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Prevalence and Outcomes of Multiple-Listing for Cadaveric Kidney and Liver Transplantation

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Transplant candidates are permitted to register on multiple waiting lists. We examined multiple-listing practices and outcomes, using data on 81 481 kidney and 26 260 liver candidates registered between 7/1/95 and 6/30/00. Regression models identified factors associated with multiple-listing and its effect on relative rates of transplantation, waiting list mortality, kidney graft failure, and liver transplant mortality. Overall, 5.8% (kidney) and 3.3% (liver) of candidates multiple-listed. Non-white race, older age, non-private insurance, and lower educational level were associated with significantly lower odds of multiple-listing. While multiple-listed, transplantation rates were significantly higher for nearly all kidney and liver candidate subgroups (relative rate [RR] = 1.42–2.29 and 1.82–7.41, respectively). Waiting list mortality rates were significantly lower while multiple-listed for 11 kidney subgroups (RR = 0.22–0.72) but significantly higher for 7 liver subgroups (RR = 1.44–5.93), suggesting multiple-listing by healthier kidney candidates and sicker liver candidates. Graft failure was 10% less likely among multiple-listed kidney recipients. Multiple- and single-listed liver recipients had similar post-transplant mortality rates. Although specific factors characterize those transplant candidates likely to multiple-list, transplant access is significantly enhanced for almost all multiple-listed kidney and liver candidates.

Key words: Kidney transplantation, liver transplantation, multiple-listing, organ allocation, organ procurement organizations, waiting list

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Introduction

The gap between the number of transplantable organs from deceased donors and the number of patients awaiting transplantation continues to increase each year (1). The complex debate over the merits, ethics, propriety, and even legality of patients placing their names on more than one waiting list for transplantation, a practice known as multiple-listing, persists amid the growing imbalance between supply and demand. After the Organ Procurement and Transplantation Network (OPTN) was formed by the National Organ Transplant Act of 1984 (2), policies designed to promote fair and equitable organ allocation were developed and adopted in 1987 by the Board of Directors of the United Network for Organ Sharing, the organization acting as the OPTN contractor. Multiple-listing was explicitly permitted. In early 1988, equity concerns led to a recommendation to rescind the option of multiple-listing. However, based on public comments received later that year, the policy remained. Proposed bans on multiple-listing were heatedly discussed again in the 1990s, but no further policy actions were taken or implemented. During the past 2 years, the OPTN has again begun to debate the issue. Aside from kidney transplant candidates in the state of New York (3), patients anywhere in the United States are permitted to multiple-list.

Opponents maintain that the opportunity to multiple-list is not available to (or even known by) all transplant candidates and is utilized by only a small proportion of them. Multiple-listed candidates, it is argued, have an unfair advantage in terms of access to organs. Further, the characteristics of those who multiple-list differ significantly from those who do not, which appears to exacerbate existing demographically defined inequalities in transplant access (4). Advocates of multiple-listing assert that patient choice is an important element of US medical practice and that those who have interest and the means to multiple-list should be free to do so. Furthermore, regional differences in access to transplant organs, which are of striking magnitude (5,6), may be ameliorated through the practice of multiple-listing by increasing effective organ distribution areas. This effect is of very limited impact, however, as it occurs on a patient-by-patient basis.

Few systematic studies of the practice and outcomes of multiple-listing for kidney transplantation have been

published (3,4,7–9), and none have been published relating to liver transplantation. We report here the results of analyses concerning the relationship of multiple-listing to access to transplantation and outcomes for patients with end-stage renal and liver disease.

Materials and Methods

Data sources

The study used the data system of the Scientific Registry of Transplant Recipients (SRTR) regarding access to transplantation, waiting list mortality, and post-transplantation graft and patient survival. The SRTR data system includes data on all wait-listed candidates and transplant recipients in the US submitted by the members of the OPTN, and is supplemented by mortality information from the Social Security Death Master File (10).

All candidates added to the kidney transplant waiting list between July 1, 1995 and June 30, 2000 were eligible for inclusion in the access to kidney transplantation and kidney waiting list mortality analyses, and all recipients of cadaveric kidney transplants between July 1, 1995 and June 30, 2000 were eligible for inclusion in the kidney graft survival analysis. All candidates added to the liver waiting list between July 1, 1997 and June 30, 2000 were eligible for inclusion in the access to liver transplantation and waiting list mortality analyses, and all recipients of cadaveric liver transplants between July 1, 1997 and June 30, 2000 were eligible for inclusion in the liver graft survival analysis. Kidney candidates or recipients who were also registered for a simultaneous kidney-pancreas transplant while waiting for a kidney-only transplant or at kidney transplantation were not included in any analyses. The study samples numbered 81 481 kidney candidates, 38 505 kidney recipients, 26 260 liver candidates, and 12 396 liver recipients.

Analytical methods

All statistical analyses were performed using SAS 8.0 (11). Multiple-listing was defined as concurrent listings with two or more transplant centers not associated with the same organ procurement organization (OPO). A logistic regression model was developed to evaluate candidate and OPO characteristics associated with whether or not a candidate was ever multiple-listed, defined as any duration of multiple-listing.

We explored OPO waiting time and distance between listing transplant centers to ascertain whether these factors influenced patients' choices of transplant center for second listing. We used the following rules for selecting the OPO of first listing and the OPO of second listing. Most patients with multiple-listings were only on waiting lists concurrently at two centers in different OPOs, and added the second listing after the first listing date. For patients who initially listed at centers in more than one OPO on the same day, we randomly selected one OPO as the first listing OPO, and another (usually the remaining) OPO as the second listing OPO. For patients who were initially listed in the service area of one OPO and then simultaneously added listings at two or more OPO service areas on a subsequent date, we randomly chose one of the subsequent OPOs as the second listing OPO. The application of these rules was only required for 2.4% of kidney cases and 1.0% of liver cases.

After identifying the OPO associated with the first listing and subsequent listings, we calculated the geographic distance between the listing transplant centers in the two OPOs. We also examined the time until 25% of all patients who entered the waiting list were transplanted in each OPO by year to determine if multiple-listed patients chose a second listing center in an OPO with a shorter waiting time. Waiting time until transplant was calculated as the time (in days) after placement on the waiting list, by which 25% of all patients initially placed on the waiting list during that year had been removed from the waiting list for receiving a transplant (cadaveric or living). The 25th percentile was chosen because median time to transplant for listings during the study period had not been reached for some OPOs by the study end date. A Kaplan-Meier analysis was used to determine the 25th percentile of time until transplant, with patient waiting time censored on (a) May 1, 2002 for those candidates still waiting on that date; or (b) the date of removal from the waiting list for recovery. The 25th percentile of transplant was calculated by OPO and year of listing for all patients in the OPO. It was then matched to each multiple-listed patient by first or second OPO and year listed at that OPO.

For recipients who were multiple-listed at the time of transplantation, we determined whether the transplant took place at the center in the original listing OPO or a subsequent center in another OPO. The proportion of multiple-listed recipients who transferred their active waiting time to the second listing center's OPO was also calculated.

Time-dependent Cox regression models of access to transplantation and waiting list mortality accounted for individual candidates changing between periods of single-listing and periods of multiple-listing over time while awaiting a transplant. In these time-to-event models, predictors of time to transplantation and time to waiting list mortality were investigated by segregating observation time while single-listed from follow-up time while multiple-listed. In this way, each patient's access to transplantation and waiting list mortality was assessed over their entire tenure on the waiting list, with appropriate attribution of single-listing or multiple-listing state to both follow-up time and outcomes of interest. Patient waiting times were calculated from waiting list registration date until transplantation, censored at the earliest of the following: living related transplant/recovery, removal from the waiting list (for any reason including death), or June 30, 2001. Patient waiting list survival times were calculated from waiting list registration date until death, censored at the earliest of transplant, removal from the waiting list (for reasons other than death), or June 30, 2001. The following candidate covariates were included in the models of access to transplantation and waiting list mortality: age, gender, race, ethnicity, body mass index (BMI), year of placement on the waiting list, ABO blood type, previous transplants, diagnosis group, primary source of payment, and education. For kidney analyses, the following covariates were also included: panel reactive antibody (PRA) closest to day of wait-listing, relative transplantation rate by human leukocyte antigen (HLA) marker index, dialysis modality, and previous transfusions. For liver analyses, medical urgency status at day of first placement on the waiting list was included.

Predictors of time to graft loss for kidney recipients and time to patient death for liver recipients were investigated using Cox regression models to determine the impact of multiple-listing at the time of transplant on these outcomes. Post-transplant kidney graft survival times were calculated from transplantation until death or graft failure, censored at the earlier of last known follow-up date or June 30, 2001. Post-transplant liver patient survival times were calculated from transplant until death, censored at June 30, 2001. The following recipient, donor, and transplant covariates were included in the models of post-transplant kidney graft and liver patient survival: recipient age, recipient gender, recipient race, recipient ethnicity, recipient BMI, year transplanted, recipient ABO blood type, primary source of payment, education, medical urgency status at transplant, previous transplants, diagnosis group, donor age, donor gender, donor race, donor ethnicity, donor cause of death, cold ischemic time, and medical condition at time of transplant (not hospitalized, hospitalized not in intensive care unit [ICU], hospitalized in ICU). Additional covariates for liver recipients included life support, reduced liver transplant, and creatinine greater than 2.0 mg/dL. Additional covariates for kidney recipients included PRA closest to day of

transplant, pretransplant transfusions, number of HLA mismatches, dual kidney transplant, donor history of diabetes or hypertension, impaired renal function (donor terminal serum creatinine greater than 1.5 mg/dL), and time on dialysis.

Results

Prevalence and odds of multiple-listing among patients on the waiting list

The prevalence and odds of multiple-listing for kidney waiting list candidates are provided in Table 1. Overall, 5.8% of kidney candidates were multiple-listed during the study period. A range of demographic, biological, and socioeconomic attributes was associated with multiple-listing. Kidney transplant candidates who were age 0–17 (vs. age 34–49), female, African-American (vs. white), blood type A or AB (vs. blood type O), and who had Medicaid or a health maintenance organization (HMO) as their primary source of payment (vs. Medicare) were each significantly less likely to multiple-list than patients in the indicated reference group. In contrast, patients with PRA 10 or greater at first listing, who were age 18–34, college or graduate school educated (vs. high school or less), and had private insurance as their primary source of payment were each significantly more likely to multiple-list. The probability of multiple-listing increased by 9% with each unit increase in the ratio of OPO waiting list size to cadaveric kidneys recovered annually in that OPO (mean ratio 3.35 ± 2.21; RR = 1.09; $p = 0.0001$).

Table 1: Prevalence (%) and adjusted odds (AOR) of multiple-listing among patients newly wait-listed for kidney transplant from 7/1/95 to 6/30/00

Measure	n	%	AOR
All patients:	4743	5.8	–
Age at first listing:			
0–9	16	2.1	0.39**
10–17	66	3.6	0.72*
18–34	974	6.7	1.13*
35–49	1686	6.0	1.00 (ref)
50–65	1616	5.6	0.98
65 +	385	5.6	0.95
Gender:			
Male	2895	6.0	1.00 (ref)
Female	1848	5.6	0.91*
Race:			
White	3323	6.4	1.00 (ref)
Black	1050	4.4	0.59**
Other	370	6.4	0.90
ABO blood type:			
A	1404	5.1	0.74**
B	734	6.3	1.02
AB	147	4.6	0.66**
O	2458	6.3	1.00 (ref)
PRA at first listing:			
0–9	3352	5.6	1.00 (ref)
10–79	778	7.0	1.31**
80 +	180	7.0	1.35**
Payment:			
Medicare	1899	5.1	1.00 (ref)
Medicaid	190	3.0	0.61**
Private	2187	7.2	1.23**
HMO	114	3.5	0.69**
Education:			
None, 0–12 years	1525	4.2	1.00 (ref)
College, Graduate	2027	7.9	1.67**

Adjusted for registrant variables including age, gender, race, ethnicity, BMI, year wait-listed, PRA closest to day of wait-listing, relative transplantation rate by HLA marker index, ABO blood type, primary source of payment, education, previous transplants, diagnosis group, dialysis modality, previous transfusions, ratio of OPO waiting list size to number of cadaveric kidneys recovered.
*$p < 0.05$; **$p < 0.0005$.

The prevalence and odds of multiple-listing for liver waiting list candidates are shown in Table 2. Overall, 3.3% of liver candidates were multiple-listed during the study period. A number of differences in the odds of multiple-listing were noted between kidney and liver candidates. Unlike kidney transplant candidates, multiple-listing rates for liver did not differ by age. African-Americans and candidates of

Table 2: Prevalence (%) and adjusted odds (AOR) of multiple-listing among patients newly wait-listed for liver transplant from 7/1/97 to 6/30/00

Measure	n	%	AOR
All patients:	859	3.3	–
Age at first listing:			
0–9	51	2.9	1.11
10–17	21	3.3	1.24
18–34	56	3.5	1.23
35–49	330	3.4	1.00 (ref)
50–65	345	3.2	0.92
65 +	56	3.2	0.96
Gender:			
Male	561	3.6	1.00 (ref)
Female	298	2.8	0.79*
Race:			
White	780	3.5	1.00 (ref)
Black	49	2.1	0.68*
Other	30	1.9	0.51*
ABO blood type:			
A	278	2.9	0.70**
B	86	2.7	0.68*
AB	25	2.5	0.62*
O	470	3.8	1.00 (ref)
Payment:			
Medicare	83	2.8	1.00 (ref)
Medicaid	48	1.2	0.45**
Private	593	4.2	1.38*
HMO	54	2.5	0.90
Education:			
None, 0–12 years	243	2.7	1.00 (ref)
College, Graduate	334	4.7	1.55**

Adjusted for registrant variables including age, gender, race, ethnicity, BMI, year wait-listed, ABO blood type, primary source of payment, education, medical urgency status at day of first wait-listing, previous transplants, diagnosis group, ratio of OPO waiting list size to number of cadaveric livers recovered.
*$p < 0.05$; **$p < 0.0005$.

other races had significantly lower odds than white candidates of being multiple-listed. Liver candidates with A, B, or AB blood types were significantly less likely to multiple-list than patients with O blood type. Like kidney candidates, males and those with college or graduate school education were significantly more likely to multiple-list than females and persons with less education, respectively. Multiple-listing was significantly more likely among patients whose primary source of payment was private insurance when compared to patients whose primary source of payment was Medicare, whereas Medicaid patients were significantly less likely to multiple-list. The probability of multiple-listing increased by 10% with each unit increase in the ratio of OPO waiting list size to cadaveric livers recovered in the OPO (mean ratio 1.99 ± 1.97; RR = 1.10; p = 0.0001).

Effect of distance and OPO waiting time on the choice of second listing center

The distribution of distance from first listing center to second listing center for multiple-listed transplant candidates is shown in Figure 1. The majority of kidney patients who were multiple-listed chose a second listing center within one day's drive of the original listing center (Figure 1a; median distance 135 miles). Figure 1b shows that multiple-listed liver patients frequently chose a second listing center that was much farther from the first listing center (median distance 342 miles). These disparate data contrast with the similar median distance between all possible combinations of kidney (941 miles) and liver (913 miles) transplant centers.

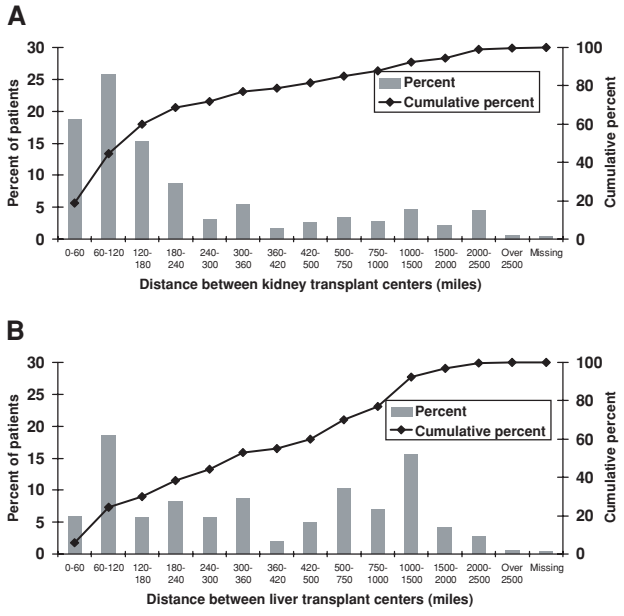

Figure 1: Frequency distribution and cumulative proportion of multiple-listed transplant candidates by distance between first and subsequent transplant program listings, for (a) kidney transplant candidates (median distance 135 miles) and (b) liver transplant candidates (median distance 342 miles).

Across all multiple-listed kidney and liver patients, the average time until 25% of candidates received a transplant (time to transplant) for the OPO of first listing was significantly longer than that for the OPO of second listing (kidney: 388 vs. 334 days; signed rank test; $p < 0.0001$; liver: 297 vs. 188 days; signed rank test; $p < 0.001$).

Multiple-listing among transplant recipients

Overall, 7.3% (2792/38 505) of kidney transplant recipients and 3.0% (370/12 396) of liver transplant recipients were listed at centers in more than one OPO at the time of their transplant. Nearly half (48.7%) of these kidney transplants occurred at the original listing center. Of the 413 (14.8%) multiple-listed kidney recipients who transferred accumulated waiting time to the second center, 78.7% received a transplant at the second center. Among multiple-listed liver recipients, only 23.2% received a transplant at the original listing center. Transfer of accumulated waiting time to the second liver transplant center was requested by 26.5%, and 91 of these 98 received a transplant at the second center.

Kidney transplantation rates, waiting list mortality, and graft outcome

The crude kidney transplant rate was 22.1 transplants per 100 patient years for single-listed patients and 41.3 per 100 patient years for multiple-listed candidates. Table 3 shows adjusted relative rates of kidney transplantation during periods of multiple-listing. Transplantation rates were 88% higher overall ($p < 0.0001$) and 35% to 129% higher by subgroup during periods of multiple-listing when compared to periods on a single waiting list. These rates were significantly higher for all patient subgroups examined except those with HMO medical coverage, although the small number of multiple-listed HMO candidates may have resulted in limited statistical power for this subgroup. The rate of transplantation for African-American patients during periods of multiple-listing was twice that of African-American patients during periods of single-listing (RR = 2.02; $p < 0.0001$). Candidates in 22 of 23 subgroups of age, gender, race, ABO blood type, PRA level, medical insurance, and education level had kidney transplant rates that were significantly higher than those for candidates from the identical subgroups during periods of single listing (RR = 1.42–2.29; all comparisons $p < 0.0005$ except age 10–17 [$p < 0.05$]).

The overall crude kidney waiting list mortality rate was 6.5% per year for single-listed candidates and 5.4% per year for multiple-listed candidates. Adjusted kidney waiting list mortality rates were lower during periods of multiple-listing than during periods of single listing overall (RR = 0.72; $p < 0.0925$) and in every subgroup (Table 3). Significantly lower waiting list mortality rates were observed in 12 of 22 subgroups analyzed, including adult candidates below age 65 (RR = 0.58–0.71), males (RR = 0.66), non-African-Americans (RR = 0.44–0.65),

Table 3: Kidney transplantation rates and wait-list mortality rates during periods of multiple-listing compared to periods of single listing. All analyses are adjusted for candidate variables

Subgroup	RR of transplant during periods of multiple-listing	RR of wait-list mortality during periods of multiple-listing
Overall:	1.88**	0.72
Age at first listing:		
0–9	–	–
10–17	1.42*	0.43
18–34	1.81**	0.58*
35–49	1.78**	0.71*
50–64	1.97**	0.65**
65 +	1.94**	0.74
Gender:		
Male	1.95**	0.66**
Female	1.97**	0.80
Race:		
White	1.84**	0.65*
Black	2.02**	0.84
Other	1.92**	0.44*
ABO blood type:		
A	1.87**	0.72**
B	1.84**	0.58**
AB	2.29**	0.56
O	1.80**	0.64*
PRA at first listing:		
0–9	1.66**	0.65
10–79	2.13**	0.81
80 +	1.78**	0.64
Payment:		
Medicare	1.87**	0.69*
Medicaid	1.63**	0.22*
Private	1.90**	0.82
HMO	1.35	0.24
Education:		
None, 0–12 years	1.89**	0.89
College, Graduate	1.93**	0.68**

*$p < 0.05$; **$p < 0.0005$; – insufficient data.

Table 4: Liver transplantation rates and wait-list mortality rates during periods of multiple-listing compared to periods of single listing. All analyses are adjusted for candidate variables

Subgroup	RR of transplant during periods of multiple-listing	RR of wait-list mortality during periods of multiple-listing
Overall:	2.95**	1.40*
Age at first listing:		
0–9	4.80**	4.20*
10–17	–	–
18–34	3.03**	5.93**
35–49	3.67**	1.71*
50–64	2.51**	0.94
65 +	2.44**	0.77
Gender:		
Male	2.73**	1.34
Female	3.77**	1.46
Race:		
White	2.98**	1.26
Black	4.64**	3.64*
Other	3.14**	1.45
ABO blood type:		
A	3.49**	1.03
B	2.37**	2.65*
AB	–	–
O	3.11**	1.29
Payment:		
Medicare	1.82*	0.42
Medicaid	2.95**	2.40
Private	3.07**	1.44*
HMO	7.41**	2.61
Education:		
None, 0–12 years	3.16**	1.70*
College, Graduate	2.43**	1.32

*$p < 0.05$; **$p < 0.0005$; – insufficient data.

those with A, B, or O blood types (RR = 0.58–0.72), college or graduate school education level (RR = 0.68), and Medicare (RR = 0.69) or Medicaid (RR = 0.22) as primary insurance coverage.

The risk of kidney graft failure was significantly lower for kidney transplant recipients who were multiple-listed at the time they received their allograft when compared to those resident on a single list at the time of transplant (RR = 0.90; $p = 0.03$).

Liver transplantation rates, waiting list mortality, and post-transplant mortality

The crude liver transplant rate was 39.3 per 100 patient years for single-listed patients and 83.4 per 100 patient years for multiple-listed candidates. Table 4 shows adjusted relative rates of liver transplantation and waiting list mortality during periods of multiple-listing. Overall, the transplantation rate was 195% higher while multiple-listed ($p < 0.0001$). Depending on the patient subgroup examined, the rates of transplantation during periods of multiple-listing were 82% to 641% higher than the rates of transplantation during periods of single-listing, and were significantly higher for all of the 19 patient subgroups with sufficient data for analysis (all $p < 0.0005$). The highest relative rates of transplant during periods of multiple-listing were seen for candidates with HMO medical coverage (RR = 7.41), children less than 9 years old (RR = 4.80), and African-Americans (RR = 4.64).

The overall crude liver waiting list mortality rate was 15.6% per year for single-listed candidates and 14.2% per year for multiple-listed candidates. However, in contrast to kidney transplant candidates, who were found to have lower crude and adjusted waiting list mortality while multiple-listed, adjusted liver waiting list mortality rates during periods of multiple-listing were significantly higher than while single-listed (RR = 1.40; $p < 0.015$); this was also true for 7 of 19 patient subgroups. Included in these subgroups were candidates less than 9 years old, 18–49 years old, of blood type B, with private medical insurance, with less than college education, and African-American.

The post-transplant mortality rate after liver transplantation among recipients who were multiple-listed at time of transplant was not significantly different from the rate for patients with a single listing at transplant (RR = 0.94; p = 0.6).

Discussion

In the current study, we provide analyses of national data to inform the multiple-listing debate by examining the relative rate of transplantation during periods when candidates were multiple-listed compared to periods of single listing. The rate of access to kidney transplantation was significantly higher while multiple-listed. The average multiple-listed patient had 88% higher access to kidney transplant. Every demographic, biological, and socioeconomic subgroup benefited from multiple-listing, and the effect was significant for all kidney subgroups except patients who had HMO coverage for their transplant. Importantly, groups known to have significantly diminished access to kidney transplantation, including African-Americans, females, and patients with blood types O and B (12), were all found to have significantly higher transplant rates while multiple-listed. In addition, candidates of lower educational attainment and those with Medicaid insurance had significantly higher transplant rates while multiple-listed. These socioeconomic factors have not been directly analyzed before, though they have been addressed indirectly through analysis of ZIP code data (4,13).

A threefold transplant access advantage was identified for liver transplant candidates. Every subgroup we studied had a significantly higher transplant rate while multiple-listed. The magnitude of the effect was even greater than for kidney patients, with some patients experiencing as much as a sixfold increase in transplant rate compared to single-listing.

Only a small proportion of all candidates register on multiple-lists. Sanfilippo et al. noted that 6.8% of candidates placed on the kidney waiting list between 1987 and 1990 were multiple-listed (14), which is slightly higher than the 5.8% reported here for a cohort of patients listed between 1995 and 2000. Ozminkowski et al. found that 4.5% of kidney transplant candidates between 1987 and 1994 were multiple-listed, which may be an underestimate, because that study only included candidates multiple-listed for at least 60 days within 30 months of initial listing (4). It thus appears that multiple-listing by patients awaiting kidney transplantation has not been increasing. To our knowledge, there are no published studies specifically addressing multiple-listing for liver transplantation. In the current study, 3.3% of liver candidates were multiple-listed.

We estimated the effect of multiple-listing on the waiting time of single-listed candidates as a way to gauge the harm imparted by this practice. With a relative rate of kidney transplant that is 1.88 times that for single-listed candidates, waiting time for multiple-listed candidates is almost 50% less. Applying the published overall median waiting time to kidney transplant of 152 weeks for the study period (1), waiting time for multiple-listed candidates is approximately 83 weeks. The waiting time for single-listed patients is calculated to be 156 weeks, about 4 weeks longer than the overall median. Calculations for liver transplant patients indicate that multiple-listing results in a waiting time that is also about 4 weeks longer than the overall median for single-listed liver candidates.

Since OPOs of secondary listing have shorter waiting times, on average, than primary listing OPOs, the practice of multiple-listing should tend to reduce waiting time disparities among OPOs. When a multiple-listed candidate receives a transplant in an OPO with a shorter waiting time, their consequent removal from the waiting list of the original OPO reduces the waiting time there. Conversely, waiting time is slightly increased for the remaining single-listed candidates in the secondary OPO where the transplant occurred.

In order to put these findings into context with other discrepancies in access to transplantation, one might consider how the effects of multiple-listing compare to existing regional discrepancies in waiting time in the United States. Under current allocation policy for kidneys and livers (15), most donated organs are distributed first to local patients awaiting transplant at a center served by the OPO servicing the donor hospital, then to a larger region, and then to the nation as a whole. Median waiting times for kidneys and livers at OPOs with the lowest and highest median waiting times demonstrate more than 10-fold and 22-fold differences, respectively (Figure 2). The effects of multiple-listing, as currently practiced, appear quite modest in comparison. In fact, regional disparities in waiting time would still dwarf the impact of multiple-listing even if its use were, for example, to double. Given the large differences in waiting time by OPO, the multiple-listed patients help to reduce these regional discrepancies, albeit to a small extent.

We found an association between multiple-listing and decreased kidney waiting list mortality rate. Although these results were significant only for patients with selected characteristics (adults 65 and younger; males; non-African-Americans; A, B, and O blood types; Medicare and Medicaid insurance, at least a college education), the analyses suggest that multiple-listed kidney patients may have lower acuity of disease. Transplantation while multiple-listed was associated with significantly better renal graft outcome. Conversely, liver candidates had significantly higher waiting list mortality while multiple-listed. Since liver transplant candidates tend to be sicker than patients awaiting kidney transplant and have no fallback therapy like dialysis, disease acuity may be a driver of multiple-listing for these individuals. Liver recipients who were multiple-listed at the time of transplantation showed no

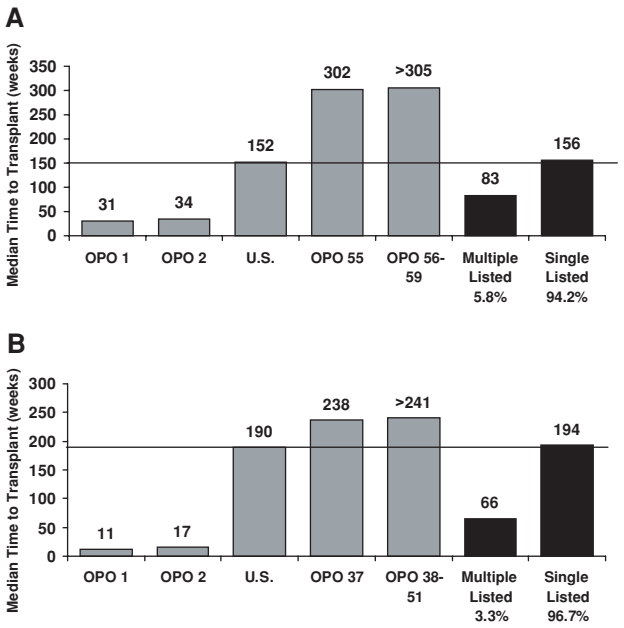

Figure 2: Ranked median time to transplant by OPO for kidney (a) and liver (b) candidates. Values for lowest and highest OPOs are shown, as well as the US median. OPOs that have not yet reached the median are grouped. Also shown are median estimated waiting times for multiple-listed and single-listed kidney and liver candidates.

difference in post-transplant survival compared to single listed recipients.

Analyses of the choice of second center by patients who elect to multiple-list indicate that kidney candidates were willing to travel modest distances, the equivalent of a 2–3-h highway trip. There was a 14% lower 25th percentile waiting time in the OPO serving the second center. For liver patients, average distance traveled to the second center was farther (median 342 miles), and the OPO serving the second center had, on average, a much shorter (37%) waiting time than that serving the original center. The difference in behavior of candidates for these two organs may reflect the higher acuity of illness and the lack of an alternative life-sustaining therapy for liver candidates.

In contrast to the consistent transplant access benefit resulting from multiple-listing of kidney and liver patients, only a small fraction of candidates utilize this option, and striking demographic and socioeconomic differences were seen for this group. Although it is beyond the scope of this investigation to discern the specific reasons why some patients multiple-list and some do not, there is clearly a need for better education, as it is likely that many patients are unaware that this option is available to them. Candidates in OPOs with long waiting times would especially benefit by multiple-listing in OPOs with shorter waiting times. Finally, it appears that enlargement of the first unit of geographic distribution of organs beyond the current OPO boundaries would tend to reduce geographic waiting time disparities for all patient subgroups and benefit patients whose biological attributes require larger donor pools, rather than the select few who multiple-list.

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