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Original Article

Evolution of out-of-sequence liver allocation, 2019-2024

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ABSTRACT

Allocation out-of-sequence (AOOS) refers to deviation from the match run order in deceased donor organ allocation and is intended for use in exceptional cases to expedite organ placement. Contemporary patterns of AOOS in liver transplantation are not well characterized. This study aimed to describe liver AOOS practices and examine their association with organ utilization. Liver match runs from 2019 to 2024 were analyzed using the Organ Procurement and Transplantation Network potential transplant recipient data set to identify AOOS events. Data from the Scientific Registry of Transplant Recipients were incorporated to analyze program- and Organ Procurement Organization (OPO)-specific organ utilization and offer acceptance. AOOS prevalence, timing, and geographic variability were examined, and correlations with adjusted utilization metrics were assessed. AOOS increased from 5% in 2019 to 18% in 2024, with use concentrated in a subset of OPOs (range, 2%-39%; median, 17%) and centers (range, 0%-55%; median, 10%), often in shared geographic areas. From 2019 to 2024, AOOS offers were initiated progressively earlier in the allocation process. OPO-level AOOS use was not correlated with donor yield, though center-level AOOS acceptance was associated with higher adjusted offer acceptance. These findings highlight a potential need for further standardization of AOOS practices in liver transplantation.

Abbreviations: AOOS, allocation out-of-sequence; DCD, deceased after circulatory death; HRSA, Health Resources and Services Administration; IQR, interquartile range; OOS, out-of-sequence; OPTN, Organ Procurement and Transplantation Network; SRTR, Scientific Registry of Transplant Recipients.

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1. Introduction

Central to deceased donor organ allocation in the United States is the match run algorithm, which prioritizes candidates for an available organ according to objective criteria, including medical urgency and geographic location. Organ offers are extended sequentially according to the match run order until organ acceptance, and deviation from the match run order is termed allocation out-of-sequence (AOOS). AOOS is intended as a mechanism to ensure efficient organ placement and improve utilization in exceptional circumstances when standard allocation is not feasible, such as in cases of late turndown or anticipated organ nonuse.

In recent years, however, AOOS has increased dramatically.[1-3] In kidney transplantation, approximately 20% of all kidney transplants in 2023 were allocated out-of-sequence (OOS), and several studies have examined the implications of this trend.[1,4-7] Similar concerns have emerged in liver transplantation.[8-10] Although AOOS may be initiated with the intent to decrease organ discard in some scenarios, its more widespread use has raised concerns regarding equity and transparency. As a result, the Health Resources and Services Administration (HRSA) recently issued a directive to the Organ Procurement and Transplantation Network (OPTN) to better understand and monitor the practice of the AOOS strategy.[11,12]

Yet, contemporary AOOS patterns in liver transplantation remain incompletely characterized. Wehrle et al[8] and Matevish et al[9] recently examined donor-level outcomes as of 2023 and found that the AOOS pathway improved placement for the highest-risk grafts, though graft quality was overall similar for organs allocated in sequence vs OOS, raising questions about the factors driving AOOS. The evolution of AOOS practices over time remains unclear, however, particularly across major policy transitions such as acuity circles and the growing adoption of machine perfusion. It is also uncertain whether the use of the AOOS is associated with organ utilization at the system level. Additional examination of contemporary AOOS practices and their association with organ utilization is therefore needed, particularly in light of the HRSA directive.

The purpose of this study was to assess the evolution of the AOOS strategy in liver transplantation over time, to examine variation in use of AOOS among Organ Procurement Organizations (OPOs) and transplant centers, and to evaluate the relationship between the AOOS strategy and OPO- and center-level liver utilization.

2. Materials and methods

2.1. Data sources and study population

This study used data from the OPTN. The OPTN data system includes data on all donor, wait-listed candidates, and transplant recipients in the US, submitted by the members of the OPTN. HRSA and the US Department of Health and Human Services provide oversight to the activities of the OPTN contractor.

We conducted a retrospective cohort study using data from the OPTN potential transplant recipient data set. The potential transplant recipient data set captures all organ offers made through the match run and includes timestamps as well as candidate identifiers and characteristics, transplant center identifiers, match OPOs, donor characteristics, and offer outcomes. Our analysis included all whole liver match runs initiated from 2019 through 2024. We excluded match runs with missing donor, OPO, or transplant center information, or that did not result in a liver acceptance and transplantation, as they may not contain finalized documentation. This restriction was necessary because nonaccepted match runs often contain retrospective or incomplete bypass coding. These data were linked to the candidate waitlist history and exception record to determine the candidates' model for the end-stage liver disease score at the time of the match run. OPO-level data were obtained from the publicly available Fall 2024 Scientific Registry of Transplant Recipients (SRTR) OPO-specific reports. Center-level characteristics and offer acceptance data were obtained from the July 2024 SRTR program-specific reports.

2.2. AOOS

AOOS was defined as any liver offer made outside of the ordered match run sequence, identified by codes indicating expedited placement or OPO-directed allocation, including codes 861, 862, 863, 887, and 888. To further identify AOOS events, free text responses were also used to identify AOOS from bypasses with "other" reasons (798, 799, 898, and 998), such as responses involving "expedite," "aggressive," and "open offer," with related phrases or spellings/typos that were found during manual cleaning.[4]

The time from match run start to AOOS was determined using the timestamps of the match run submit time and the offers' final responses. We first identified the match run end time as the time of organ offer acceptance. Next, the first offer before this date with a bypass code indicating AOOS was identified. This data provided the sequence number in the match run at which AOOS occurred, though not necessarily the time, as the timestamps of bypassed offers are often not accurately recorded. The AOOS strategy start time was therefore approximated by the latest final response time among offers in the match run preceding the first AOOS bypass sequence number (that was also before the organ offer acceptance time). A schematic of this process is shown in Supplementary Figure S1.

2.3. Organ utilization

OPO-level liver donor utilization was determined from the SRTR observed/expected liver donor yield, which is adjusted for donor characteristics. A ratio above 1.0 indicates utilization greater than would be expected given the national experience; a ratio less than 1.0 indicates lower utilization. The data in the most recent OPO-specific reports included donors from July 1, 2022, until June 30, 2024.

Center-level liver offer acceptance during 2024 was assessed using the SRTR adjusted liver offer/acceptance ratio for all donors, as well as specifically for deceased after circulatory death (DCD) organs and hard-to-place organs (>50 offers).

Similarly, a ratio above 1.0 indicates greater than expected offer acceptance, while a ratio less than 1.0 indicates lower acceptance.

2.4. Outcomes

The proportion of match runs with AOOS was compared in the years between 2019 and 2024 to evaluate the change over time. The proportion of AOOS was assessed by OPO and by transplant center to characterize variability in practice, and the association between use of AOOS and OPO-level organ utilization and center-level liver acceptance was evaluated from July 1, 2022, until June 30, 2024. The time from match run initiation to acceptance of an AOOS-allocated liver offer was examined to understand the timelines associated with AOOS. We also examined characteristics of donors involved in AOOS, including distance from the accepting transplant program, donor age $\geq$65 years, DCD donors, and the use of machine perfusion.

2.5. Statistical analysis

Descriptive statistics were used to summarize counts and proportions for categorical variables and medians, interquartile ranges (IQRs), and ranges for continuous variables. The correlations between the proportion of AOOS and OPO- and program-level liver utilization measures were evaluated. All analyses were conducted in Stata/SE 18.0 and SAS Studio 3.81, with a significance level of $P < .05$. This study was approved by the Duke University Institutional Review Board.

3. Results

3.1. Prevalence and trends in AOOS practices

A total of 53 281 liver transplant match runs from 2019 to 2024 were included. The proportion of match runs with AOOS rose from 5.0% (n = 402) in 2019 to 17.8% (n = 1868) in 2024.

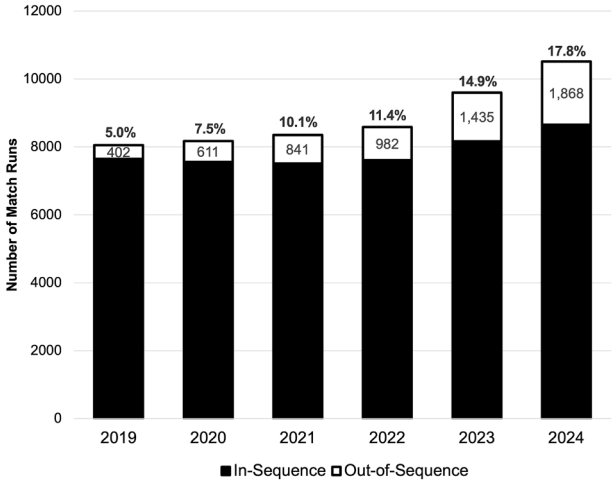

Figure 1. Number and proportion of organs allocated in- vs out-of-sequence from 2019 to 2024.

Annual trends from 2019 to 2024 are shown in Figure 1. This increase was accompanied by broader OPO participation in AOOS: 5 out of 58 (8.6%) of OPOs did not distribute organs in OOS allocation in 2019, but all OPOs participated in AOOS in 2024. Similarly, 51.4% (73/142) of transplant centers accepted organs allocated OOS in 2019, compared with 70.6% (101/143) of transplant centers in 2024.

3.2. AOOS by OPOs

AOOS practices increased in 55 of 56 OPOs that existed in both 2019 and 2024 (Fig. 2A). In 2019, nearly all (56/58) OPOs used AOOS for $<$10% of match runs. By 2024, the median OPO-level AOOS use was 17.0%, though it ranged from 1.7% to as high as 38.8%, and 23 out of 58 used AOOS for $>$20% of match runs. The pattern of organ sharing between OPOs and centers also evolved over time. In 2019, most OPOs distributed the more limited AOOS offers relatively narrowly (median 3 [IQR, 1-6] centers). By 2024, this sharing occurred more broadly (median 10 [IQR, 7-15] centers) (Supplementary Fig. S2). The concentration of AOOS offers varied, with some of the highest-volume AOOS OPOs distributing to relatively fewer unique centers, including 2 of the top 3 OPOs distributing to fewer than 5 centers. (Table 1, Supplementary Fig. S2). The geographic distribution of AOOS use by OPO and by quartile in 2024 is shown in Figure 3A, which demonstrates OPOs with high AOOS rates scattered across several regions, showing no clear geographic patterns. When the proportion of organs allocated OOS by an OPO between July 1, 2022, and June 30, 2024 was compared with the adjusted observed/expected liver donor yield for that time frame, no significant correlation was observed (r = 0.10, P = .45; Fig. 3B, Fig. 4A, Table 1).

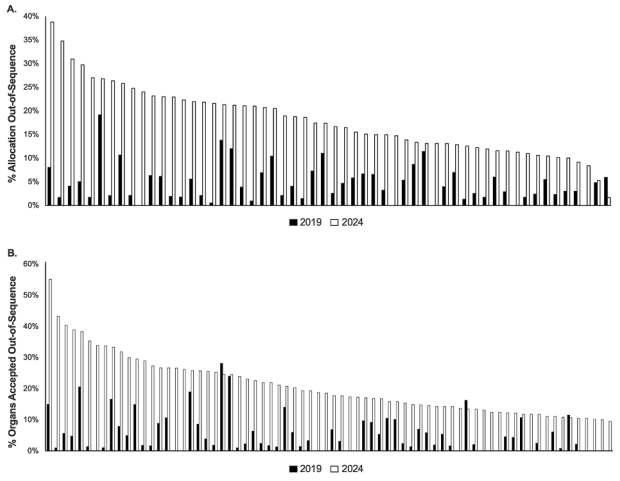

Figure 2. Proportion of organs distributed OOS by OPO (A) and accepted by the center (B) in 2019 and 2024. Each pair of bars represents an OPO or transplant center, with the black bar depicting the proportion of OOS in 2019 and the white bar indicating the proportion in 2024. In (B), only centers with $\geq$10% OOS in 2024 are shown. OOS, out-of-sequence; OPO, Organ Procurement Organization.

Table 1
OPO and transplant center characteristics by quartile of OOS allocation or acceptance in 2024.

Characteristic	Quartile 1	Quartile 2	Quartile 3	Quartile 4
OPO				
% AOOS	10.5 (9.2-11.5)	14.3 (13.1-15.1)	20.8 (18.8-21.3)	26.1 (23.2-29.7)
No. of unique centers with AOOS distribution	7 (5-10)	10 (9-15)	12 (9-16)	12 (10-19)
Observed/expected donor yield	1.01 (0.94-1.03)	1.00 (0.98-1.05)	0.98 (0.96-1.01)	1.02 (1.0-1.08)
Center				
% AOOS	0	5.6 (4.1-7.8)	13.4 (11.7-15.8)	26.0 (22.3-32.6)
% of accepted organs with machine perfusion	0 (0-3.0)	12.3 (0-32.5)	21.9 (4.3-44.7)	21.4 (6.4-47.0)
Deceased donor transplant volume	9 (5-19)	61 (39-99)	81 (62-121)	124 (76-165)
Offer/acceptance ratio	0.76 (0.44-1.09)	0.78 (0.67-1.07)	1.00 (0.71-1.12)	1.23 (0.90-1.58)
Offer/acceptance ratio, hard-to-place organs	0.94 (0.36-0.98)	0.36 (0.25-0.62)	0.62 (0.45-1.00)	1.08 (0.58-1.87)
Offer/acceptance ratio, DCD organs	0.90 (0.37-1.00)	0.65 (0.41-0.97)	0.95 (0.47-1.27)	1.25 (0.81-1.92)

Quartile represents the quartile of the proportion of AOOS among distributed (OPO) or accepted (center) organs. Data shown as median (IQR). Hard-to-place organs are defined as >50 declines.
DCD, deceased after circulatory death; IQR, interquartile range; AOOS, allocation out-of-sequence; OPO, Organ Procurement Organization.

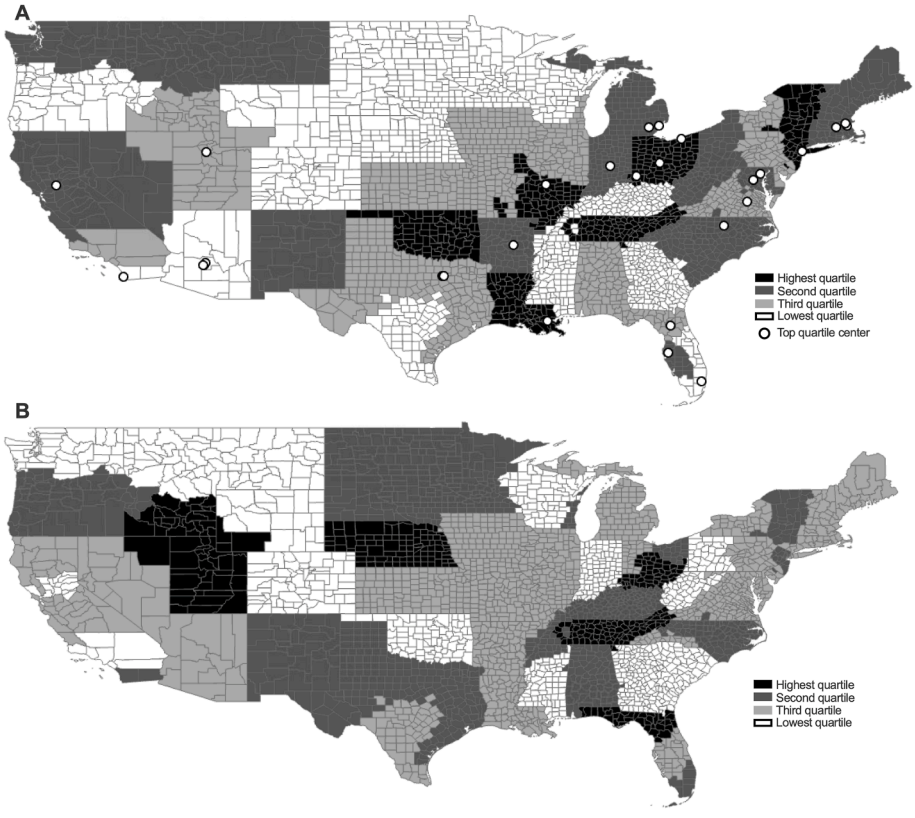

Figure 3. Quartile of proportion of match run acceptances allocated OOS by OPO in 2024 (A) and quartile of OPO-level adjusted donor yield from July 1, 2022, until June 30, 2024 (B). OOS, out-of-sequence; OPO, Organ Procurement Organization.

3.3. AOOS by transplant centers

In 2019, the median center accepted 1.0% of offers through AOOS (IQR, 0%-5.0%), with 89% accepting less than 10%. Three centers accounted for 26% of all AOOS acceptances. In 2024, AOOS use increased for 67% (91/135) of centers that were operational in both years. The median center accepted 10.0% (IQR, 0%-18.2%) of offers through AOOS practices in 2024, and the highest center accepted 55.0% (Fig. 2B). The centers in the upper quartiles of organs accepted through AOOS were larger volume transplant centers and generally utilized machine perfusion more often than centers in the lower quartiles, though 3 of the top 10 accepting centers used machine perfusion in 1% of donors or less (Table 1). Supplementary Figure S3 depicts the

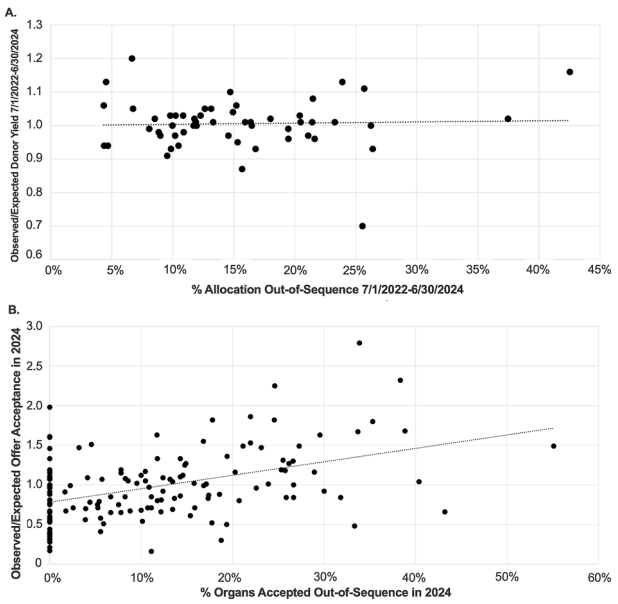

Figure 4. Donor yield by OPO by proportion of organs allocated OOS between July 1, 2022, and June 30, 2024 (A), and offer acceptance ratio by transplant center in 2024 by proportion of organs accepted OOS (B). Each dot represents an OPO or transplant center. The dashed line depicts a linear trend line. OOS, out-of-sequence; OPO, Organ Procurement Organization.

acceptance of organs for AOOS by deceased donor transplant volume quartile in 2024.

Centers' proportion of AOOS acceptances was associated with their overall liver offer/acceptance ratio ($r = 0.39$, $P < .001$; Fig. 4B) and the liver offer/acceptance ratio for hard-to-place organs ($r = 0.28$, $P = .001$) and DCD donors ($r = 0.39$, $P < .001$) in 2024.

When overlaid on OPOs by quartile of AOOS in 2024, transplant centers in the top quartile of AOOS acceptance were often geographically colocated with OPOs with higher AOOS utilization (Fig. 3A).

3.4. Timing of AOOS

AOOS occurred progressively earlier in the match run sequence during the study period. In 2024, the median match-run position at which AOOS began was 11 (IQR, 4-32) compared with 38 (IQR, 9-99) in 2019 (Table 2). Similarly, the time from match-run initiation to the first AOOS event decreased from a median of 21.5 (IQR, 10.6-31.5) hours in 2019 to 14.9 (IQR, 3.0-30.4) hours in 2024. In addition, in 2019, AOOS primarily occurred after donor clamp time, at a median of 1.3 (IQR, –4.0 to 6.6) hours afterward. The median time in 2024, however, was before donor clamp time (median, –3.7 [IQR –9.9 to 1.5] hours), and an increased proportion of match runs started AOOS before donor clamp time (68% vs 42%).

3.5. Characteristics of donors allocated OOS and candidates

A higher proportion of donors allocated through OOS vs in-sequence allocation strategies were DCD grafts in 2024 (37% vs 27%), though this was more similar in the other years (Table 2). The proportion of older donors ≥65 years old allocated through OOS vs in-sequence allocation strategies was similar across the time period (2019, 9% vs 9%; 2024, 16% vs 13%). In 2019, centers receiving organs through AOOS were further away from the donor compared with when in-sequence (median 264 vs 72 miles). However, by 2024, AOOS donors were a similar distance to the accepting hospital compared with in-sequence donors (median 148 vs 140 miles). The proportion of donors for whom machine perfusion was utilized was similar for organs allocated OOS vs in-sequence (2024, 34% vs 29%). Candidates with accepted AOOS offers had lower Model for End-Stage Liver Disease scores during both time periods (Table 2).

4. Discussion

In this national analysis of liver transplant match run data, we found that AOOS has increased substantially from 5% of all match run acceptances in 2019 to 18% in 2024, with an increase observed each year. The use of AOOS has expanded broadly across the transplant system, but a disproportionate share of AOOS placements has occurred in a subset of OPOs and transplant centers. In addition, we observed that OOS allocations are being initiated earlier in the allocation process. Importantly, higher AOOS use was not associated with higher organ utilization at the OPO level, even when accounting for donor risk. AOOS is intended to increase organ utilization and facilitate the placement of difficult-to-place organs and may be necessary when time constraints or logistical barriers make match-run allocation infeasible.[13] When used in this context, AOOS serves an important role in reducing organ discard. Although organ non-use may be avoided in many individual situations, more widespread use of AOOS does not appear to be associated with greater OPO- or system-level organ utilization. Our results highlighted changes in the patterns and timing of AOOS use that merit further examination.

Wehrle et al[8] and Matevish et al[9] previously found increased organ utilization for some high-risk organs with AOOS, though the graft quality of organs allocated in-sequence vs OSS allocation strategies was similar, raising questions about the factors driving AOOS use.[8,9] Our study complements these prior donor-level analyses by evaluating AOOS patterns using the SRTR risk-adjusted OPO liver yield, a nationally benchmarked indicator of organ utilization performance. In our analysis, OPOs with higher AOOS usage did not demonstrate higher liver utilization after accounting for donor case mix. This is despite the concurrent rise in machine perfusion devices, which have facilitated the increased use of more marginal organs by adopting centers.[14] Notably, the organs allocated through the OOS allocation strategy were not clearly more marginal based upon match run position, DCD status (with the exception of 2024), and older age, and a similar proportion of organs allocated OOS vs in-sequence utilized machine perfusion. These findings are consistent with Wehrle et al,[8] who found that the primary driver behind the use of AOOS was not graft characteristics but OPO

Table 2
Timing of AOOS and donor and candidate characteristics from 2019 to 2024.

Characteristic	2019	2020	2021	2022	2023	2024
Sequence number						
Organ accepted	5 (2-13)	9 (4-22)	9 (4-26)	9 (4-28)	9 (4-31)	10 (4- 38)
First AOOS offer	38 (9-99)	19 (9-60)	16 (8-38)	16 (7-39)	12 (6-32)	11 (4-32)
Time						
Time from match run start to AOOS start, h	21.5	20.2	21.5	22.3	19.9	14.9
	(10.6-31.5)	(8.6-30.4)	(10.8-31.0)	(10.4-33.5)	(7.2-33.0)	(3.0-30.4)
Time from match run start to organ	10.3	10.7	9.9	10.0	10.2	8.8
acceptance, non-AOOS, h	(4.2-22.5)	(4.9-20.9)	(4.4-20.4)	(4.7-19.7)	(4.4-20.2)	(4.0-18.5)
Time from match run start to organ	27.5	27.3	27.1	27.3	26.7	24.4
acceptance, AOOS, h	(16.8-43.0)	(16.5-42.3)	(17.2-39.6)	(16.6- 41.2)	(15.0-41.3)	(10.9-40.5)
Time from donor clamp time to AOOS start, h	1.3	–0.5	–0.7	–1.5	–3.2	–3.7
	(–4.0 to 6.6)	(–5.2 to 3.4)	(–5.7 to 2.3)	(–7.8 to 2.3)	(–8.9 to 1.6)	(–9.9 to 1.5)
Time from donor clamp time to organ	–8.7	–10.8	–12.0	–14.3	–15.2	–17.3
acceptance, non-AOOS, h	(–16.6 to –0.1)	(–17.7 to –4.0)	(–19.2 to –5.7)	(–21.9 to –7.8)	(–22.6 to –8.4)	(–25.3 to –9.8)
Time from donor clamp time to organ	5.6	3.4	2.1	1.5	1.2	1.7
acceptance, AOOS, h	(1.3-11.2)	(–0.6 to 9.7)	(–1.0 to 7.0)	(-3.3, 6.9)	(–4.1 to 6.7)	(–3.5 to 7.1)
Time from AOOS start to organ acceptance, h	1.5 (0.4-10.5)	1.6 (0.4-8.2)	1.4 (0.4-5.3)	1.4 (0.3-5.0)	1.6 (0.4-6.1)	2.0 (0.5-9.3)
Donor characteristics						
Distance from donor to accepting	72.4	141.4	146.9	145.7	146.3	140.3
center, non-AOOS, NM	(11.5-203.2)	(46.6-300.9)	(51.2-308.5)	(48.8-313.6)	(54.8-311.8)	(46.1-299.1)
Distance from donor to accepting	263.5	122.6	121.2	125.1	119.0	148.2
center, AOOS, NM	(90.0-502.8)	(26.2-394.1)	(16.1-328.6)	(22.0-334.1)	(22.1-355.8)	(30.4-351.6)
DCD donors, non-AOOS, %	8	10	11	12	17	27
DCD donors, AOOS, %	15	11	10	11	20	37
Age ≥65 y, non-AOOS, %	9	8	9	9	10	13
Age ≥65 y, AOOS, %	9	10	10	10	15	16
Machine perfusion, non-AOOS, %	1	1	0	6	16	29
Machine perfusion, AOOS, %	0	1	1	8	22	34
Candidate characteristics						
MELD score of accepted candidate, non-AOOS	29 (24-35)	29 (24-35)	30 (25-36)	30 (25-36)	29 (24-36)	28 (24-36)
MELD score of accepted candidate, AOOS	19 (14-24)	20 (15-24)	21 (15-25)	20 (14-26)	20 (15-26)	20 (15-27)

Data shown as median (IQR) or %.
DCD, deceased after circulatory death; IQR, interquartile range; MELD, model for end stage liver disease; NM, nautical miles; AOOS, allocation out-of-sequence; OPO, Organ Procurement Organization.

practice variation. These observations, together with the earlier initiation of AOOS, suggest that it may, in some settings, be used beyond the narrow context of the most marginal grafts or late-stage placement failure.

The substantial growth in AOOS use over time may reflect increasing operational complexity in liver allocation and increased regulatory pressure on OPOs to maximize organ recovery and placement under the Centers for Medicare and Medicaid Services performance metrics.[15] The implementation of acuity circle-based distribution in 2020 replaced local sharing boundaries with concentric distance bands, with the goal of reducing geographic disparities.[16] The consequences of this have included increased transport distances between donor and recipient hospitals as well as greater logistical complexity, longer

cold ischemic time, and an increased likelihood of late offer declines, particularly for lower-quality or marginal organs.[17] In this context, greater reliance on expedited placement mechanisms such as AOOS may be both reasonable and necessary to maintain efficiency and avoid nonutilization, though notably, organs allocated OOS in 2024 were not located in closer proximity to accepting centers than organs allocated in-sequence. Although these factors may plausibly explain some increased overall AOOS use, they do not necessarily fully explain why AOOS use has continued to rise every year or why AOOS has been initiated progressively earlier in the match run. These findings raise questions about whether the threshold for invoking AOOS has shifted—an issue that cannot be fully resolved using administrative data alone, but that warrants further study.

Our findings generally parallel patterns reported for kidney transplantation. In 2023, 20% of all kidney transplants were allocated OOS.[1] Growth in OOS kidney allocation has disproportionately occurred among a small number of OPOs and transplant centers, and there are demographic characteristic differences between the patients at these centers, potentially benefiting some and those not receiving as many organs through AOOS.[1,5,7] This has been attributed to several factors, including heightened regulatory pressure on OPOs as well as increased logistical challenges in the kidney allocation process after the implementation of the KAS250 distance-based allocation policy in 2021.[1,6,18] These parallels suggest that broader system-level forces, rather than organ-specific factors alone, may be contributing to increased reliance on AOOS across solid organ transplantation.

The rise in AOOS of livers has occurred broadly but similarly appears to be used disproportionately by a subset of OPOs and transplant centers. We observed a wide variation in AOOS across OPOs, with some using AOOS mechanisms for fewer than 5% of match runs and others for over 20%. There was some geographic overlap between the OPOs with the highest AOOS placement and the centers accepting the most AOOS organs. In addition, several of the OPOs with the greatest use of AOOS placed these organs to patients listed at a relatively smaller number of unique centers, including 2 of the 3 highest-volume OPOs. Together, these findings indicate that established local or regional OPO-center relationships may be leveraged for AOOS placements in these areas with high AOOS use. It is conceivable that OPOs rely on local centers in these circumstances to minimize cold ischemic time, particularly when centers have a demonstrated willingness and capacity to accept higher-risk grafts.

The centers with a high proportion of AOOS acceptances tended to be high-volume transplant centers. These centers likely have larger candidate pools and greater familiarity with expedited placement, facilitating their ability to accept these AOOS organs. They were also more willing to accept hard-to-place organs, which are features often associated with AOOS placements. This concentration of a higher proportion of AOOS organs among a subset of centers (often near OPOs with high OOS allocation) raises important questions as to whether all centers (and therefore their patients) have equal access to these organs and whether structural or resource differences contribute to how they are distributed. In this context, AOOS could disproportionately benefit centers with greater operational flexibility, staffing resources, or an established history of organ offer acceptance—factors that may influence access to organs independently of patient-level urgency. One potential resource difference that may contribute to center-level variation in OOS allocation is differential use of normothermic machine perfusion devices. These devices can prolong graft viability and enable functional assessment, which is particularly important for marginal livers or those with prolonged cold times. They do have an associated increased organ acquisition cost, which could pose a barrier for some programs.[19,20] We observed that centers in the upper half of organs accepted OOS generally utilized machine perfusion more commonly than centers in the lower half. Yet, 3 of the top 10 accepting centers used this in 1% of donors or less, so this is clearly not the only factor driving our results.[21] Although more detailed data on machine perfusion use were not available for this analysis, the impact of this practice on AOOS acceptance warrants further investigation.

The need for AOOS typically arises when sequential match-run allocation becomes inefficient under time-sensitive conditions, necessitating expedited placement mechanisms. Although AOOS was initiated earlier in the match run process over time, it still occurred late in absolute time from match run initiation relative to non-AOOS acceptances, indicating use in time-constrained placement scenarios. A more efficient offer dispatch mechanism could expedite the allocation process and potentially reduce the need for AOOS. For example, an OPO could send organ information to multiple centers simultaneously and allow centers to propose a willing candidate within a certain timeframe; the organ could then be allocated to the highest-ranked among all proposed patients. This would allow centers to process candidate availability and compatibility in parallel, without having to wait for the preceding candidates' decisions, which could potentially shorten the overall placement time. Alternatively, there could be a trigger, such as a time frame after the match run starts or a specified number of sequential declines, after which AOOS could be initiated to help prevent organ nonutilization. The logistical details, theoretical implications, and empirical effects of such mechanisms on allocation efficiency and fairness, however, require further studies.

Understanding the current state of OOS allocation is particularly important given the recent HRSA directive to the OPTN regarding this issue.[11] Our results underscore the need for greater transparency and standardization in OOS liver allocation practices and are particularly timely in light of the recent HRSA directive. Currently, there is limited guidance on when and how AOOS should occur, creating the potential for variability and unintended differences in access. These findings highlighted the need for ongoing policy refinement to ensure that organs are allocated equitably while also optimizing their utilization.

Our study has several limitations. Most importantly, these administrative data lack clinical context for individual allocation decisions and should also be interpreted in the context of limitations related to measurement and aggregation. Aggregate

metrics derived from SRTR data cannot capture heterogeneity in individual-level decision-making. For example, in practice, at the center level, individuals may adopt more aggressive acceptance strategies for marginal grafts—both in-sequence and OOS allocations—without meaningfully shifting center-level offer acceptance metrics. In addition, our results were conditional on match runs that resulted in organ transplantation because their match run and AOOS records are believed to be more complete.[4] Excluding nontransplant organs limits our ability to assess AOOS attempts that did not result in placement. AOOS status was determined using allocation codes and timestamps, but inconsistencies in documentation or use of free-text fields across centers and OPOs may have led to misclassification. Additionally, parallel or multidecline scenarios may not be well-captured, which could influence the recorded sequence position and timing of AOOS initiation. We also attempted to incorporate the use of machine perfusion, though this may be underreported, and we lacked more detailed data, which limits our ability to assess their influence on AOOS behavior.[22] Finally, our system-level approach does not directly model the counterfactual of what would have happened to a given liver had AOOS not been used. Organs placed using AOOS may still have had the possibility of acceptance in sequence, or conversely, many AOOS-placed livers may have avoided discard. Donor-level analyses such as those by Wehrle et al[8] and Matevish et al[9] complement our findings, and future work linking organ-level and system-level outcomes will be needed to fully assess the impact of AOOS on utilization, equity, and post-transplant outcomes.

In conclusion, AOOS in liver transplantation has increased significantly from 2019 to 2024, with AOOS being initiated earlier in the allocation process and with some concentration among a subset of OPOs and high-volume transplant centers. AOOS is intended as a pathway to reduce discards in exceptional circumstances, and when used appropriately, serves a role in increasing organ utilization. However, at the OPO level, the expanding use of AOOS from 2019 to 2024 was not associated with higher organ utilization as measured using SRTR risk-adjusted donor yield. Together with earlier initiation of AOOS, these findings highlight areas for continued monitoring and thoughtful policy development to ensure that AOOS supports both efficient organ utilization and equitable access.

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Declaration of competing interest

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Data availability

The data that support the findings of this study are available on request from the United Network for Organ Sharing or are publicly available from the Scientific Registry of Transplant Recipients.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajt.2026.01.021.

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