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Allocation Out of Sequence in Lung Transplant
An Analysis of the UNOS Registry

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IMPORTANCE Allocation out of sequence (AOOS) allows organ procurement organizations (OPOs) to offer organs outside of standard allocation and bypass those atop the match run. AOOS may allow OPOs to successfully place medically complex organs; however, increasing use of AOOS also raises concern for inefficiencies within the allocation process and may exacerbate systemic inequities.

OBJECTIVE To characterize patterns of lung AOOS among organ procurement organizations and transplant centers and compare lung transplant characteristics and outcomes between in-sequence and AOOS groups.

DESIGN, SETTING, AND PARTICIPANTS In this retrospective cohort study, the United Network for Organ Sharing registry was queried for lung transplants performed between September 1, 2021, and June 30, 2024. Data were linked to the Potential Transplant Recipient file to identify all offers for included donor lungs. These data were analyzed from October 2024 to February 2025. Participants included adult donors who donated at least 1 lung for transplant and corresponding primary isolated lung transplant recipients. The final cohort included 7914 lung donor-recipient pairs.

EXPOSURE(S) Lung AOOS vs in sequence, defined by match-run refusal codes for donor lung offers.

MAIN OUTCOME(S) AND MEASURE(S) Donor and recipient characteristics, posttransplant outcomes, and OPO-level and transplant center-level rates of lung AOOS.

RESULTS Overall, 7914 lung transplants were included, of which 558 used AOOS (7.1%). Rates of lung AOOS ranged from 0% to 30% among OPOs and 0% to 50% among transplant centers. Use of lung AOOS increased in the continuous distribution era (10% vs 4%; $P < .001$). Donors of AOOS lungs were more likely to donate after circulatory death and had lower partial pressure of oxygen/fraction of inspired oxygen ratios, longer ischemic times, and longer travel distances. AOOS recipients were less likely to require pretransplant hospitalization, intensive care, and ventilator or extracorporeal membrane oxygenation support. On multivariable analysis, lung AOOS was associated with lower odds of prolonged intubation and early acute rejection and shorter posttransplant hospital length of stay.

CONCLUSIONS AOOS is increasingly used in lung transplant and is associated with transplant of medically complex lungs into lower acuity recipients. Further investigation is needed to understand how AOOS affects lung utilization, especially in the era of continuous distribution.

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Supplemental content

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In the US, organ allocation and utilization rely on organ procurement organizations (OPOs). Per Organ Procurement and Transplantation Network (OPTN) policy, OPOs individually define acceptable deceased donor organs. Within these frameworks, OPOs identify potential donors, obtain donor authorization, oversee donor management, screen donor quality, and facilitate organ allocation to potential transplant recipients.[1] In lung transplant (LTx), this latitude portends significant OPO-level variability in donor pursuit and lung utilization, particularly among extended criteria or nonideal donors.[2] Prior work has sought to motivate increased lung utilization by proposing algorithms to standardize donor evaluation, risk stratify potential donors, identify allografts at heightened risk of discard, and facilitate targeted donor-recipient matching.[3-8] Despite these efforts, only 17% of available donor lungs are used for transplant.[9,10]

Allocation out of sequence (AOOS) is an accepted mechanism by which OPOs bypass the match run sequence to allocate organs to transplant centers for more rapid placement and to avoid non-use.[11] Historically, AOOS offers accounted for less than 5% of solid organ transplants annually and were intended for cases of locoregional or intraoperative decline and donor time constraints.[11,12] However, use has increased in recent years, prompting efforts to standardize AOOS through formal programs and policies, particularly in abdominal transplant.[11-18] In many cases, preexisting relationships between OPOs and transplant centers motivate preferential allocation of nonideal organs to centers that are more likely to accept.[11,16] In LTx, AOOS has not been studied; however, as transplant centers vary widely in lung offer acceptance,[19] AOOS could represent an opportunity to improve utilization by directing organ offers to centers with historically higher acceptance rates, in addition to facilitating rapid allocation amidst logistical constraints imposed by donor hospitals or families. Similar rescue allocation tactics have been used in Europe to salvage nonideal donor lungs, reducing organ wastage without compromising posttransplant outcomes.[20,21]

AOOS is widely used in kidney transplant, though its application varies significantly across OPOs and transplant centers.[16] Increasing use of AOOS in LTx suggests a shift in allocation practices, yet little is known about its impact on donor lung selection, recipient characteristics, or posttransplant outcomes. The need to better understand the impact of AOOS is pressing, particularly amidst recent spotlighting by the public media[22] and concern that this practice may erode trust in the organ allocation system.[23,24] Accordingly, we sought to characterize patterns of AOOS in LTx and compare donor and recipient characteristics and posttransplant outcomes between AOOS and in sequence LTx. We hypothesized that OPOs use AOOS variably and primarily to facilitate placement of nonideal lungs while maintaining acceptable posttransplant outcomes.

Key Points

Question How is lung allocation out of sequence (AOOS) used by US organ procurement organizations (OPOs) and transplant centers?

Findings In this study of 7914 lung transplants, 558 used AOOS (7.1%) and AOOS increased after implementation of continuous distribution (10% vs 4% of lung transplants). AOOS lung donors were more medically complex than in sequence donors, recipients were less acutely ill, and AOOS was associated with lower odds of prolonged intubation, early acute rejection, and shorter length of stay.

Meaning These findings suggest that lung AOOS does not compromise posttransplant outcomes; however, further investigation is needed to fully elucidate the net benefit or harm of lung AOOS on transplant candidates and recipients.

Methods

Data Sources

We conducted a retrospective cohort analysis using United Network for Organ Sharing (UNOS) Standard Analysis and Research Data. These data were linked with the Potential Transplant Recipient (PTR) file, which contains match-run information for every offer made for each lung allograft that is accepted and used for transplant.[16,19] Within the PTR file, lung offers are designated as accepted, provisionally accepted, bypassed, or declined. For each offer that is declined or bypassed, specific refusal codes are provided.[16] The data reported here have been supplied by UNOS as the contractor for the OPTN. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of or interpretation by the OPTN or the US government. This study was approved by the Mass General Brigham institutional review board. Individual consent was not required because data were deidentified.

Study Population and Cohort Determination

Unique donors were the units of analysis. The UNOS deceased donor data file was queried for adult (age 18 years or older) donors who donated at least 1 lung for transplant between September 1, 2021 and June 30, 2024, including 18 months preimplementation and postimplementation of the Composite Allocation Score (CAS). Unique donor identifiers were then used to (1) link donors to corresponding LTx recipients in the UNOS thoracic data file and (2) identify all lung offers for each individual donor in the PTR file. Pediatric, multiorgan, and redo LTx recipients were excluded. Donors from whom lung offer(s) had been bypassed and were missing corresponding refusal codes were excluded (**Figure 1**).

Lung AOOS

Based on review of the literature on AOOS in abdominal transplant,[11,16] donors with lung(s) placed out of sequence were classified as AOOS based on presence of any of the following refusal codes in the match run: (860) medical urgency of another potential recipient, (861) operational—OPO, (862) donor medical urgency, and (863) offer not made due to expedited placement attempt. Donors with lung(s) placed in sequence or out of sequence with other refusal codes not consistent with AOOS were classified as in sequence.

Trends in Use of Lung AOOS

Transplants performed using AOOS lungs were grouped by OPO, transplant center, and year to evaluate OPO-level and center-level practice patterns and temporal trends in AOOS. Distributions of total and AOOS LTx for OPOs and transplant centers are shown in eFigures 1 and 2 in Supplement 1. Outlier OPOs and centers with the highest and lowest use of AOOS were defined as those above the 95th percentile and below the 5th percentile, respectively. Outlier OPOs and transplant centers were characterized based on size (average annual lung donor volume during the study period) and location (UNOS region). As a proxy for aggressiveness, we examined nonideal lung donor volume among outlier OPOs and transplant centers. Nonideal donors were those with any of age older than 50 years, smoking history of 20 or more pack-years, partial pressure of oxygen/fraction of inspired oxygen (P/F) ratio of 350 or less, donation after circulatory death (DCD) status, or Public Health Service increased risk for disease transmission.[2]

To further investigate the impact of allocation policy era on AOOS, we performed subanalyses stratifying unique lung donor-recipient pairs by transplant date before vs after (1) initiation of continuous distribution (CD) in LTx, which was implemented with the CAS on March 9, 2023,[10,25] and (2) implementation of lung offer filters, which were introduced on January 31, 2024.[26] AOOS rates were compared between pre- and post-CAS and offer filter eras.

Association Between Lung AOOS and Posttransplant Outcomes

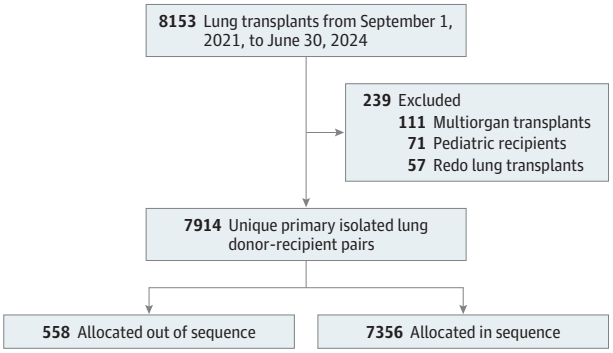
Unique lung donor-recipient pairs were stratified by AOOS vs in-sequence allocation. Posttransplant outcomes, including 30-day mortality and rates of posttransplant extracorporeal membrane oxygenation (ECMO) support at 72 hours, prolonged intubation, acute rejection prior to discharge, and posttransplant hospital length of stay (LOS), were compared between groups.

Statistical Analysis

Continuous variables were summarized using means and SDs or medians and IQRs for normally and nonnormally distributed variables, respectively. Normality was assessed using histograms. Categorical variables were summarized using counts and percentages. Donor and recipient characteristics and posttransplant outcomes were compared between allocation strata using Wilcoxon rank sum tests for continuous variables and χ^2 or Fisher exact tests for categorical variables. Associations between AOOS and posttransplant outcomes were further investigated using logistic regression for binary outcomes (30-day mortality, posttransplant ECMO, prolonged intubation, acute rejection) and linear regression for continuous outcomes (LOS). Multivariable models were constructed using covariates with *P* value <.10 on univariable analysis.

A 2-sided *P* value less than .05 was considered statistically significant. Covariates included in the analysis had less than 5% missing data; therefore, complete case analysis was performed in cases with missing data. All analyses were performed using SAS Enterprise Guide 8.3 (SAS Institute).

Figure 1. Flow Diagram of Study Cohort Selection



There were 660 potential transplant recipients with data containing the organ procurement organization (OPO) refusal codes: 860, medical urgency of another potential recipient; 861, operational—OPO; 862, donor medical urgency; and 863, offer not made due to expedited placement attempt. Donors with lungs placed in sequence or out of sequence with other refusal codes not consistent with allocation out of sequence were classified as in sequence.

Results

OPO- and Transplant Center-Level Use of Lung AOOS

A total of 66 transplant centers and 57 OPOs were included, of which most used AOOS (58 of 66 centers [87.9%]; 51 of 57 OPOs [89.5%]). Among centers and OPOs that used AOOS, unadjusted AOOS rates ranged from 0.58% to 50% among centers and 0.86% to 29.73% among OPOs and varied within and across UNOS regions (**Figure 2**).

Characteristics of OPOs and Transplant Centers More Frequently Using Lung AOOS

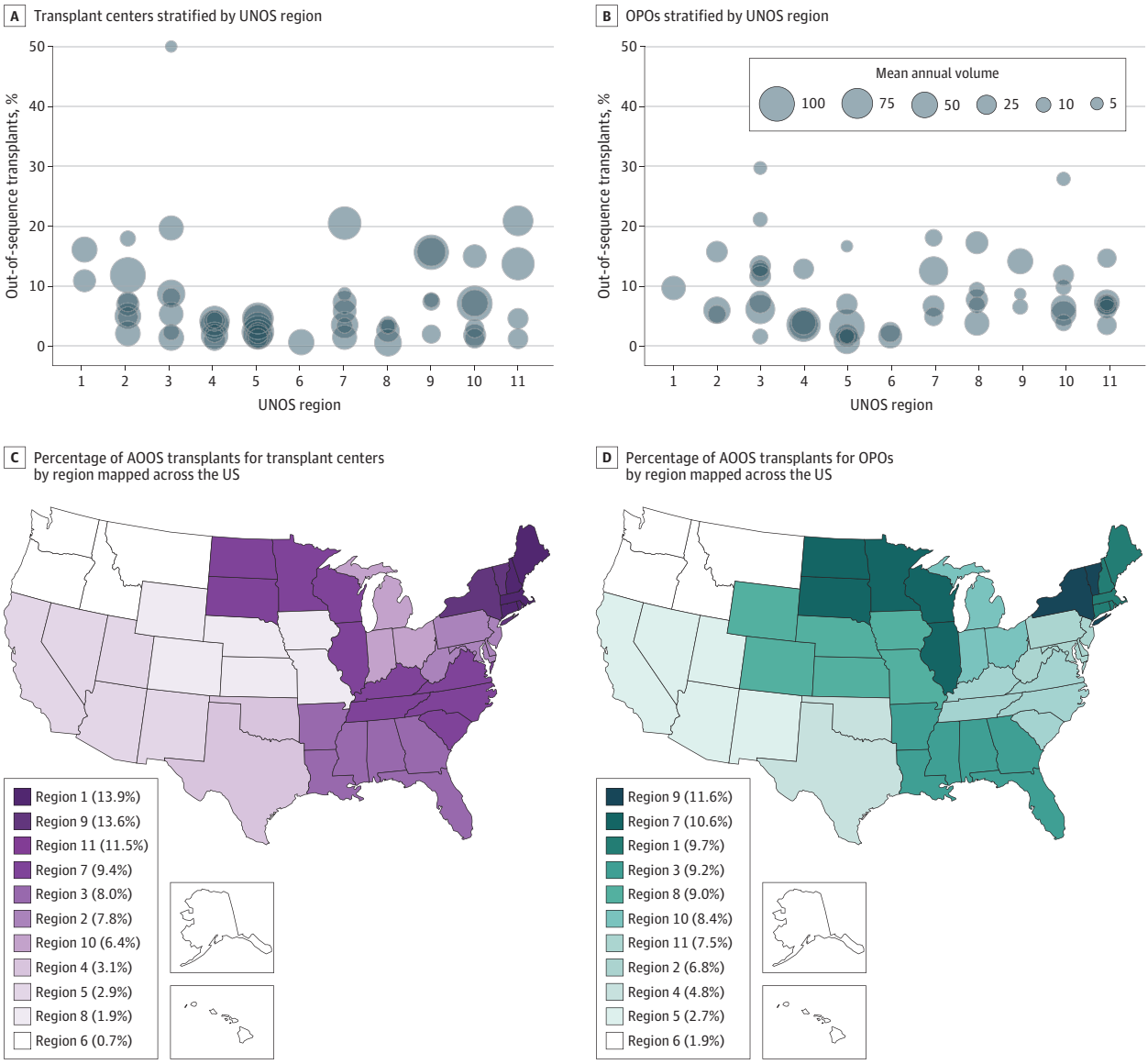
A median of 10 AOOS LTx originated from a given OPO during the study period, while centers performed a median of 4 transplants using AOOS lungs. OPOs allocated lungs AOOS to median 7 (IQR, 3-9) unique transplant centers (eFigure 3 in Supplement 1). There were 3 OPOs in each of the high (>95th percentile) and low (<5th percentile) AOOS groups. High- and low-AOOS OPOs accounted for 99 (18%) and 3 (0.5%) AOOS LTx, respectively. High-AOOS OPOs were larger than low-AOOS OPOs, corresponding to higher average annual lung donor volume. High-AOOS OPOs also facilitated more nonideal donor LTx than low-AOOS OPOs (eTable 1A and 1B in Supplement 1).

Similarly, there were 3 transplant centers in the high-AOOS group, while 11 centers were in the low-AOOS group. Transplant centers received AOOS lung offers from median 3.5 (IQR, 2-8) unique OPOs (eFigure 4 in Supplement 1). High- and low-AOOS centers performed 148 (27%) and 11 (2%) AOOS LTx, respectively. Like OPOs, high-AOOS centers were larger than low-AOOS centers and performed more nonideal donor LTx (eTable 1C and 1D in Supplement 1).

Temporal Trends in Use of Lung AOOS

Lung AOOS increased over time, particularly after CAS implementation (eFigure 5 in Supplement 1). During the CAS era, 10%

Figure 2. Distribution of Unadjusted Rates of Lung Allocation Out of Sequence (AOOS)



Transplant centers (n = 58) and organ procurement organizations (OPOs) (n = 51) were stratified by United Network for Organ Sharing (UNOS) region (A and B). Circles represent unique centers and OPOs with representative points scaled according to the average number of lung donors at that center/OPO for each year of the study period. The overall percentage of AOOS lung transplants for transplant centers and OPOs were stratified by UNOS region and mapped across the country (C and D).

of LTx used AOOS compared with 4% during the Lung Allocation Score era (odds ratio [OR], 2.67; 95% CI, 2.20-3.23; $P < .001$). During the study period, 12 of 66 centers (18%) used lung offer filters, receiving at least 1 offer bypassed with code (886) not offered—offer filters criteria met. AOOS increased after lung offer filters were introduced (10% vs 7%; OR, 1.53; 95% CI, 1.25-1.87; $P < .001$).

Donor, Recipient, and Transplant Characteristics

Overall, 7914 unique LTx were included of which 558 were AOOS (7.1%). Donors of AOOS lungs were younger, had lower P/F ratios, and were more likely to be DCD donors than donors of in-sequence lungs. Compared with in-sequence lungs, AOOS lungs were procured from donors located farther from the transplant center, had longer ischemic times, and were more likely to be preserved with ex-vivo lung perfusion (**Table 1**).

Compared with recipients of in-sequence lungs, recipients of AOOS lungs were older, had lower mean pulmonary artery pressures, were less likely to undergo bilateral LTx, more likely to have a history of smoking, more likely to have obstructive lung disease, and less likely to be ABO identical to corresponding lung donors with a greater percentage of blood type O recipients in the AOOS group. Additionally, AOOS recipients were less likely to be hospitalized, in the intensive care

Table 1. Donor Characteristics

Characteristic	No. (%)			P value	Missing
	Overall (n = 7914)	Out-of-sequence allocation (n = 558)	In-sequence allocation (n = 7356)		
Age, y, mean (SD)	37 (14)	35.8 (12.7)	36.9 (13.6)	.04	0
Sex					
Female	3139 (40)	193 (35)	2946 (40)	.01	0
Male	4775 (60)	365 (65%)	4410 (60)		
BMI,[a] mean (SD)	27 (6)	27.8 (6.4)	27 (5.9)	.003	8
Race[b]					
Asian	233 (3)	15 (3)	218 (3)	.64	0
Black	1390 (18)	109 (20)	1281 (18)		
Hispanic	1498 (19)	98 (18)	1400 (19)		
White	4682 (59)	330 (59)	4352 (59)		
Other[c]	95 (1)	5 (1)	90 (1)		
Creatinine, mg/dL, median (IQR)	1.0 (0.7-1.7)	1.0 (0.7-1.6)	1.0 (0.7-1.7)	.76	1
Diabetes	824 (11)	71 (13)	753 (10)	.07	135
Smoking history	672 (9)	37 (7)	635 (9)	.09	259
Cause of death					
Anoxia	3185 (40)	220 (39)	2965 (40)	.83	0
Stroke	1945 (25)	143 (26)	1802 (25)		
Head trauma	2591 (33)	183 (33)	2408 (33)		
CNS tumor	29 (0.4)	3 (0.5)	26 (0.4)		
Other	164 (2)	9 (2)	155 (2)		
Distance from donor hospital to transplant center, nautical miles, median (IQR)	244 (100-557)	370 (127-710)	239 (98-543)	<.001	0
Ischemic time, h, median (IQR)	6.4 (5.1-8.2)	7.6 (5.5-12.8)	6.3 (5.1-8.0)	<.001	34
DCD donor	786 (10)	76 (14)	710 (10)	.003	0
Partial pressure of oxygen/fraction of inspired oxygen ratio, mean (SD)	450 (391-506)	433 (375-498)	451 (392-507)	.002	35
PHS increased risk	1424 (18)	87 (16)	1337 (18)	.13	0
Ex vivo lung perfusion	564 (7)	73 (13)	491 (7)	<.001	0
Mechanism of death					
Respiratory depression	2009 (25)	143 (26)	1866 (25)	.40	0
Neurologic injury	2104 (27)	152 (27)	1952 (27)		
Trauma	2808 (36)	207 (37)	2601 (35)		
Cardiovascular injury	891 (11)	52 (9)	839 (11)		
Other	102 (1)	4 (0.7)	98 (1)		
Match run sequence number, median (IQR)	11 (4-33)	86 (39-183)	10 (3-27)	<.001	224

Abbreviations: BMI, body mass index; CNS, central nervous system; DCD, donation after circulatory death; PHS, Public Health Service.

[a] Calculated as weight in kilograms divided by height in meters squared.

[b] In some instances, donor race may have been self-reported and is otherwise collected through a variety of means, including hospital documentation, donor families, organ procurement organizations, etc.

[c] Includes American Indian/Alaska Native, Native Hawaiian/other Pacific Islander, Multiracial, and unknown.

unit, on mechanical ventilation, or on ECMO prior to LTx, and were more likely to be independent in activities of daily living. AOOS lungs were allocated to recipients farther down the match run than in sequence lungs (**Table 2**).

Posttransplant Outcomes

Compared with in-sequence recipients, AOOS recipients had lower rates of early acute rejection, posttransplant ECMO, and prolonged intubation. Posttransplant LOS was shorter among AOOS vs in-sequence recipients. Rates of 30-day mortality and posttransplant airway dehiscence were similar between groups (**Table 3**). After adjustment for donor and recipient factors, AOOS was independently associated with lower odds of early acute rejection (adjusted OR [aOR], 0.53; 95% CI, 0.30-0.96; $P = .04$) and prolonged intubation (aOR, 0.72; 95% CI, 0.56-0.94; $P = .01$) and shorter LOS (adjusted β, −4.31; 95% CI −7.82 to −0.81; $P = .02$) (eTables 2 through 7 in Supplement 1).

Discussion

In the US, donor lungs are primarily offered to potential recipients in order of the match run.[27] However, increasingly, organs are AOOS, bypassing patients atop the list. In this contemporary analysis of the UNOS national registry, we examined AOOS in LTx. We found that AOOS varies among OPOs and transplant centers, though nearly 90% of each use AOOS and have done so increasingly since implementation of CAS. In our study, AOOS was associated with allocation of lungs from more medically complex donors, such as those with DCD status or

Table 2. Recipient Characteristics

Characteristic	No. (%) Overall (n = 7914)	Out-of-sequence allocation (n = 558)	In-sequence allocation (n = 7356)	*P* value	Missing
Age, y, median (IQR)	63 (55-67)	66 (60-70)	62 (55-67)	<.001	0
Sex					
Female	3204 (41)	215 (39)	2989 (41)	.33	0
Male	4710 (59)	343 (61)	4367 (59)		
Bilateral lung transplant	6434 (81)	323 (58)	6111 (83)	<.001	0
BMI,[a] mean (SD)	26.4 (4.3)	26.5 (4.1)	26.3 (4.3)	.37	1
Race[b]					
Asian	279 (4)	14 (3)	265 (4)		
Black	732 (9)	48 (9)	684 (9)		
Hispanic	1150 (15)	63 (11)	1087 (15)	.08	16
White	5616 (71)	422 (76)	5194 (71)		
Other[c]	137 (2)	11 (2)	126 (2)		
Diabetes	1528 (19)	104 (19)	1424 (19)	.67	8
Mean PA pressure	25 (20-31)	23 (18-28)	25 (20-32)	<.001	349
Creatinine, mg/dL, median (IQR), mg/dL	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	<.001	28
History of cigarette use	4230 (54)	331 (59)	3899 (53)	.004	0
Etiology of lung disease					
Obstructive	1471 (19)	135 (24)	1336 (18)		
Restrictive	4468 (57)	331 (59)	4137 (56)		
Cystic fibrosis	282 (4)	8 (1)	274 (4)	<.001	0
Primary pulmonary hypertension	373 (5)	18 (3)	355 (5)		
Other	1320 (17)	66 (12)	1254 (17)		
Pretransplant condition					
Hospitalized	2501 (32)	78 (14)	2423 (33)	<.001	24
In the intensive care unit	1387 (18)	28 (5)	1359 (19)	<.001	24
Mechanically ventilated	406 (5)	7 (1)	399 (5)	<.001	0
On ECMO	601 (8)	5 (1)	596 (8)	<.001	0
On dialysis	38 (0.5)	2 (0.4)	36 (0.5)	>.99	30
Independent of ADLs	1565 (21)	130 (24)	1435 (20)	.02	273
ABO match identical	7121 (90)	447 (80)	6674 (91)	<.001	0
ABO					
A	3072 (39)	195 (35)	2877 (39)		
B	916 (12)	35 (6)	881 (12)	<.001	0
AB	288 (4)	12 (2)	276 (4)		
O	3638 (46)	316 (57)	3322 (45)		
Waitlist time, d, median (IQR)	30 (10-91)	33 (12-102)	30 (10-90)	.08	0

Abbreviations: ADLs, activities of daily living; BMI, body mass index; ECMO, extracorporeal membrane oxygenation; PA, pulmonary artery.

[a] Calculated as weight in kilograms divided by height in meters squared.

[b] In some instances, donor race may have been self-reported and is otherwise collected through a variety of means, including hospital documentation, donor families, organ procurement organizations, etc.

[c] Includes American Indian/Alaska Native, Native Hawaiian/other Pacific Islander, Multiracial, and unknown.

poorer pulmonary function to lower acuity recipients located lower on the match run and geographically farther away. Our findings suggest that AOOS LTx is associated with acceptable short-term outcomes despite use of more complex organs. Further investigation is warranted to understand how AOOS affects lung utilization and longer-term outcomes in the current era.

In our study, AOOS LTx recipients had better short-term outcomes than in-sequence recipients and were healthier at LTx. Although the literature increasingly supports use of nonideal donor lungs,[28] use of medically complex organs for higher-acuity patients may compromise posttransplant outcomes.[29] In Europe, rescue allocation represents a corollary to AOOS to place donor lungs that have previously been declined.[20] In these instances, lungs are allocated to transplant centers and the optimal patient on the local wait list may then receive the allograft.[21] Unsurprisingly, rescue allocation lungs predominantly originate from less ideal donors (ie, older age, lower P/F ratios); likewise, these lungs are often allocated to stable recipients whereas urgent patients receive lungs offered through standard allocation pathways.[20] While this phenomenon may partially represent typical functionality of European lung allocation in which higher-acuity patients undergo LTx without use of ancillary allocation pathways, it may also denote targeted donor-recipient matching and patient selection by transplant centers to optimize outcomes when nonideal donor lungs are used. Our study suggests that US OPOs and transplant centers may use AOOS in a

Table 3. Posttransplant Outcomes

Outcome	No. (%) Overall	Out of sequence allocation (n = 558)	In sequence allocation (n = 7356)	Unadjusted effect estimate, OR (95% CI)[a]	*P* value	Missing
30-d Mortality	181 (98)	8 (1)	173 (2)	0.61 (0.30-0.24)	.17	24
Acute rejection	417 (5)	16 (3)	401 (6)	0.51 (0.31-0.85)	.01	30
ECMO at 72 h posttransplant	840 (11)	37 (7)	803 (11)	0.58 (0.41-0.82)	.002	35
Prolonged intubation	2416 (31)	122 (23)	2294 (32)	0.63 (0.51-0.77)	<.001	113
Airway dehiscence	124 (2)	5 (1)	119 (2)	0.55 (0.22-1.35)	.19	99
Hospital length of stay, d	31 (37)	26.1 (28.6)	31.8 (37.4)	−5.73 (−8.95 to −2.52)	.001	194

Abbreviations: ECMO, extracorporeal membrane oxygenation; OR, odds ratio.

[a] Unadjusted effect estimates represented as ORs from univariable logistic regression models for binary outcomes (30-day mortality, acute rejection, ECMO at 72 hours, prolonged intubation, and airway dehiscence) and as a β coefficient from a univariable linear regression for the continuous variable of hospital length of stay.

similar fashion—to mitigate undue risk to patients and transplant programs by directing allografts of perceived lower quality to less acutely ill recipients who achieve excellent outcomes with these organs, reserving ideal lungs for sicker patients to optimize outcomes for patients at all levels of the wait list.

Compared with in-sequence recipients, AOOS recipients were more likely to have blood type O and less likely to be ABO identical to corresponding donors. Previously, Barac and colleagues[30] found that LTx candidates with blood type O spent longer on the wait list despite higher acuity of illness, were more likely to be removed from the wait list due to death or decompensation, and were less likely to undergo LTx compared with matched patients with non-O blood types.[30] CD was used in the US in an attempt to specifically address this type of immutable biological disadvantage, yet 1-year post-CAS data suggest that type O candidates continue to experience lower rates of LTx, even after further ABO adjustments were incorporated in September 2023.[10] Amidst a concurrent increase in AOOS, our findings suggest that the present iteration of CAS may not offer adequate compensation for biological disadvantages, such as blood type necessitating alternative pathways to ensure that these patients receive opportunities to undergo timely LTx.

To our knowledge, this is the first study to investigate AOOS in LTx. However, the transplant community has turned increasing attention to AOOS recently, particularly in kidney transplant. Multiple groups have noted a significant increase in AOOS kidney transplant in recent years, especially since implementation of circle-based allocation with Kidney Allocation System 250.[24,31,32] Similar to our findings, AOOS in kidney transplant was associated with allocation of kidneys from medically complex, comorbid donors to healthier patients farther down the match run.[31-34] Importantly, despite increasing AOOS, kidney non-use rates remain largely unchanged.[35] Accordingly, the utility of AOOS across solid organ transplant remains to be determined as current evidence suggests little improvement in organ utilization.

As use of AOOS rises, provisions to monitor and standardize these events are required. In August 2024, the Health Resources and Services Administration (HRSA) solicited comments from the OPTN regarding AOOS and current avenues to track and adjudicate these events.[36] While the Membership and Professional Standards Committee is meant to review each instance of AOOS, surging use has challenged its capabilities.[31] Thus, HRSA asked the OPTN to clarify whether patients involved in AOOS events are notified, whether offers occurring outside the match run are tracked and monitored, and to delineate current AOOS policies.[37] Preliminary results of this investigation raised concern for widespread noncompliance with regulatory requirements of organ allocation.[38] Accordingly, the OPTN was tasked with devising a plan to reenforce compliance with organ allocation policy and improve transparency by March 31, 2025.[38] Alongside this ongoing national effort, our study should motivate the LTx community to scientifically study the impact of AOOS on overall lung utilization and candidate outcomes and identify a transparent and optimal policy for lung AOOS.

Limitations

There are several limitations in our study. Retrospective reviews using large national databases have the inherent limitation of unmeasured confounders that cannot be accounted for within the analysis. In addition, offer refusal codes provide limited information regarding specific circumstances surrounding each instance of lung AOOS. In our cohort, 96% of AOOS transplants were identified based on code (863), offer not made due to expedited placement attempt. While the other examined refusal codes indicate whether AOOS was motivated by recipient or donor factors, code 863 is particularly vague and could encompass patient-, logistical-, or cost-related issues that are not expressly stipulated nor otherwise documented within the UNOS database. Active efforts to revise the national system for auditing AOOS are critical to better understand instances in which this pathway is used and provisions to notify patients affected by AOOS. Likewise, the PTR file does not explicitly delineate open offers in which lungs are offered to transplant centers, facilitating center-level discretion to allocate lungs to any candidate on the waitlist. This practice introduces further center-level decision-making in recipient selection beyond the documented match run that cannot be accounted for within our analysis. We were unable to determine the point in each match run at which AOOS was

invoked as specific time and process stamps are not captured in the UNOS registry. Only lungs that were used for transplant were included in our analysis. Accordingly, we are unable to comment on patterns of AOOS among lungs that were offered, but not used. Lastly, as our study period ended in June 2024, 1-year outcomes were not available for all patients. Future work should examine 1-year and longer-term outcomes to assess the impact of lung AOOS on transplant center metrics and evaluate lasting effects of AOOS on LTx recipients in the contemporary era.

Conclusions

In this national analysis of lung AOOS, we found that AOOS is increasingly used in the current policy era and is associated with transplant of nonideal organs into lower acuity recipients. AOOS likely plays an important role in helping OPOs maximize the utility of individual donor lungs and may also be used to address some existing LTx inequities, such as those related to candidate blood type, sensitization, or stature. However, AOOS may exacerbate other inequities by bypassing high-acuity recipients to allocate available lungs to patients located farther away and farther down the wait list. Our findings suggest that AOOS may offset risk associated with nonideal donor lungs by transplanting these organs into less acutely ill recipients who reap superior short-term outcomes in these instances. As we enter the third year of the CD era in LTx, further efforts are warranted to increase transparency and standardize indications for AOOS in LTx, while optimizing its impact on lung utilization in the current allocation policy era.

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REFERENCES

1. OPTN. Deceased donor organ procurement. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/eavh5bf3/optn_policies.pdf

2. Halpern SE, McConnell A, Peskoe SB, et al. A three-tier system for evaluation of organ procurement organizations' willingness to pursue and utilize nonideal donor lungs. *Am J Transplant*. 2021;21(3):1269-1277. doi:10.1111/ajt.16347

3. Oto T, Levvey BJ, Whitford H, et al. Feasibility and utility of a lung donor score: correlation with early post-transplant outcomes. *Ann Thorac Surg*. 2007;83(1):257-263. doi:10.1016/j.athoracsur.2006.07.040

4. Whited WM, Trivedi JR, van Berkel VH, Fox MP. Objective donor scoring system for lung transplantation. *Ann Thorac Surg*. 2019;107(2):425-429. doi:10.1016/j.athoracsur.2018.08.034

5. Grimm JC, Valero V III, Magruder JT, et al. A novel risk score that incorporates recipient and donor variables to predict 1-year mortality in the current era of lung transplantation. *J Heart Lung Transplant*. 2015;34(11):1449-1454. doi:10.1016/j.healun.2015.07.001

6. Loor G, Radosevich DM, Kelly RF, et al. The University of Minnesota Donor Lung Quality Index: a consensus-based scoring application improves donor lung use. *Ann Thorac Surg*. 2016;102(4):1156-1165. doi:10.1016/j.athoracsur.2016.04.044

7. Heiden BT, Yang Z, Bai YZ, et al. Development and validation of the lung donor (LUNDON) acceptability score for pulmonary transplantation. *Am J Transplant*. 2023;23(4):540-548. doi:10.1016/j.ajt.2022.12.014

8. Reul RM, Loor G, Garcha PS, Goss JA, Rana AA. Allograft discard risk index for lung transplantation. *J Heart Lung Transplant*. 2021;40(12):1658-1667. doi:10.1016/j.healun.2021.08.017

9. Israni AK, Zaun DA, Gauntt K, et al. OPTN/SRTR 2022 Annual Data Report: deceased organ donation. *Am J Transplant*. 2024;24(2S1):S457-S488. doi:10.1016/j.ajt.2024.01.018

10. Weiss S, Hawkins C. Lung continuous distribution one year monitoring report. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/srino34s/data_report_lung_cd_1year_20240509.pdf

11. Kinkhabwala M, Lindower J, Reinus JF, Principe AL, Gaglio PJ. Expedited liver allocation in the United States: a critical analysis. *Liver Transpl*. 2013;19(10):1159-1165. doi:10.1002/lt.23675

12. Hunter RA. Expedited organ placement concept paper. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/2383/opo_publiccomment_concept_20180122.pdf

13. Whitrock J, Delman A, Price A, et al. It's a new world: Safety and use of expedited donor liver allografts to increase rate of transplant. *HPB (Oxford)*. 2023;25:S4. doi:10.1016/j.hpb.2023.05.015

14. Noreen SM, Klassen D, Brown R, et al. Kidney accelerated placement project: outcomes and lessons learned. *Am J Transplant*. 2022;22(1):210-221. doi:10.1111/ajt.16859

15. Giorgakis E, Mathur AK. Expedited placement to maximize utilization of marginal organs. *Curr Opin Organ Transplant*. 2020;25(6):640-646. doi:10.1097/MOT.0000000000000827

16. King KL, Husain SA, Perotte A, Adler JT, Schold JD, Mohan S. Deceased donor kidneys allocated out of sequence by organ procurement organizations. *Am J Transplant*. 2022;22(5):1372-1381. doi:10.1111/ajt.16951

17. Alcorn J. Expedited placement variance public comment proposal. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/fydgopqm/exec_expplcmntvariance_specialpcwinter2024.pdf

18. Alcorn J. Expedited placement variance briefing paper. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/lmja54ay/briefing-paper-expedited-placement-variance-2024-03.pdf

19. Mulvihill MS, Lee HJ, Weber J, et al. Variability in donor organ offer acceptance and lung transplantation survival. *J Heart Lung Transplant*. 2020;39(4):353-362. doi:10.1016/j.healun.2019.12.010

20. Sommer W, Kühn C, Tudorache I, et al. Extended criteria donor lungs and clinical outcome: results of an alternative allocation algorithm. *J Heart Lung Transplant*. 2013;32(11):1065-1072. doi:10.1016/j.healun.2013.06.021

21. Holm AM, Immer F, Benden C. Lung allocation for transplant: the European perspective. *Clin Transplant*. 2020;34(7):e13883. doi:10.1111/ctr.13883

22. Rosenthal BM, Hansen M, White J. Organ transplant system "in chaos" as waiting lists are ignored. Accessed June 9, 2025. https://www.nytimes.com/interactive/2025/02/26/us/organ-transplants-waiting-list-skipped-patients.html

23. Pullen LC. Out-of-sequence allocation: It is useful, but is it ethical? *Am J Transplant*. 2025;25(3):451-453. doi:10.1016/j.ajt.2025.01.008

24. Adler JT, Sharma S. Out-of-sequence allocation: a necessary innovation or a new inequity in transplantation? *Am J Transplant*. 2025;25(2):234-236. doi:10.1016/j.ajt.2024.09.022

25. Stewart DE, Wood DW, Alcorn JB, et al. Notice of OPTN policy, guidance, and guideline changes: establish continuous distribution of lungs. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/4157/2020-10_report_community_ahp_prioritization.pdf

26. UNOS. Offer filters now available for lung allocation. Accessed June 3, 2025. https://unos.org/news/offer-filters-now-available-for-lung-allocation/

27. OPTN. Policy 5: organ offers, acceptance, and verification. Accessed June 9, 2025. https://optn.transplant.hrsa.gov/media/eavh5bf3/optn_policies.pdf

28. Halpern SE, Jawitz OK, Raman V, et al. Aggressive pursuit and utilization of non-ideal donor lungs does not compromise post-lung transplant survival. *Clin Transplant*. 2021;35(9):e14414. doi:10.1111/ctr.14414

29. Mulligan MJ, Sanchez PG, Evans CF, et al. The use of extended criteria donors decreases one-year survival in high-risk lung recipients: a review of the United Network of Organ Sharing Database. *J Thorac Cardiovasc Surg*. 2016;152(3):891-898.e2. doi:10.1016/j.jtcvs.2016.03.096

30. Barac YD, Mulvihill MS, Cox ML, et al. Implications of blood group on lung transplantation rates: a propensity-matched registry analysis. *J Heart Lung Transplant*. 2019;38(1):73-82. doi:10.1016/j.healun.2018.09.013

31. Liyanage LN, Akizhanov D, Patel SS, et al. Contemporary prevalence and practice patterns of out-of-sequence kidney allocation. *Am J Transplant*. 2025;25(2):343-354. doi:10.1016/j.ajt.2024.08.016

32. Cron DC, Husain SA, Kuk AE, Mohan S, Adler JT. Increasing incidence of out-of-sequence allocation of deceased donor kidneys. *Kidney360*. 2025;6(1):145-149. doi:10.34067/KID.0000000640

33. King KL, Husain SA, Yu M, Adler JT, Schold J, Mohan S. Characterization of transplant center decisions to allocate kidneys to candidates with lower waiting list priority. *JAMA Netw Open*. 2023;6(6):e2316936. doi:10.1001/jamanetworkopen.2023.16936

34. Jadlowiec CC, Ohara SY, Punukollu R, et al. Outcomes with transplanting kidneys offered through expedited allocation. *Clin Transplant*. 2023;37(11):e15094. doi:10.1111/ctr.15094

35. Adler JT, Cron DC, Kuk AE, et al. Association between out of sequence allocation and deceased donor kidney non-utilization across organ procurement organizations. *Am J Transplant*. Published online February 17, 2025. doi:10.1016/j.ajt.2025.02.005

36. Nair S. Critical comment redacted letter to OPTN. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/q2qiywew/08302024-aoos-critical-comment-letter-to-optn-508.pdf

37. Nair S. Letter to the Organ Procurement and Transplantation Network: critical comment response. Accessed June 3, 2025. https://optn.transplant.hrsa.gov/media/d3lpgq4j/hrsa-critical-comment-response-27nov2024.pdf

38. Nair S. Letter to the Organ Procurement and Transplantation Network: critical comment response. https://optn.transplant.hrsa.gov/media/km3fskz1/hrsa-directive-to-optn-on-aoos-022125.pdf