Reduced Racial Disparity in Kidney Transplant Outcomes in the United States from 1990 to 2012

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ABSTRACT

Earlier studies reported inferior outcomes among black compared with white kidney transplant (KT) recipients. We examined whether this disparity improved in recent decades. Using the Scientific Registry of Transplant Recipients and Cox regression models, we compared all-cause graft loss among 63,910 black and 145,482 white adults who received a first-time live donor KT (LDKT) or deceased donor KT (DDKT) in 1990–2012. Over this period, 5-year graft loss after DDKT improved from 51.4% to 30.6% for blacks and from 37.3% to 25.0% for whites; 5-year graft loss after LDKT improved from 37.4% to 22.2% for blacks and from 20.8% to 13.9% for whites. Among DDKT recipients in the earliest cohort, blacks were 39% more likely than whites to experience 5-year graft loss (adjusted hazard ratio [aHR], 1.39; 95% confidence interval [95% CI], 1.32 to 1.47; $P<0.001$), but this disparity narrowed in the most recent cohort (aHR, 1.10; 95% CI, 1.03 to 1.18; $P=0.01$). Among LDKT recipients in the earliest cohort, blacks were 53% more likely than whites to experience 5-year graft loss (aHR, 1.53; 95% CI, 1.27 to 1.83; $P<0.001$), but this disparity also narrowed in the most recent cohort (aHR, 1.37; 95% CI, 1.17 to 1.61; $P<0.001$). Analyses revealed no statistically significant differences in 1-year or 3-year graft loss after LDKT or DDKT in the most recent cohorts. Our findings of reduced disparities over the last 22 years driven by more markedly improved outcomes for blacks may encourage nephrologists and patients to aggressively promote access to transplantation in the black community.

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Kidney transplant (KT) is the optimal treatment for most patients with ESRD, offering longer life expectancy and improved quality of life, as compared with dialysis treatment.[1–4] Despite these benefits, previous findings suggest that black transplant recipients experience poorer outcomes (*i.e.*, worse graft and patient survival) than white recipients.[5–9] Racial differences in KT outcomes have been attributed to both immunologic barriers (*e.g.*, HLA matching and sensitization) and nonimmunologic barriers (*e.g.*, medication nonadherence, comorbid conditions, and socioeconomic barriers), with prior work suggesting that these factors contribute to increased rates of graft loss in black transplant recipients.[5–8,10]

Historic findings of worse outcomes among black KT recipients may contribute to pervasive disparities in access to KT.[4,11–14] Although black patients with ESRD appear to encounter unique

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barriers during each of the required steps (*e.g.*, pursuit, evaluation, and surgery) to successful receipt of a KT, nephrologists play an important role in KT education and referral. Prior research suggests that nephrologists' views about the benefits of KT for blacks may influence their presentation of KT as a treatment option.[15] Recently, in a 2012 study of US Renal Data System data, Johansen *et al.*[16] reported that black patients were less likely to be informed about a KT owing to lower likelihood of being assessed for KT eligibility around the time of dialysis initiation. Suboptimal KT education and provider communication might engender unmet concerns about KT and facilitate less willingness to pursue KT among black patients.[14,17–19]

In general, patient and graft survival after KT have dramatically improved in the United States,[4] reflecting advances in transplant care in recent years. We hypothesized that advances in immunosuppression and post-transplant management might differentially benefit black KT recipients (who were disproportionately burdened by immunologic barriers) and contribute to reduced racial disparities in KT outcomes.

To inform clinical decision making, we assessed 22-year trends in KT outcomes, stratified by race, to assess whether the rate of improvement in KT outcomes was significantly different for black and white KT recipients using robust, risk-adjusted statistical models. We also tested whether the disparity in KT outcomes between black versus white transplant recipients substantially changed over the study period.

RESULTS

Population Characteristics

Overall, 63,910 black and 145,482 white adults within the Scientific Registry of Transplant Recipients (SRTR) received a first-time live donor KT (LDKT) or deceased donor KT (DDKT) in the United States between January 1, 1990, and December 31, 2012. Black recipients were younger and had a higher prevalence of Medicare-only insurance, a higher body mass index, higher prevalence of hypertension-attributed ESRD, were less likely to receive a pre-emptive or living donor transplant, and were less likely to receive zero HLA mismatched kidneys as compared with white recipients. (Table 1).

Reduced Racial Disparity in All-Cause Graft Loss after LDKT

Graft survival after LDKT significantly improved from 1990 to 2012 (Figure 1A) with greater improvements observed among blacks compared with whites (P for race/time interaction <0.001). Among black LDKT recipients, graft loss at 1 year improved from 11.6% to 4.4% (adjusted hazard ratio [aHR], 0.30; 95% confidence interval [95% CI], 0.20 to 0.45), graft loss at 3 years improved from 22.4% to 11.2% (aHR, 0.47; 95% CI, 0.35 to 0.62); and graft loss at 5 years improved from 37.4% to 22.2% (aHR, 0.60; 95% CI, 0.48 to 0.75) (Table 2). In comparison, among white LDKT recipients, graft loss at 1 year improved from 7.3% to 2.6% (aHR, 0.40; 95% CI, 0.30 to 0.52), graft loss at 3 years improved from 12.7% to 7.5% (aHR, 0.64; 95% CI, 0.52 to 0.79), and graft loss at 5 years improved from 20.8% to 13.9% (aHR, 0.67; 95% CI, 0.56 to 0.79) (Table 2).

Differential improvements in all-cause graft survival translated into a reduced disparity comparing blacks and whites in the earliest transplant cohort (1990–1992) to the most recent transplant cohorts (2007–2008 for 5-year outcomes, 2009–2010 for 3-year outcomes, and 2011–2012 for 1-year outcomes). Blacks in the earliest cohort were 53% more likely than whites to experience 5-year graft loss (aHR, 1.53; 95% CI, 1.27 to 1.83), whereas blacks in the most recent cohort were 37% more likely than whites to experience this (aHR, 1.37; 95% CI, 1.17 to 1.61). Blacks in the earliest cohort were 44% more likely than whites to experience 3-year graft loss (aHR, 1.44; 95% CI, 1.15 to 1.79), but there were no statistically significant differences in 3-year graft loss in the most recent cohort (aHR, 1.05; 95% CI, 0.86 to 1.29). In addition, there were no statistically significant differences in 1-year graft loss for blacks compared with whites in the earliest transplant cohort (aHR, 1.28; 95% CI, 0.94 to 1.74) or most recent cohort (aHR, 0.96; 95% CI, 0.68 to 1.35) (Table 3).

Reduced Racial Disparity in All-Cause Graft Loss after DDKT

Blacks also experienced greater improvements in graft survival after DDKT than whites (P for race/time interaction <0.001) (Figure 1B). Among black DDKT recipients, graft loss at 1 year improved from 20.4% to 6.9% (aHR, 0.24; 95% CI, 0.20 to 0.28), graft loss at 3 years improved from 37.8% to 18.8% (aHR, 0.36; 95% CI, 0.32 to 0.40), and graft loss at 5 years improved from 51.4% to 30.6% (aHR, 0.41; 95% CI, 0.37 to 0.45) (Table 2). In comparison, among white DDKT recipients, graft loss at 1 year improved from 18.9% to 6.8% (aHR, 0.28; 95% CI, 0.24 to 0.32), graft loss at 3 years improved from 28.1% to 16.7% (aHR, 0.47; 95% CI, 0.43 to 0.52), and graft loss at 5 years improved from 37.3% to 25.0% (aHR, 0.52; 95% CI, 0.47 to 0.56) (Table 2).

As a result, the disparity in graft survival after DDKT significantly narrowed. Blacks in the earliest transplant cohort were 39% more likely than whites to experience 5-year graft loss (aHR, 1.39; 95% CI, 1.32 to 1.47), whereas blacks in the most recent cohort were only 10% more likely than whites to experience this (aHR, 1.10; 95% CI, 1.03 to 1.18). Blacks in the earliest cohort were 30% more likely than whites to experience 3-year graft loss (aHR, 1.30; 95% CI, 1.22 to 1.39), but there were no statistically significant racial differences in 3-year graft loss in the most recent cohort (aHR, 0.98; 95% CI, 0.90 to 1.07). In addition, there were no statistically significant differences in 1-year graft loss for blacks compared with whites in the earliest cohort (aHR, 1.06; 95% CI, 0.97 to 1.15) or most recent cohort (aHR, 0.91; 95% CI, 0.80 to 1.04) (Table 3).

Similar Improvements in Death-Censored Graft Loss and Patient Survival after Transplantation

Similar to our primary findings for all-cause graft loss, blacks also experienced greater improvements in death-censored

Table 1. Characteristics of black and white adults who received a first KT in the United States 1990–2012

Recipient Characteristics	Overall Study Period 1990–2012		Earliest Cohort 1990–1992		Most Recent Cohort 2010–2012	
	White (*n*=145,482)	Black[a] (*n*=63,910)	White (*n*=15,009)	Black[a] (*n*=5043)	White (*n*=20,559)	Black[a] (*n*=10,948)
Age, mean (SD)	49.3 (13.8)	47.3 (13)	43.2 (12.9)	41.5 (12.1)	53.9 (13.7)	50.9 (12.6)
Sex, female %	38.5	41.1	40.1	40	37.5	41.5
Primary insurance, %						
Employer group	49	26.9	29.1	8.8	46	25
Medicare	46.6	65.6	63.7	77.2	50.5	68.8
Medicaid	2.5	5.5	4.4	7	1.9	4.2
No coverage	0.3	0.1	1.7	0	0.2	0.1
Other coverage	1.6	1.9	1.1	7	1.4	1.9
Cause of ESRD, %						
Diabetes	22.3	20.7	24	15.8	24.5	28.3
Hypertension	14.1	42	8.2	36	17.7	40.8
Glomerular diseases	25.8	21.8	30.4	29.9	23.1	20.3
Cystic diseases	14.4	3.4	12.6	2.7	16.1	4.1
Other causes	23.4	12.1	24.8	15.6	18.6	6.5
Body mass index, %						
<30 kg/m^2	73.5	67.7	87	81.3	62.3	57.9
30–34.9 kg/m^2	17.9	20.8	9.2	12.9	24.4	25.6
>34.9 kg/m^2	8.6	11.5	3.8	5.8	13.3	16.5
RRT, median years (IQR)	1.2 (0.3–2.6)	3 (1.5–5)	1 (0.4–2)	1.9 (1–3.3)	3.9 (2–6)	1.7 (0.5–3.4)
Pre-emptive transplant, %	19	5.2	13	4.9	25.6	6.7
Peak PRA/CPRA, median (IQR)	0 (0–8)	3 (0–20)	2 (0–8)	3 (0–13)	0 (0–20)	0 (0–8)
Donor characteristics						
Living donor, %	43.5	21.9	27.4	13.6	47.7	19.8
Donor age, mean (SD)	39.1 (15)	37.2 (15.6)	34.3 (15.5)	32 (15.4)	41.7 (14.4)	38.9 (15)
Donor sex, female %	48.9	43.8	43.1	38.2	51.4	44.4
Donor race, black %	4.8	35.4	4.8	30	6.4	32.8
Characteristics – deceased donor transplants only						
Donor history of hypertension, %	19.1	22.9	0	0	30.5	30.5
Donation after circulatory death, %	6.2	7.2	0	0	16.9	14.9
Zero HLA mismatch, %	15.5	4.1	7.2	0.9	9.5	2.4
Cold ischemia time, median hours (IQR)	18.2 (14–24.6)	18.2 (13.7–24.1)	23 (16–31)	23 (16–31)	15.9 (10.6–21.1)	16.5 (11.5–22.5)

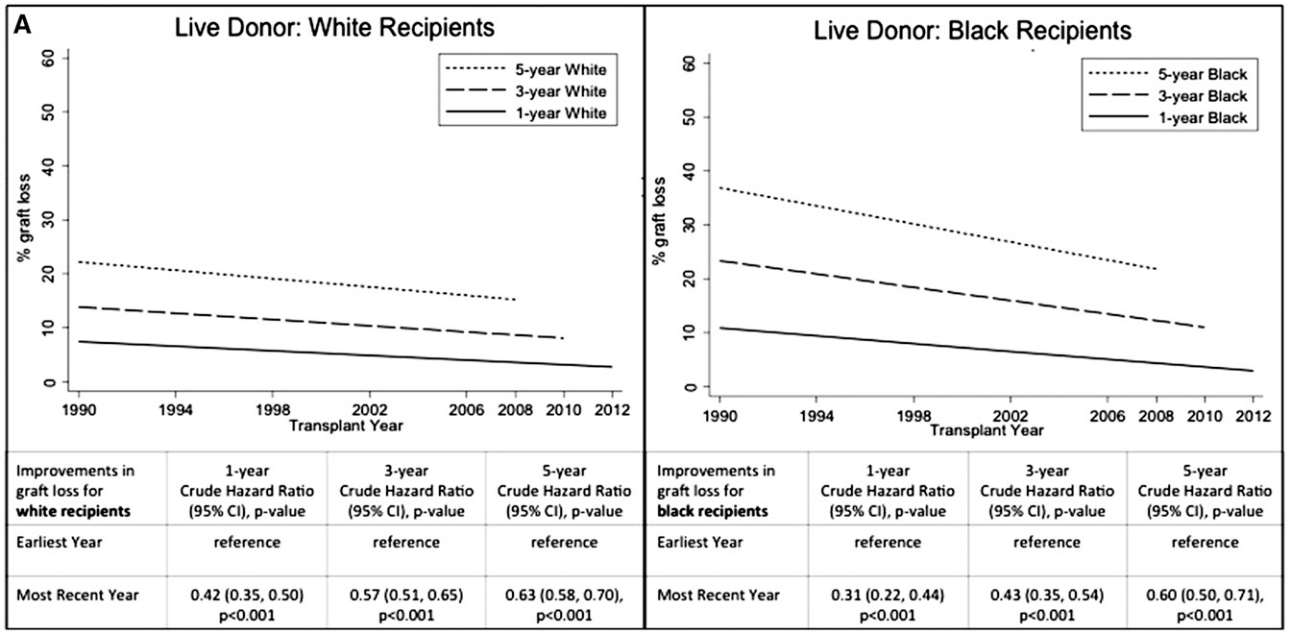
Results were calculated based upon complete data from study participants. Complete data were available from 209,392 (100%) of participants for the following variables: recipient age, recipient sex, time on RRT, pre-emptive transplant, donor type, donor age, donor sex, donor race, and cold ischemia time. The following variables were missing in some of the study participants, although this was mostly limited to the earliest time periods (1990–1994): recipient primary insurance (13.7% missing overall; 0.2% missing in 1995–2012), recipient cause of ESRD (0.1% missing overall; 0.1% missing in 1995–2012), recipient body mass index (3.4% missing overall; 1.9% missing in 1995–2012), peak PRA/CPRA (1% missing overall; 0.8% missing in 1995–2012), donor history of hypertension (17.2% missing overall; 1% missing in 1995–2012), donation after circulatory death (6.6% missing overall; 0.2% missing in 1995–2012), and HLA mismatches (0.7% missing overall; 0.6% missing in 1995–2012). IQR, interquartile range; PRA, panel reactive antibody; CPRA, calculated panel reactive antibody.

[a]There were statistically significant differences ($P<0.001$) in study characteristics for every comparison between blacks and whites.

graft loss and patient survival than their white counterparts (Supplemental Material). Among LDKT recipients, death-censored graft loss at 5 years improved from 14.1% to 8% (aHR, 0.59; 95% CI, 0.49 to 0.70) for whites and from 33.4% to 17.2% (aHR, 0.53; 95% CI, 0.43 to 0.66) for blacks. Patient survival at 5 years after LDKT improved from 89.6% to 92.1% (aHR, 0.37; 95% CI, 0.33 to 0.42) for whites and from 87.9% to 90.9% (aHR, 0.32; 95% CI, 0.25 to 0.40) for blacks. Among DDKT recipients, death-censored graft loss at 5 years improved from 26% to 11.9% (aHR, 0.49; 95% CI, 0.45 to 0.53) for whites and from 43.4% to 21.3% (aHR, 0.41; 95% CI, 0.38 to 0.45) for blacks. Patient survival at 5 years after DDKT improved from 78.8% to 81.2% (aHR, 0.42; 95% CI, 0.39 to 0.46) for whites and from 79.9% to 84.2% (aHR, 0.36; 95% CI, 0.33 to 0.39) for blacks. Differential improvements in death-censored graft loss and patient survival by recipient race were also noted at 1 and 3 years after LDKT and DDKT (Supplemental Material).

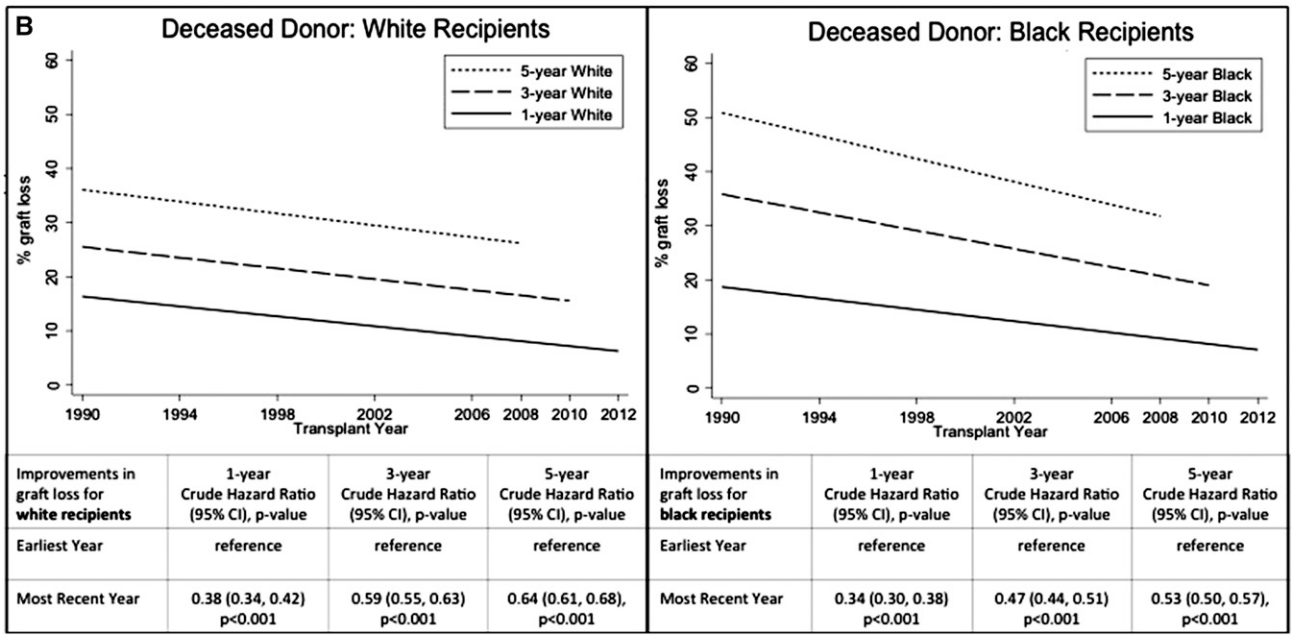
Potential Mechanisms Contributing to the Reduced Racial Disparity in KT Outcomes

In subsequent models, we explored whether there was a reduced racial disparity in closely related factors (*i.e.*, acute rejection and



Improvements in graft loss for **white recipients**	1-year Crude Hazard Ratio (95% CI), p-value	3-year Crude Hazard Ratio (95% CI), p-value	5-year Crude Hazard Ratio (95% CI), p-value
Earliest Year	reference	reference	reference
Most Recent Year	0.42 (0.35, 0.50) p<0.001	0.57 (0.51, 0.65) p<0.001	0.63 (0.58, 0.70), p<0.001

Improvements in graft loss for **black recipients**	1-year Crude Hazard Ratio (95% CI), p-value	3-year Crude Hazard Ratio (95% CI), p-value	5-year Crude Hazard Ratio (95% CI), p-value
Earliest Year	reference	reference	reference
Most Recent Year	0.31 (0.22, 0.44) p<0.001	0.43 (0.35, 0.54) p<0.001	0.60 (0.50, 0.71), p<0.001



Improvements in graft loss for **white recipients**	1-year Crude Hazard Ratio (95% CI), p-value	3-year Crude Hazard Ratio (95% CI), p-value	5-year Crude Hazard Ratio (95% CI), p-value
Earliest Year	reference	reference	reference
Most Recent Year	0.38 (0.34, 0.42) p<0.001	0.59 (0.55, 0.63) p<0.001	0.64 (0.61, 0.68), p<0.001

Improvements in graft loss for **black recipients**	1-year Crude Hazard Ratio (95% CI), p-value	3-year Crude Hazard Ratio (95% CI), p-value	5-year Crude Hazard Ratio (95% CI), p-value
Earliest Year	reference	reference	reference
Most Recent Year	0.34 (0.30, 0.38) p<0.001	0.47 (0.44, 0.51) p<0.001	0.53 (0.50, 0.57), p<0.001

Figure 1. Time trends in all-cause graft loss after KT for white and black adults in the United States. The graphs illustrate unadjusted trends in 1-year, 3-year, and 5-year all-cause graft loss (%) after (A) LDKT and (B) DDKT, stratified by recipient race.

delayed graft function) that may be associated with observed reductions in the racial disparity in graft survival. Among DDKT recipients, blacks in the earliest cohort had 68% higher odds of experiencing acute rejection within 1 year than whites (adjusted odds ratio [aOR], 1.68; 95% CI, 1.41 to 2.00), but blacks in the most recent cohort had only 14% higher odds than whites of acute rejection (aOR, 1.14; 95% CI, 1.00 to 1.30). Additionally, black DDKT recipients in the earliest cohort had 55% higher odds of experiencing delayed graft function than whites (aOR, 1.55; 95% CI, 1.39 to 1.73), whereas blacks in the most recent cohort had 40% higher odds than whites of experiencing this (aOR, 1.40; 95% CI, 1.27 to 1.54). Among LDKT recipients, there were no statistically significant racial differences in acute rejection within 1 year in the earliest cohort (aOR, 1.45; 95% CI, 0.55 to 3.84) or the most recent cohort (aOR, 0.99; 95% CI, 0.72 to 1.36). There were also no statistically significant racial differences in delayed graft function in the earliest cohort (aOR, 0.90; 95% CI, 0.25 to 3.23) or the most recent cohort (aOR, 1.05; 95% CI, 0.64 to 1.74).

Table 2. Greater improvements in graft survival after KT for black compared with white adults in the United States

Transplant Year	White Recipients			Black Recipients		
	1-Year aHR (95% CI)	3-Year aHR (95% CI)	5-Year aHR (95% CI)	1-Year aHR (95% CI)	3-Year aHR (95% CI)	5-Year aHR (95% CI)
LDKT[a]						
1990–1992	Reference	Reference	Reference	Reference	Reference	Reference
1993–1994	1.03 (0.85 to 1.24)	1.12 (0.96 to 1.31)	1.05 (0.92 to 1.19)	0.82 (0.59 to 1.14)	0.92 (0.73 to 1.17)	0.94 (0.78 to 1.15)
1995–1996	1.12 (0.87 to 1.44)	1.19 (0.98 to 1.45)	1.09 (0.93 to 1.28)	0.87 (0.60 to 1.25)	1.01 (0.78 to 1.32)	0.92 (0.74 to 1.14)
1997–1998	0.94 (0.73 to 1.22)	1.08 (0.89 to 1.32)	1.05 (0.90 to 1.23)	0.59 (0.40 to 0.86)	0.71 (0.54 to 0.92)	0.72 (0.58 to 0.89)
1999–2000	0.84 (0.65 to 1.08)	1.10 (0.90 to 1.34)	1.01 (0.86 to 1.19)	0.66 (0.46 to 0.94)	0.78 (0.60 to 1.02)	0.75 (0.61 to 0.93)
2001–2002	0.78 (0.61 to 1.01)	1.05 (0.85 to 1.29)	0.98 (0.83 to 1.16)	0.56 (0.39 to 0.80)	0.79 (0.61 to 1.02)	0.78 (0.63 to 0.96)
2003–2004	0.70 (0.54 to 0.89)	0.97 (0.79 to 1.20)	0.89 (0.75 to 1.05)	0.47 (0.33 to 0.66)	0.69 (0.53 to 0.89)	0.67 (0.54 to 0.83)
2005–2006	0.63 (0.49 to 0.81)	0.85 (0.69 to 1.04)	0.80 (0.68 to 0.95)	0.40 (0.28 to 0.57)	0.58 (0.44 to 0.76)	0.57 (0.46 to 0.71)
2007–2008	0.46 (0.35 to 0.59)	0.69 (0.56 to 0.85)	0.67 (0.56 to 0.79)	0.39 (0.27 to 0.57)	0.61 (0.46 to 0.80)	0.60 (0.48 to 0.75)
2009–2010	0.44 (0.34 to 0.57)	0.64 (0.52 to 0.79)	—	0.30 (0.20 to 0.44)	0.47 (0.35 to 0.62)	—
2011–2012	0.40 (0.30 to 0.52)	—	—	0.30 (0.20 to 0.45)	—	—
DDKT[b]						
1990–1992	Reference	Reference	Reference	Reference	Reference	Reference
1993–1994	1.02 (0.94 to 1.11)	1.02 (0.95 to 1.09)	1.02 (0.97 to 1.08)	0.90 (0.81 to 1.02)	0.92 (0.85 to 1.01)	0.90 (0.84 to 0.97)
1995–1996	0.79 (0.70 to 0.89)	0.85 (0.77 to 0.93)	0.87 (0.81 to 0.95)	0.70 (0.61 to 0.81)	0.74 (0.67 to 0.83)	0.75 (0.69 to 0.82)
1997–1998	0.66 (0.58 to 0.74)	0.78 (0.70 to 0.86)	0.80 (0.74 to 0.87)	0.57 (0.49 to 0.67)	0.64 (0.58 to 0.72)	0.67 (0.61 to 0.74)
1999–2000	0.66 (0.58 to 0.76)	0.78 (0.70 to 0.86)	0.81 (0.74 to 0.88)	0.62 (0.53 to 0.71)	0.69 (0.62 to 0.77)	0.69 (0.63 to 0.76)
2001–2002	0.58 (0.51 to 0.66)	0.74 (0.67 to 0.82)	0.77 (0.71 to 0.84)	0.52 (0.45 to 0.61)	0.59 (0.53 to 0.66)	0.60 (0.55 to 0.66)
2003–2004	0.48 (0.42 to 0.55)	0.64 (0.57 to 0.70)	0.67 (0.61 to 0.73)	0.48 (0.41 to 0.55)	0.57 (0.51 to 0.64)	0.55 (0.50 to 0.61)
2005–2006	0.45 (0.39 to 0.51)	0.58 (0.52 to 0.64)	0.60 (0.55 to 0.66)	0.41 (0.36 to 0.48)	0.48 (0.43 to 0.54)	0.48 (0.43 to 0.52)
2007–2008	0.35 (0.31 to 0.40)	0.46 (0.42 to 0.52)	0.52 (0.47 to 0.56)	0.37 (0.32 to 0.42)	0.41 (0.37 to 0.45)	0.41 (0.37 to 0.45)
2009–2010	0.36 (0.31 to 0.41)	0.47 (0.43 to 0.52)	—	0.29 (0.25 to 0.33)	0.36 (0.32 to 0.40)	—
2011–2012	0.28 (0.24 to 0.32)	—	—	0.24 (0.20 to 0.28)	—	—

Table shows the 1-year, 3-year, and 5-year aHRs comparing all-cause graft loss in recent transplant cohorts to the earliest transplant cohort (1990–1992). When comparing black and white recipients, there were greater improvements in graft survival over time for black recipients. —, data not available; DSA, donor service area; PRA/CPRA, panel reactive antibody/calculated panel reactive antibody.

[a]LDKT models adjusted for donor age, donor race/ethnicity, donor relationship, donor/recipient weight ratio, HLA mismatches, peak plasma renin activity (PRA)/CPRA, previous solid organ transplant, recipient age at transplant, recipient body mass index, recipient cause of ESRD, recipient hepatitis C serology, recipient insurance coverage, recipient race/ethnicity, recipient sex, and time on RRT.

[b]DDKT models adjusted for cold ischemia time, donation after circulatory death, donor age, donor cause of death, donor history of diabetes, donor history of hypertension, pumped donor kidney, donor race/ethnicity, donor serum creatinine, donor/recipient weight ratio, HLA mismatches, organ shipped outside recovery DSA, peak PRA/CPRA, previous solid organ transplant, recipient age at transplant, recipient body mass index, recipient cause of ESRD, recipient hepatitis C serology, recipient insurance coverage, recipient race/ethnicity, recipient sex, and time on RRT.

DISCUSSION

In this national study of more than 200,000 adults who received a first kidney-only transplant in the United States from 1990 to 2012, blacks experienced greater improvements in all-cause graft loss than whites, which translated into a statistically significant reduction in the disparity in graft survival. Five-year graft loss after DDKT improved from 51.4% to 30.6% for blacks compared with an improvement from 37.3% to 25.0% for whites, whereas 5-year graft loss after LDKT improved from 37.4% to 22.2% for blacks and from 20.8% to 13.9% for whites. Blacks who received a DDKT during 1990–1992 were 39% more likely than whites to experience all-cause graft loss at 5 years, whereas blacks who received a DDKT during 2007–2008 were only 10% more likely than whites. Blacks who received an LDKT during 1990–1992 were 52% more likely than whites to experience all-cause graft loss at 5 years, but this disparity was reduced for blacks compared with whites who received an LDKT during 2007–2008. Notably, there were no racial differences in all-cause graft loss at 3 years for black compared with white recipients of LDKT or DDKT in the most recent cohorts (2009–2010). There were also no racial differences in all-cause graft loss at 1 year after LDKT or DDKT in the most recent cohort (2011–2012). Similar to all-cause graft loss, improvements in racial disparities were also observed for death-censored graft loss and patient survival after LDKT and DDKT.

Temporal changes in deceased donor organ allocation policies, Medicare coverage, immunosuppressive regimens, surgical techniques, and desensitization strategies likely contributed to narrowed racial disparities. Immunosuppression strategies dramatically changed over the study period with increased use of induction agents and widespread replacement of azathioprine by mycophenolate, as well as increased tacrolimus use and decreased cyclosporin use at discharge.[20] These advancements in immunosuppressive regimens may have disproportionately benefited black transplant recipients, who were historically more likely to encounter immunologic barriers.[6,7] In addition, an important change in

Table 3. Narrowed racial disparity in graft survival after KT between black and white adults in the United States

Transplant Year	LDKT[a]			DDKT[b]		
	1-Year aHR (95% CI)	3-Year aHR (95% CI)	5-Year aHR (95% CI)	1-Year aHR (95% CI)	3-Year aHR (95% CI)	5-Year aHR (95% CI)
1990–1992	1.28 (0.94 to 1.74)	1.44 (1.15 to 1.79)	1.53 (1.27 to 1.83)	1.06 (0.97 to 1.15)	1.30 (1.22 to 1.39)	1.39 (1.32 to 1.47)
1993–1994	1.02 (0.73 to 1.41)	1.19 (0.94 to 1.49)	1.38 (1.15 to 1.66)	0.94 (0.85 to 1.04)	1.18 (1.09 to 1.27)	1.22 (1.15 to 1.31)
1995–1996	1.00 (0.73 to 1.36)	1.22 (0.98 to 1.51)	1.29 (1.08 to 1.54)	0.94 (0.84 to 1.05)	1.14 (1.05 to 1.24)	1.20 (1.12 to 1.28)
1997–1998	0.80 (0.58 to 1.11)	0.94 (0.75 to 1.17)	1.04 (0.87 to 1.25)	0.93 (0.83 to 1.04)	1.08 (0.99 to 1.17)	1.16 (1.09 to 1.25)
1999–2000	1.01 (0.75 to 1.35)	1.02 (0.84 to 1.25)	1.14 (0.96 to 1.34)	0.98 (0.88 to 1.10)	1.16 (1.07 to 1.26)	1.19 (1.11 to 1.27)
2001–2002	0.92 (0.69 to 1.21)	1.09 (0.90 to 1.31)	1.22 (1.04 to 1.42)	0.96 (0.86 to 1.08)	1.05 (0.96 to 1.13)	1.09 (1.02 to 1.17)
2003–2004	0.86 (0.64 to 1.14)	1.02 (0.84 to 1.23)	1.15 (0.99 to 1.34)	1.05 (0.93 to 1.18)	1.18 (1.08 to 1.28)	1.15 (1.07 to 1.23)
2005–2006	0.81 (0.60 to 1.09)	0.99 (0.81 to 1.20)	1.08 (0.93 to 1.26)	0.98 (0.88 to 1.10)	1.09 (1.00 to 1.18)	1.10 (1.03 to 1.17)
2007–2008	1.10 (0.80 to 1.51)	1.27 (1.04 to 1.56)	1.37 (1.17 to 1.61)	1.10 (0.98 to 1.24)	1.14 (1.05 to 1.24)	1.10 (1.03 to 1.18)
2009–2010	0.86 (0.62 to 1.20)	1.05 (0.86 to 1.29)	—	0.85 (0.75 to 0.96)	0.98 (0.90 to 1.07)	—
2011–2012	0.96 (0.68 to 1.35)	—	—	0.91 (0.80 to 1.04)	—	—

The table shows the 1-year, 3-year, and 5-year aHRs comparing all-cause graft loss for blacks versus whites by transplant cohort year, for LDKT and DDKT. —, data not available; DSA, donor service area; PRA/CPRA, panel reactive antibody/calculated panel reactive antibody.

[a]LDKT models adjusted for donor age, donor race/ethnicity, donor relationship, donor/recipient weight ratio, HLA mismatches, peak plasma renin activity (PRA)/CPRA, previous solid organ transplant, recipient age at transplant, recipient body mass index, recipient cause of ESRD, recipient hepatitis C serology, recipient insurance coverage, recipient race/ethnicity, recipient sex, and time on RRT.

[b]DDKT models adjusted for cold ischemia time, donation after circulatory death, donor age, donor cause of death, donor history of diabetes, donor history of hypertension, pumped donor kidney, donor race/ethnicity, donor serum creatinine, donor/recipient weight ratio, HLA mismatches, organ shipped outside recovery DSA, peak PRA/CPRA, previous solid organ transplant, recipient age at transplant, recipient body mass index, recipient cause of ESRD, recipient hepatitis C serology, recipient insurance coverage, recipient race/ethnicity, recipient sex, and time on RRT.

the deceased donor organ allocation policy that eliminated priority HLA-B matching in 2003 has also been shown to be associated with a 23% reduction in the disparity in rates of DDKT between blacks and whites,[21] as well as reduced transplant waiting times and improved 2-year outcomes for nonwhite DDKT recipients.[22] In our study, there was a statistically significant change in pretransplant duration of RRT; median years on RRT changed from 1.0 to 3.9 for whites and from 1.9 to 1.7 for blacks (Table 1). Although we adjusted for this differential change in RRT duration within the statistical modeling approach, the shorter RRT duration for black patients who make the waiting list may have helped to facilitate a better clinical and immunologic profile for successful transplant outcomes. Prior studies further suggest that socioeconomic barriers, such as high costs of immunosuppressant medications, may also be associated with inferior transplant outcomes among recipients living in high poverty and/or racially segregated neighborhoods.[10,23–27] Two major Medicare policy initiatives that occurred during the study period extended immunosuppression coverage from 1 year to 3 years for all transplant recipients (implemented between 1993 and 1995) and provided lifetime coverage of immunosuppressant medications for Medicare-insured recipients who are disabled or >65 years (beginning January 1, 2000).[23,26,27] These policy initiatives to extend Medicare immunosuppression coverage and improve long-term affordability of immunosuppressant medications may have disproportionately benefited black recipients who rely on Medicare coverage (versus employer-based coverage) and partially contributed to reduced disparities over the study period.[23,26,27] Finally, in additional analyses using SRTR data, we observed substantial reductions in the racial disparity in acute rejection within 1 year and delayed graft function among DDKT recipients. This likely also contributed to the observed reduction in the racial disparity in graft survival among DDKT recipients.

Our findings of a narrowed disparity in transplant outcomes in recent years reinforce the need to improve access to transplantation for black patients with ESRD. Despite longstanding recognition of the need to reduce disparities in access to transplantation, relatively little progress has been made in narrowing these disparities.[4,11] Our findings of significant improvements in transplant outcomes for black recipients may help to alleviate unmet concerns that might impede black patients' willingness to pursue transplantation.[13,17–19] Standardized transplant education, which incorporates the latest research findings, might also help to improve transplant knowledge and communication among black patients, their families, and health-care providers not directly involved in the transplant process (*e.g.*, primary care providers and general nephrologists).[15,19,28]

Our study was limited by the variables captured in SRTR, including provider-reported race, which has the potential for misclassification bias. We were also unable to account for individual-level patient income, which may be associated with differences in transplant outcomes. The future availability of patient-level socioeconomic measures within national registries would be beneficial for needed analyses to better delineate the extent to which changes in socioeconomic status over time may have contributed to the reduced racial disparity in outcomes. Our study also has several important strengths, including the ability to comprehensively analyze patient and graft survival for the entire population of transplant recipients in the United States over the past 22 years. We were also able to

account for many important patient, donor, and transplant characteristics that might confound or potentially mediate the association of race and graft survival.

In conclusion, our findings of a reduced racial disparity in KT outcomes driven by significant improvements for black recipients may provide added confidence to aggressively promote access to KT among black patients with ESRD. Timely decision support regarding the full range of treatment options may help to ensure that all clinically suitable patients have an opportunity to consider transplantation as a treatment option in a fully informed manner. Ongoing provider-patient and provider-family communication highlighting the benefits of KT may also help to alleviate unmet concerns and improve knowledge and consideration for black patients.

CONCISE METHODS

Data Source and Study Population

This study used data from the SRTR, a national registry of all solid organ transplants. The SRTR data system includes data on all donors, wait-listed candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). Each transplant center uniformly reports recipient, donor, and transplant factors. The Health Resources and Services Administration, US Department of Health and Human Services, provides oversight to the activities of the OPTN and SRTR contractors. We limited our study population to black or white American adults aged ≥18 years who received a first kidney-only transplant in the United States between January 1, 1990, and December 31, 2012.

Exposures and Outcomes

Our primary outcome of interest was all-cause graft loss (*i.e.*, death-censored graft loss or patient death with functioning graft) after LDKT or DDKT. We followed patients until graft loss or the end of the study period. The primary exposure for all analyses was recipient race (black or white) on the basis of provider-reported information collected at the time of transplant.

Statistical Analyses

Primary Analysis

We described recipient, donor, and transplant characteristics stratified by recipient race and transplant period. We used Kaplan–Meier methods to examine time to all-cause graft failure by recipient race and transplant year, and we performed log-rank tests to assess statistical significance.

Cox Proportional Hazards Models

We estimated racial differences in improvements in all-cause graft loss using multivariable Cox proportional hazards regression models (estimating aHRs) with censoring at 1, 3, and 5 years post-transplant. We adjusted all models for recipient characteristics (HLA mismatches, peak panel reactive antibody/calculated panel reactive antibody, previous solid organ transplant, age, body mass index, cause of ESRD, hepatitis C serology, insurance coverage, race, gender, time on RRT) and donor characteristics (age, race, serum creatinine, relationship to recipient, donor/recipient weight ratio). We also adjusted DDKT models for additional characteristics including cold ischemia time, donation after circulatory death, donor cause of death, donor history of diabetes, donor history of hypertension, pumped donor kidney, and organ shipped outside recovery donor service area. We assessed the proportional hazards assumption both graphically using complementary log-log plots and statistically using Schoenfeld residuals. We tested for colinearity among the vector of explanatory variables using the variance inflation factor and Eigen values. We used the standard SRTR risk-adjustment approach for handling missing data. With the SRTR risk-adjustment approach, missing variable levels are modeled separately from known variable levels in regression models, which may introduce residual confounding. Within sensitivity analysis, we tested the robustness of our estimates by comparing results from an alternative modeling approach to handle missing data (multiple imputation), and our inferences remained the same for our outcomes of interest. We considered a two-tailed P value <0.05 as statistically significant. All statistical analyses were conducted using Stata Statistical Software (Stata SE version 13.0; StataCorp, College Station, TX).

Additional Sensitivity Analyses

In additional models, we examined racial differences in death-censored graft survival and patient survival to assess whether our inferences remained the same for these outcomes. We defined death-censored graft survival as the time between date of LDKT or DDKT and date of graft failure (defined by retransplantation or return to dialysis) or last date of follow-up with a functioning graft with censoring for patient death and administrative end of study. In subsequent models, we also explored whether racial differences in acute rejection within 1 year and delayed graft function significantly changed over the study period.

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DISCLOSURES

None.

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See related editorial, "The End of Racial Disparities in Kidney Transplantation? Not So Fast!," on pages 2224–2226.

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