
171 Status 2

Total=2583

Under the former allocation system, 2234 (19.8%) of the 11264 patients transplanted as Status 1A were initially listed as low urgency (Status 2). Under the revised allocation system, 328 (12.7%) of the 2583 transplanted as high urgency (Status 1 or 2) were initially listed as low urgency (Status 6).