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Multiple Listing in Lung Transplant Candidates: A Cohort Study

Joshua J. Mooney, MD,MS¹, Lingyao Yang, MS², Haley Hedlin, PhD², Paul Mohabir, MD¹, and Gundeep S Dhillon, MD,MPH¹

¹Division of Pulmonary and Critical Care Medicine, Department of Medicine, Stanford University, Stanford, CA;

²Quantitative Sciences Unit, Department of Medicine, Stanford University, Stanford, CA

Abstract

Lung transplant candidates can be waitlisted at more than one transplant center, a practice known as multiple listing. The factors associated with multiple listing and whether multiple listing modifies waitlist mortality or likelihood of lung transplant is unknown. US lung transplant waitlist candidates were identified as either single or multiple listed using data from the Scientific Registry of Transplant Recipients. Characteristics of single and multiple listed candidates were compared and multivariable logistic regression was used to estimate associations with multiple listing. Multiple listed candidates were matched to single listed candidates using a combination of exact and propensity score matching methods. Cox proportional hazard models were used to estimate the relationship of multiple listing on waitlist mortality and receiving a transplant. Multiple listing occurred in 2.3% of lung transplant waitlist candidates. Younger age, female gender, white race, short stature, high antibody sensitization, college or post-college education, lower lung allocation score, and a cystic fibrosis diagnosis were independently associated with multiple listing. Multiple listing was associated with an increased likelihood of lung transplant (adjusted hazard ratio [aHR] 2.74, 95% CI 2.37 to 3.16) but was not associated with waitlist mortality (aHR 0.99, 95% CI 0.68 to 1.44).

Introduction

Within the United States, lung transplant candidates receive priority for donor lungs according to their transplant centers location relative to the donor and by their lung allocation score (LAS), which reflects their medical urgency and expected transplant benefit.^{1–3} The geographic location of a transplant center can influence a candidate's waitlist outcome as candidates listed at transplant centers in donor service areas with low local lung availability have higher waitlist mortality and lower transplant access.⁴ Although recent changes to lung allocation policy have slightly broadened donor lung allocation priority from beyond the local donor service area, the geographic location of a candidate's transplant

Corresponding Author: Joshua J. Mooney, MD, MS, Department of Medicine, Stanford University, 300 Pasteur Drive, Stanford, CA 94305. jjmooney@stanford.edu.

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center relative to a lung donor remains a central component of prioritizing donor lung allocation.^{3,5}

Transplant candidates within the United States are allowed by the Organ Procurement and Transplantation Network (OPTN) to register for transplantation at more than one transplant center, a practice known as multiple listing. Multiple listing at lung transplant centers in differing geographic locations can theoretically allow a candidate LAS-based prioritization to a greater number of donor lungs and thereby potentially modify waitlist mortality or likelihood of lung transplant. The factors associated with multiple listing and the effect of multiple listing on candidate waitlist outcomes has been assessed in other solid organ transplants.^{6–10} White race, higher education level, and the presence of private insurance are associated with an increased likelihood of multiple listing within liver, kidney, and heart transplant candidates.^{6,11} Moreover, these multiple listed kidney, liver, and heart transplant candidates have an increased likelihood of transplant compared to similar single center listed candidates and multiple listed kidney and heart transplant candidates also have lower waitlist mortality.^{6,11}

As multiple listing contributes to inequalities in the likelihood of transplant and waitlist mortality in other solid organ transplant candidates, we hypothesize that similar findings may be present within lung transplant candidates. In this study we sought to understand the lung transplant candidate factors associated with multiple listing and the relationship of multiple listing on lung transplant waitlist outcomes including waitlist mortality and likelihood of receiving a transplant. Better understanding of the impact of multiple listing within lung transplant can help inform policies that improve allocation equity for all lung transplant candidates.

METHODS

Subjects

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donor, waitlisted candidates, and transplant recipients in the U.S., submitted by the members of the Organ Procurement and Transplantation Network. 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. Using SRTR standard analysis files, we identified all lung transplant candidates on the waitlist during the post LAS period of May 4, 2005 and March 5, 2015. To be included in our analysis, candidates had to be at least 18 years old, be awaiting their initial lung transplant, and have a non-zero LAS. We removed candidates who had a diagnosis of “other.” Candidates who were listed simultaneously by at least two different centers were classified as multiple listed (ML) candidates. The date of active listing at the second center was used as the date of multiple listing. Candidates listed only at a single center or whose active listings at different centers did not overlap were classified as single listed (SL) candidates. This study received an exemption from the Stanford University Institutional Review Board as it uses previously collected de-identified data.

Statistical Analysis

Descriptive variables were generated from the existing SRTR data fields and compared between SL and ML candidates. Karnofsky performance scale scores were categorized as needed into 3 functional status categories according to previously described thresholds.¹² Categorical variables were displayed as number (%) and continuous variables were displayed as median (interquartile range, IQR). To understand whether candidates who multiple list do so at a transplant center, organ procurement organization (OPO), or OPTN region with a higher transplant rate, the transplant rates for all transplant centers, OPOs, and OPTN regions were calculated and then the difference between the multiple listing transplant rate and initial listing transplant rate was calculated. Transplant rate was determined by calculating the number of transplants per 100 waitlist years during the study period. To determine whether candidates who multiple list do so at specific transplant centers or in a specific OPO or OPTN region, the proportion of all multiple listed candidates by individual transplant center, OPO and OPTN region was calculated. To understand the association between sociodemographic and clinical characteristics with multiple listing, we fit a multivariable logistic regression model with multiple listing status as the outcome to all candidates who met the inclusion criteria for this study. We fit an adjusted, stratified Cox proportional hazards regression model to estimate the association between multiple listing status and the outcome of transplant or death in the matched dataset, i.e. the matched multiple listed candidates and the single listed candidates matched to them.

Matching—In order to balance the covariates observed in the SL and ML groups, we *a priori* selected the following variables to be used to match SL patients to ML patients in a 4:1 ratio: lung diagnosis group, time on the waitlist, initial LAS, year of first listing, initial OPTN region, height, antibody crossmatch requirement, blood type, single/bilateral transplant preference, gender, age at listing, race, and median household income of the candidate's county. Given the number of potential confounders selected *a priori*, we employed a matching method that allowed us to match SL and ML candidates. We matched candidates using the following criteria: in the same diagnosis group, same year of first listing, and within a caliper distance equal to 10% of the median on initial LAS and height, and a propensity score.¹³ Pairs of SL and ML candidates with distances outside the caliper were not matched. The propensity score was created by fitting a logistic regression with an outcome of multiple listing status and covariates including DSA, antibody crossmatch requirement, blood type, single/bilateral transplant preference, gender, age at listing, race, and household income. To ensure that the SL candidates were still at risk of transplant or death at the time that a ML candidate was multiply listed, we only matched a SL candidate to a ML candidate if the SL candidate's time on the waitlist was longer than the time until multiple listing for a ML candidate. We checked the matching by comparing the frequency distribution of the categorical variables between the multiple and single listed candidates and by comparing the standardized mean difference, a measure of the difference in means between two groups expressed in units of standard deviation, between single and multiple listed candidates in the unmatched and matched datasets.¹⁴

Modeling—A logistic regression model was fit in the full dataset including all candidates eligible for inclusion in our study to assess the relationship between multiple listing status

and the following variables: age at listing, diagnosis group, gender, race (white versus non-white), initial listing LAS, height, blood type, insurance type (public versus private), highest education level attained (high school education or below, college education, post college graduate degree), antibody crossmatch requirement, and county median household income.

To assess whether multiple listed candidates have a decreased likelihood of waitlist death or increased likelihood of transplant, two Cox proportional hazards models stratified by the matched 1 ML: 4 SL sets were fit in the matched dataset, one for the waitlist outcome of death and another for the waitlist outcome of transplant. The primary exposure of interest was whether the candidate was multiple listed. Waitlist outcomes were determined by the SRTR reported removal code. Candidates removed from the waitlist for being too sick for transplant were considered to have the same outcome as those removed for death. Time 0 for both the SL and ML candidates was set as the time of multiple listing for the ML patient in the matched set; this study design approach was chosen to reduce bias as comparable candidates would be evaluated during the follow-up period when candidates are multiple listed. Candidates who were removed from the list in error, not in contact with their center, listed by a program that was inactive for at least 2 years, transferred to another center, removed from the list for an unspecified reason, or remained alive on the waitlist were right-censored. Candidates were followed until the event of interest or until right censoring. SL candidates who were not matched to a ML candidate were not included in this analysis. Models were adjusted for status of multiple listing, age at listing, gender, race, initial listing LAS, height, blood type, antibody crossmatch requirement, single/bilateral lung preference, OPTN region, insurance type, and median household income. The proportional hazards assumption was assessed by visual examination of Schoenfeld residual plots and Kaplan-Meier plots.

In exploratory secondary analyses, we fit our primary models to a subset of the matched candidates where the multiple listing candidates had higher medical urgency as indicated by a listing LAS of at least 40. In sensitivity analyses, we additionally adjusted the multivariable logistic regression by initial listing OPTN region and functional status and the primary and secondary waitlist outcome analyses by functional status.

All statistical analyses were performed with R 3.1.3.¹⁵ To address missing data, imputations were applied to all models. Multiple imputations were used in the Cox proportional hazards model and the logistic regression models where we calculated confidence intervals (CI). A single imputation was used in the model used to create the propensity scores. Matching was performed using the R package ‘Matching’ and multiple imputations were performed with the ‘mice’ package.^{16,17} All tests were two-sided and conducted at the 0.05 significance level and all model estimates are shown with 95% CI.

Results

There were 43,578 patients ever listed for lung transplant in SRTR. 20,848 subjects met the eligibility criteria for inclusion in our study and 2,570 subjects are included in the matched dataset (Figure 1). Multiple listed candidates comprised 2.3% of US lung transplant waitlist candidates during the study period with a general increase in the number of annual multiple

listing registrations from 2006–2014 (Figure 2). The characteristics of all SL and ML candidates are shown in Table 1. A greater proportion of ML candidates were female (63.2% ML versus 44.6% SL), required a preliminary antibody crossmatch (10.3% ML versus 5.9% SL), and had cystic fibrosis (24.3% ML versus 11.4% SL). Multiple listed candidates had a longer total time on the waitlist (median 282 days; IQR 86, 616) than SL candidates (median 90 days; IQR 25, 281). Multiple listed candidates were more likely to have received a college (44.7% ML versus 41.3% SL) or post college graduate degree (13.0% ML versus 8.0%) and have private insurance (64.6% ML versus 57.9% SL). The median difference (IQR) in LAS from initial listing to multiple listing was 0.9 (0, 4.0).

Of ML candidates, 82.1% obtained their second transplant registration at a transplant center outside their initial OPO and 46.9% within a different OPTN region. 43.7% of ML candidates did so at a transplant center with a higher transplant rate with a median difference in transplant rate between the multiple listing center and initial listing center of −3.0 transplants per 100 waitlist years (IQR −25.0, 19.0). The proportion of ML candidates by each transplant center is shown in Figure 3. One-third (34.1%) of all multiple listing registrations occurred at one of 5 lung transplant centers. Of ML candidates who underwent lung transplant, 26% underwent transplant at their initial listing center and 74% at the center of multiple listing.

Of ML candidates, 32.4% obtained their second listing in an OPO with a higher transplant rate (median difference of 0.0 transplants per 100 waitlist years; IQR −16.0, 6.0) and 33.1% in an OPTN region with a higher transplant rate (median difference of 0.0 transplants per 100 waitlist years, IQR 0.0, 17.2). The proportion of ML candidates in each OPO and OPTN region are shown in Figures 4 and 5. Greater than 50% of all multiple listing registrations were within 7 OPOs or within 3 OPTN regions.

After multivariable adjustment, age (adjusted odds ratio (aOR) 0.98, 95% CI 0.97–0.99), cystic fibrosis (aOR 1.44, 95% CI 1.03–2.02), initial LAS (aOR 0.96, 95% CI 0.95–0.97), height (aOR 0.99, 95% CI 0.98–1.00), male gender (aOR 0.64, 95% CI 0.51–0.81), white race (aOR 1.38, 95% CI 1.03–1.86), college education (aOR 1.34, 95% CI 1.09–1.66), post college graduate education (aOR 2.64, 95% CI 1.98–3.52), and preliminary antibody crossmatch requirement (aOR 1.62, 95% CI 1.23–2.14) were associated with the likelihood of multiple listing (Figure 6). In a sensitivity analysis that added the initial listing OPTN region, the previously statistically significant variables except for white race remained significant and OPTN region 1 (aOR 2.44, 95% CI 1.67–3.57), region 5 (aOR 1.38, 95% CI 1.01–1.88), region 6 (aOR 0.26, 95% CI 0.10–0.66), and region 9 (aOR 1.56, 95% CI 1.03–2.36) were also independently associated with multiple listing when treating region 2 as the reference region. An additional sensitivity analysis that added an indicator for functional status did not modify the significance of the previously identified variables but did demonstrate an additional association of needing full assistance (as compared to no assistance) with a reduced likelihood of multiple listing (aOR 0.62, 95% CI 0.44–0.88).

The characteristics of matched SL and ML candidates included in the analysis of likelihood of transplant and waitlist mortality are shown in Table 2. Multiple listing was associated with a 2.7-fold increase in receiving a lung transplant (adjusted hazard ratio (aHR) 2.72,

95% CI 2.36–3.14). Multiple listing was not associated with waitlist mortality (aHR 1.02, 95% CI 0.70–1.48). Sensitivity analyses that additionally adjusted for functional status did not modify the relationship of multiple listing with the likelihood of lung transplant (aHR 2.71, 95% CI 2.34–3.13) or waitlist mortality (aHR 1.06, 95% CI 0.73–1.55). In an exploratory secondary analysis of a matched subset of 312 SL and 78 ML candidates in pairs where the ML candidate had a listing LAS 40, multiple listing increased the likelihood of lung transplant (aHR 1.98, 95% CI 1.36–2.89) but was not associated with waitlist mortality (aHR 0.59, 95% CI 0.18–1.91).

Discussion

A small number of US lung transplant waitlist candidates are multiple listed but those who are multiple listed have an increased likelihood of receiving a lung transplant compared to single listed candidates. The majority of multiple listing registrations occurred in a different OPO than their initial listing OPO. The likelihood of being multiple listed was greater in candidates of younger age, female gender, white race, shorter stature, greater antibody sensitivity, lower LAS, or with a higher education level or diagnosis of cystic fibrosis. While being listed at multiple centers increased the likelihood of receiving a lung transplant, it was not associated with decreased waitlist mortality.

The factors associated with multiple listing included clinical factors that have been shown to influence waitlist outcomes, such as short stature, antibody sensitization and LAS. Short stature is associated with reduced access to lung transplant and increased risk of waitlist death, which is related to the need to match candidates to donors of similar height and a smaller number of short stature donors than short stature candidates.¹⁸ Multiple listing may therefore be used as a strategy in short stature candidates to increase access to a greater pool of short stature donors. Candidates with greater pre-transplant human leukocyte antibody (HLA) sensitivity had a longer waitlist time and reduced access to lung transplant within a single center study.¹⁹ Within our cohort, the need for a preliminary antibody crossmatch served as a surrogate for greater HLA antibody sensitivity due to the absence of alternative information, such as panel reactive antibodies or avoided antigens, within SRTR thoracic candidate standard analysis files. Therefore, similar to short stature, multiple listing may be used in candidates with greater antibody sensitivity to allow access to a greater pool of HLA compatible donors. The current lung allocation system does not adjust prioritization for short stature or highly sensitized candidates; broader geographic access to donor lungs or adjustments in LAS prioritization for short stature or highly sensitized candidates may improve equitable access to transplant for these candidates, particularly candidates unable to pursue multiple listing. Notably, multiple listing was more common in candidates with lower medical urgency as measured by LAS rather than candidates with a higher LAS or high medical urgency. Candidates with a lower LAS have a lower risk of waitlist mortality and also intuitively have a lower transplant rate.²⁰ Therefore, multiple listing may also be used as a strategy to increase transplant likelihood for candidates with otherwise low transplant priority by their calculated LAS.

In renal, liver, and heart transplant candidates, socioeconomic factors including white race, higher education level, and private insurance have been associated with multiple listing.^{6,11}

Similarly, in our study white candidates and candidates with a college or post college degree were more likely to be multiple listed for lung transplant compared to non-white candidates and candidates with a high school or below level of education. Private insurance was more common in multiple listed candidates, but was not statistically significant after adjusting for other factors associated with multiple listing. Our results suggest that multiple listing is a source of demographic and socioeconomic inequity in lung transplant access. We hypothesize that patients with a higher level of education are more likely to understand their right to be listed at multiple centers, understand the potential advantages of multiple listing, and have the means to allow multiple listing. The differences in multiple listing status by race may also explain previously described disparities in transplant access amongst non-white waitlist candidates.²¹

The socioeconomic factors associated with multiple listing and advantages of multiple listing seen in our study and previous solid organ studies on multiple listing raise the long-debated question of whether multiple listing is fair and in concordance with the Final Rule on organ allocation.^{11,22} Multiple listing is not typically practiced or has been banned in other countries transplant allocation systems, such as Eurotransplant. Following the approval of the practice of multiple listing within the United States in 1987, there have been several national and local attempts to ban multiple listing including proposed national bans in 1988 and again in 1994–1995 that were not implemented.^{7,23,24} In 1990, the state of New York banned transplant candidates who were already listed for organ transplant from subsequently registering on another waitlist within the state, however its efficacy was limited by the inability to prohibit subsequent out of state transplant listings.^{7,23} Regardless of future policy decisions on whether multiple listing should continue within the United States, understanding and addressing the underlying reasons why candidates pursue multiple listing is needed to truly improve allocation equity for all. The majority of multiple listing candidates (82.1%) were listed in a different OPO than their initial listing OPO and thereby had access to another donor pool. This suggests that prioritized access to a broader geographic donor pool may have driven the decision for candidates to multiply list. Notably, there were specific transplant centers, OPOs, and OPTN regions with a greater proportion of the multiple listing registrations, however only a minority of multiple listing candidates (43.7%) obtained their multiple listing at a center with a higher transplant rate. Therefore, while some candidates likely targeted multiple listing towards specific transplant centers (i.e. 1/3 of multiple listing registrations were at 5 transplant centers), the decision to be multiple listed at a high transplant rate center was not universal.

Our results are limited by the observational nature of the study, in which differences in measured and unmeasured characteristics of single listed and multiple listed candidates may influence both the decision to multiple list as well as waitlist mortality and transplant outcomes. Although we performed a logistic regression model to identify the measured variables associated with multiple listing there are likely additional unmeasured variables or confounders that are not available in registry data. There was missing data present, which we addressed through multiple imputations to mitigate the limitations of the missing data; however results based on data are not as ideal as results based on fully observed data. To mitigate the differences in measured variables, single and multiple listed candidates were carefully matched on a number of demographic and clinical variables and the non-identically

matched characteristics were again adjusted for in our models to isolate the effect of multiple listing status on waitlist outcome. In analyzing the effect of multiple listing on waitlist outcomes, time zero was set as the time of multiple listing for the matched SL and ML candidates and the time spent prior to multiple listing was discarded. Although this approach has limitations, it was used instead of a time-dependent analysis to reduce bias as waitlist time differed between SL and ML candidates and candidates who do not survive long enough to become multiple listed would have contributed time to the model only as single listed candidates, whereas given sufficient time those candidates may have gone on to multiple listing.

In summary, our findings demonstrate that only 2.3% of lung transplant waitlist candidates are multiple listed with younger, female, white, short stature, highly sensitized, college or post-college educated, lower LAS, and cystic fibrosis candidates more likely to be multiple listed. These multiple listed candidates have a greater likelihood of lung transplant than comparable single listed candidates. Addressing geographic and other clinical disparities in lung transplant access may help decrease the need and advantages of multiple listing and improve waitlist equity in lung transplant.

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Abbreviations:

LAS	Lung allocation score
OPTN	Organ Procurement and Transplantation Network
SRTR	Scientific Registry of Transplant Recipients
HRSA	Health Resources and Services Administration
ML	multiple listed
SL	single listed
IQR	interquartile range
OPO	organ procurement organization
CI	confidence interval
aOR	adjusted odds ratio
aHR	adjusted hazard ratio
HLA	human leukocyte antibody

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Figure 1. STROBE diagram.

The diagram displays the numbers of candidates meeting study inclusion and exclusion criteria and the number of candidates included in the matched dataset.

Figure 2. Annual Number of Multiple Listing Registrations.

The figure displays the number of new multiple listing registrations within each calendar year from 2006 to 2014.

Figure 3. Multiple Listing Registrations by Transplant Center.

The figure demonstrates the distribution of all multiple listing registrations by lung transplant center. Each bar demonstrates the percentage of nationwide multiple listings that are registered within an individual transplant center.

Figure 4. Multiple Listing Registrations by Organ Procurement Organization.

The figure demonstrates the distribution of all multiple listing registrations by organ procurement organization. Each bar demonstrates the percentage of nationwide multiple listings that are registered within an individual organ procurement organization.

Figure 5. Multiple Listing Registrations by Organ Procurement and Transplantation Network (OPTN) Region.

The figure demonstrates the distribution of all multiple listing registrations by OPTN region. Each bar demonstrates the percentage of nationwide multiple listings that are registered with an individual OPTN region.

Figure 6. Candidate Characteristics Associated with Multiple Listing.

The adjusted odds ratio for each variable included in a multivariable logistic regression model of multiple listing is displayed. Reference groups for categorical variables included chronic obstructive pulmonary disease for diagnosis group, A blood type for blood type, and high school education level or below for education level. The odds ratio for age is per 1 year, for LAS is per 1 point, and for income is per \$1.

Table 1.

Characteristics of Single Listed and Multiple Listed Lung Transplant Candidates

	Single Listed n = 20,255	Multiple Listed n = 593	Standardized Mean Difference
Age, median (IQR), years	58 (48, 63)	53 (37, 60)	0.397
Female, No (%)	9035 (44.6)	375 (63.2)	0.38
Race, No (%)			0.108
White	17857 (88.2)	539 (90.9)	
Black	1917 (9.5)	40 (6.7)	
Asian	340 (1.7)	9 (1.5)	
Other	140 (0.7)	5 (0.9)	
Missing	1 (0.0)	0 (0.0)	
Height, median (IQR), cm	170.0 (162.6, 177.8)	165.1 (157.5, 172.7)	0.345
Lung Diagnosis, No (%)			0.377
Group A - Obstructive Lung Disease	6415 (31.7)	192 (32.4)	
Group B - Pulmonary Vascular Disease	1006 (5.0)	32 (5.4)	
Group C - Cystic Fibrosis	2310 (11.4)	144 (24.3)	
Group D - Pulmonary Fibrosis	10524 (52.0)	225 (37.9)	
Restricted Bilateral Lung Preference, No (%)	16114 (79.6)	499 (84.1)	0.119
Antibody Crossmatch Required, No (%)	1203 (5.9)	61 (10.3)	0.16
ABO Blood Type, No (%)			0.035
A	7967 (39.3)	242 (40.8)	
AB	756 (3.7)	23 (3.9)	
B	2217 (10.9)	61 (10.3)	
O	9315 (46.0)	267 (45.0)	
Functional Status, No (%)			0.307
Needs No Assistance	3049 (15.1)	115 (19.4)	
Needs Some Assistance	12789 (63.1)	409 (69.0)	
Needs Full Assistance	4002 (19.8)	55 (9.3)	
Missing	415 (2.0)	14 (2.4)	
Lung Allocation Score at Initial Listing, median (IQR)	36.4 (34.5, 43.5)	34.5 (32.4, 38)	0.401
Year of Initial Listing, No (%)			0.326

	Single Listed n = 20,255	Multiple Listed n = 593	Standardized Mean Difference
Pre-2005	1721 (8.5)	105 (17.7)	
2005 – 2008	5911 (29.2)	159 (26.8)	
2009 – 2011	5925 (29.3)	191 (32.2)	
2012 – 2015	6698 (33.1)	138 (23.3)	
Highest Level of Education, No (%)			0.209
High School or below	7984 (39.4)	188 (31.7)	
College	8368 (41.3)	265 (44.7)	
Post College Graduate Degree	1628 (8.0)	77 (13.0)	
Missing	2275 (11.2)	63 (10.6)	
Insurance Type, No (%)			0.145
Private	11737 (57.9)	383 (64.6)	
Medicare	6075 (30.0)	143 (24.1)	
Medicaid	1519 (7.5)	43 (7.3)	
Other	743 (3.7)	20 (3.4)	
Missing	181 (0.9)	4 (0.7)	
Initial Organ Procurement Transplant Network Region, No (%)			0.351
Region 1	653 (3.2)	50 (8.4)	
Region 2	3139 (15.5)	72 (12.1)	
Region 3	2319 (11.4)	72 (12.1)	
Region 4	2337 (11.5)	49 (8.3)	
Region 5	2884 (14.2)	103 (17.4)	
Region 6	610 (3.0)	5 (0.8)	
Region 7	1780 (8.8)	45 (7.6)	
Region 8	1304 (6.4)	40 (6.7)	
Region 9	821 (4.1)	37 (6.2)	
Region 10	2450 (12.1)	80 (13.5)	
Region 11	1958 (9.7)	40 (6.7)	
Household Income, median (IQR), US Dollars	52070 (45140, 60370)	52530 (46130, 62270)	0.071
Waitlist Time, median (IQR)	90 (25, 281)	282 (86, 616)	0.397

Table 2.

Characteristics of Matched Single and Multiple Listed Lung Transplant Candidates

	Single Listed n = 2,064	Multiple Listed n = 516	Standardized Mean Difference
Age, median (IQR), years	53 (40.0, 60.0)	54 (40.8, 61.0)	0.082
Female, No (%)	1234 (59.8)	315 (61.0)	0.026
Race, No (%)			0.114
White	1836 (89.0)	470 (91.1)	
Black	189 (9.2)	35 (6.8)	
Asian	29 (1.4)	7 (1.4)	
Other	9 (0.4)	4 (0.8)	
Missing	1 (0.0)	0 (0.0)	
Height, median (IQR), cm	165.1 (158.8, 172.7)	165.1 (158.6, 172.7)	0.002
Lung Diagnosis, No (%)			<0.001
Group A - Obstructive Lung Disease	728 (35.3)	182 (35.3)	
Group B - Pulmonary Vascular Disease	104 (5.0)	26 (5.0)	
Group C - Cystic Fibrosis	416 (20.2)	104 (20.2)	
Group D - Pulmonary Fibrosis	816 (39.5)	204 (39.5)	
Restricted Bilateral Lung Preference, No (%)	1749 (84.7)	425 (82.4)	0.064
Antibody Crossmatch Required, No (%)	177 (8.6)	48 (9.3)	0.025
ABO Blood Type, No (%)			0.077
A	806 (39.1)	215 (41.7)	
AB	60 (2.9)	19 (3.7)	
B	191 (9.3)	47 (9.1)	
O	1007 (48.8)	235 (45.5)	
Functional Status, No (%)			0.171
Needs No Assistance	529 (52.6)	96 (18.6)	
Needs Some Assistance	1322 (64.1)	364 (70.5)	
Needs Full Assistance	172 (8.3)	46 (8.9)	
Missing	41 (2.0)	10 (1.9)	
Lung Allocation Score at Initial Listing, median (IQR)	34.1 (32.3, 37.2)	34.2 (32.3, 37.4)	0.024
Year of Initial Listing, No (%)			<0.001

	Single Listed n = 2,064	Multiple Listed n = 516	Standardized Mean Difference
Pre-2005	372 (18.0)	93 (18.0)	
2005 – 2008	544 (26.4)	136 (26.4)	
2009 – 2011	668 (32.4)	167 (32.4)	
2012 – 2015	480 (23.3)	120 (23.3)	
Highest Level of Education, No (%)			0.262
High School or below	847 (41.0)	170 (32.9)	
College	845 (40.9)	224 (43.4)	
Post College Graduate Degree	135 (6.5)	69 (13.4)	
Missing	237 (11.5)	53 (10.3)	
Insurance Type, No (%)			0.168
Private	1305 (63.2)	330 (64.0)	
Medicare	486 (23.5)	133 (25.8)	
Medicaid	199 (9.6)	31 (6.0)	
Other	73 (3.5)	19 (3.7)	
Missing	1 (0.0)	3 (0.6)	
Organ Procurement Transplant Network Region, No (%)			0.15
Region 1	119 (5.8)	34 (6.6)	
Region 2	246 (11.9)	66 (12.8)	
Region 3	270 (13.1)	64 (12.4)	
Region 4	178 (8.6)	46 (8.9)	
Region 5	261 (12.6)	83 (16.1)	
Region 6	21 (1.0)	5 (1.0)	
Region 7	223 (10.8)	43 (8.3)	
Region 8	168 (8.1)	33 (6.4)	
Region 9	122 (5.9)	32 (6.2)	
Region 10	318 (15.4)	73 (14.1)	
Region 11	138 (6.7)	37 (7.2)	
Household Income, median (IQR), US Dollars	51940 (44980, 60240)	52110 (45750, 61800)	0.068
Waitlist Time, median (IQR)	567.5 (244, 1154)	249.5 (71.8, 546.8)	0.697