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Implications of blood group on lung transplantation rates: A propensity-matched registry analysis

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Abstract

BACKGROUND: Blood type O lung allografts may be allocated to blood type identical (type O) or compatible (non-O) candidates. We tested the hypothesis that the current organ allocation schema in the United States—based on the Lung Allocation Score—prejudices against the allocation of allografts to type O candidates, given that the pool of potential donors is smaller.

METHODS: We performed a retrospective cohort review of the Organ Procurement and Transplantation Network/United Network of Organ Sharing registry from May 2005 to March 2017 for adult candidates on the waiting list for first-time isolated lung transplantation. Demographic data were compiled and described, and 1:1 nearest-neighbor propensity score matching was used to adjust for age and Lung Allocation Score at listing.

RESULTS: A total of 26,396 candidates met inclusion criteria: 14,329 type non-O and candidates and 12,068 type O candidates. After matching, 11,951 candidates were included in each group. Of these, 77.0% of type non-O underwent lung transplantation vs 73.1% type O ($p < 0.001$). At 1 year, the waiting list mortality was higher for type O candidates (12.5%) than for non-O candidates (10.1%, $p < 0.001$). Of those undergoing transplantation, 5-year survival rates were similar.

CONCLUSIONS: Type O candidates experience lower rates of transplantation and higher rates of waiting list mortality compared with matched type non-O candidates. Further evaluation of regional sharing of allografts to increase transplantation rates for type O candidates may be warranted to optimize equity in access to transplants.

Keywords

blood type O; lung allografts; organ allocation system; waiting list mortality; donor pool

Lung transplantation is the gold standard therapy for end-stage lung disease. Lung transplantation continues to be provided to an increasing number of recipients: a total of 2,345 lung transplants were performed in the United States in 2016, the highest volume year

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to date.¹ Due to an ongoing mismatch between donor organ supply and the demand for suitable organs, waiting list mortality continues to represent a major concern in thoracic transplantation.²

The discrepancy between the need of organs and their availability has driven the development and evolution of the Lung Allocation Score (LAS), in which candidate factors are assessed to model the likelihood of survival on the waiting list and the candidate's likelihood of benefit from transplantation.¹

The candidate priority for available allografts is set on the LAS, blood type, and the distance between the transplanting center and the donor location.² In each distinct geographic area, the specific sequence of LAS, blood type, and distance priorities dictate the order in which offers are made.² The allocation system recognizes the risk of prolonged ischemic times and the need to minimize travel time from the donor hospital to the recipient hospital by setting geographic priority zones around the donor hospital. Within a given geographic priority zone, offers are then made first to blood type-identical and then blood type-compatible candidates. The LAS is then used to stratify candidates within blood group-identical and blood group-compatible priorities.

Blood type O organs can be used in compatible recipients, but type O candidates do not enjoy any potential compatible allografts to supplement identical matches. Although ABO-incompatible renal transplantation has been introduced, this is not currently a viable strategy in lung transplantation.^{3,4} As such, for candidates of similar urgency and geographic proximity, type non-O candidates enjoy more potential offers than type O candidates, who require an identical, type O offer to proceed with transplantation. This may allow for a discrepancy with the Final Rule, which dictates organ allocation should be equitably distributed and free from arbitrary geographic determinants.

In this study, we sought to ascertain the magnitude by which an allocation system based on LAS that allows for compatible blood types puts type O lung transplant candidates at a disadvantage compared with non-O blood type lung transplant candidates. We hypothesized that the US allocation system leads to longer waiting list times and greater waiting list mortality for type O lung transplant recipients.

Methods

Data source

A retrospective cohort analysis was performed using the Organ Procurement and Transplantation Network (OPTN)/United Network of Organ Sharing (UNOS) Standard Analysis and Research database. UNOS administers the OPTN under contract with the U.S. Department of Health and Human Services. This database contains data on all transplant candidates undergoing listing for solid organ transplantation in the US since October 1987. The data set used for this investigation included all candidates listed for lung transplantation between May 2005 (time of introduction of the LAS) and March 2017. As of 1999, all data in the OPTN/UNOS transplantation database has been collected via an internet-based database application called "UNet." Data are entered by transplant professionals. Electronic

data validation and on-site audits are performed for quality assurance. The Duke University Institutional Review Board approved this study before data collection.

Study design

All first-time adult candidates listed for isolated lung transplantation during the study dates were included. Exclusion criteria included candidates aged < 18 years, those undergoing simultaneous heart, liver, or abdominal transplantation, and those with incomplete data for survival, LAS, or blood group typing. The study population was then stratified by blood group (type O and type non-O).

Statistical analysis

Demographic data were compiled and described. Baseline characteristics and outcomes were compared between groups using the Kruskal-Wallis analysis of variance test for continuous variables and the Pearson chi-square test for categorical variables. Cumulative incidence functions were used to examine the cumulative incidences of transplantation, recovery, or decompensation on the waiting list, all stratified by blood type. Competing risks analysis was then used to measure the competing likelihoods of survival to transplantation, recovery, or death on the waiting list. Cumulative hazards for each waiting list outcome were measured by each blood group.

Of note, recovery defined as removal from the waiting list due to a reason of transplantation no longer being required. Decompensation consisted of removal from the waiting list due to a reason of death or decompensation that precluded transplantation.

To adjust for demographic factors that may influence the rate of each competing outcome from the waiting list, propensity score matching was performed to address differences in candidate demographics. Propensity scores were developed conditional on LAS, age, sex, diagnostic grouping, need for extracorporeal membrane oxygenation (ECMO) at registration, UNOS region, and height in centimeters at the time of listing. Candidates were then matched by propensity scores using a 1:1 nearest-neighbor algorithm. The effectiveness of reduction of bias within the model after matching was assessed by standardized mean differences. Cohen's suggested threshold of 0.2 was used to denote a meaningful imbalance in the comparison of baseline covariates. Adjusted outcomes between the propensity-matched groups were then compared using the competing risks technique and calculation of the cumulative hazard for each waitlist outcome. Finally, the Kaplan-Meier method was used to estimate post-transplant survival for those candidates in each propensity-matched group that underwent lung transplantation.

The log-rank test was used to determine statistical significance. Secondary end points included hospital length of stay, dialysis within the first week, and episodes of acute rejection before discharge. Definitions of these secondary end points are standard in the Standard Analysis and Research file and have been defined previously. Analyses were performed using R 3.4.1 software (R Core Team, Vienna, Austria) with a p -value < 0.05 indicating statistical significance.

Results

Demographic characteristics

A total of 26,397 candidates met inclusion criteria for analysis. Of these, 12,068 (45.7%) were blood type O and 14,329 (54.3%) were blood type non-O, of which 71.6% were group A, 20.7% group B, and 6.7% type AB. At the time of listing, type O candidates tended to be younger (mean, 53.73 vs 54.15 years; $p = 0.015$) and were equally distributed with respect to sex (54.8% male for type O, 55.3% male for type non-O, $p = 0.455$). Distribution across diagnostic groupings was similar between cohorts: type O distribution was 29.6% obstructive, 4.6% pulmonary vascular, 12.2% cystic fibrosis and associated, and 53.7% restrictive lung diseases; and type non-O distribution was 31.0% obstructive, 4.7% pulmonary vascular, 12.3% cystic fibrosis and associated, and 52.0% restrictive lung disease ($p = 0.039$). The LAS at the time of listing was higher for type O (mean, 40.90 vs 40.25; $p = 0.002$). Height was similar between groups (mean, 169.05 cm for type O and 168.83 cm for type non-O; $p = 0.082$).

By the end of the study period, a higher fraction of non-O candidates had undergone transplantation (75.8% vs 72.9% for type O, $p < 0.001$) and a lower fraction had been removed from the waiting list due to death or decompensation (14.1% vs 15.5% for type O, $p < 0.001$). Mean waiting list duration was longer for type O (mean, 233.50 vs 206.60 days; $p < 0.001$) despite the LAS at time of transplant being higher for type O (mean, 47.30 vs 46.64; $p = 0.01$). At the time of transplantation, a higher fraction of type O candidates were in the intensive care unit (10.7% vs 9.5%) compared with 79.9% not hospitalized for type O vs 82.0% for type non-O ($p < 0.001$). The percentage of recipients supported on ECMO at the time of transplantation was similar (3.1% for type O vs 2.9% for type non-O, $p = 0.351$), and serum creatinine at the time of transplantation was the same (mean, 0.84 mg/dL for both groups; $p = 0.598$).

The rate of bilateral transplantation was similar: 68.4% of type-O recipients and 68.3% of type non-O recipients ($p < 0.001$). All type O candidates who underwent transplantation received an ABO-identical allograft. Of type non-O candidates who underwent transplantation, 89.3% received ABO-identical allografts, and 10.7% received ABO-compatible allografts.

Complete demographic data for the unadjusted cohort are reported in Table 1. The distribution of our cohort recipient blood type matched the reported distribution of recipient blood type in the most recent Scientific Registry of Transplant Recipients report¹; nonetheless, the distribution of the donors was significantly different ($p < 0.001$). There was a higher fraction of non-O type recipients and a lower fraction of type O recipients, thus further supporting the findings that some of the type O organs are going to non-type O recipients (Donors: A 36%, AB 2.2%, B 10.7%, O 51.1%; Recipients: A 40.3%, AB 3.8%, B 11.1%, O 44.8%).

Competing risks

At 1 year on the waiting list, 69.3% of type non-O candidates underwent transplantation, and 11.4% were removed from the waiting list due to death or decompensation. In contrast,

65.2% of type-O candidates underwent transplantation, and 12.5% were removed from the waiting list due to death or decompensation. Competing risks for transplantation, death or decompensation, and recovery are represented in the unadjusted cohort across type O and type non-O in Figure 1. Cumulative hazard for transplantation, as reported in Figure 2, was higher for type non-O than for type O ($p < 0.001$).

Adjusted analysis

Propensity score matching was used to develop a 1:1 balanced cohort representing 11,951 candidates in each cohort. Demographic data were again compiled and described. The performance of the match was assessed through examination of standardized mean differences, revealing that the groups were well balanced across all covariates included in the match: age, sex, height, LAS, diagnostic group, need for ECMO at registration, need for ventilator at registration, single/bilateral preference, crossmatch requirement, and UNOS region (Table 2).

At the conclusion of the study period, a lower fraction of type O candidates had undergone transplantation (73.1% vs 77.0% for type non-O), and a higher fraction were removed from the waiting list due to death or decompensation (15.5% vs 13.0% for type non-O, $p < 0.001$).

Competing risks—adjusted analysis

Competing risks of transplantation, death, or decompensation, and recovery were assessed at 1 year on the waiting list. A lower fraction of type O candidates had undergone transplantation (65.2% vs 70.2%), and a higher fraction were removed due to death or decompensation (12.5% vs 10.1%), a 1.24-fold increase in risk of death at 1 year on the waiting list (Figure 3). In this propensity-matched cohort, the cumulative hazard for transplantation was higher through all time points for type non-O candidates ($p < 0.001$, Figure 4).

Long-term post-transplant survival was estimated in the propensity-matched cohort using the Kaplan-Meier method. At 5 years, there was no difference in survival (54.8% for type O and 55.3% for type non-O, $p = 0.22$; Figure 5).

Discussion

ABO compatibility is a primary matching criterion in all solid organ transplantation, and although efforts are ongoing to make ABO-incompatible transplantation clinically feasible, this approach to date remains relevant only in the most highly sensitized renal transplant candidates. In lung transplantation, ABO compatibility is considered in conjunction with the LAS and geographic proximity to determine priority for organ allocation. Blood type O lungs are commonly used in compatible ABO recipients and thus may create a disadvantage for blood type O recipients, because these candidates are not eligible for type non-O organs in conventional transplantation.

To answer this question, we conducted this retrospective review of the OPTN/UNOS registry from May 2005 to March 2017 on 26,396 lung transplant recipients and have demonstrated that type O candidates experience lower rates of transplantation and higher rates of waiting

list mortality compared with matched type non-O candidates. This disparity represents a modifiable disadvantage that could be addressed through rational modification of the lung allocation process. Ultimately, altering this allocation process may provide a system more aligned with the Final Rule than the current structure.

Lung allocation has gone through a dramatic change since April 2005 when the LAS system was introduced. By developing the score, the lung transplant community aimed to (1) cause a reduction of mortality on the waiting list; (2) prioritize candidates based on urgency while avoiding futile transplants, meaning making sure that the recipient survival benefit and organ utilization will be optimal; and (3) put a decreased emphasis on the role of waiting time and geography in lung allocation within the limits of ischemic time.⁵ Indeed, the implementation of the LAS score in 2005 resulted in increasing the number of recipients receiving transplants each year while decreasing the time on the waiting list and waiting list mortality, but without significantly adversely affecting post-transplant survival.⁶

During the time of this study, however, lungs were being allocated by geographic location and ABO before addressing the patient LAS score.⁷ Geographically, the lungs were offered first to the organ procurement organization in the local donor service area (DSA) and then according to the distance from the donor hospital; zones A to E, distances of 500 miles from each other. In each region, the lungs were offered to the identical blood type and then to a compatible one before moving to the next region. Although type O candidates should then receive local type O offers before offers are made to compatible (type non-O) candidates, the treatment of non-local type O allografts should be reevaluated to reprioritize identical type O candidates before being offered to compatible candidates.

The local allocation was recently changed, however. During the years since the LAS was instituted, numerous studies have showed that more than 50% of the lungs transplanted in local DSAs are to patients with lower LASs than other nearby waiting list patients. However, after a court order, the allocation protocol for lungs was changed on November 24, 2017, to become within the first 250 miles⁸ and removing the reliance on the local DSA. Blood type O candidates remain at a disadvantage in the new allocation protocol, although the magnitude remains to be determined.

Reevaluation of the treatment of blood type compatible vs identical allografts in thoracic transplantation has contemporary international precedent. Two different studies recently examined the survival of ABO-compatible recipients and found that there was no survival difference in bilateral or single orthotopic lung transplantation in ABO-compatible recipients after transplant.^{9,10} However, the blood type O transplantation rate and death ratio on the waiting list was never addressed, neglecting an important component of the broader care of the transplant candidate from the time of listing. According to the OPTN/SRTR 2016 annual data report in 2016, the transplant rate increased to 191.9 transplants per 100 waiting list-years, with a slight decrease in waiting list mortality to 15.1 deaths per 100 waiting list-years.¹

Hussey et al¹¹ examined the influence of blood group on mortality and waiting time before heart transplantation in the United Kingdom. They examined 622 new, non-urgent, adult,

heart-only registrations from April 1, 1999, to March 31, 2003. In their cohort, a smaller proportion of blood group O patients received a transplant at 1 year after registration, with a significant difference in waiting time to transplant between blood groups: blood group A and AB patients generally received a transplant sooner than O and B patients. As a consequence of their study the United Kingdom Transplant Cardiothoracic Advisory Group (CTAG) changed the allocation protocol so that “out-of-zone” offers of blood group O donors for non-urgent patients are now restricted to O and B recipients. The effect of this change has not yet been described.¹¹

In the US allocation system, it seems that ~12% of non-O recipients receive a compatible lung. Those organs should potentially be offered to the identical type O candidate before being offered to a compatible recipient. In one possible scenario, for example, a type O candidate in zone B (500 nautical miles from the donor hospital) would gain priority and an offer ahead of the blood type compatible candidate in the zone A (250 nautical miles from the donor hospital). To date, according to the UNOS report, the effect of the change to 250 nautical miles has had an overall modest change to allocation.

Several limitations bear review in discussion of this work. As with all retrospective studies using large national databases, there exists the possibility of potential unmeasured confounders for which we cannot account. Because these data originate from the US, these findings may be most applicable to transplant settings with similar donor, recipient, and operative characteristics.

In summary, blood type O candidates are disadvantaged in lung transplantation with respect to rates of transplantation and waiting list mortality, with a nearly 2-fold increase in the risk of dying while waiting for an acceptable lung allograft. How the latest changes to the lung allocation system in the US will affect recipient waiting list times based on blood type is unclear. However, these changes are only in effect for 1 year, or until the UNOS Executive Committee approves a permanent allocation protocol. We would therefore suggest that any reevaluation of the regional lung allocation system consider blood type matching to increase equality of organ allocation by increasing transplantation rates and reducing waiting list mortality for type O candidates.

Disclosure statement

None of the authors has a financial relationship with a commercial entity that has an interest in the subject of the presented manuscript or other conflicts of interest to disclose.

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Unadjusted Competing Risks for Lung Transplant Waitlist by Blood Group

Figure 1. Unadjusted competing risks for transplantation, death or decompensation, and recovery for candidates listed for lung transplantation, stratified by candidate blood group.

Figure 2. Unadjusted cumulative hazard for transplantation for candidates listed for lung transplantation, stratified by candidate blood group. The shaded areas in the top graph indicate the 95% confidence interval.

Figure 3. Propensity-matched competing risks for transplantation, death or decompensation, and recovery for candidates listed for lung transplantation, stratified by candidate blood group.

Figure 4. Propensity-matched cumulative hazard for transplantation for candidates listed for lung transplantation, stratified by candidate blood group. The shaded areas in the top graph indicate the 95% confidence interval.

Figure 5.
The 10-year Kaplan-Meier estimate of long-term survival of recipients after lung transplantation in the propensity-matched cohort, stratified by candidate blood group.

Table 1
Demographic Characteristics of Candidates Listed for Lung Transplantation, Segregated by Blood Group

Variable	Type non-O (n = 14,329)	Type O (n = 12,068)	p-value
Registration characteristics			
Age at registration, mean (SD), years	54.15 (13.90)	53.73 (14.17)	0.015
Male sex, No. (%)	7,926 (55.3)	6,619 (54.8)	0.455
Diagnosis group, No. (%)			0.039
Obstructive lung disease	4,448 (31.0)	3,568 (29.6)	
Pulmonary vascular disease	671 (4.7)	552 (4.6)	
Cystic fibrosis	1,758 (12.3)	1,471 (12.2)	
Restrictive lung disease	7,452 (52.0)	6,477 (53.7)	
Blood group, No. (%)			<0.001
A	10,256 (71.6)	0 (0.0)	
AB	963 (6.7)	0 (0.0)	
B	2,962 (20.7)	0 (0.0)	
O	0 (0.0)	12,068 (100.0)	
Body mass index, mean (SD), kg/m ²	25.15 (4.63)	25.15 (4.67)	0.944
Lung Allocation Score			
At registration, mean (SD)	40.25 (16.68)	40.90 (16.85)	0.002
End, mean (SD)	46.64 (20.74)	47.30 (21.25)	0.01
Ventilator at registration, No. (%)	538 (3.8)	429 (3.6)	0.408
ECMO at registration, No. (%)	205 (1.4)	170 (1.4)	0.922
Waiting list outcome, No. (%)			<0.001
Not applicable (still waiting)	1,259 (8.8)	1,170 (9.7)	
Removed due to death or decompensation	2,025 (14.1)	1,876 (15.5)	
Recovery	187 (1.3)	220 (1.8)	
Transplantation	10,858 (75.8)	8,802 (72.9)	
Total waiting list days, mean (SD)	206.60 (344.16)	233.50 (379.19)	<0.001
Recipient characteristics at transplant and post-transplant			
At transplant			
FEV ₁ , mean (SD), L	38.70 (20.78)	39.22 (20.82)	0.088

Variable	Type non-O (<i>n</i> = 14,329)	Type O (<i>n</i> = 12,068)	<i>p</i> -value
FVC, mean (SD), L	48.91 (17.57)	48.13 (17.59)	0.003
Serum creatinine, mean (SD), mg/liter	0.84 (0.40)	0.84 (0.41)	0.538
ECMO, No. (%)	305 (2.9)	267 (3.2)	0.349
Ventilator, No. (%)	629 (6.0)	562 (6.7)	0.076
Medical condition, No. (%)			0.001
In ICU	998 (9.6)	903 (10.8)	
Hospitalized, not in ICU	882 (8.5)	794 (9.5)	
Not hospitalized	8,515 (81.9)	6,700 (79.8)	
Ischemic time, mean (SD), h	5.21 (1.74)	5.10 (1.74)	<0.001
Transplantation procedure, No. (%)			0.323
Bilateral transplantation	7,131 (66.2)	5,758 (65.9)	
Single transplantation	3,281 (30.5)	2,649 (30.3)	
Degree of ABO match, No. (%)			<0.001
Blood group identical	8,946 (83.1)	8,407 (100.0)	
Blood group compatible	1,466 (13.6)	0 (0.0)	
Length of stay, mean (SD) days	24.20 (27.55)	24.39 (28.51)	0.656
Donor characteristics			
Donor age, mean (SD), y	34.20 (14.23)	34.59 (14.17)	0.058
Male sex, No. (%)	6,301 (44.0)	5,133 (42.5)	<0.001

ECMO, extracorporeal membrane oxygenation; FEV₁, forced expiratory volume in 1 second; FVC, forced vital capacity; ICU, intensive care unit; SD, standard deviation.

Propensity-Matched Demographic Characteristics of Candidates Listed for Lung Transplantation, Segregated by Blood Group

Table 2

Variable	Type non-O (n = 11,951)	Type O (n = 11,951)	p-value	SMD
Registration characteristics				
Age at registration, mean (SD), years	55.39 (13.24)	53.79 (14.13)	< 0.001	0.117
Male sex, No. (%)	6,786 (56.8)	6,560 (54.9)	0.003	0.038
Diagnosis group, No. (%)			< 0.001	0.119
Obstructive lung disease	4,126 (34.5)	3,528 (29.5)		
Pulmonary vascular disease	565 (4.7)	544 (4.6)		
Cystic fibrosis	1,504 (12.6)	1,454 (12.2)		
Restrictive lung disease	5,756 (48.2)	6,425 (53.8)		
Blood group, No. (%)			< 0.001	0.879
A	8,621 (72.1)	0 (0.0)		
AB	786 (6.6)	0 (0.0)		
B	2,413 (20.2)	0 (0.0)		
O	0 (0.0)	11,951 (100.0)		
Body mass index, mean (SD), kg/m ²	25.18 (4.58)	25.16 (4.66)	0.824	0.003
Lung Allocation Score				
At registration, mean (SD)	38.42 (15.44)	40.90 (16.85)	< 0.001	0.154
End, mean (SD)	44.93 (19.56)	47.44 (21.23)	< 0.001	0.123
Ventilator at registration, No. (%)	486 (4.1)	428 (3.6)	0.055	0.025
ECMO at registration, No. (%)	165 (1.4)	170 (1.4)	0.826	0.004
Preliminary crossmatch required, No. (%)	858 (7.2)	968 (8.1)	0.008	0.035
Candidate height, mean (SD), cm	169.73 (9.98)	168.83 (10.22)	< 0.001	0.089
Total waiting list days, mean (SD)	208.65 (339.94)	231.47 (375.49)	< 0.001	0.064
UNOS region				
1	393 (3.3)	360 (3.0)	< 0.001	0.081
2	1,899 (15.9)	1,875 (15.7)		
3	1,417 (11.9)	1,392 (11.6)		
4	1,439 (12.0)	1,426 (11.9)		
5	1,685 (14.1)	1,928 (16.1)		

Variable	Type non-O (n = 11,951)	Type O (n = 11,951)	p-value	SMD
6	333 (2.8)	334 (2.8)		
7	1,027 (8.6)	928 (7.8)		
8	770 (6.4)	631 (5.3)		
9	433 (3.6)	448 (3.7)		
10	1,440 (12.0)	1,508 (12.6)		
11	1,115 (9.3)	1,121 (9.4)		
Waiting list outcome, No. (%)			< 0.001	0.095
Not applicable (still waiting)	1,035 (8.7)	1,154 (9.7)		
Removed due to death or decompensation	1,550 (13.0)	1,856 (15.5)		
Recovery	158 (1.3)	209 (1.7)		
Transplantation	9,208 (77.0)	8,732 (73.1)		
Characteristics at transplantation and post-transplantation				
At transplantation				
FEV ₁ , mean (SD)	38.70 (20.78)	39.22 (20.82)	0.088	0.026
FVC, mean (SD)	48.91 (17.57)	48.13 (17.59)	0.003	0.097
Serum creatinine, mean (SD), mg/liter	0.84 (0.40)	0.84 (0.41)	0.538	0.014
ECMO, No. (%)	305 (2.9)	267 (3.2)	0.349	0.038
Ventilator, No. (%)	629 (6.0)	562 (6.7)	0.076	0.036
Medical condition, No. (%)			0.001	0.1
In ICU	998 (9.6)	903 (10.8)		
Hospitalized, not in ICU	882 (8.5)	794 (9.5)		
Not hospitalized	8,515 (81.9)	6,700 (79.8)		
Ischemic time, mean (SD), h	5.21 (1.74)	5.10 (1.74)	< 0.001	0.045
Transplantation procedure (%)			0.323	0.096
Bilateral Transplantation	7,131 (66.2)	5,758 (65.9)		
Single transplantation	3,281 (30.5)	2,649 (30.3)		
Degree of ABO match, No. (%)			< 0.001	
Blood group identical	8,946 (83.1)	8,732 (100.0)		
Blood group compatible	1,466 (13.6)	0 (0.0)		
Length of stay, mean (SD), days	24.20 (27.34)	24.43 (28.56)	0.574	0.018
Donor characteristics				

Variable	Type non-O (<i>n</i> = 11,951)	Type O (<i>n</i> = 11,951)	<i>p</i> -value	SMD
Age, mean (SD), years	34.21 (14.24)	34.59 (14.17)	0.064	0.028
Male sex, No. (%)	6,254 (58.1)	5,088 (58.3)	< 0.001	0.097

ECMO, extracorporeal membrane oxygenation; FEV₁, forced expiratory volume in 1 second; FVC, forced vital capacity; ICU, intensive care unit; SD, standard deviation; SMD, standardized mean difference; UNOS, United Network of Organ Sharing.