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Outcomes for Patients With a Deceased Donor Kidney Offer in the New Allocation System

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Introduction: In the United States (US), disparities in access to kidney transplantation exist for waitlisted candidates with end-stage kidney disease. Meanwhile, changes in kidney allocation policy have been associated with a dramatic increase in the number of organ offers declined before an organ is successfully placed.

Methods: We describe transplant and mortality rates for waitlisted candidates from 2015 to 2022 following these allocation changes.

Results: Among 249,145 incident waitlisted adults, 180,039 received at least 1 offer and were included in the study. Of these, 37.7% received a deceased donor kidney allograft, 14.7% received a living donor allograft, 7.4% died while on the waiting list, 12.7% were removed, and 27.5% were still waitlisted by the study end period. Overall, candidates' median number of days to receiving their first offer declined from 20 (7–48) in 2015 to 5 (2–13) in 2022. Candidates who died while on the waiting list received a median of 25 (9–56) offers and candidates who were removed received a median of 22 (8–53) offers during the study period. The total number of offers generated by the match-run algorithm, including those from nonutilized kidneys, increased sharply from 7,911,688 offers in 2015 to 13,682,914 in 2019, and to 29,332,516 in 2022.

Conclusion: These findings emphasize the inefficiencies inherent in our current allocation algorithms and the need to rethink how waitlisted patients are prioritized for a given deceased donor organ in order to maximize the probability of appropriate utilization of lifesaving organs .

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Kidney transplantation is the optimal treatment for patients with end-stage kidney disease. For individuals who do not have a living donor, obtaining a transplant requires receiving an organ offer after adding them to the national waitlist. The timing and priority for a given deceased donor organ offer are determined by an objective allocation algorithm that encodes the priorities and choices made by the transplant community via the Organ Procurement and Transplantation Network. For each procured organ, a "match run" is generated that lists all patients eligible to receive the organ in the order of priority.[1]

The majority of organ offers are evaluated by transplant centers and declined without direct patient engagement or even awareness of the offer.[1-3] After an organ is declined for a patient, the organ is offered to the transplant center with the next listed patient until reaching a center that is willing to accept the organ. The organ is discarded if no center accepts the organ for transplantation.

Recent changes in the US kidney allocation policy, referred to as "KAS250," have been associated with a dramatic increase in the number of organ offers declined before an organ is successfully placed, along with a rapid uptick in the proportion of kidneys

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discarded.[4] Historically, transplant candidates were given priority if they were within the administrative boundaries of one of the 57 donation areas where an organ was recovered. With the introduction of KAS250 in 2021, these 57 donation service areas were replaced by a distance-based allocation where recipients who were located within 250 nautical miles of the donor hospital were prioritized, with the intended goal to increase geographic equity in access to transplantation. The impact of these changes and the associated inefficiencies appear to be contributing to the increase in the current discard rate of deceased donor organs.[5-8] Outcomes for patients waitlisted for a kidney transplant who have an organ offer declined on their behalf should inform future iterations of allocation policy development, especially given the current consideration for a continuous distribution policy in the US and concerns about the declining rate of organ utilization.[6-9]

METHODS

Study Design

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donors, wait-listed candidates, and transplant recipients in the US, submitted by the members of the Organ Procurement and Transplantation Network. The Health Resources and Services Administration, US Department of Health and Human Services provides oversight to the activities of the Organ Procurement and Transplantation Network and SRTR contractors. The data reported here have been supplied by the Hennepin Healthcare Research Institute as the contractor for the SRTR. The interpretation and reporting of these data are the responsibility of the author(s) and in no way should be seen as an official policy of or interpretation by the SRTR or the US Government.

The SRTR Potential Transplant Recipient data set includes an ordered list of all matched kidney transplant candidates to whom deceased donor kidneys were offered, including the offers for nonutilized kidneys and those ultimately accepted for transplant. Of note, neither transplanted nor nonutilized kidneys can be distinguished until all match-run efforts are exhausted. To be eligible for kidney transplantation, patients must be waitlisted; however, offers are given to only waitlisted patients with an active status. We used the SRTR Standard Analysis File for demographic and outcomes data on candidates and donors and followed the Strengthening the Report of Observational Studies in Epidemiology reporting guidelines.

Main Study Cohort

The study cohort included all adult, incident waitlisted candidates residing in the US who received at least 1 deceased donor kidney offer from January 1, 2015 to December 31, 2022. Multiorgan kidney candidates and candidates who were waitlisted at more than 1 center were excluded from the study.

We excluded matches that were automatically declined by the allocation system bypasses (e.g., directed donation, payback agreements, and military allocation) because candidates were unable to receive these deceased donor kidneys, although they were recorded as offers (Supplementary Table S1). In contrast, bypass offers that were associated with codes for predetermined center filter criteria were retained because candidates were theoretically able to receive these kidneys. We also excluded offers received after the candidate's documented death date, transplant date, or waitlist removal date. All offers for kidneys that were eventually discarded were excluded from analyses of the main study cohort.

The final cohort of candidates were classified into 5 event groups as follows: received a deceased donor allograft, received a living donor allograft, still waiting for a transplant, died without undergoing a transplant, or removed from the waitlist because of one of the 3 reasons (deteriorating condition, transferred to another center or inability to be contacted, or for a reason other than death or transplant). We identified the date of each candidate's first offer and calculated the total number of offers they received during the study period before their event date. The end of follow-up for each candidate was either transplant, death, removal from the waiting list, or the end of the study (i.e., December 31, 2022). Annual trends in the median number of days from listing and activation to the first offer were assessed.

Among all offers from transplanted kidneys, offer refusal codes provided by transplant centers were grouped into 1 of 5 reasons for declining the offers: candidate-related, organ or donor quality, logistical, center bypass filter criteria, or immunological or others. Because updates to refusal codes were implemented by the Organ Procurement and Transplantation Network in December 2021 to allow for more granular insights into refusal and acceptance practices, we stratified the proportion of each refusal reason by old and new codes. The annual number of offers from transplanted kidneys at each center were examined.

Post-KAS250 Analysis

Candidate characteristics of the full study cohort were also compared in a subset of candidates who were first activated on the waiting list following the

implementation of the 2021 distance-based KAS250. The cumulative incidence of deceased donor transplant in the presence of competing events, including living donor transplant, waitlist removal, and death were assessed from time of first offer. The cumulative incidence of transplant (i.e., deceased and living donor) was also stratified based on ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic Other, and Hispanic), age (18–40, 41–65, and 65+ years), and sex (male and female). Sex is defined as the biologic and physiologic traits at birth.

Annual Trends Among Prevalent Waitlisted Candidates

To examine overall annual trends during the study period, the total number of offers and kidneys accepted without a decline were evaluated using the adult prevalent waitlisted population from 2015 to 2022. Multi-organ, multi-listed patients, and patients with no offers were excluded. Matches that were automatically declined by the allocation system bypasses were also excluded. Offers resulting in transplant and offers resulting in nonutilization were considered.

Statistical Analysis

Candidate characteristics were compared across the 5 groups using analysis of variance for normally distributed continuous variables, Kruskal-Wallis tests for nonnormally distributed continuous variables, and Peason chi-square tests for categorical variables. Pairwise comparisons between the death event group and each of the other event groups were performed using the Bonferroni multiple comparisons adjustment, as well as the Dunn test for continuous variables and multinomial regression for categorical variables. Means and SDs or medians with interquartile ranges (IQRs) were presented for continuous characteristics. Percentages were given for categorical characteristics. Cumulative incidence of deceased donor transplant was evaluated with living donor transplant, waitlist removal, and death as competing events using STATA package *stcompet*, which utilizes the delta method described by Marubini and Valsecchi.[10,11]

This study was approved by the institutional review board at Columbia University Medical Center. Informed consent was not required. The clinical and research activities being reported are consistent with the Principles of the Declaration of Istanbul as outlined in the "Declaration of Istanbul on Organ Trafficking and Transplant Tourism." Statistical significance was defined by a 2-sided alpha < 0.05. Analyses were performed using STATA/MP 17.0 (StataCorp, College Station, TX).

RESULTS

Of the 258,371 incident waitlisted kidney-only transplant candidates between January 1, 2015 and December 31, 2022, we excluded pediatric ($n = 7538$), non-US residing ($n = 1688$), multi-listed ($n = 32,547$) patients, and patients with no offers ($n = 30,628$) to yield a total of 185,970 eligible adult candidates who received at least 1 offer for a deceased donor kidney during the study period (Figure 1). Excluding offers made after the event ($n = 62$ candidates who only received offers after death or transplant) and offers from nonutilized kidneys ($n = 5869$ candidates who received only offers from discarded kidneys) resulted in our final cohort of 180,039 candidates.

Mean (SD) age at listing was 52.7 (13.1) years and the patients were predominately male among the final cohort (112,008 [62.3%]) (Table 1 and Supplementary Table S2). Median (IQR) time receiving dialysis at listing was 1.5 (0.8–3.2) years. Of the candidates, 80,942 (44.9%) had a history of diabetes, 21,968 (12.2%) had a history of vascular disease, and 21,385 (14.1%) had panel reactive antibody $> 80\%$.

Among candidates in our study, 68,870 (37.7%) received a deceased donor kidney allograft, 26,465 (14.7%) received a living donor allograft, and 13,394 (7.4%) died while on the waiting list. Of the candidates, 49,476 (27.5%) were still waitlisted as of December 31, 2022. In addition, 11,503 (6.4%) were removed from the waiting list because of deteriorating condition, 2057 (1.1%) were removed to be transferred, and 9247 (5.2%) were removed because of other reasons. Among candidates who were removed from the waiting list for any reason, the most commonly used removal codes were "candidate condition deteriorated" (50.4%), "other" (32.5%), and "unable to contact candidate" (6.1%) (Supplementary Table S3).

Candidates received their first organ offer after a median (IQR) of 12 (4–33) days from their initial activation onto the waitlist. Candidates who underwent a kidney transplant from a living donor received a median of 9 (IQR: 4–22) offers while waitlisted, with a median of 198.5 (IQR: 89–411) days between first offer and transplant. Candidates who underwent a deceased donor kidney transplant received a median of 14 (IQR: 5–44) offers over a median of 231 (IQR: 44–739) days before the transplant. Candidates who died on the waitlist received a median of 25 (IQR: 9–56) offers while waitlisted.

Among the entire cohort, the median number of days from initial activation to first offer declined from 20 (IQR: 7–48) in 2015 to 5 (IQR: 2–13) in 2022 (Table 2). Among only candidates who were activated on the waitlist in the post-KAS250 era, candidates

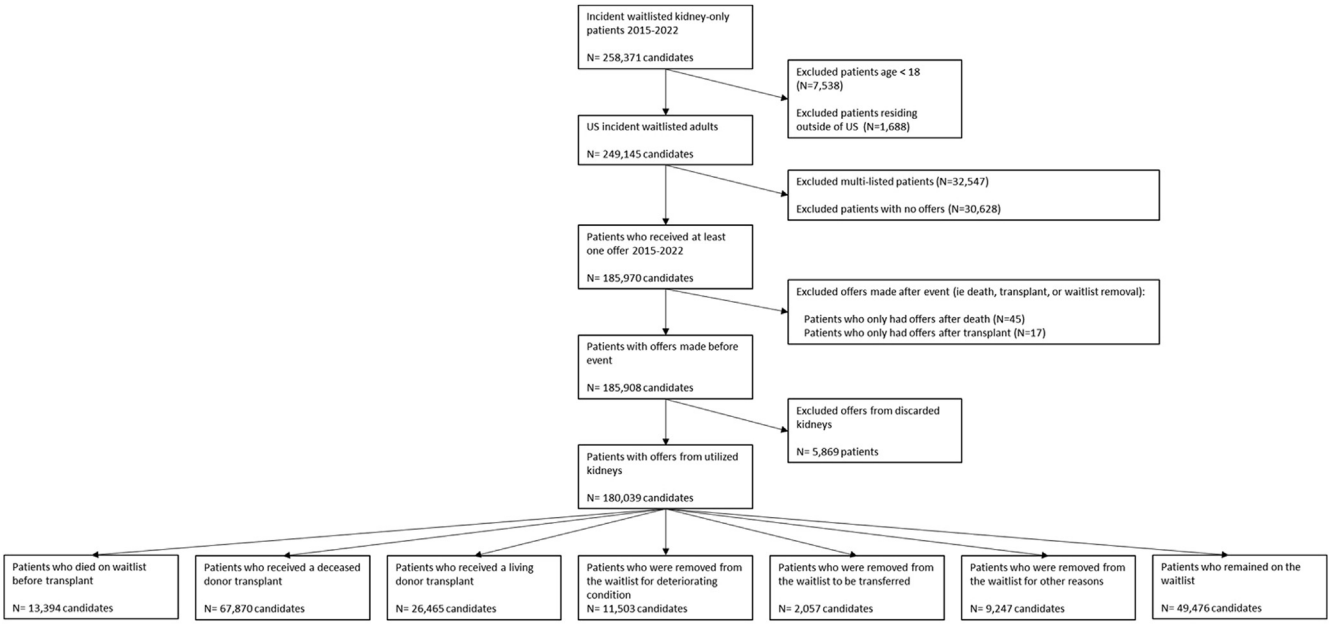

Figure 1. Flow diagram for cohort selection and categorizing waitlist outcomes of incident adult deceased donor kidney transplant candidates in the United States, 2015 to 2022.

received their first organ offer over a median of 6 (IQR: 2–16) days after activation (Table 3, Supplementary Table S4 and Figure S1). During this period, candidates who underwent a deceased donor transplant received a median of 9 (IQR: 3–22) offers over a median of 59 (IQR: 13–166) days compared to candidates who died on the waitlist who received a median of 16 (IQR: 7–36) offers over a median of 194 (IQR: 99–340) days.

The proportion of kidneys that were accepted for transplant without a decline (i.e., accepted for the intended recipient at the top of the match run) increased from 21% in 2015 to 24% in 2019, but dropped to 16% in 2022 following updates to both Organ Procurement Organization (OPO) metrics and the kidney allocation system (Figure 2, Supplementary Table S5). The cumulative incidence of deceased donor transplant was higher among candidates activated on the waitlist after KAS250, compared with the overall cumulative incidence among all candidates in the cohort (Figure 3). In both periods, candidates with non-Hispanic White ethnicity had a greater cumulative incidence to transplant than all other subgroups (non-Hispanic Black, non-Hispanic Other, and Hispanic ethnicity) (Supplementary Figure S2). Cumulative incidence of death did not differ by ethnicity subgroup or pre- or post-KAS250 period. Among our age groups, candidates aged 41 to 65 years and those aged > 65 years had slightly increased cumulative incidence of transplant in the post-KAS250 period; however, the younger 18 to 40 years age group kept a 10% to 15% higher incidence rate in both periods. Death rates in both periods were comparable (Supplementary Figure S3). Cumulative incidence of transplant and of death did not differ by period for either sex (Supplementary Figure S4). Female candidates had a greater cumulative incidence of transplant in both periods around 1 year after receiving their first offer.

As reported by the centers, organ or donor quality concerns accounted for the majority (50%–80%) of all declined offers (Supplementary Table S6). Annual trends in refusal reasons showed a change following KAS250, with 14% of refusals in 2022 being due to logistical limitations and 29% because of the center bypass filter settings (Supplementary Table S7). At the center level, the median number of offers in 2015 increased from 296 (IQR: 109–658) to 6050 (IQR: 1364–13,438) in 2022 (Figure 4).

Among the prevalent adult waitlist population, the total number of offers, including those from nonutilized kidneys, rose sharply from 7,911,688 offers in 2015 to 13,682,914 in 2019, to 29,332,516 in 2022. Furthermore, there was a 3-fold increase in the number of offers per candidate from the start to end of our study period (Figures 5 and 6).

DISCUSSION

There has been a steady increase in the number of kidney transplants performed annually in the US.[12] However, the decreasing efficiency of the system and increasing discard rate have attenuated this increase in transplants; for example, if the discard rate from 2016

Table 1. Characteristics of incident transplant candidates who received at least 1 deceased donor kidney offer, 2015 to 2022

Candidate characteristic		Event				
Mean ± SD, Col (%), or Median (IQR)	Total	Died on WL	Transplanted (DD)	Transplanted (LD)	Removed	Remaining on WL
	n = 180,039	n = 13,394 (7.44%)	n = 67,870 (37.70%)	n = 26,465 (14.70%)	n = 22,834 (12.68%)	n = 49,476 (27.48%)
Age at listing (yrs)	52.74 ± 13.13	56.60 ± 10.82	51.85 ± 13.34	49.26 ± 14.05	56.62 ± 12.53	52.98 ± 12.44
Age at first offer (yrs)	52.95 ± 13.13	56.80 ± 10.82	52.09 ± 13.34	49.44 ± 14.05	56.82 ± 12.53	53.19 ± 12.45
Female sex	67,951 (37.74%)	4446 (33.19%)	27,483 (40.49%)	9845 (37.20%)	8243 (36.10%)	17,934 (36.25%)
Ethnicity						
Hispanic	36,264 (20.14%)	2668 (19.92%)	13,430 (19.79%)[a]	4301 (16.25%)	4258 (18.65%)	11,607 (23.46%)
Non-Hispanic	143,775 (79.86%)	10,726 (80.08%)	54,440 (80.21%)	22,164 (83.75%)	18,576 (81.35%)	37,869 (76.54%)
Race						
White	72,505 (40.27%)	5365 (40.06%)	24,817 (36.57%)	16,883 (63.79%)	9134 (40.00%)	16,306 (32.96%)
Black	53,937 (29.96%)	4052 (30.25%)	23,289 (34.31%)	3391 (12.81%)	7430 (32.54%)	15,775 (31.88%)
Asian	13,495 (7.50%)	1014 (7.57%)	4789 (7.06%)[a]	1518 (5.74%)	1428 (6.25%)	4746 (9.59%)
Other[b]	40,102 (22.27%)	2963 (22.12%)	14,975 (22.06%)[a]	4673 (17.66%)	4842 (21.21%)[a]	12,649 (25.57%)
BMI[c]	29.01 ± 5.44	29.31 ± 5.26	28.80 ± 5.48	28.38 ± 5.50	29.25 ± 5.28[a]	29.43 ± 5.42[a]
History of diabetes	80,942 (44.96%)	9023 (67.37%)	26,361 (38.84%)	7679 (29.02%)	13,783 (60.36%)	24,096 (48.70%)
History of vascular disease	21,968 (12.20%)	2010 (15.01%)	8376 (12.34%)	2471 (9.34%)	3159 (13.83%)	5952 (12.03%)
PRA[d]	0.24 ± 0.35	0.19 ± 0.32	0.25 ± 0.37	0.11 ± 0.23	0.21 ± 0.33	0.44 ± 0.34
PRA > 80%[d]	21,385 (14.10%)	1337 (10.04%)	11,867 (17.61%)	950 (3.62%)	2639 (11.72%)	4564 (20.81%)
EPTS at listing	40 (18–66)	56 (36–75)	40 (16–68)	23 (8–45)	55 (32–76)	39 (19–61)
EPTS at first offer	41 (18–67)	58 (37–76)	41 (17–69)	24 (9–46)	57 (33–78)	40 (20–63)
Dialysis vintage at listing (yrs)	1.51 (0.76–3.22)	1.39 (0.76–2.53)	2.35 (1.03–5.07)	0.73 (0.38–1.43)	1.46 (0.80–2.68)	1.21 (0.67–2.14)
Dialysis vintage at first offer (yrs)	1.62 (0.85–3.31)	1.50 (0.86–2.66)	2.47 (1.15–5.15)	0.82 (0.45–1.53)	1.58 (0.90–2.80)	1.29 (0.74–2.24)
Waitlisted preemptively	55,583 (30.87%)	2956 (22.07%)	14,630 (21.56%)[a]	14,407 (54.44%)	5257 (23.02%)[a]	18,333 (37.05%)
Started dialysis between waitlisting and event[e]	15,191 (8.44%)	1124 (8.39%)	4354 (6.42%)	2147 (8.11%)	1935 (8.47%)[a]	5631 (11.38%)
Median (IQR) days between listing and first offer	18 (6–59)	21 (7–61)	17 (5–61)	21 (7–60)[a]	21 (7–61)[a]	16 (5–56)
Median (IQR) days between initial activation and first offer	12 (4–33)	16 (6–40)	11 (3–32)	14 (5–34)	16 (6–41)[a]	10 (4–27)
Median (IQR) days between first offer and event[e]	408 (124–931)	680.5 (336–1137)	231 (44–739)	198.5 (89–411)	799 (444–1241)	569 (232–1148)
Median (IQR) days between last offer and event[e]	4 (1–46)	47 (8–272)	2 (1–2)	16 (5–40)	189 (27–490)	10 (2–109)
Median (IQR) number of offers before event[e]	20 (6–56)	25 (9–56)	14 (5–44)	9 (4–22)	22 (8–53)	42 (15–101)
Median (IQR) days between first offer and last offer	316 (87–763)	457 (188–872)	234 (42–751)	163 (54–375)	452 (191–853)[a]	429 (162.5–911)[a]

BMI, body mass index; Col, column; DD, deceased donor; EPTS, estimated post transplant survival; IQR, interquartile range; LD, living donor; PRA, panel reactive antibody; WL, waitlist.
[a]Indicates a nonsignificant ($P > 0.05$) pairwise comparison between death group and that event group.
[b]Includes Hispanic, Other, and Unknown.
[c]BMI <10 and >45 recoded as outliers.
[d]Calculated panel reactive antibody is the candidate's most recent calculated PRA.
[e]Event is defined as death, transplant, removal from waitlist, or end of follow-up period (December 31, 2022) for those remaining on the waitlist. For transplant events, candidates' last offer is defined as the offer before their final acceptance.
Note: All variables significant for overall group differences with P-values < 0.001.

Table 2. Annual trends in time to first and final accepted offer among incident transplant candidates who received at least 1 deceased donor kidney offer

Year	Number of candidates waitlisted	Median (IQR) days between listing and first offer	Number of candidates activated	Median (IQR) days between initial activation and first offer	Number of candidates transplanted	Median (IQR) days between initial activation and accepted offer
2015	22,017	28 (9–86)	19,975	20 (7–48)	3038	82 (35–150)
2016	21,977	25 (8–75)	21,406	19 (6–46)	7177	153 (61–290)
2017	21,324	23 (7–72)	21,100	17 (6–44)	9169	218 (83 –454)
2018	23,268	22 (7–70)	22,821	16 (6–41)	11,300	252 (91– 606)
2019	24,636	19 (6–60)	24,463	13 (5–34)	13,600	281 (94–707)
2020	21,107	16 (5–59)	21,186	11 (4–28)	14,379	331 (108–829)
2021	23,320	13 (4–42)	23,820	8 (3–21)	16,025	326 (89–903)
2022	22,390	7 (2–21)	25,260	5 (2–13)	17,225	301 (81–930)
All	180,039	18 (6–59)	180,031	12 (4–33)	94,335	254 (84–666)

IQR, interquartile range.

Table 3. Time to first offer and event among incident transplant candidates activated on the waiting list following implementation of the 2021 distance-based kidney allocation system (KAS250)

Candidate characteristic		Event				
	Total post-KAS250	Died on WL	Transplanted (DD)	Transplanted (LD)	Removed	Remaining on WL
n (Col %), or median (IQR)	*N* = 44,720	*n* = 890 (1.99%)	*n* = 11,771 (26.32%)	*n* = 4217 (9.43%)	*n* = 1342 (3.0%)	*n* = 26,500 (59.26%)
Dialysis vintage at listing (yrs)	1.54 (0.78–3.13)	1.56 (0.81–2.80)	2.99 (1.27–6.03)	0.79 (0.42–1.53)	1.65 (0.87–3.04)[a]	1.29 (0.71–2.28)
Dialysis vintage at first offer (yrs)	1.61 (0.84–3.20)	1.72 (0.91–2.90)	3.10 (1.37–6.14)	0.85 (0.47–1.57)	1.69 (0.92–3.13)[a]	1.35 (0.76–2.35)
Waitlisted preemptively	14,780 (33.05%)	191 (21.46%)	2306 (19.59%)[a]	2213 (52.48%)	331 (24.66%)	9739 (36.75%)
Started dialysis between waitlisting and event[b]	2437 (5.45%)	45 (5.06%)	371 (3.15%)	264 (6.26%)	78 (5.81%)[a]	1679 (6.34%)
Days between listing and first offer	11 (3–43)	11 (4–44)	8 (2–42)	15 (5–55)	11 (4–42)[a]	11 (4–42)a
Days between initial activation and first offer	6 (2–16)	7 (3–17)	4 (1–13)	8 (3–18)[a]	8 (3–10)[a]	7 (3–17)a
Days between first offer and event[b]	176 (62–358)	194 (99–340)	59 (13–166)	130 (60–237)	289 (150–414)	253 (112–422)
Days between last offer and event[b]	4 (2–14)	14 (3–66)	2 (1–2)	11 (3–32)	60 (12–168)	6 (2–17)
Number of offers before event[b]	17 (6–41)	16 (7–36)	9 (3–22)	11 (4–23)	16 (6–36)[a]	24 (10–52)
Days between first offer and last offer	144 (44–308)	135.5 (57–262)	53 (10–161)	101 (36–206)	150 (54–279)[a]	207 (80–374)

Col, column; DD, deceased donor; IQR, interquartile range; LD, living donor; WL, waitlist.
[a]Indicates a nonsignificant ($p > 0.05$) pairwise comparison between death group and that event group.
[b]Event is defined as death, transplant, removal from waitlist, or end of follow-up period (December 31, 2022) for those remaining on the waitlist.
Note: All variables significant for overall group differences with *P*-values < 0.001.

were maintained, we could have performed 3,013 additional kidney transplants through 2022.[7]

Over time, there has been a dramatic decrease in the efficiency of the allocation system.[4] In 2022 alone, there were 2.78 million organ offers needed to successfully place kidneys among 64,689 candidates; an average of approximately 43 offers per unique candidate. Although this may not seem excessive in isolation, the rate of offers per candidate represents a > 3-fold increase compared to 2015 and is double the rate before the introduction of KAS250 in 2021. In addition, these offers need to be considered in the broader context of another 27 million offers that are made concomitantly to place organs that are eventually discarded. With transplant centers facing such a large volume of offers, it is unclear as to what extent centers can adequately and meaningfully evaluate each of the organs available.[13,14] Moreover, it is not clear to what extent organ discard is a function of inefficiencies that are overwhelming the system, rather than a consequence of organ quality itself.[15,16]

Although the source of these inefficiencies is likely multifactorial, the contribution of the allocation algorithm cannot be understated, particularly given the temporal association between the introduction of the current algorithm and a dramatic decrease in allocation efficiency.[6,8,13] Although this algorithm encodes the preferences[17] and priorities of the transplant community and attempts to balance utility and equity, it needs to consider the logistical challenges associated with

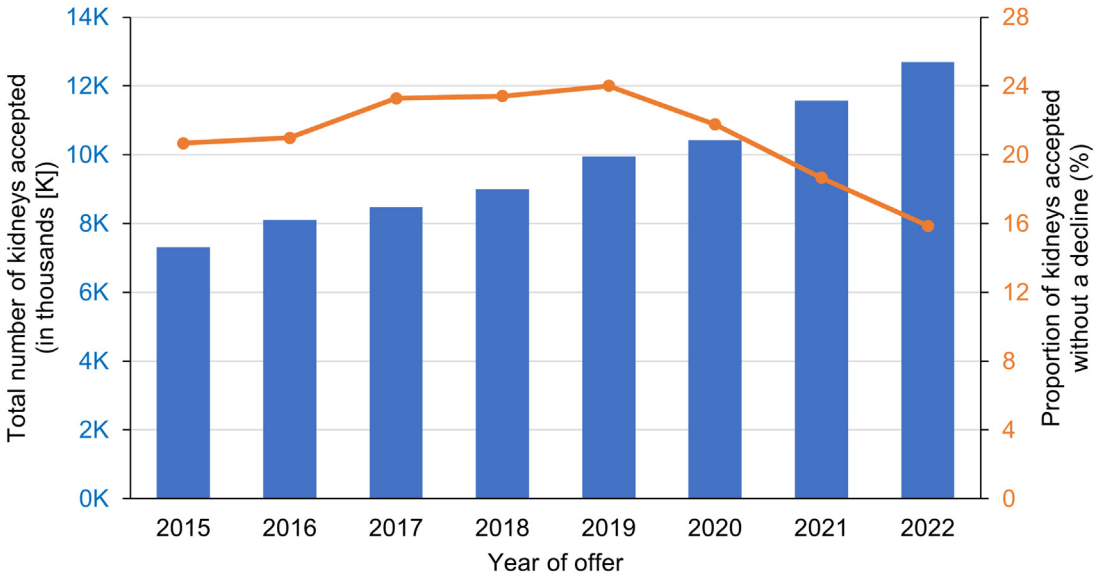

Figure 2. Total number of kidneys accepted, and the proportion of kidneys accepted without a decline in the incident adult kidney waitlist population, 2015 to 2022. Multiorgan and multi-listed patients were excluded. Matches that were automatically declined by the allocation system bypasses were also excluded.

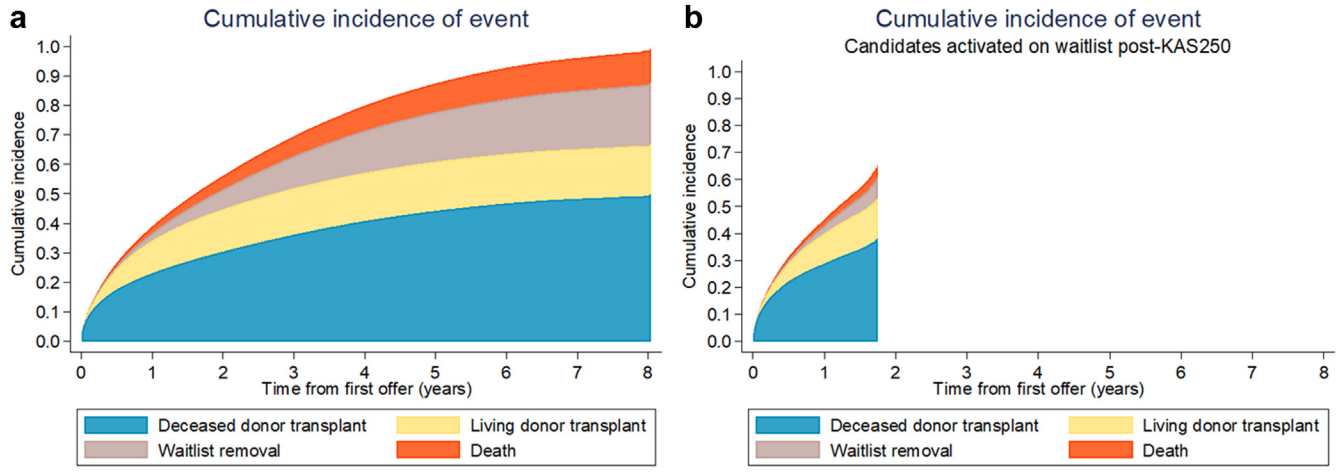

Figure 3. Cumulative incidence of deceased donor transplant with competing risks (living donor transplant, waitlist removal, and death) among (a) all candidates and (b) candidates activated on the waitlist after implementation of KAS250.

getting an organ from the donor to the intended recipient.[6,8] Specifically, allocation algorithms must attempt to get organs to recipients who are likely to both benefit from and accept the offered organs.[18] The current iteration of the allocation system is viewed as a step to "continuous allocation."[19,20] However, this notion overlooks the fact that currently, organs are frequently allocated to patients in locations that are quite far from where they are procured, and that much of the geographic variation seen in the access to transplantation is not a function of variation in the underlying organ supply, but rather a function of differences in the organ offer acceptance rate.[4,16,21,22] As a result of the logistical challenges, organ procurement organizations are increasingly turning to out-of-sequence organ placements, which undermines the objective nature of the allocation system and risks further exacerbating existing disparities among transplant recipients.[23]

The current allocation algorithm has removed the seemingly arbitrary administrative boundaries of donation service areas, replacing them with 250-nautical mile circles centered on a donor hospital. Although these circles may appear to be uniform boundaries, it is important to recognize that large variations in population density and disease prevalence may mean that these areas are not as equitable as they seem. For example, a 250-nautical mile circle around Washington, DC includes 60 million people, approximately a fifth of the US population. A similar

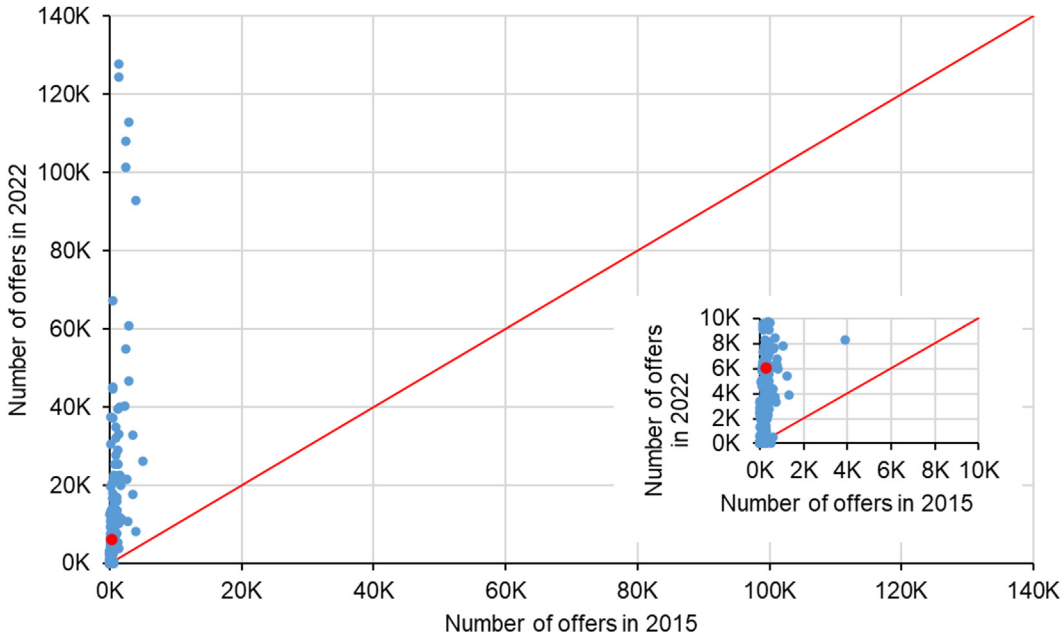

Figure 4. Center-level differences between the number of offers in 2015 compared with the number of offers in 2022 in the incident adult kidney waitlist population. The red dot indicates the median number of offers among all centers and the diagonal line indicates the line of identity. A close-up of the data is featured on the inset figure.

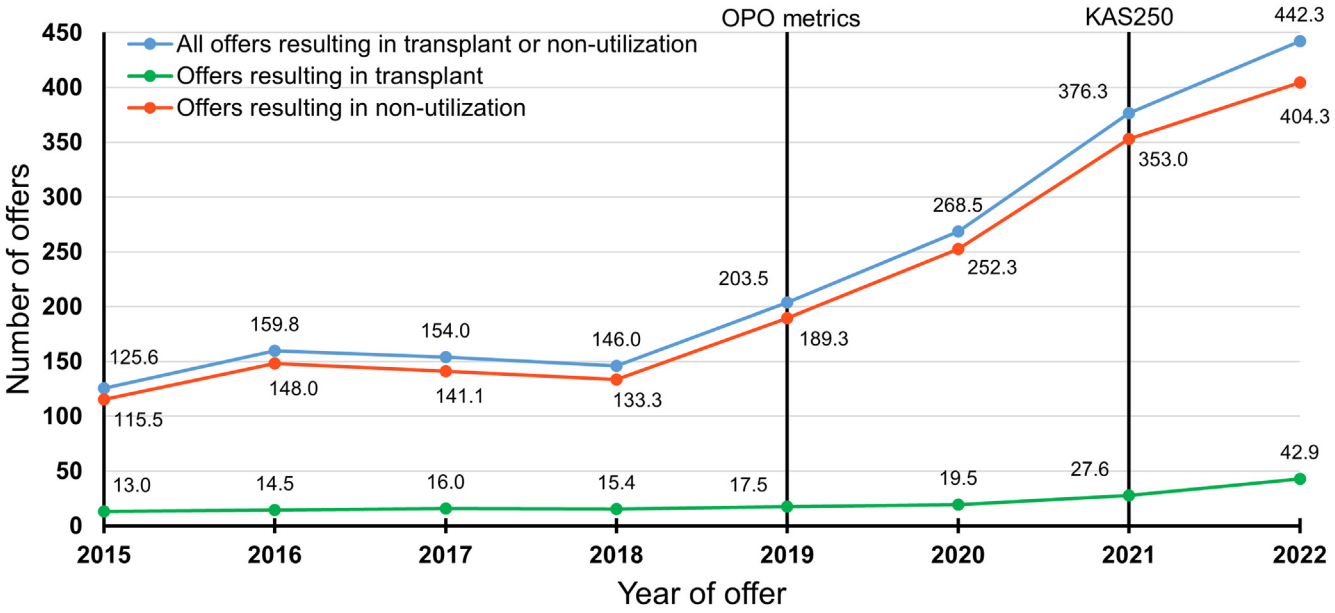

Figure 5. Number of offers per candidate in the prevalent adult kidney waitlist population, 2015 to 2022. Multiorgan, multi-listed patients, and patients with no offers were excluded. Matches that were automatically declined by the allocation system bypasses were also excluded. The blue line describes the number of offers per candidate among all offers; the orange line describes the number of offers per candidate among only offers resulting in transplant. Of note, neither transplanted nor nonutilized kidneys can be distinguished until all match-run efforts are exhausted.

circle around Salt Lake City, UT would include a population closer to 5 million people—with a very different prevalence of kidney disease—whereas more coastal parts of the country may find large portions of their corresponding circle covering the ocean.

The resulting failure to adequately consider these challenges in the current algorithm iteration may explain the steady decrease in the proportion of kidneys accepted for the intended recipient at the top of the match run—from a high of 24% to a low of just 16% of all transplanted kidneys. Meanwhile, the time

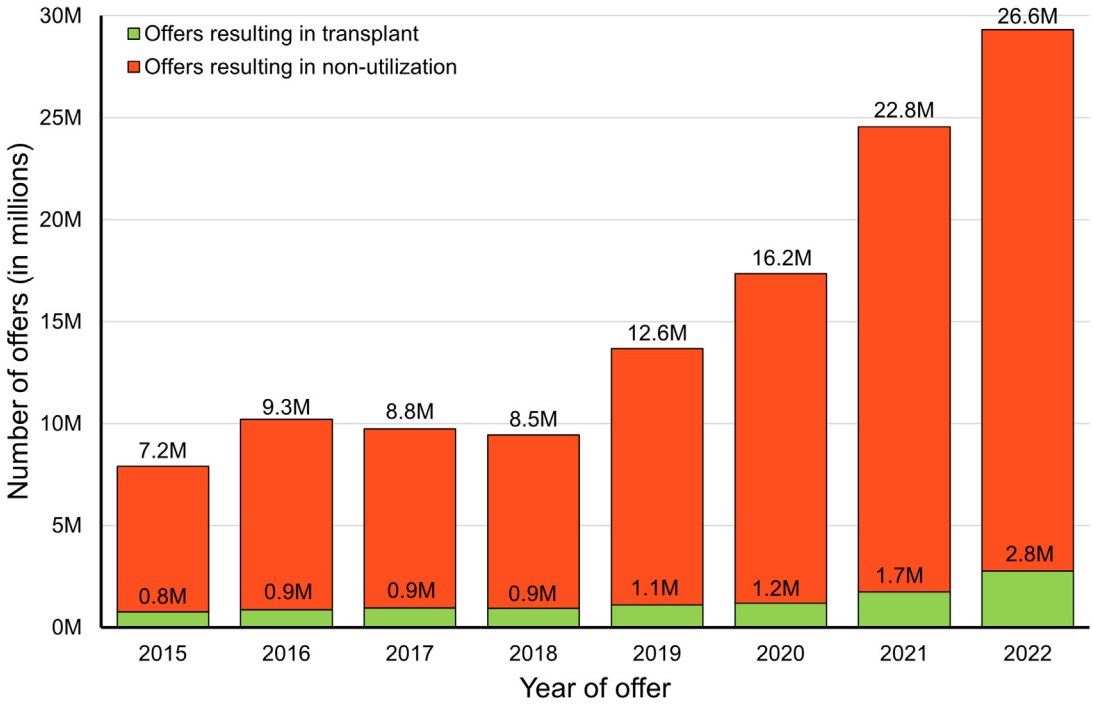

Figure 6. Total offers per year in the prevalent adult kidney waitlist population for transplanted and nonutilized kidneys, 2015 to 2022. Multiorgan, multi-listed patients, and patients with no offers were excluded. Matches that were automatically declined by the allocation system bypasses were also excluded.

and effort taken to identify the eventual recipient of an organ likely contribute to the currently growing discard rate and the increasing placement of organs out of sequence.[23]

The large number of offers and frequent declines of these offers have resulted in a steady decrease in time to the first offer after being added to the waitlist— the median time to first offer for an organ that is eventually accepted for a candidate is now a mere 7 days. Given the detrimental impact of even relatively short periods of dialysis, it is imperative that the allocation system attempts to maximize the use of organs by identifying those subsets of candidates who would benefit from accepting a less-than-ideal organ in exchange for spending little to no time on the national waitlist.[24,25]

The reasons that organs are declined, often without patients' knowledge, remain poorly understood but are likely a reflection of a bias on the part of their transplant centers that they will receive a better offer in a relatively short period of time.[2,25–27] This bias is probably valid for individuals with the highest allocation points who may be offered less-than-ideal organs amidst receiving multiple offers in quick succession. However, this bias may poorly serve individuals with few allocation points who are receiving infrequent offers and for whom the consequences of a lower quality organ may be offset by the benefits of shortened time on the waitlist.[28] At the same time, significant increases in transplants in recent years have led to facility constraints, with limited resources ultimately leading to increased declines.[13] It is important to note that these challenges are not unique to kidney transplantation given the current evidence of variable organ offer practices in both liver and heart transplantation as well.[29,30] Our findings emphasize the need to rethink our allocation algorithms and how waitlisted patients are prioritized for a given deceased donor organ in order to maximize the probability that lifesaving organs are appropriately allocated in a manner that ensure that a much higher proportion of organs are accepted for the intended recipient, thereby increasing organ utilization rates.

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DATA AVAILABILITY STATEMENT

The data used for this analysis are available upon request to the SRTR.

AUTHOR CONTRIBUTIONS

SM, MY, LM, SAH, and JDS conceptualized the study. MY was responsible for data curation and methodology and was responsible for formal analysis and visualization. SM was responsible for funding acquisition, resources, and supervision; MY, LM, and SM were responsible for writing the original draft. All the authors reviewed and edited the manuscript.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Figure S1. Median number of offers before event outcome among patients activated on the waitlist post-KAS250.

Figure S2. Cumulative incidence of transplant and death, stratified by ethnicity, among patients activated on the waitlist pre- and post-KAS250. Among the pre-KAS250 subgroup, follow-up time was censored on March 14, 2021.

Figure S3. Cumulative incidence of transplant and death, stratified by age, among patients activated on the waitlist pre- and post-KAS250. Among the pre-KAS250 subgroup, follow-up time was censored on March 14, 2021.

Figure S4. Cumulative incidence of transplant and death, stratified by sex, among patients activated on the waitlist pre- and post-KAS250. Among the pre-KAS250 subgroup, follow-up time was censored on March 14, 2021.

Table S1. Refusal codes indicating automatic bypasses.

Table S2. Characteristics of incident transplant candidates who were removed from the waiting list, 2015 to 2022.

Table S3. Removal codes among candidates who were removed from the waiting list.

Table S4. Time to first offer and event among incident transplant candidates activated on the waiting list following implementation of the 2021 distance-based kidney allocation system (KAS250) and were removed from the waiting list.

Table S5. Proportion of kidneys accepted without a decline in the prevalent adult kidney waitlist population, 2015 to 2022.

Table S6. Primary reason provided by centers for declining deceased donor kidney offers.

Table S7. Annual trends in reasons for deceased donor kidney offer refusal.

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