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Association of transplant center market concentration and local organ availability with deceased donor kidney utilization

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Although there is a shortage of kidneys available for transplantation, many transplantable kidneys are not procured or are discarded after procurement. We investigated whether local market competition and/or organ availability impact kidney procurement/utilization. We calculated the Herfindahl–Hirschman Index (HHI) for deceased donor kidney transplants (2015–2019) for 58 US donation service areas (DSAs) and defined 4 groups: HHI ≤ 0.32 (high competition), HHI = 0.33–0.51 (medium), HHI = 0.53–0.99 (low), and HHI = 1 (monopoly). We calculated organ availability for each DSA as the number kidneys procured per incident waitlisted candidate, grouped as: <0.42, 0.42–0.69, >0.69. Characteristics of procured organs were similar across groups. In adjusted logistic regression, the HHI group was inconsistently associated with composite export/discard (reference: high competition; medium: OR 1.16, 95% CI 1.11–1.20; low 1.01, 0.96–1.06; monopoly 1.19, 1.13–1.26) and increasing organ availability was associated with export/discard (reference: availability <0.42; 0.42–0.69: OR 1.35, 95% CI 1.30–1.40; >0.69: OR 1.83, 95% CI 1.73–1.93). When analyzing each endpoint separately, lower competition was associated with higher export and only market monopoly was weakly associated with lower discard, whereas higher organ availability was associated with export and discard. These results indicate that local organ utilization is more strongly influenced by the relative intensity of the organ shortage than by market competition between centers.

KEYWORDS

donors and donation: deceased, health services and outcomes research, organ allocation, organ procurement, organ procurement and allocation, organ procurement organization, organ transplantation in general

Abbreviations: CI, confidence interval; DSA, donation service area; ESKD, end stage kidney disease; HCV, hepatitis C virus; HHI, Herfindahl–Hirschman Index; KAS, Kidney Allocation System; OPO, organ procurement organization; OR, odds ratio.

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1 | INTRODUCTION

Kidney transplantation provides better survival, quality of life, and cost effectiveness compared to dialysis for patients with end-stage kidney disease (ESKD).[1–5] Unfortunately, given the organ shortage in the United States, most patients with ESKD never receive a transplant, and even those who do typically spend several years on the waiting list prior to transplantation.[6,7] Despite this mismatch between organ supply and demand, there is suboptimal procurement and utilization of deceased donor kidneys in the United States.[8–11] More than 1000 potentially transplantable kidneys are never procured each year, over 99% of organ offers for kidneys that are ultimately transplanted are declined, and approximately 20% of procured kidneys are discarded.[7,9,12–14] Given the disproportionate impact of ESKD cost on annual Medicare spending, understanding and improving deceased donor kidney utilization has been a major focus of the federal government.

Suboptimal rates of kidney procurement/utilization despite demand that outpaces supply suggests a market failure, especially since many unused kidneys are likely transplantable.[9,15,16] Much scrutiny has been placed on subjective assessments by organ procurement organizations (OPOs) and transplant centers when determining whether to procure a given kidney and whether a given organ offer should be accepted for transplantation, respectively. OPOs are federally-designated not-for-profit entities exclusively responsible for organ procurement within each of the nation's donation service areas (DSAs); the decision to procure a donor kidney is left to the discretion of the potential donor hospital's OPO. Kidneys procured for transplant are offered to centers on behalf of their waitlisted candidates, but centers can accept/decline each offer based on criteria of their own choosing. The subjectivity of these decisions appears to be independent of organ quality and leads to considerable practice variations.[17,18] Organs that experience frequent turndowns are more likely to be discarded, and this processes has been hypothesized to create a negative feedback loop that discourages OPOs from procuring marginal quality organs. Improving organ procurement and subsequent acceptance is therefore key to expanding kidney transplantation in the United States.

Two factors that may influence procurement and utilization practices are local organ availability and market competition between centers. To maintain transplant volume, centers in DSAs where the relative shortage of donated kidneys is more intense may be more willing to utilize less-than-ideal kidneys compared to centers facing a less-intense organ shortage. Additionally, centers in markets where center competition is high may similarly be more willing to utilize such kidneys due to the pressures of local competition. Understanding the role of each of these factors can help inform transplant policy aimed at improving utilization, including adding incentives and removing barriers to open new transplant centers. We therefore aimed to assess the impact of transplant center market concentration and local organ availability on organ utilization. The recent implementation of KAS250 also makes the impact of these market forces particularly important to understand, as this allocation change was projected to make organ availability less heterogeneous (which was its goal) but also increase market competition for individual organs as we have previously described.[19]

2 | METHODS

We conducted a retrospective cohort study using United States data from the Scientific Registry of Transplant Recipients. We identified all deceased donor kidneys procured for the purpose of transplantation from 2015–2019, whether or not they were ultimately transplanted ($n = 93\,085$). To analyze local kidney utilization, we excluded 4455 kidneys used as part of multi-organ transplants and 5404 kidneys used in kidney-only transplants for candidates with calculated panel reactive antibody (CPRA) ≥99%, yielding a primary cohort of 83 226 recovered kidneys.

2.1 | Exposure variables

We defined the market concentration of each of 58 US donation service areas (DSAs) by calculating the Herfindahl–Hirschman Index (HHI) for deceased donor kidney transplants performed 2015–2019, a period following the implementation of the Kidney Allocation System ("KAS") but before a transition to circle allocation ("KAS250"), using the Stata HHI module.[20] HHI is a measure of market competition ranging from 0 to 1 in which higher values indicate reduced competition within a given market. This study period allowed the analysis of well-defined allocation markets (i.e. DSAs). We also calculated the HHI based on all (living and deceased) transplants, but given the strong correlation between the two values, all analyses used only HHI derived from deceased donor transplants (Figure 1). HHI was subsequently categorized into 4 groups: HHI ≤ 0.32 (high competition), HHI = 0.33–0.51 (medium competition), HHI = 0.53–0.99 (low competition), HHI = 1 (no competition/monopolistic), thresholds used by prior investigators.[21]

Organ availability ratio for the study period was defined for each DSA as the number of deceased donor kidneys procured divided by the number of incident candidates (ie number of patients added to the waitlist across all centers in a DSA) as previously described.[14] Organ availability ratio was categorized into 3 groups based on the distribution among DSAs (lowest quartile: <0.42, middle 50%: 0.42–0.69; highest quartile: >0.69).

Variables included in analytic models were selected a priori based on clinical relevance and availability in the dataset (see Data S1).

2.2 | Outcomes

We identified three potential dispositions for procured kidneys: (1) "Local Transplant"—transplant within the DSA of procurement; (2) "Export-to-Transplant"/"Export"—transplant outside of the OPO of procurement; (3) "Discard"—not transplanted. We defined 3

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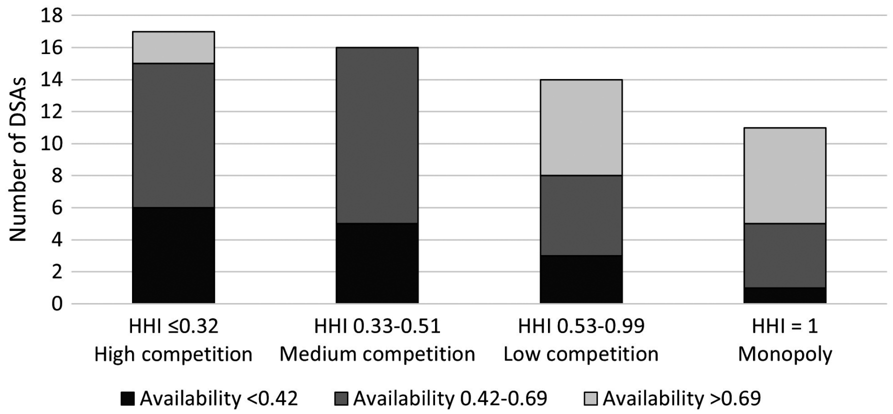
FIGURE 1 Distribution of organ availability group by market competition group. HHI, Herfindahl–Hirschman Index



outcomes of interest indicative of potential local underutilization: discard, export, and a combined outcome of export/discard.

2.3 | Statistical analysis

We first grouped kidneys by HHI group of the DSA of procurement and by organ availability ratio group of the DSA of procurement and compared donor characteristics and final disposition using chi-squared and ANOVA tests for categorical and continuous variables, respectively. Next, we grouped kidneys by final disposition and compared donor characteristics across groups as above.

We used logistic regression to calculate the odds of each outcome (discard, export, and export/discard) in unadjusted models separately by HHI group and by organ availability ratio group. We then recalculated the odds of each outcome in adjusted logistic regression models that included both HHI group and organ availability ratio group, as well as donor characteristics (see Data S1).

We then conducted an exploratory post-hoc analysis to assess whether the relationship between market competition and organ disposition differed based on the organ availability of the recovering DSA. We stratified the primary cohort by organ availability group, then repeated the logistic regression analyses above within each group.

We next used unadjusted linear regression to display the correlation (Spearman's correlation coefficient) between DSA organ availability ratio or DSA HHI as continuous variables with the proportion of kidneys exported, discarded, or exported/discarded.

Finally, we conducted a sensitivity analysis repeating the logistic regression analyses above after restricting the cohort to kidneys from the primary cohort with KDPI ≤ 85%, then to those with KDPI > 85%.

Statistical significance was identified by a two-sided $\alpha < 0.05$. Analyses were performed using Stata/MP17 (StataCorp).

3 | RESULTS

Among the nation's 58 DSAs during the study period, 11 (19%) had center monopolies during the study period (i.e., only one transplant center within the DSA). Of the remainder, 17 (29%) had high competition, 16 (28%) had medium competition, and 14 (24%) had low competition (Figure 1). Organ availability ratio was <0.42 in 15 (26%) DSAs, 0.42–0.69 in 29 (50%) DSAs, and >0.69 in 14 (24%) DSAs, with a greater proportion of monopolistic DSAs in the highest organ availability group (55%) compared to those with high (12%), medium (0%), or low (43%) competition (Figure 1). When treated as a continuous variable, organ availability ratio was highest in monopolistic DSAs (median 0.71, IQR 0.62–0.96), followed by low competition (0.62, 0.49–0.78), medium competition (0.49, 0.35–0.64), and high competition (0.44, 0.38–0.55) ($p = .01$).

3.1 | Characteristics of recovered kidneys

A total of 83 226 deceased donor kidneys were included in the primary analysis. Donors had a median age 41 years, 40% were female, and 15% had Black race.

Differences in key donor characteristics including age, sex, height, weight, diabetes, hypertension, and final creatinine between kidneys procured in DSAs of each HHI group were statistically significant but not clinically meaningful (Table 1). However, there was larger variation in the proportion of kidneys from Black donors (range 14%–19%), donors with a >20 pack-year smoking history (range 20%–24%), and donors after cardiac death (range 19%–24%) by competition group.

Similarly, there were no meaningful differences in donor age, sex, height, weight, diabetes status, hypertension status, donation after cardiac death, and final creatinine between kidneys procured in DSAs of each organ availability group (Table 2). However, there was again larger variation in the proportion of kidneys from donors with a >20 pack-year smoking history (range 19%–24%).

3.2 | Disposition of recovered kidneys

Among all procured kidneys, 55% were locally transplanted within the DSA of procurement, 23% were export-to-transplant, and 22% were discarded. When analyzing kidneys grouped by disposition, there were large differences in donor age, diabetes, hypertension,

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TABLE 1 Characteristics of procured kidneys by transplant center market concentration of the donation service area of procurement

n (column %) or median (IQR)	All *n* = 83 226 (100)	HHI ≤ 0.32 *n* = 38 609 (46)	HHI 0.33–0.51 *n* = 23259 (28)	HHI 0.53–0.99 *n* =13265 (16)	HHI = 1 *n* = 8093 (10)	*p*
Age, years	41 (27–54)	42 (28–54)	40 (27–53)	40 (27–53)	42 (27–55)	<.001
Female	33120 (40)	15278 (40)	9378 (40)	5369 (40)	3095 (38)	.003
Black/African American	12568 (15)	5301 (14)	3642 (16)	2069 (16)	1556 (19)	<.001
Height, cm	170 (163–178)	170 (163–178)	170 (163–178)	173 (165–180)	173 (164–178)	<.001
Weight, kg	80 (67–95)	80 (67–96)	80 (67–95)	80 (68–95)	80 (67–96)	.009
Diabetes	8826 (11)	4295 (11)	2422 (10)	1258 (10)	851 (11)	<.001
Hypertension	27955 (34)	13135 (34)	7773 (33)	4257 (32)	2790 (34)	<.001
Final creatinine, mg/dl	1.0 (0.7–1.5)	1.0 (0.7–1.6)	1.0 (0.7–1.5)	1.0 (0.7–1.5)	1.0 (0.7–1.5)	<.001
Donation after cardiac death	18145 (22)	9399 (24)	4501 (19)	2675 (20)	1570 (19)	<.001
HCV positive or indeterminate	3890 (5)	1692 (4)	1122 (5)	763 (6)	313 (4)	<.001
>20 pack-year smoker	17658 (21)	7892 (20)	4878 (21)	3148 (24)	1740 (22)	<.001
Disposition						
Local transplant	45818 (55)	21703 (56)	12839 (55)	7212 (54)	4064 (50)	<.001
Export transplant	19337 (23)	8008 (21)	5495 (24)	3422 (26)	2412 (30)	
Discard	18071 (22)	8898 (23)	4925 (21)	2631 (20)	1617 (20)	

Abbreviations: HCV, hepatitis C virus; HHI, Herfindahl–Hirschman Index.

TABLE 2 Characteristics of procured kidneys by organ availability of the donation service area of procurement

n (column %) or median (IQR)	All *n* = 83226 (100)	Availability <0.42 *n* = 21192 (25)	Availability 0.42–0.69 *n* = 47576 (57)	Availability >0.69 *n* = 14458 (17)	*p*
Age, years	41 (27–54)	42 (28–54)	41 (27–54)	41 (27–54)	.04
Female	33120 (40)	8838 (39)	19409 (40)	5733 (40)	.21
Black/African American	12568 (15)	3550 (17)	6703 (14)	2315 (16)	<.001
Height, cm	170 (163–178)	170 (163–178)	170 (163–178)	173 (165–180)	<.001
Weight, kg	80 (67–95)	80 (68–95)	80 (67–96)	80 (67–95)	.36
Diabetes	8826 (11)	2092 (10)	5244 (11)	1490 (10)	<.001
Hypertension	27955 (34)	6944 (33)	16102 (34)	4909 (34)	.01
Final creatinine, mg/dl	1.0 (0.7–1.5)	1.0 (0.7–1.5)	1.0 (0.7–1.6)	1.0 (0.7–1.5)	<.001
Donation after cardiac death	18145 (22)	4332 (20)	10636 (22)	3177 (22)	<.001
HCV positive or indeterminate	3890 (5)	962 (5)	2298 (5)	630 (4)	.04
>20 pack-year smoker	17658 (21)	4040 (19)	10126 (21)	3492 (24)	<.001
Disposition					
Local transplant	45818 (55)	12873 (61)	25819 (54)	7126 (49)	<.001
Export transplant	19337 (23)	4208 (20)	10840 (23)	4289 (30)	
Discard	18071 (22)	4111 (19)	10917 (23)	3043 (21)	

Abbreviation: HCV, hepatitis C virus.

final creatinine, HCV, and smoking, with discarded kidneys more likely to come from donors with higher-risk characteristics (Table S1). Among transplanted kidneys, those transplanted locally had lower median cold ischemia time at transplant (14.6, IQR 10.0–19.5 h vs 23.5, IQR 18.4–29.7, $p < .001$) and a lower raw incidence of delayed graft function (26% vs 29%, $p < .001$) compared to those that were exported, although each of these variables was missing for 21% of exported kidneys.

Disposition differed significantly by HHI group of the procuring DSA ($p < .001$, Table 1). Local transplant increased with increasing

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competition (monopolistic: 50%, low: 54%; medium: 55%; high: 56%), whereas export-to-transplant decreased as competition increased (30%, 26%, 24%, 21%). The proportion of kidneys discarded ranged from 20% to 23% across HHI groups and was highest among kidneys procured in high-competition markets. Disposition also differed significantly by organ availability group of the DSA of procurement ($p < .001$, Table 2), as local transplant decreased with increasing organ availability (availability <0.42: 61%, availability 0.42–0.69: 54%, availability >0.69: 49%) whereas export-to-transplant increased as organ availability increased (20%, 23%, 30%).

In unadjusted logistic regression models, HHI group (reference: high competition; medium: OR 1.07, 95% CI 1.04–1.11, $p = .01$; low 1.08, 1.04–1.12, $p < .001$; monopolistic 1.27, 1.21–1.34, $p < .001$) and organ availability group (reference: availability <0.42; availability 0.42–0.69: OR 1.30, 95% CI 1.26–1.35, $p < .001$; availability >0.69: OR 1.60, 95% CI 1.53–1.66, $p < .001$) were associated with the composite outcomes of export/discard (Table 3). In adjusted models, HHI group was inconsistently associated with export/discard (reference: high competition; medium: OR 1.16, 95% CI 1.11–1.20, $p < .001$; low 1.01, 0.96–1.06, $p = .81$; monopolistic 1.19, 1.13–1.26, $p < .001$) but there was a strong relationship between organ availability ratio and export/discard (reference: availability <0.42; availability 0.42–0.69: OR 1.35, 95% CI 1.30–1.40, $p < .001$; availability >0.69: OR 1.83, 95% CI 1.73–1.93, $p < .001$). When analyzing discard and export-to-transplant as separate outcomes, only monopolistic HHI group was associated with lower adjusted odds of discard (reference: high competition; medium: OR 0.99, 95% CI 0.94–1.03, $p = .57$; low 0.95, 0.89–1.01, $p = .12$; monopolistic 0.85, 0.79–0.91, $p < .001$) and higher organ availability ratio was associated with higher odds of discard (reference: availability <0.42; availability 0.42–0.69: OR 1.28, 95% CI 1.22–1.34, $p < .001$; availability >0.69: OR 1.29, 95% CI 1.20–1.38, $p < .001$). However, each of these DSA characteristics remained strongly associated with export even after adjusting for donor characteristics (HHI group- reference: high competition; medium: OR 1.24, 95% CI 1.19–1.30, $p < .001$; low 1.07, 1.01–1.13, $p = .02$; monopolistic 1.37, 1.29–1.46, $p < .001$; organ availability ratio- reference: availability <0.42; availability 0.42–0.69: OR 1.32, 95% CI 1.27–1.38, $p < .001$; availability >0.69: OR 1.95, 95% CI 1.29–1.46, $p < .001$) (Table 3).

In a post-hoc analysis exploring whether the relationship between market competition and organ disposition differed based on the organ availability of the recovering DSA, the relationship between HHI group and export/discard, export, and discard varied by organ availability ratio group (Tables S2 and S3). However, this analysis was limited by the small number of distinct DSAs represented in many subgroups (Figure 1).

When examining HHI and organ availability ratio as continuous variables, organ availability ratio had a significant positive linear correlation with export ($r = 0.48$, $p < .001$) and export/discard ($r = 0.47$, $p < .001$), but no correlation with discard alone ($r = 0.13$, $p = .32$) (Figure 2). Similarly, HHI had no correlation with discard ($r = -0.16$, $p = .23$) but was modestly correlated with export ($r = 0.42$, $p < .001$) and export/discard ($r = 0.28$, $p = .04$).

3.3 | Sensitivity analysis

Finally, we conducted a sensitivity analysis stratifying kidneys in the primary cohort at a threshold of KDPI 85%. Among kidneys with KDPI ≤ 85%, decreasing DSA competition was associated with a lower proportion of recovered kidneys being transplanted locally (high: 64%, medium: 63%, low: 60%, monopolistic: 58%) and a higher proportion of recovered kidneys exported-to-transplant (22%, 24%, 26%, 30%) (Figure 3A). Increasing organ availability was associated with lower local transplant (availability <0.42: 68%, availability 0.42–0.69: 62%, availability >0.69: 57%) but higher export-to-transplant (20%, 24%, 30%) (Figure 3).

Among kidneys with KDPI > 85%, there were similar relationships although the proportion of kidneys that were discarded was higher overall. The proportion of recovered kidneys transplant locally was lowest in monopolistic DSAs (high competition: 22%, medium: 18%, low: 20%, monopolistic: 14%) and in those with the highest organ availability (availability <0.42: 28%, availability 0.42–0.69: 18%, availability >0.69: 13%). In contrast, the proportion exported-to-transplant was highest in monopolistic DSAs (high competition: 17%, medium: 23%, low: 23%, monopolistic: 29%) and those with the highest organ availability (availability <0.42: 19%, availability 0.42–0.69: 19%, availability >0.69: 29%). Over 50% of these kidneys were discarded in each DSA group.

In adjusted logistic regression, the associations of HHI group and organ availability ratio group and organ disposition were similar to the primary analysis for kidneys with KDPI ≤ 85% and those with KDPI > 85%, with the exception of a lack of a significant relationship between DSA monopoly and discard of kidneys with KDPI > 85% (Table S4).

4 | DISCUSSION

There has been recent regulatory scrutiny on the influence of suboptimal deceased donor kidney procurement and utilization practices on propagating the shortage of organs available for transplant. Optimizing organ utilization requires understanding the factors that inappropriately reduce the procurement and acceptance of transplantable kidneys in order to inform policy solutions to reduce kidney discard and ensure that allocation system changes do not have adverse upstream effects.[13,22] In this retrospective analysis, we found that market competition was not meaningfully associated with the characteristics of kidneys that were procured among the 58 DSAs in the study. There was a small but significant association between market monopoly and lower kidney discard, but kidneys procured in less competitive DSAs were more likely to be exported than kidneys procured in more competitive DSAs. A higher organ availability ratio was strongly associated with the likelihood of export and modestly with discard, and the linear relationships between DSA characteristics and each organ disposition were strongest for organ availability. Together, these findings indicate that local organ availability has a

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TABLE 3 Association of donation service area market concentration and organ availability ratio with deceased donor kidney disposition

	Unadjusted			Adjusted[a]		
	OR	95% CI	*p*	OR	95% CI	*p*
Export or discard						
HHI group						
HHI ≤ 0.32 (high competition)	Reference			Reference		
HHI 0.33–0.51 (medium competition)	1.07	1.04–1.11	.01	1.16	1.11–1.20	<.001
HHI 0.53–0.99 (low competition)	1.08	1.04–1.12	<.001	1.01	0.96–1.06	.81
HHI = 1 (monopoly)	1.27	1.21–1.34	<.001	1.19	1.13–1.26	<.001
Organ availability ratio group						
Availability ratio <0.42	Reference			Reference		
Availability ratio 0.42–0.69	1.30	1.26–1.35	<.001	1.35	1.30–1.40	<.001
Availability ratio >0.69	1.60	1.53–1.66	<.001	1.83	1.73–1.93	<.001
Export						
HHI group						
HHI ≤ 0.32 (high competition)	Reference			Reference		
HHI 0.33–0.51 (medium competition)	1.16	1.11–1.21	<.001	1.24	1.19–1.30	<.001
HHI 0.53–0.99 (low competition)	1.29	1.23–1.35	<.001	1.07	1.01–1.13	.02
HHI = 1 (monopoly)	1.61	1.52–1.70	<.001	1.37	1.29–1.46	<.001
Organ availability ratio group						
Availability ratio <0.42	Reference			Reference		
Availability ratio 0.42–0.69	1.28	1.23–1.34	<.001	1.32	1.27–1.38	<.001
Availability ratio >0.69	1.84	1.75–1.94	<.001	1.95	1.83–2.07	<.001
Discard						
HHI group						
HHI ≤ 0.32 (high competition)	Reference			Reference		
HHI 0.33–0.51 (medium competition)	0.90	0.86–0.93	<.001	0.99	0.94–1.03	.57
HHI 0.53–0.99 (low competition)	0.83	0.79–0.87	<.001	0.95	0.89–1.01	.12
HHI = 1 (monopoly)	0.83	0.79–0.88	<.001	0.85	0.79–0.91	<.001
Organ availability ratio group						
Availability ratio <0.42	Reference			Reference		
Availability ratio 0.42–0.69	1.24	1.19–1.29	<.001	1.28	1.22–1.34	<.001
Availability ratio >0.69	1.11	1.05–1.17	<.001	1.29	1.20–1.38	<.001

Abbreviation: HHI, Herfindahl–Hirschman Index.

[a]Adjusted models include HHI group, organ availability ratio group, and donor age, female sex, Black/African American race, height, weight, diabetes status, hypertension status, final creatinine, donation after cardiac death status, hepatitis C virus status, and >20 pack-year smoker status.

greater impact on centers' utilization practices than the presence of market competitors.

In a prior study of the impact of market competition on a subset of OPO performance metrics, we found that higher competition was associated with a higher number of eligible deaths and lower quality of accepted organs.[23] The current analysis adds to those findings by studying the quality of recovered organs rather than accepted organs, as well as by both demonstrating the impact of competition on organ disposition and accounting for organ availability as an opposing force to consider, the latter of which might explain our prior finding that higher competition was associated with high patient mortality and longer waitlists—but not the number of transplants per capita—within a given DSA.[21] In the current analysis, we found that DSA-level characteristics of procured organs were similar regardless of competition group, indicating a lack of influence of competition on the range of procured organ quality despite the fact that less competitive DSAs also had higher organ availability. Further, when considering kidney disposition, the differences between competition groups in the median proportion of kidneys that were discarded (20%–23%) was small compared to the differences in the proportion of kidneys exported (21%–30%).

The analysis of both export and discard of procured kidneys adds a new layer to existing literature on kidney utilization, and the combination of both outcomes provides a more complete picture of local willingness to transplant organs within the market

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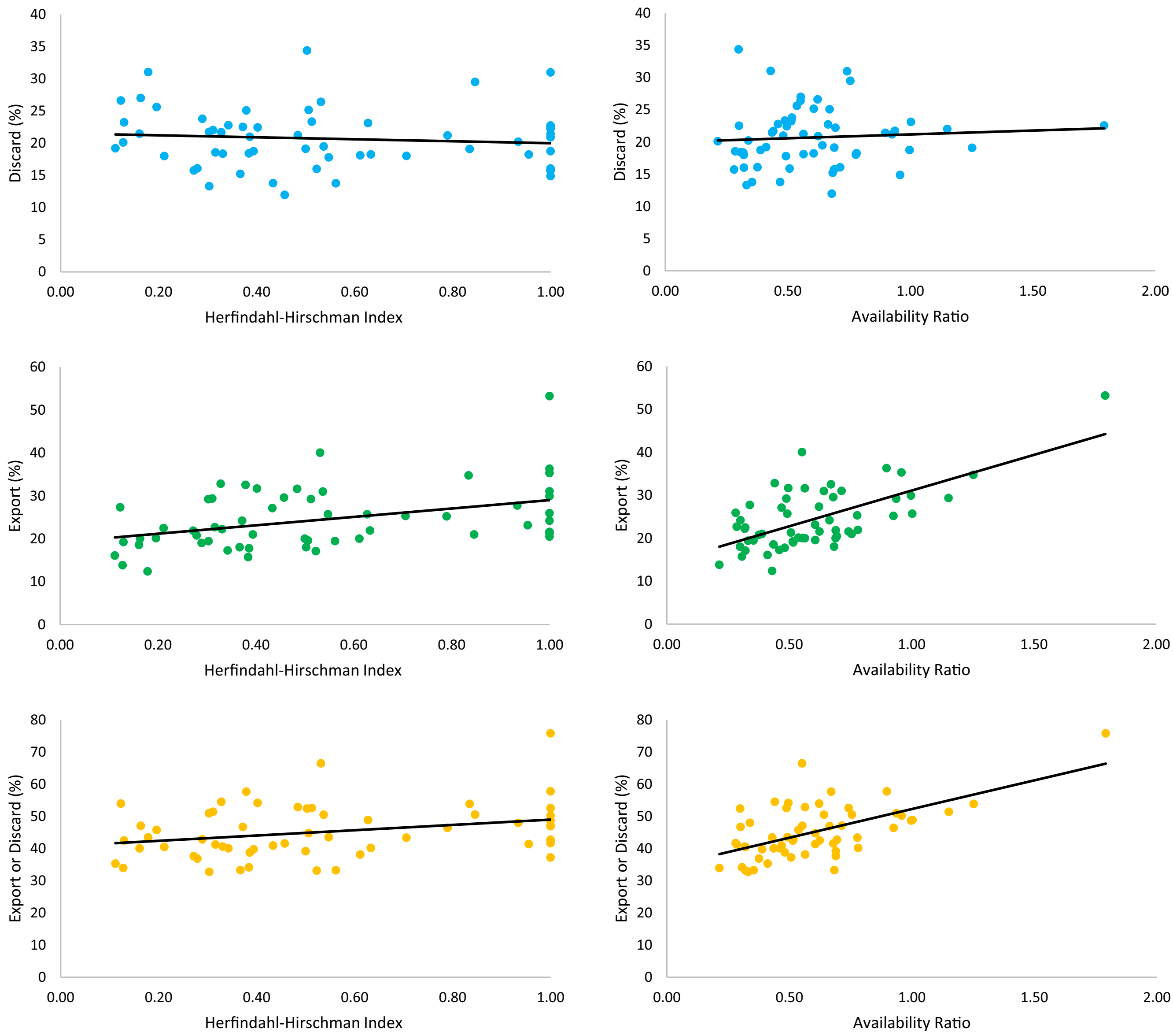

FIGURE 2 Donation service area level association of market concentration or deceased donor kidney availability ratio with local organ nonutilization

of recovery compared to examining discard alone. DSA-based allocation that preceded KAS250 allowed the definition of a local market in which all centers had access to organs before they were exported. Although there has been increasing scrutiny on organ discard, kidneys in our study that are exported or discarded have the same outcome from the standpoint of the local market, in that they were declined by all local centers within a DSA on behalf of all of their patients. In fact, exports may best represent missed opportunities for transplant during the DSA-based allocation era, since these organs were deemed to be transplantable by another center and therefore might have benefitted local candidates with low waitlist priority who otherwise have ongoing time on the waitlist during which they risk death, delisting, or the accumulation of comorbidities that worsen post-transplant outcomes.[6,7,24,25]

Local utilization and procurement have been typically thought to be related, given that OPOs may be less willing to procure kidneys that will ultimately be discarded.[26] However, although the overall pool of potentially recoverable organs is difficult to ascertain precisely, our findings that donor characteristics were similar between groups but the odds of export varied indirectly suggest that individual OPOs are willing to procure kidneys that will ultimately need to be exported. However, even though OPO procurement practices may be insensitive to local center competition, the potential impact of reducing the consequences for OPOs who procure organs that are ultimately not placed nevertheless warrants study. It may also be reasonable to place independent scrutiny on transplant center organ offer acceptance practices, such as through the proposed addition of organ acceptance ratio as a formal transplant program quality metric. This is especially true given the likely impact of ongoing

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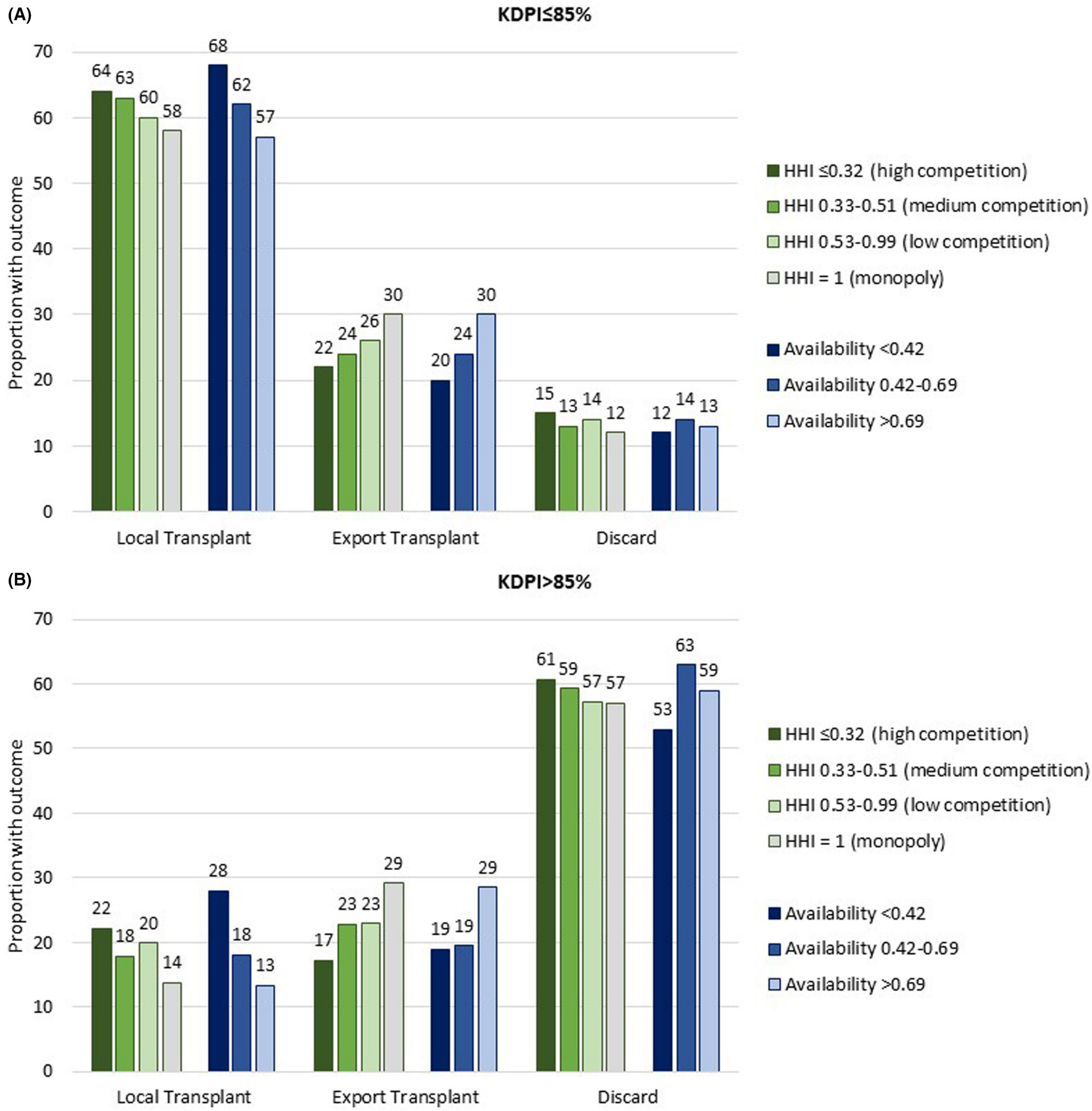

FIGURE 3 Disposition of kidneys in the primary cohort with Kidney Donor Profile Index (KDPI) <85% (A) or ≥85% (B) by market concentration or deceased donor kidney availability ratio groups. Abbreviations: HHI, Herfindahl–Hirschman Index

regulatory pressure OPOs from federal bodies aimed at increasing the number of organs available for transplant.[27] It will also be important to study the potential impact of revisions to the outcomes measures in the OPO Conditions for Coverage Final Rule which took force in November 2020.[28] It is possible that, by increasing OPO recovery rates, this policy change may impact local organ utilization via changes in the quantity and quality of organ offers received by local centers serviced by previously low-performing OPOs. Similarly, in the absence of an association between market competition and procurement practices, identifying and addressing other factors that influence OPO recovery performance—such as leadership strategies and operational practices—will be a key part of maximizing the number of organs recovered for transplant.

The small association between decreased market competition and increased kidney export suggests that center-level utilization decisions are not primarily a response to local competition for organs from other centers. It is therefore unlikely that incentivizing increased transplant center competition by encouraging the opening of additional centers will increase local utilization or reduce system-wide discards. Similarly, insofar as it increases local competition for

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donated organs, the elimination of DSA borders as implemented through KAS250 cannot be relied upon to meaningfully improve kidney utilization and may actually have the opposite effect.[29] Our results suggest that kidneys are less likely to be locally utilized when centers are faced with a less intense local organ shortage, reflected in our analysis by a higher organ availability ratio. Further, the weaker associations of both competition and organ availability with discard (compared to export) suggest that organs procured in DSAs with less competition and more selective centers are nevertheless likely to find accepting centers elsewhere. These findings are concordant with prior evidence that centers decline organ offers on behalf of candidates in anticipation of a better organ offer within a reasonable time frame, an event that is perceived to be more likely when organ availability is higher.[12] As a result, only a minority of transplanted kidneys are used for the candidate with the highest priority for that organ.[12] However, such reasoning often results in detrimental outcomes for patients given that each declined offer increases the time patients spend on dialysis and that nearly a third of these patients will die or be removed from the waitlist without ever receiving a transplant.[7] Importantly, the persistence of the relationships of DSA market concentration and organ availability with organ disposition for kidneys with KDPI ≤ 85% and >85% in our study also indicates that these market forces impact the local willingness to use both standard-quality and low-quality organs.

The recent kidney allocation change to allocation based on circles centered around donor hospitals was intended to decrease heterogeneity in organ availability, in part by making more centers "local" to a given organ.[29,30] Based on our analysis, decreasing center-to-center variability in organ availability may lead to centers in previously high-availability areas (who are used to declining and allowing the export of kidneys) to increase their offer acceptance to maintain transplant volume. It is also possible that centers whose perceived organ shortage decreases as they gain access to additional "local" kidneys may likewise become less willing to transplant marginal organs rather than maintain the same acceptance criteria and increase the number of transplants being performed. These bidirectional changes may negate each other, resulting in a lack of improvement in utilization—and perhaps even an increased discard rate—under KAS250. Importantly, the market competition centers face with each offer will now vary based on the location of each donor's hospital, and allocation complexity will increase as OPOs and transplant centers interact in ways they have not before.[19] Additionally, our data suggests that increasing the number of "local" centers with which each OPO interacts is unlikely to change the characteristics of the organs that are procured. In this new system, monitoring the effects on procurement, discard, and utilization among the OPOs and transplant centers experiencing the most change in market complexity will be critical.

Center-level incentives that promote organ utilization must be developed, tested, and implemented. Both the large degree of heterogeneity between centers in the willingness to utilize less-than-ideal organs and the correlation of organ offer acceptance rates with the center-level probability of transplantation are well-established.[31,32] Incentives such as higher reimbursements for utilizing organs at high risk for discard, fast-track allocation of these organs to centers likely to use them, and/or public recognition on patient-facing sites may improve utilization. Additionally, factors that disincentivize utilization must be eliminated. Updating transplant center regulatory metrics to decrease the focus on early post-transplant outcomes was an important first step in accomplishing these goals.[33-36] Other strategies may also have a role, such as reducing the negative patient-level consequences of rare early allograft failures and increasing reimbursement to account for the increased initial cost of care when using less-than-ideal organs.[37,38]

Strengths of our study include the use of nationwide data and established markers of competition and organ availability. Limitations include the possibility of residual confounding. Given that the denominator of all potentially procurable organs is not captured in any registry, our analysis of procurement practices is limited to comparing the characteristics of procured organs rather than a direct analysis of the likelihood of organ procurement. Importantly, the organ availability ratio can be influenced by both the numerator (more organs procured) or the denominator (fewer registrants on the waitlist compared to the true extent of transplantable patients). Although we define organ availability based on number of incident waitlisted candidates, it is possible centers are also responsive to the availability of organs relative to the total burden of patients with ESKD in their catchment area, including those never waitlisted. Additional research is needed regarding how to accurately identify the market pressures generated by this group of patients unaccounted for in the current analysis. To fully understand these findings, there must also be further study of the impact of center competition on waitlisting practices, which may also affect relative organ availability and the number of local offers extended.

In conclusion, we found that procured deceased donor kidneys had similar characteristics regardless of the market competition of the DSA of procurement. Procurement in a monopolistic DSA was associated with a higher likelihood of kidney export and lower likelihood of discard, and there was a strong association between procuring DSA organ availability and kidney export. Thus, while the recent allocation system changes that increase organ sharing may modestly increase local kidney utilization through increased competition, additional changes are likely to be necessary to improve utilization more broadly and decrease kidney discard.

DISCLAIMERS

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donor, wait-listed candidates, and transplant recipients in the US, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration (HRSA), US Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors.

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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.

DISCLOSURE

The authors of this manuscript have conflicts of interest to disclose as described by the *American Journal of Transplantation*. SM reports grant support and is a member of the scientific advisory board for Angion Biomedica. The other authors declare that they have no conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

Data used in this study are available upon request to the SRTR.

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SUPPORTING INFORMATION

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