Geographic Variation in the Availability of Deceased Donor Kidneys per Wait-Listed Candidate in the United States

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The burden of end-stage kidney disease is increasing in the United States alongside a worsening shortage of organs for transplantation that is exacerbated by the suboptimal recovery and inappropriate discard of kidneys from deceased donors.[1–3] Despite a stated goal of eliminating candidate location as a factor determining likelihood of transplantation, known geographic disparities in access to transplantation have persisted even under the new allocation system.[4] The current kidney allocation system first offers deceased donor kidneys to eligible candidates within the donation service area (DSA) where they were recovered, followed by the Organ Procurement and Transplantation Network region, and then finally nationwide.[5] Solid organ recovery success rates are variable, and a precise estimate of the number of potential organ donors within a DSA is difficult to ascertain. However, the number of deceased donors from whom at least 1 solid organ was recovered is available, and often 1 or both kidneys are not recovered from these donors (i.e., these are heart, lung, or liver donors from whom at least 1 kidney was not recovered). Thus, the aggregate number of kidneys from all solid organ donors represents a minimum estimate of the total number of deceased donor kidneys available for recovery in the United States from existing solid organ donors. We aimed to describe regional and DSA-level differences in deceased donor kidney recovery to assess whether improving deceased donor kidney recovery from existing solid organ donors and utilization rates could help mitigate geographic disparities in transplantation.

Using Scientific Registry of Transplant Recipients data, we identified all deceased donors with any solid organ recovered in the United States between January 1, 2015, and June 1, 2018, including donors who did not have their kidneys recovered. We excluded those without consent for kidney donation and those with a kidney recovered for reasons other than transplantation (e.g., for research) for a final cohort of 33,172 potential deceased kidney donors. Assuming 2 recoverable kidneys per solid organ donor, we calculated the proportion of kidneys that were actually recovered ("recovery rate") as the number of kidneys recovered for transplantation as a fraction of the total number of kidneys in donors who had at least 1 organ recovered for transplantation. In addition, we calculated the proportion of recovered kidneys discarded without being transplanted ("discard rate"), and the Kidney Donor Profile Index (KDPI) (using a 2015 scaling factor) as a measure of organ quality.

We calculated the ratio of kidneys recovered to the number of adult (age ≥18 years) candidates added to the wait-list during the same study period within each DSA and region. We estimated how many additional kidneys could have been recovered and transplanted during this period from existing organ donors and the resulting ratio of kidneys to candidates if each region had performed at the same recovery and discard rates as the most efficient region (region 6) currently. We compared the proportion recovered, discarded, and KDPI across the 58 DSAs and 11 regions using χ^2 and Kruskal-Wallis tests. Analyses were conducted in Stata 15.1 (StataCorp, College Station, TX) with 2-sided alpha of 0.05.

Nationwide, there were 126,011 incident kidney transplant candidates wait-listed and 33,172 deceased donors who donated at least 1 solid organ during our study period. The proportion of kidneys recovered, discarded, and the organ quality (KDPI) of kidneys from these donors varied significantly across DSAs and regions (all $P < 0.001$). Potential organ-per-candidate ratio varied widely across DSAs, ranging from 0.21 to 1.79 kidneys recovered per newly listed candidate (Figure 1). Only 5 DSAs (each of which was in a different Organ Procurement and Transplantation Network region) had more kidneys recovered than candidates added to the wait-list. There was considerable variation in organ-per-candidate ratio between DSAs within the same regions, highlighted by region 5 containing the DSA with the highest ratio of kidneys recovered per candidate (1.79) and the second lowest (0.28). There was also wide variation in the proportion of kidneys discarded: the DSA with the lowest discard rate of recovered kidneys (10.5%) was in region 5, whereas the highest (31.3%) was in Region 2.

At the regional level, both the proportion of kidneys recovered and the number of kidneys recovered per new candidate were highest in region 6 (95.7%, 0.69 kidneys/candidate) and lowest in region 9 (88.1%, 0.29) (Table 1). Donors after cardiac death accounted for 18% of deceased donors overall, ranging from 11% in region 3 to 26% in region 6. Region 6 also had the highest donor quality (lowest KDPI) (median KDPI 42%, interquartile range 21%–68%) and the lowest discard of recovered kidneys (13.3%). If the other 10 Organ Procurement and Transplantation Network regions in the country were able to replicate the recovery and utilization patterns of region 6, there would have been 2430 additional kidneys recovered (711 annually) nationwide, but large disparities in organ-per-candidate ratio across regions would persist (range: 0.31–0.69 kidneys/candidate). In addition, the proportion of all wait-listed kidney transplant candidates who eventually received a living donor transplant varied from 8% (regions 3, 5, 11) to 16% (region 7).

The significant differences in deceased donor kidney organ-per-candidate ratio that we identified both between DSAs within the same region as well as between Organ Procurement and Transplantation Network regions highlight large supply-demand mismatches entrenched by the currently defined allocation boundaries that contribute to geographic disparities in access to transplantation in violation of the Organ Procurement and Transplantation Network final rule.[6] We found variations in recovery practice and a potential opportunity for increasing the pool of transplantable kidneys by recovering kidneys from consented deceased donors who are donating other solid organs. However, it should be noted that even if all the regions were similarly effective at organ recovery and placement, geographic variations in organ supply relative to wait-listed candidates would persist, underscoring the need for additional measures to eliminate the current variations in access to transplantation across the country. Current geographic boundaries for organ allocation sequences do not account for the large geographic variation in the incidence of end-stage

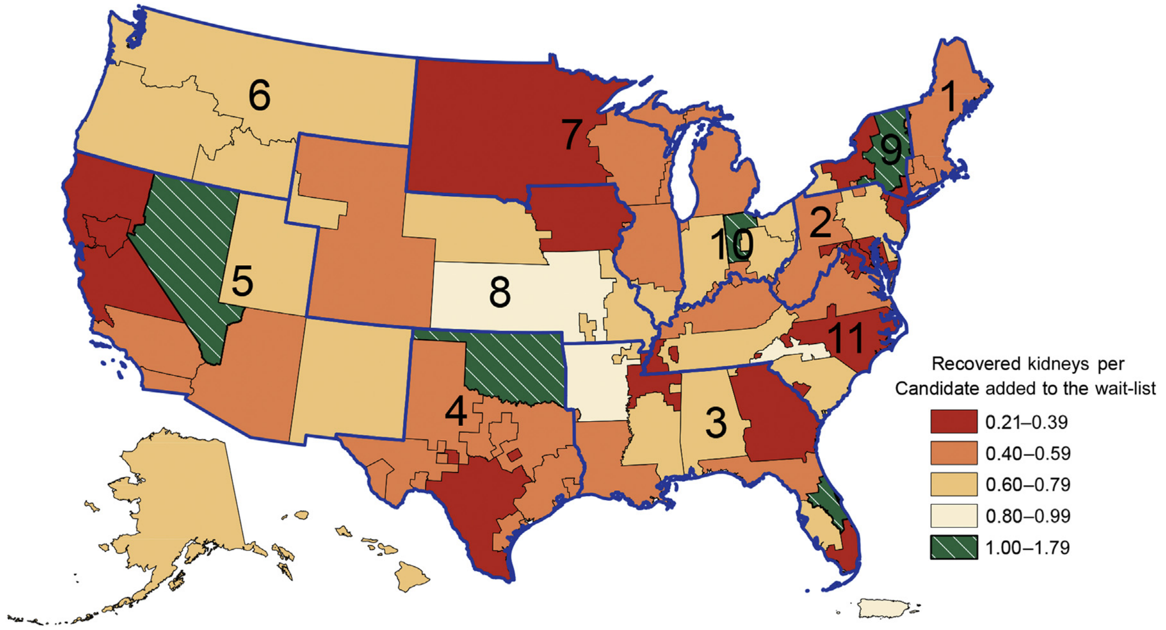

Figure 1. Ratio of deceased donor kidneys recovered per candidate added to the wait-list, by donation service area (DSA; 2015–2018). The organ-per-candidate ratio varied from 0.21 to 1.79 kidneys recovered per new candidate. Only 5 of 58 DSAs had more kidneys recovered than candidates added to the wait-list. Alaska and Hawaii are in region 6; Puerto Rico is in region 3. Data source: Scientific Registry of Transplant Recipients standard analytic file, June 2018. Map created in ArcGIS ArcMap, version 10.6.

Table 1. Comparing deceased donor kidney recovery, utilization, and quality across OPTN regions, 2015–2018

OPTN region	All	1	2	3	4	5	6	7	8	9	10	11
Candidates, *n* (row%)	126,011 (100)	5207 (4)	17,096 (14)	17,665 (14)	13,479 (11)	21,858 (17)	3619 (3)	10,299 (8)	6769 (5)	8886 (7)	8984 (7)	12,149 (10)
Solid organ donors, *n* (row%)	33,172 (100)	1197 (4)	4164 (13)	5180 (16)	3555 (11)	5028 (15)	1305 (4)	2605 (8)	2350 (7)	1440 (4)	2888 (9)	3460 (10)
Kidneys recovered (%)	92.0	93.2	91.4	88.5	91.3	94.8	95.7	92.9	92.7	88.1	92.0	93.8
Range of DSA recovery rates	83.8–98.0	92.9–94.7	89.7–94.1	83.8–93.8	88.5–96.9	91.4–96.2	94.1–98.0	91.6–93.7	86.9–96.8	85.0–96.0	88.1–94.5	92.3–95.3
Proportion discarded (%)	19.5	18.0	23.3	18.5	18.2	19.8	13.3	21.6	16.3	18.2	20.7	20.0
KDPI,[a] median (IQR)	54 (28–79)	52 (30–75)	57 (33–83)	57 (31–82)	51 (24–78)	55 (27–81)	42 (21–68)	58 (31–82)	48 (24–74)	58 (32–84)	50 (27–75)	52 (28–78)
DCD donors (% of all donors)	18	24	17	11	18	17	26	23	21	22	20	14
Ratio of recovered kidneys/candidates	0.48	0.43	0.45	0.52	0.48	0.44	0.69	0.47	0.64	0.29	0.59	0.53
Candidates receiving a living donor transplant, *n* (col%)	13,322 (11)	730 (14)	1772 (10)	1342 (8)	1359 (10)	1802 (8)	371 (10)	1597 (16)	785 (12)	1314 (15)	1277 (14)	973 (8)
Assuming benchmark performance[b]:												
Recovered kidneys/candidates	0.50	0.44	0.47	0.56	0.50	0.44	0.69	0.48	0.66	0.31	0.62	0.55
Additional kidneys recovered	2430	61	358	752	313	89	0	146	141	219	217	134
Additional kidneys transplanted	2106	53	310	651	271	77	0	127	123	190	188	116

DCD, donor after cardiac death; DSA, donation service area; IQR, interquartile range; KDPI, Kidney Donor Profile Index; OPTN, Organ Procurement and Transplantation Network.
[a]KDPI was calculated for each potential donor as described by the OPTN using the 2015 mapping table. KDPI ranges from 0 to 100%, with higher KDPI indicating lower donor quality.
[b]"Assuming benchmark performance" simulates the ratio of recovered kidneys to candidates and the number of additional kidneys recovered and transplanted if all regions had performed at the level of the most efficient region (region 6, recovery rate: 95.71%, discard rate: 13.33%) during the 3.42-year study period.

renal disease and the resulting differences in need for kidneys for transplantation.[7]

These differences in relative organ availability combine with clinical practice variation, such as diverging organ recovery and discard rates, to result in large geographic disparities in access to deceased donor kidneys. Proposals to replace fixed allocation boundaries with geographic feasibility scores for each organ may address the former by eliminating arbitrary borders that currently serve as barriers to sharing kidneys and result in the observed differences in relative organ availability between neighboring DSAs. However, such changes must be accompanied by optimization of organ recovery and utilization, as the intent of changes to the allocation system should be to eliminate structural disparities in access to transplantation rather than compensate for disparities that result from practice pattern variation.

Although our analysis identifies potential missed opportunities for kidneys from existing solid organ donors, our analysis does not include variations in processes further upstream, such as organ donor registration rates or rates of consent among potential donor candidates, which also could contribute to the donor pool if improved on.[8] In addition, we are unable to determine the quality of kidneys from all potential donors and whether geographic differences in this aspect of donor selection exist as well. Further, our analysis uses the currently wait-listed patients as a measure of the organ need, although there are probably many more transplant-eligible patients with end-stage renal disease who are not wait-listed. Therefore, areas with low wait-list access may display inflated organ-per-candidate ratios independent of organ availability or recovery practices. In addition, centers where large numbers of candidates are initially listed as inactive but never activated on the wait-list may potentially inflate the perceived demand for kidneys in locales. A more precise estimate of the demand for deceased donor kidneys may be available after the implementation of the new end-stage renal disease quality improvement program that incentivizes the wait-listing of prevalent patients by dialysis facilities, as well as following the increase in wait-listing called for by the recent *Executive Order on Advancing American Kidney Health*. Given the large number of factors to combine to determine the supply and demand for deceased donor kidneys, either recovery rates alone or the number of kidneys recovered per candidate added to the wait-list should not be used in isolation to rank or grade organ procurement organizations or regions.

In summary, wide geographic variation in the number of kidneys recovered per wait-listed candidate both within and between regions affects access to deceased donor kidney transplantation. Although there is geographic heterogeneity in organ recovery and utilization rates, geographic disparities in access to organs for transplantation would persist because of the current allocation system borders even if practice variation was reduced. Allocation proposals eliminating the current arbitrary DSA and regional boundaries (i.e., a "borderless allocation system") are being considered,[9] and our findings suggest that updating or eliminating allocation boundaries may improve equity in access to deceased donor kidney transplantation among wait-listed candidates in the United States.

DISCLOSURE

All the authors declared no competing interests.

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AUTHOR CONTRIBUTIONS

Study design: KLK, SAH, SM; data analysis: KLK; data interpretation: KLK, SAH, SM; supervision and mentorship: SM. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

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Implementing the Kidney Health Initiative Surrogate Efficacy Endpoint in Patients With IgA Nephropathy (the PROTECT Trial)

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