Racial Disparities in Pediatric Kidney Transplantation under the New Kidney Allocation System in the United States

Jill R. Krissberg,[1,2] *Matthew B. Kaufmann*,[3] *Anshal Gupta*,[4] *Eran Bendavid*,[3] *Margaret Stedman*,[4] *Xingxing S. Cheng*,[4] *Jane C. Tan*,[4] *Paul C. Grimm*,[5] *and Abanti Chaudhuri*[5]

Abstract

Background and objectives In December 2014, the Kidney Allocation System (KAS) was implemented to improve equity in access to transplantation, but preliminary studies in children show mixed results. Thus, we aimed to assess how the 2014 KAS policy change affected racial and ethnic disparities in pediatric kidney transplantation access and related outcomes.

Design, setting, participants, & measurements We performed a retrospective cohort study of children <18 years of age active on the kidney transplant list from 2008 to 2019 using the Scientific Registry of Transplant Recipients. Log-logistic accelerated failure time models were used to determine the time from first activation on the transplant list and the time on dialysis to deceased donor transplant, each with KAS era or race and ethnicity as the exposure of interest. We used logistic regression to assess odds of delayed graft function. Log-rank tests assessed time to graft loss within racial and ethnic groups across KAS eras.

Results All children experienced longer wait times from activation to transplantation post-KAS. In univariable analysis, Black and Hispanic children and other children of color experienced longer times from activation to transplant compared with White children in both eras; this finding was largely attenuated after multivariable analysis (time ratio, 1.16; 95% confidence interval, 1.01 to 1.32; time ratio, 1.13; 95% confidence interval, 1.00 to 1.28; and time ratio, 1.17; 95% confidence interval, 0.96 to 1.41 post-KAS, respectively). Multivariable analysis also showed that racial and ethnic disparities in time from dialysis initiation to transplantation in the pre-KAS era were mitigated in the post-KAS era. There were no disparities in odds of delayed graft function. Black and Hispanic children experienced longer times with a functioning graft in the post-KAS era.

Conclusions No racial and ethnic disparities from activation to deceased donor transplantation were seen before or after implementation of the KAS in multivariable analysis, whereas time on dialysis to transplantation and odds of short-term graft loss improved in equity after the implementation of the KAS, without compromising disparities in delayed graft function.

CJASN 16: 1862–1871, 2021. doi: https://doi.org/10.2215/CJN.06740521

[1]Department of Pediatrics, Division of Nephrology, Northwestern University Feinberg School of Medicine, Chicago, Illinois
[2]Department of Nephrology, Ann & Robert H. Lurie Children's Hospital, Chicago, Illinois
[3]Stanford Health Policy, Centers for Health Policy and Primary Care and Outcomes Research, Department of Medicine, Stanford University School of Medicine, Stanford, California
[4]Department of Medicine, Stanford University School of Medicine, Stanford, California
[5]Department of Pediatrics, Division of Nephrology, Stanford University School of Medicine, Stanford, California

Correspondence:
Dr. Jill R. Krissberg, Ann and Robert H. Lurie Children's Hospital of Chicago, 225 E. Chicago Avenue, Box #37, Chicago, IL 60611. Email: jkrissberg@luriechildrens.org

Introduction

Racial and ethnic disparities in pediatric kidney transplantation are well described. Black children are less likely to receive a transplant (1), are less likely to be on the transplant waiting list (2), and have overall longer wait times to transplantation (3) compared with White children. Lower transplant access is linked to a 64% higher mortality rate for Black compared with White children, regardless of income (1).

On December 4, 2014, the Kidney Allocation System (KAS) was implemented to reduce racial and ethnic disparities and increase access for sensitized candidates (4). Specific changes include (*1*) preregistration dialysis time added to calculated wait time, (*2*) prioritization for sensitized candidates using a sliding scale for calculated panel reactive antibodies (cPRAs), and (*3*) prioritization of deceased donor kidneys with a Kidney Donor Profile Index (KDPI) <35% for pediatric candidates (4). Preliminary evidence indicated that the new KAS improved transplant access (5–9), but racial and ethnic disparities persisted for highly sensitized candidates (10). There was also concern that longer ischemia times from the mandatory sharing rules would lead to higher rates of delayed graft function (6,8,11). Many of these studies had minimal follow-up time after the KAS policy change and focused mostly on adult populations.

Accordingly, this study explores how the 2014 KAS change affected access to transplant and transplant-related outcomes in children across racial and ethnic groups with 5 years of follow-up time to evaluate the current policy landscape and guide

future improvements in equity. We hypothesized that the 2014 KAS decreased time to transplantation across all racial and ethnic groups but was associated with worse short-term transplant outcomes.

Materials and Methods

Data Sources and Study Population

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donors, waitlisted candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN) under the administration of the Health Resources and Services Administration, US Department of Health and Human Services (12).

We included all kidney transplant candidates in the SRTR database who were activated on the transplant list at <18 years of age between January 1, 2008 and December 31, 2019. Those who were listed for multiorgan transplant, received a prior organ transplant, or received a living donor transplant were excluded. To eliminate outliers who were on dialysis for an extended period of time, we excluded candidates who were initiated on dialysis prior to January 1, 2003 (1) (Figures 1 and 2). This study was approved by the institutional review board of Stanford University.

Exposures, Outcomes, and Covariates

The exposures of interest were the 2014 KAS policy change and race and ethnicity. We defined the pre-2014 KAS era as up to December 3, 2014 and the post-2014 KAS era as on or after December 4, 2014 (Figures 1 and 2). Racial and ethnic groups were consolidated into the following mutually exclusive categories: non-Hispanic White (White), Black (included patients of Black race and any ethnicity), Hispanic (not White), and other (which includes other races not included in the previous categories and any ethnicity). Outcomes of interest were time from activation to deceased donor transplantation, time from dialysis initiation to deceased donor transplantation, occurrence of delayed graft function defined as the need for dialysis 1 week after transplantation, and time to graft loss.

Recipient demographic characteristics examined were age at listing, payer, blood type, dialysis days, underlying diagnosis, and cPRA. Donor and transplant characteristics examined were KDPI (manually calculated for all recipients and generated using the 2015 scaling factor) and cold ischemic time.

Statistical Analyses

All recipient, donor, and transplant characteristics were reported as numbers and percentages for categorical variables and medians and interquartile ranges for continuous variables. Kaplan–Meier curves were generated to show time from activation to transplantation, time from dialysis initiation to transplantation, and time to graft loss after transplantation, stratified by racial and ethnic group in both eras.

Parametric accelerated failure time (AFT) models were used to examine how KAS affected time to transplantation for different racial and ethnic groups. We chose AFT models over the traditional Cox proportional hazards models as the proportional hazards assumption was not met for the

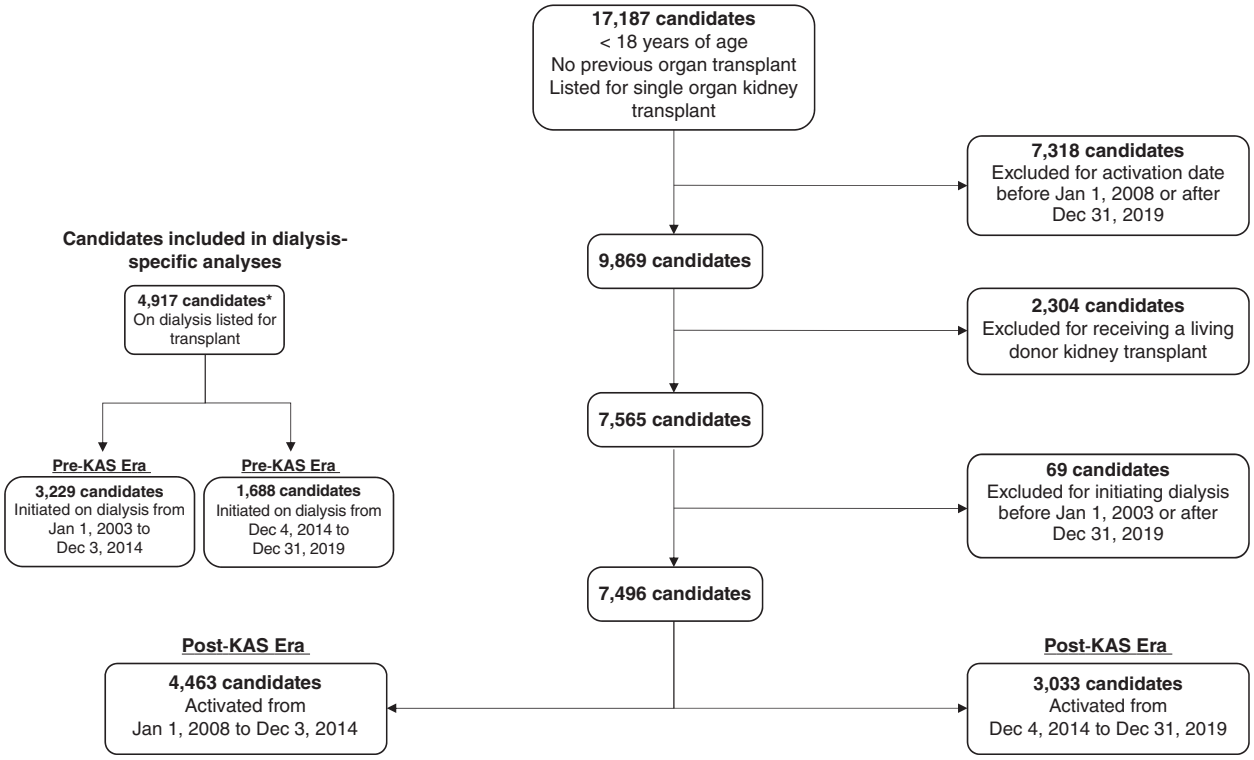

Figure 1. | **Cohort construction.** Subject enrollment and selection for inclusion in this current study. KAS, Kidney Allocation System. *Subjects included in dialysis-only analyses.

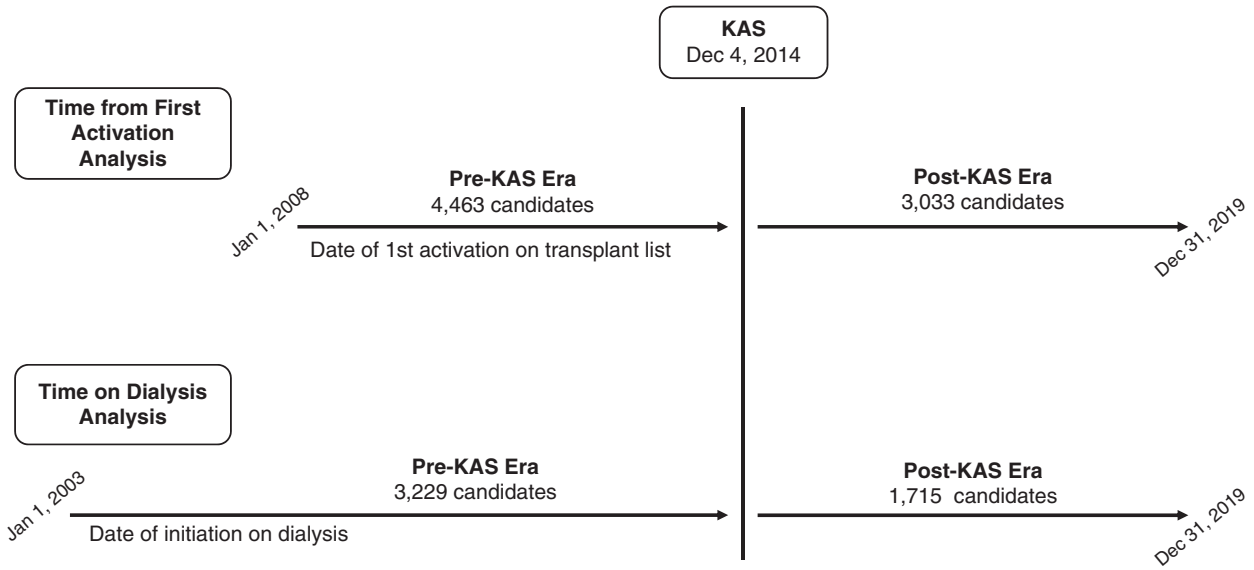

Figure 2. | **Cohort construction timeline and division of eras for analysis.** Timeline of subjects starting from activation on transplant list or from initiation on dialysis. Subjects are censored at the time of death, end of collection data, or removal from the list. Subjects are restricted to stay within the era when they were initially activated for transplant or initiated on dialysis for all analyses.

transplantation outcome. AFT models generate time ratios, which express covariates' effect on differences in survival (*e.g.*, a time ratio of 1.3 means a 30% longer survival time per one unit higher value of the covariate). AFTs require a specified distribution to fit the underlying hazard of the model. Goodness of fit was determined by a visual examination of Cox–Snell residuals compared with the cumulative hazard of the sample (13). We determined that the log-logistic distribution was an appropriate choice for every model (Supplemental Figure 1).

We ran two sets of AFT models with two different time variables. The first modeled time from initial activation on the transplant list to deceased donor transplant, where candidates temporarily transitioned out of the model if they were deactivated and transitioned back in upon reactivation. The second modeled time from initiation of dialysis until transplantation. We tested each model for an interaction between race and ethnicity and era, and a likelihood ratio test determined significance. To assess if racial disparities changed in each era, we ran regressions for each era with race and ethnicity as the exposure of interest. Then, to assess the effect of the 2014 KAS, we ran regressions for each racial and ethnic group with KAS as the exposure of interest (14). In addition to crude analyses, we adjusted for patient- and transplant-related confounders, donor service area, and year of activation or dialysis start year using multivariable analyses. Candidates were censored by death (98 candidates), end of the data collection period (1178 candidates), or removal from the list (666 candidates). Because AFT models estimate a cause-specific hazard function, they are well suited for the consideration of competing risks (*e.g.*, death, removal from waiting list) (15). Because of the effect that KAS could have on waiting list time with the addition of back-calculated preregistration dialysis, candidates were restricted to stay within their own era of activation or initiation of dialysis (Figure 2).

We performed a secondary analysis on those who were transplanted to explore racial and ethnic disparities in short-term transplant outcomes. We used logistic regression to determine disparities in odds of delayed graft function, where univariable and multivariable models were run separately for the two eras. We then performed log-rank tests to compare time to graft loss after transplant in each era. Data analysis was conducted using Stata 14 (16). The amount of missing data was 7% or less for all variables (Table 1). Donor service area was missing for 1% of the cohort. Multivariable analyses were restricted to those with complete data for all variables.

Results

Patient Characteristics

Among the 7496 children studied, 2848 (38%) were White, 1738 (23%) were Black, 2347 (31%) were Hispanic, and 563 (8%) were in the other racial and ethnic category. Other children of color had the lowest proportion of children transplanted (72% versus 75%–79%). Black and Hispanic children were more likely to have public insurance compared with White children or other children of color. Black and Hispanic children had the longest time on dialysis (648 days for Black children and 636 days for Hispanic children versus 537 days for White children and 586 days for other children). Black (3%) or other (5%) children of color were most likely to have a cPRA>80% compared with White (1%) or Hispanic (2%) children. Black children who were transplanted had the highest proportion of delayed graft function (9% versus 6%–7%) (Table 1). Demographic data and transplant characteristics where children were divided on the basis of activation era have similar differences among racial and ethnic groups (Supplemental Table 1). Characteristics of those with complete data were very similar to those with missing data (Supplemental

Table 1. Patient, donor, and transplant characteristics of the study population by race and ethnicity

Characteristic	White, *n*=2848	Black, *n*=1738	Hispanic, *n*=2347	Other, *n*=563	Total, *n*=7496
Transplants, *n* (%)	2150 (75)	1374 (79)	1827 (78)	403 (72)	5754 (77)
Age at listing, yr					
0–4	575 (20)	272 (16)	388 (17)	135 (24)	1370 (18)
5–9	474 (17)	246 (14)	335 (14)	76 (13)	1131 (15)
10–14	750 (26)	478 (27)	677 (29)	145 (26)	2050 (27)
>15	1049 (37)	742 (43)	947 (40)	207 (37)	2945 (39)
Male, *n* (%)	1702 (60)	1090 (63)	1269 (54)	295 (52)	4356 (58)
Payer, *n* (%)					
Private	1308 (46)	442 (25)	454 (19)	231 (41)	2435 (32)
Medicaid/CHIP	907 (32)	796 (46)	1317 (56)	220 (39)	3240 (43)
Medicare	466 (16)	451 (26)	405 (17)	87 (15)	1409 (19)
Other	167 (6)	49 (3)	171 (7)	25 (5)	412 (6)
Blood type, *n* (%)					
A	1047 (37)	456 (26)	613 (26)	155 (28)	2271 (30)
AB	126 (4)	66 (4)	49 (2)	24 (4)	265 (4)
B	322 (11)	341 (20)	203 (9)	118 (21)	984 (13)
O	1353 (48)	875 (51)	1482 (63)	266 (47)	3976 (53)
Days on dialysis[a]	537 (292–969)	648 (362–1114)	636 (370–1105)	586 (345–994)	601 (337–1048)
Primary diagnosis, *n* (%)					
CAKUT	1311 (46)	665 (38)	893 (38)	229 (40)	3098 (41)
GN	248 (9)	134 (8)	212 (9)	61 (11)	655 (9)
Secondary GN	240 (8)	232 (13)	291 (12)	62 (11)	827 (11)
FSGS	227 (8)	360 (21)	294 (13)	69 (12)	947 (13)
Other	822 (29)	347 (20)	655 (28)	145 (26)	1969 (26)
cPRA, %					
0–39	2641 (93)	1567 (91)	2173 (92)	489 (87)	6879 (92)
40–79	164 (6)	114 (6)	134 (6)	48 (8)	460 (6)
80+	43 (1)	48 (3)	40 (2)	26 (5)	157 (2)
KDPI[b]					
<20	858 (40)	494 (36)	727 (40)	155 (39)	2234 (39)
20–35	769 (36)	538 (39)	729 (40)	166 (42)	2202 (39)
35+	509 (24)	331 (25)	360 (20)	77 (19)	1278 (22)
Cold ischemic time, h[c]	11 (8–16)	12 (9–17)	12 (8–16)	11 (7–15)	12 (8–16)
Delayed graft function[d], *n* (%)	136 (7)	118 (9)	116 (7)	25 (6)	395 (7)

All values represent *n* (percentage) or median (interquartile) unless otherwise indicated. CHIP, Children's Health Insurance Program; CAKUT, congenital anomalies of the kidney and urinary tract; cPRA, calculated panel reactive antibody; KDPI, Kidney Donor Profile Index.
[a]Restricted to patients who were on dialysis (*n*=4917).
[b]Restricted to patients who were transplanted (*n*=5754; 1% missing).
[c]Restricted to patients who were transplanted (*n*=5754; 7% missing).
[d]Restricted to patients who were transplanted (*n*=5754; 4% missing).

Table 2) and, so, were generalizable to the remainder of the cohort.

Time from Activation to Deceased Donor Transplantation

In both eras, Black and Hispanic children and other children of color had longer median times from activation to deceased donor transplant compared with White children. Overall, median times to transplant were substantially longer post-KAS (Figure 3, Table 2). Black and Hispanic children and other children of color had lower transplant rates per 1000 person-years compared with White children, and these rates were overall lower in the post-KAS era compared with the pre-KAS era (Table 2).

In univariable AFT models exploring associations of race and ethnicity within each era, Black and Hispanic children and other children of color had significantly longer wait times compared with White children in both eras. In the multivariable analysis, these findings were largely attenuated. Black children had a 14% longer wait time (time ratio, 1.14; 95% confidence interval [95% CI], 1.00 to 1.29) pre-KAS and a 16% longer wait time (time ratio, 1.16; 95% CI, 1.01 to 1.32) post-KAS. Hispanic children had a 12% longer wait time (time ratio, 1.12; 95% CI, 0.99 to 1.28) pre-KAS and a 13% longer wait time (time ratio, 1.13; 95% CI, 1.00 to 1.28) post-KAS. Other children of color had an 8% longer wait time (time ratio, 1.08; 95% CI, 0.87 to 1.33) pre-KAS and a 17% longer wait time post-KAS (time ratio, 1.17; 95% CI, 0.96 to 1.41) (Table 2).

In multivariable AFT models exploring associations of era within each group, every racial and ethnic group had significantly longer wait times post-KAS compared with pre-KAS. White children waited 169% longer (time ratio, 2.69; 95% CI, 2.15 to 3.36), Black children waited 197% longer (time ratio, 2.97; 95% CI, 2.27 to 3.91), Hispanic children waited 229% longer (time ratio, 3.29; 95% CI, 2.56 to 4.22), and other children of color waited 173% longer (time ratio, 2.36; 95% CI, 1.63 to 4.56) (Table 2).

Time on Dialysis to Deceased Donor Transplantation

In both eras, Black and Hispanic children and other children of color had longer times on dialysis to transplant compared with White children. Overall, median times were

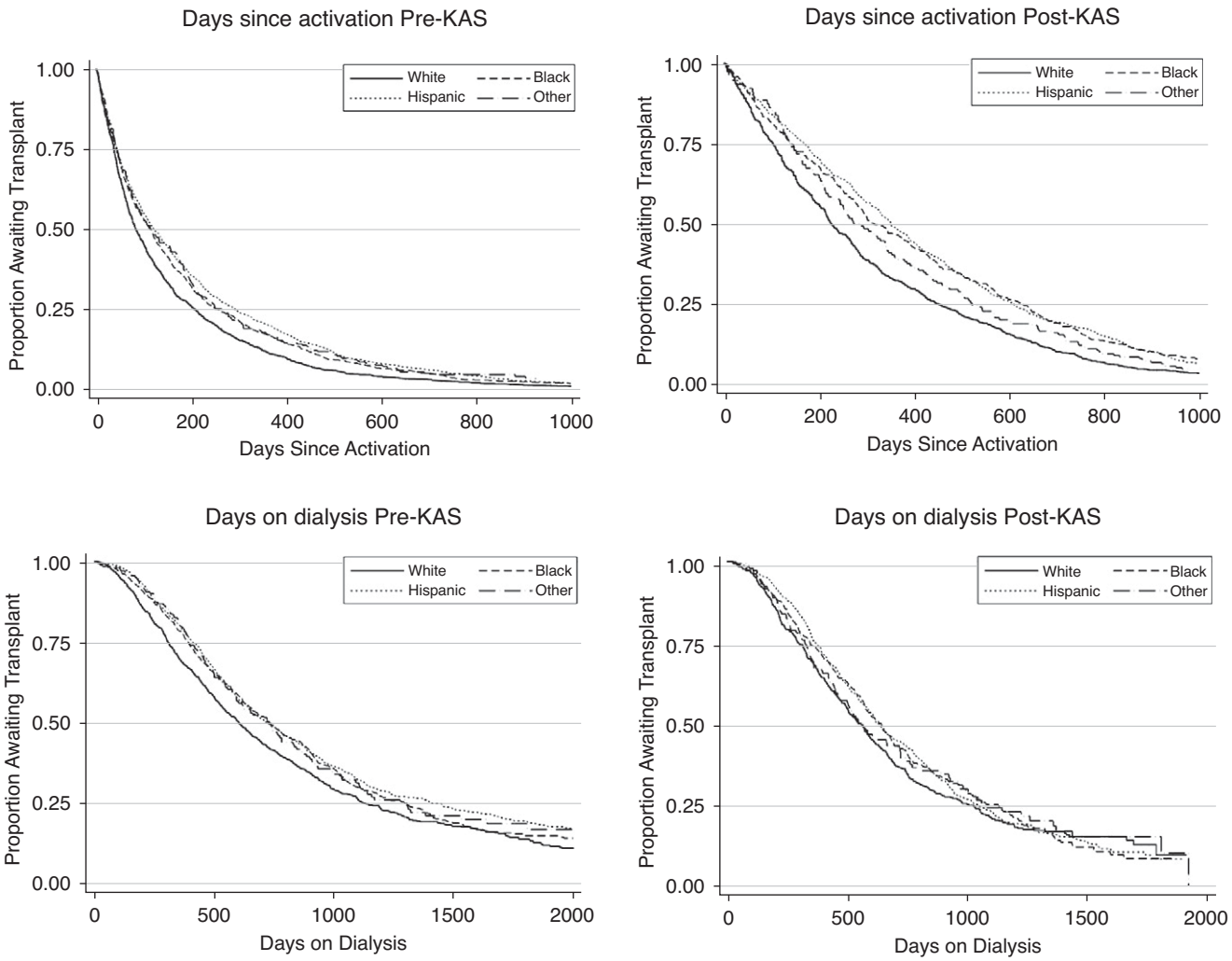

Figure 3. | **Kaplan–Meier survival curves for time to deceased donor transplant by race and ethnicity.**

shorter in the post-KAS era (Figure 3, Table 3). Black and Hispanic children and other children of color had lower rates of transplantation per 1000 person-years compared with White children. Rates were overall higher in the post-KAS era (Table 3).

In univariable AFT models exploring associations of race and ethnicity within each era, Black and Hispanic children and other children of color had significantly longer times on dialysis compared with White children in both eras. In the pre-KAS era in multivariable models, these findings are attenuated but still showed differences (time ratio, 1.20; 95% CI, 1.09 to 1.32 for Black children; time ratio, 1.13; 95% CI, 1.02 to 1.24 for Hispanic children; time ratio, 1.17; 95% CI, 1.01 to 1.36 for other children). In the post-KAS era, there were no significant differences in time on dialysis for Black and Hispanic children and other children of color compared with White children in multivariable models (Table 3).

In multivariable AFT models exploring associations of era within each group, Black and Hispanic children experienced longer times on dialysis post-KAS compared with pre-KAS (time ratio, 1.31; 95% CI, 1.08 to 1.59 for Black children; time ratio, 1.27; 95% CI, 1.07 to 1.52 for Hispanic children) (Table 3).

Delayed Graft Function and Graft Loss

In the pre-KAS era, Black children had higher odds of delayed graft function compared with White children (odds ratio, 1.46; 95% CI, 1.08 to 1.96) in unadjusted analysis. This finding was no longer significant in multivariable analysis (odds ratio, 1.17; 95% CI, 0.85 to 1.60). There were no significant associations between race and ethnicity and delayed graft function in the post-KAS era in univariable or multivariable analyses (Table 4). Black and Hispanic children had longer time to graft loss post-KAS compared with pre-KAS (log-rank $P=0.03$ and $P=0.01$, respectively) (Figure 4).

Discussion

This retrospective cohort study of pediatric kidney transplant recipients is the first to assess how the 2014 KAS policy affected racial and ethnic disparities in

Table 2. Log-logistic accelerated failure time regression analyses for time from activation to deceased donor transplant for the entire study population: Effect of the 2014 Kidney Allocation System and race and ethnicity

Factor	Median Days to Transplant (Interquartile Range)	Absolute Transplant Rate per 1000 Person-yr	Crude Time Ratio (95% Confidence Interval)	Adjusted[a] Time Ratio (95% Confidence Interval)
Effect of race and ethnicity				
Pre-KAS, *n*=3351				
White	84 (38–210)	5.61	Reference	Reference
Black	116 (44–260)	4.63	1.25 (1.09 to 1.42)	1.14 (1.00 to 1.29)
Hispanic	122 (42–296)	4.19	1.37 (1.21 to 1.55)	1.12 (0.99 to 1.28)
Other	119 (44–265)	4.38	1.30 (1.04 to 1.63)	1.08 (0.87 to 1.33)
Post-KAS, *n*=2066				
White	226 (103–454)	3.24	Reference	Reference
Black	315 (104–630)	2.43	1.39 (1.21 to 1.61)	1.16 (1.01 to 1.32)
Hispanic	351 (170–610)	2.43	1.47 (1.29 to 1.67)	1.13 (1.00 to 1.28)
Other	286 (141–522)	2.75	1.24 (1.00 to 1.54)	1.17 (0.96 to 1.41)
Effect of era				
White, *n*=2044				
Pre-KAS	84 (38–210)	5.61	Reference	Reference
Post-KAS	226 (103–454)	3.24	2.41 (2.13 to 2.74)	2.69 (2.15 to 3.36)
Black, *n*=1299				
Pre-KAS	116 (44–260)	4.63	Reference	Reference
Post-KAS	315 (104–630)	2.43	2.69 (2.30 to 3.16)	2.97 (2.27 to 3.91)
Hispanic, *n*=1697				
Pre-KAS	122 (42–296)	4.19	Reference	Reference
Post-KAS	351 (170–610)	2.43	2.57 (2.24 to 2.95)	3.29 (2.56 to 4.22)
Other, *n*=377				
Pre-KAS	119 (44–265)	4.38	Reference	Reference
Post-KAS	286 (141–522)	2.75	2.26 (1.68 to 3.05)	2.73 (1.63 to 4.56)

P value interaction for race and ethnicity × era is *P*=0.70. This analysis includes all candidates who were activated on the transplant list from January 1, 2008 to December 31, 2019. Pre-KAS indicates activated from January 1, 2008 to December 13, 2014. Post-KAS indicates activated from December 14, 2014 to December 31, 2019. Time variable is the time from first activation on the transplant list to deceased donor transplant. The event is deceased donor transplant. The censor event is the loss of follow-up, death, removal from the waiting list, and end of era. Sample sizes are provided for adjusted models. KAS, Kidney Allocation System.

[a]This analysis was adjusted for age at listing, sex, primary diagnosis, payer, blood type, calculated panel reactive antibodies, donor service area, and year of activation.

deceased donor transplantation with 5 years of follow-up. After the 2014 KAS policy change, racial and ethnic disparities in time from activation and time on dialysis to deceased donor transplant began to exist for Black and Hispanic children and other children of color compared with White children, but this finding is largely explained by differences in patient demographic– and transplant-related factors as these findings are attenuated in multivariable analyses. We also found improvements in odds of delayed graft function for Black children and longer time to graft loss for Black and Hispanic children post-KAS.

Preliminary studies were optimistic that the 2014 policy change improved disparities. A study of transplant rates 1 year after the change showed a 21% higher rate of transplants for Black patients and a 9% higher rate of transplants for Hispanic patients (9). Another study using a difference-in-difference analysis showed narrowing of gaps in transplant rates among patients of color compared with White patients 20 months after the policy change (7). For children specifically, a quasiexperimental time series study in children 15 months after the KAS policy change estimated a 46% higher rate of transplants for Black children (5). Our study similarly shows that 5 years after the policy change, racial and ethnic disparities are not exacerbated as a result of the 2014 KAS.

Prior studies have shown that for adults with cPRA>80%, racial and ethnic disparities still exist post-KAS (10). Our results show that disparities in access to transplantation for children in univariable analysis are explained by patient factors as opposed to race and ethnicity itself. Because race and ethnicity are social constructs, as opposed to biologic differences among individuals, future work should focus on the effect of KAS on patient-specific barriers for children of color, such as cPRA, geography, or blood type, to help improve these disparities. Additionally, as studies have described lower acceptance rates for pediatric patients post-KAS (17), how organ offer and acceptance rates differ by racial and ethnic group post-KAS should be explored.

This study indicates that the 2014 KAS may be decreasing the availability of transplants for children overall. A study 15 months after the KAS policy change showed that children 0–6 years of age had a 21% lower likelihood of transplant (5). Another study of children and adults 1 year after the policy change reported that pediatric transplant rates were higher compared with adults but decreased after the policy change—a finding that leveled off after a bolus effect (8). Decreasing access to transplantation for children overall will further disparities for already vulnerable children.

Table 3. Log-logistic accelerated failure time regression analyses for time on dialysis to deceased donor transplant for those on dialysis and active on the transplant list: Effect of the 2014 Kidney Allocation System and race and ethnicity

Factor	Median Days to Transplant (Interquartile Range)	Absolute Transplant Rate per 1000 Person-yr	Crude Time Ratio (95% Confidence Interval)	Adjusted[a] Time Ratio (95% Confidence Interval)
Effect of race and ethnicity				
Pre-KAS, *n*=3083				
White	600 (304–1105)	1.11	Reference	Reference
Black	731 (392–1296)	0.94	1.22 (1.09 to 1.34)	1.20 (1.09 to 1.32)
Hispanic	715 (408–1398)	0.86	1.27 (1.16 to 1.39)	1.13 (1.02 to 1.24)
Other	721 (390–1301)	0.90	1.23 (1.05 to 1.44)	1.17 (1.01 to 1.36)
Post-KAS, *n*=1713				
White	577 (292–1048)	1.21	Reference	Reference
Black	654 (369–1145)	1.07	1.18 (1.04 to 1.33)	1.10 (0.99 to 1.24)
Hispanic	658 (377–1079)	1.07	1.20 (1.07 to 1.34)	1.03 (0.93 to 1.15)
Other	568 (329–1142)	1.10	1.09 (0.91 to 1.30)	1.10 (0.94 to 1.29)
Effect of era				
White, *n*=1627				
Pre-KAS	600 (304–1105)	1.11	Reference	Reference
Post-KAS	577 (292–1048)	1.21	0.94 (0.85 to 1.05)	0.98 (0.81 to 1.18)
Black, *n*=1234				
Pre-KAS	731 (392–1296)	0.94	Reference	Reference
Post-KAS	654 (369–1145)	1.07	0.91 (0.81 to 1.03)	1.31 (1.08 to 1.59)
Hispanic, *n*=1589				
Pre-KAS	715 (408–1398)	0.86	Reference	Reference
Post-KAS	658 (377–1079)	1.07	0.89 (0.81 to 0.99)	1.27 (1.07 to 1.52)
Other, *n*=346				
Pre-KAS	721 (390–1301)	0.90	Reference	Reference
Post-KAS	568 (329–1142)	1.10	0.84 (0.68 to 1.04)	1.14 (0.79 to 1.66)

P value interaction for race and ethnicity × era is *P*=0.50. This analysis includes all candidates who were initiated on dialysis and subsequently activated on the transplant list from January 1, 2008 to December 31, 2019. Pre-KAS indicates initiated on dialysis from January 1, 2008 to December 13, 2014. Post-KAS indicates initiated on dialysis and activated on the transplant list from December 14, 2014 to December 31, 2019. Time variable is the time from start of dialysis to deceased donor transplant. The event is deceased donor transplant. The censor event is the loss of follow-up, death, removal from the waiting list, and end of era. Sample sizes are provided for adjusted models. KAS, Kidney Allocation System.

[a]This analysis was adjusted for age at listing, sex, primary diagnosis, payer, blood type, calculated panel reactive antibodies, donor service area, and dialysis start year.

Previous studies can help explain why children have longer wait times post-KAS. One reason is that KDPI does not accurately assess pediatric donors as no donor below age 6 years old is assigned a KDPI<35 (18). As donors with a KDPI<35 are prioritized to children, acceptable pediatric donors are preferentially being offered to adult recipients. One study found that children received 34% fewer pediatric donors, with a substantial increase in >35-year-old donors (11). Another study 3 years post-KAS found that children were 79% less likely to receive offers of donors ages <18 and 18–34 years old (17). Changes in acceptance patterns could be contributing as kidneys from donors 18–34 years old and KDPI<35% were 23% less likely to be accepted post-KAS, whereas donors 35+ years old with KDPI<35% were three-fold more likely to be accepted (17). Finally, prioritization of ever increasing numbers of adult multiorgan transplants over pediatric kidney-only recipients may be contributing (19).

Adding preregistration dialysis time to candidate wait time improved racial and ethnic disparities for those on dialysis prior to transplant as there is now equity in time on dialysis to transplantation post-KAS in multivariable analysis. This is especially important as previous studies describe longer times on dialysis to transplantation for Black or Hispanic children, resulting in higher mortality (1,20). Our results are contrary to studies that found longer time on dialysis prior to transplantation post-KAS for children (21) and adults (7). These studies only followed patients up to 2 years; therefore, the results were likely due to an initial bolus effect where preregistration dialysis time was added to transplant waiting time post-KAS, making wait times appear longer.

Initial studies of the 2014 KAS policy change were concerning for higher rates of delayed graft function post-KAS (8). A study of the OPTN data up to 2016 found a 69% higher odds in delayed graft function in recipients <10 years of age post-KAS compared with pre-KAS explained by age or size of donors and pretransplant dialysis duration (11). Separately, another study reported higher likelihood of delayed graft function post-KAS for all adults but more so for those of Black or Hispanic race and ethnicity (6). Our study finds that with prolonged follow-up time, delayed graft function did not differ among racial and ethnic pediatric groups. We also found that time to graft loss improved for Black and Hispanic children after KAS.

There are important limitations of this study. Although this is a comprehensive dataset of US pediatric transplants, sample sizes were low for some racial and ethnic groups. Our data are limited to 5 years after policy change, so longer-term transplant outcomes cannot be evaluated. We used insurance status as a proxy of socioeconomic status as we lacked more granular information of income. Finally, as

Table 4. Odds of delayed graft function after deceased donor transplantation before and after the 2014 Kidney Allocation System by racial and ethnic group

Group	Before the Kidney Allocation System,[a] $n=3641$		After the Kidney Allocation System,[b] $n=1695$	
	Crude Odds Ratio (95% Confidence Interval)	Adjusted[c] Odds Ratio (95% Confidence Interval)	Crude Odds Ratio (95% Confidence Interval)	Adjusted[c] Odds Ratio (95% Confidence Interval)
White	Reference	Reference	Reference	Reference
Black	1.46 (1.08 to 1.96)	1.17 (0.85 to 1.60)	1.06 (0.63 to 1.77)	0.73 (0.42 to 1.27)
Hispanic	1.03 (0.76 to 1.39	0.84 (0.61 to 1.17)	0.88 (0.54 to 1.42)	0.71 (0.42 to 1.20)
Other	1.00 (0.59 to 1.71)	0.84 (0.47 to 1.49)	0.93 (0.42 to 2.02)	0.76 (0.34 to 1.72)

This analysis includes all candidates who were activated and then received a deceased donor transplant from January 1, 2008 to December 31, 2019. Sample sizes are provided for the adjusted model.
[a]Before the Kidney Allocation System: activated and transplanted between January 1, 2008 to December 3, 2014.
[b]After the Kidney Allocation System: activated and transplanted between December 4, 2014 to December 31, 2019.
[c]This analysis was adjusted for sex, primary diagnosis, payer, days on dialysis, Kidney Donor Profile Index, cold ischemic time, and calculated panel reactive antibodies.

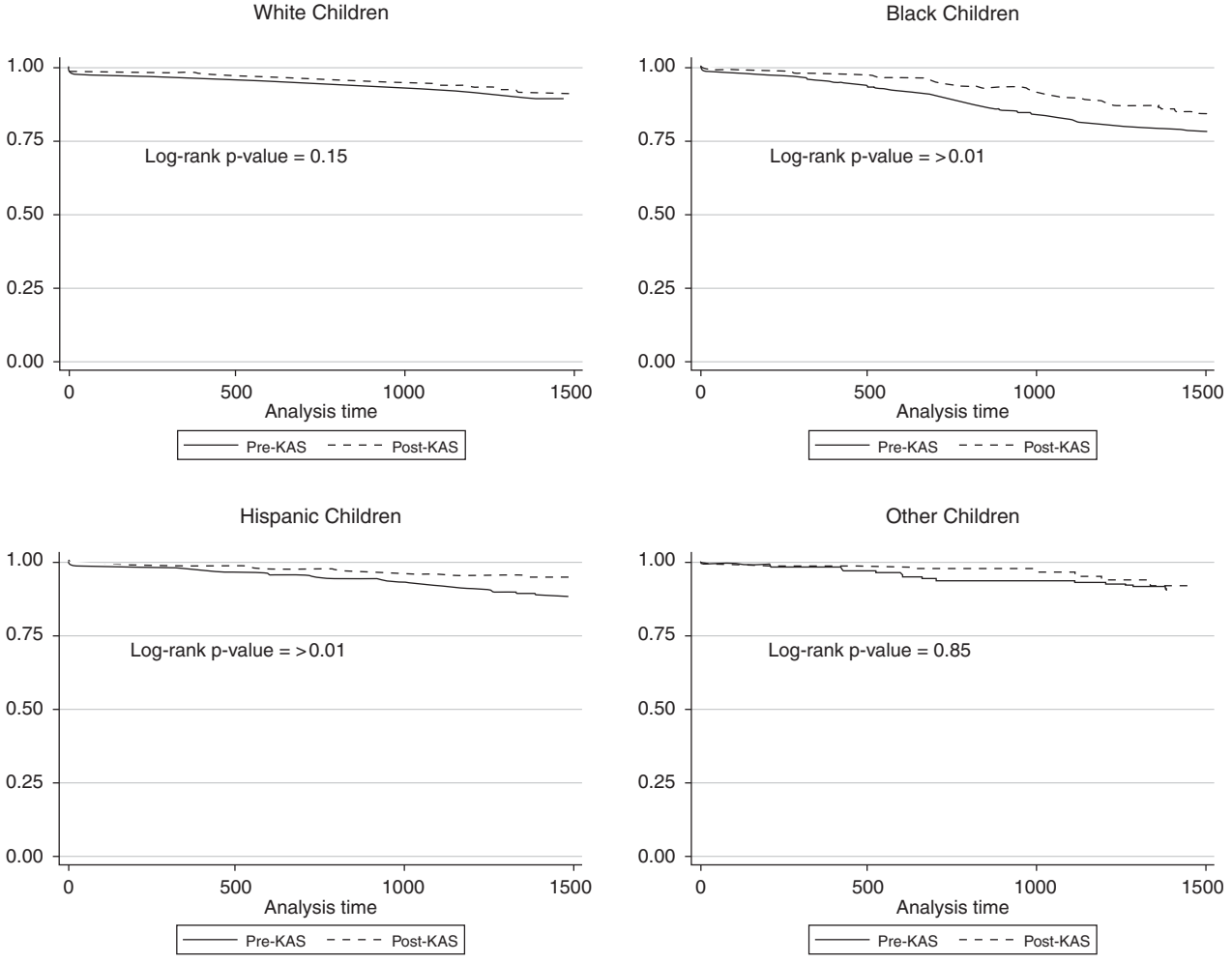

Figure 4. | **Kaplan–Meier survival curves for time to graft loss for each race and ethnicity by era.**

only patients on dialysis subsequently listed for transplantation were included in this study, our findings are not generalizable to the whole kidney failure population.

Assessing the 2014 KAS policy change does not address racial and ethnic disparities that occur throughout the transplant listing process. The pediatric nephrology community needs to remain diligent in considering all aspects of kidney failure care, steps to transplantation, and consequences of systemic racism and provider biases in this process to truly address racial and ethnic disparities: from early identification of CKD to access to subspecialty care, activation, and preemptive and living related donors (22). A study found that with adherence being equal, referral to transplantation varied by race and ethnicity (23). How racism independently affects outcomes as a social determinant of health should be the focus of future studies (24). Additionally, removal of donor service areas and integration of proximity points to transplant centers were implemented on March 15, 2021. It is too early to comment on how this policy change will affect racial and ethnic disparities, but this deserves attention in future studies.

In conclusion, wait times for children from activation to deceased donor transplantation were equitable before and after implementation of KAS, whereas racial and ethnic disparities for time on dialysis to transplantation and odds of short-term graft loss improved in equity after KAS, after adjusting for patient- and transplant-related factors. These improvements occurred without causing disparities in delayed graft function. Wait times overall for children have increased since the policy change, requiring discussion among the pediatric nephrology community and policy makers to implement further changes to prevent vulnerable children from having increased barriers to pediatric transplantation.

Disclosures

X.S. Cheng reports receiving honoraria from ClarityCo and Medscape Education and receiving research funding from the American Heart Association and the National Institutes of Health. P.C. Grimm reports consultancy agreements with Eloxx and Horizon; receiving research funding from Alexion Pharmaceuticals; receiving honoraria from Eloxx, Horizon, and Recordati; and serving as a board member of the Improve Renal Outcomes Collaborative. J.C. Tan reports serving as an associate editor of *Clinical Transplantation*, serving as a scientific advisor or member of *American Journal of Kidney Diseases*, and serving on the American Society of Transplantation Scientific Review Board. J.C. Tan's spouse is employed by and has ownership interest in GNE/Roche. All remaining authors have nothing to disclose.

Funding

The John M. Sobrato Gift Fund was used for purchase of the SRTR database. J.R. Krissberg was a Stanford Maternal and Child Health Research Institute Tashia and John Morgridge Endowed Postdoctoral fellow at the time this study was conducted. M.B. Kaufmann is supported by Agency for Healthcare Research and Quality grant T32HS026128.

Acknowledgments

The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality.

Data Sharing Statement

Individual participant deidentified data will not be shared by the authors because of restrictions of data use agreements. SRTR registry data can be obtained from SRTR.

Supplemental Material

This article contains the following supplemental material online at http://cjasn.asnjournals.org/lookup/suppl/doi:10.2215/CJN.06740521/-/DCSupplemental.

Supplemental Figure 1. Hazard versus Cox–Snell residuals testing fit for log-logistic AFT models.

Supplemental Table 1. Patient, donor, and transplant characteristics of the study population by race and ethnicity separated by activation era.

Supplemental Table 2. Differences in recipient, donor, and transplant characteristics for the cohort with missing data versus the cohort with full data.

References

1. Laster M, Soohoo M, Hall C, Streja E, Rhee CM, Ravel VA, Reddy U, Norris KC, Salusky IB, Kalantar-Zadeh K: Racial-ethnic disparities in mortality and kidney transplant outcomes among pediatric dialysis patients. *Pediatr Nephrol* 32: 685–695, 2017
2. Furth SL, Garg PP, Neu AM, Hwang W, Fivush BA, Powe NR: Racial differences in access to the kidney transplant waiting list for children and adolescents with end-stage renal disease. *Pediatrics* 106: 756–761, 2000
3. Leonard MB, Donaldson LA, Ho M, Geary DF: A prospective cohort study of incident maintenance dialysis in children: An NAPRTC study. *Kidney Int* 63: 744–755, 2003
4. Chaudhuri A, Gallo A, Grimm P: Pediatric deceased donor renal transplantation: An approach to decision making. I. Pediatric kidney allocation in the USA: The old and the new. *Pediatr Transplant* 19: 776–784, 2015
5. Shelton BA, Sawinski D, Ray C, Reed RD, MacLennan PA, Blackburn J, Young CJ, Gray S, Yanik M, Massie A, Segev DL, Locke JE: Decreasing deceased donor transplant rates among children (≤6 years) under the new kidney allocation system. *Am J Transplant* 18: 1690–1698, 2018
6. Sanchez D, Dubay D, Prabhakar B, Taber DJ: Evolving trends in racial disparities for peri-operative outcomes with the new kidney allocation System (KAS) implementation. *J Racial Ethn Health Disparities* 5: 1171–1179, 2018
7. Melanson TA, Hockenberry JM, Plantinga L, Basu M, Pastan S, Mohan S, Howard DH, Patzer RE: New kidney allocation system associated with increased rates of transplants among Black and Hispanic patients. *Health Aff (Millwood)* 36: 1078–1085, 2017
8. Stewart DE, Kucheryavaya AY, Klassen DK, Turgeon NA, Formica RN, Aeder MI: Changes in deceased donor kidney transplantation one year after KAS implementation. *Am J Transplant* 16: 1834–1847, 2016
9. Hart A, Gustafson SK, Skeans MA, Stock P, Stewart D, Kasiske BL, Israni AK: OPTN/SRTR 2015 Annual Data Report: Early effects of the new kidney allocation system. Available at: https://www.srtr.org/reports/srtroptn-annual-data-report/. Accessed January 14, 2021
10. Kulkarni S, Ladin K, Haakinson D, Greene E, Li L, Deng Y: Association of racial disparities with access to kidney transplant after the implementation of the new kidney allocation system. *JAMA Surg* 154: 618–625, 2019
11. Parker WF, Ross LF, Thistlethwaite Jr. JR, Gallo AE: Impact of the kidney allocation system on young pediatric recipients. *Clin Transplant* 32: e13223, 2018
12. Massie AB, Kucirka LM, Segev DL: Big data in organ transplantation: Registries and administrative claims [published correction appears in *Am J Transplant* 14: 2673, 2014]. *Am J Transplant* 14: 1723–1730, 2014
13. Collett D: *Modelling Survival Data in Medical Research*, Boca Raton, FL, CRC Press, 2015

14. Amaral S, Patzer RE, Kutner N, McClellan W: Racial disparities in access to pediatric kidney transplantation since share 35. *J Am Soc Nephrol* 23: 1069–1077, 2012
15. Austin PC, Lee DS, Fine JP: Introduction to the analysis of survival data in the presence of competing risks. *Circulation* 133: 601–609, 2016
16. StataCorp LP: *Stata Statistical Software: Release 14*, College Station, TX, StataCorp LP, 2015
17. Jackson KR, Bowring MG, Kernodle A, Boyarsky B, Desai N, Charnaya O, Garonzik-Wang J, Massie AB, Segev DL: Changes in offer and acceptance patterns for pediatric kidney transplant candidates under the new Kidney Allocation System. *Am J Transplant* 20: 2234–2242, 2020
18. Nazarian SM, Peng AW, Duggirala B, Gupta M, Bittermann T, Amaral S, Levine MH: The kidney allocation system does not appropriately stratify risk of pediatric donor kidneys: Implications for pediatric recipients. *Am J Transplant* 18: 574–579, 2018
19. Westphal SG, Langewisch ED, Robinson AM, Wilk AR, Dong JJ, Plumb TJ, Mullane R, Merani S, Hoffman AL, Maskin A, Miles CD: The impact of multi-organ transplant allocation priority on waitlisted kidney transplant candidates. *Am J Transplant* 21: 2161–2174, 2021
20. Ng DK, Moxey-Mims M, Warady BA, Furth SL, Muñoz A: Racial differences in renal replacement therapy initiation among children with a nonglomerular cause of chronic kidney disease. *Ann Epidemiol* 26: 780–787.e1, 2016
21. Jackson KR, Zhou S, Ruck J, Massie AB, Holscher C, Kernodle A, Glorioso J, Motter J, Neu A, Desai N, Segev DL, Garonzik-Wang J: Pediatric deceased donor kidney transplant outcomes under the Kidney Allocation System. *Am J Transplant* 19: 3079–3086, 2019
22. Krissberg JR, Sutherland SM, Chamberlain LJ, Wise PH: Policy in pediatric nephrology: Successes, failures, and the impact on disparities. *Pediatr Nephrol* 36: 2177–2188, 2021
23. Furth SL, Hwang W, Neu AM, Fivush BA, Powe NR: Effects of patient compliance, parental education and race on nephrologists' recommendations for kidney transplantation in children. *Am J Transplant* 3: 28–34, 2003
24. Ogedegbe G: Responsibility of medical journals in addressing racism in health care. *JAMA Netw Open* 3: e2016531, 2020

Received: May 12, 2021 **Accepted:** September 27, 2021

Published online ahead of print. Publication date available at www.cjasn.org.