

Access and Outcomes Among Minority Transplant Patients, 1999–2008, with a Focus on Determinants of Kidney Graft Survival

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Coincident with an increasing national interest in equitable health care, a number of studies have described disparities in access to solid organ transplantation for minority patients. In contrast, relatively little is known about differences in posttransplant outcomes between patients of specific racial and ethnic populations. In this paper, we review trends in access to solid organ transplantation and posttransplant outcomes by organ type, race and ethnicity. In addition, we present an analysis of categories of factors that contribute to the racial/ethnic variation seen in kidney transplant outcomes. Disparities in minority access to transplantation among wait-listed candidates are improving, but persist for those awaiting kidney, simultaneous kidney and pancreas and intestine transplantation. In general, graft and patient survival among recipients of

solid organ transplants is highest for Asians and Hispanic/Latinos, intermediate for whites and lowest for African Americans. Although much of the difference in outcomes between racial/ethnic groups can be accounted for by adjusting for patient characteristics, important observed differences remain. Age and duration of pretransplant dialysis exposure emerge as the most important determinants of survival in an investigation of the relative impact of center-related versus patient-related variables on kidney graft outcomes.

Key words: Access, ethnicity, heart transplantation, intestine transplantation, kidney transplantation, liver transplantation, lung transplantation, minorities, outcomes, pancreas transplantation, race, survival

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Introduction

The existence of disparities in access to solid organ transplantation among minority patients with end-stage organ failure has been recognized for many years (1–3). However, relatively little is known about differences in posttransplant outcomes between patients of specific racial and ethnic populations (4–6). Nevertheless, it is widely believed that graft and patient survivals for minority transplant recipients are inferior to those observed for whites. In this paper, we will review trends in access to solid organ transplantation and posttransplant outcomes by race and ethnicity for candidates and recipients of kidney, liver, heart, lung, simultaneous kidney and pancreas, pancreas-alone and intestine transplants. Specific differences by race and ethnicity in access, transplant trends and outcomes are demonstrated. In addition, we will present an analysis of the relative contribution of center- and patient-related factors on the racial/ethnic variation seen in kidney graft outcomes.

Methods

These analyses are based on the Organ Procurement and Transplantation Network/Scientific Registry of Transplant Recipients (OPTN/SRTR) database, which includes information on all wait-listed transplant candidates, transplant recipients and donors in the United States (7). The

OPTN/SRTR data source was supplemented with end-stage renal disease (ESRD) statistics from the Centers for Medicare and Medicaid Services (CMS) and with vital status information from the Social Security Death Master File (SSDMF). (For survival adjustments and diagnosis categories, see Tables TN-4 and TN-5 in the Technical Notes of the OPTN/SRTR Annual Report [8].) The models for time at risk for graft and patient survival began on the date of transplant. Graft failure for kidney transplants was defined as the earliest date among death, retransplant of the same organ type or initiation of maintenance dialysis. Adjusted survival probabilities for each organ type by race/ethnicity were computed using separate Cox regression models, with adjustments for age, sex and primary diagnosis. Analyses were performed in SAS 9.2 (SAS Institute, Cary, NC). Following the OPTN data collection format, Hispanic and non-Hispanic blacks were counted as African American. Hispanic and non-Hispanic Asians were counted as Asians. Non-Hispanic whites (whites) and Hispanic whites (Hispanic/Latinos) were tabulated and evaluated separately. Results for Native Americans and patients of other racial/ethnic groups are not reported because of small numbers.

Results

Kidney transplant trends and outcomes

Access to kidney transplantation: The number and distribution by race/ethnicity for three representative years is shown for active waiting-list patients and transplants for seven organ types (kidney, liver, heart, lung, kidney-pancreas, pancreas and intestine) in Table 1. Deceased donor (DD) kidney transplant percentages for African Americans, Hispanic/Latinos and Asians lag behind their respective proportions of the waiting list. With an ideal kidney allocation system, there would be no barriers to transplantation except for the availability of donor organs. A consequence of such a system would be that, over time, the proportion of racial/ethnic groups receiving transplants

Table 1: Active waiting list and deceased donor transplants by organ type and race/ethnicity, 2000–2008

Organ Race/ethnicity	2000		2004		2008	
	WL ¹	TX ²	WL ¹	TX ²	WL ¹	TX ²
Kidney (N)	36 951	8124	45 475	9357	48 677	10 551
White (%)	42.7	53.7	38.9	48.8	37.9	46.3
African American (%)	36.5	28.7	35.9	29.5	34.1	30.9
Hispanic/Latino (%)	13.2	11.4	16.2	14.0	18.1	15.4
Asian (%)	6.5	5.1	7.6	6.1	8.5	6.1
Liver (N)	12 049	4595	12 627	5848	12 198	6069
White (%)	75.3	74.0	72.3	71.8	71.4	69.7
African American (%)	7.1	9.0	7.1	10.0	6.8	10.3
Hispanic/Latino (%)	12.6	12.9	15.2	12.5	16.5	13.9
Asian (%)	4.4	3.3	4.8	4.9	4.5	5.0
Heart (N)	2477	2199	1808	2015	1406	2163
White (%)	79.3	77.2	74.9	70.4	73.5	65.5
African American (%)	13.4	13.3	14.9	16.8	16.6	20.2
Hispanic/Latino (%)	6.0	6.7	7.7	9.0	7.3	9.9
Asian (%)	0.8	2.2	1.9	2.8	1.6	3.3
Lung (N)	2429	941	2315	1157	1006	1478
White (%)	85.5	89.7	83.6	86.2	83.5	83.1
African American (%)	9.7	7.1	9.5	7.6	9.1	8.9
Hispanic/Latino (%)	3.4	2.7	5.1	5.0	5.4	5.5
Asian (%)	1.2	0.2	1.4	0.8	1.5	1.6
Intestine (N)	71	82	127	152	168	185
White (%)	59.2	61.0	66.1	68.4	60.7	67.0
African American (%)	25.4	17.1	15.7	11.2	22.6	16.8
Hispanic/Latino (%)	11.3	19.5	14.2	15.1	13.1	11.4
Asian (%)	4.2	2.4	2.4	3.9	2.4	3.2
SPK ³ (N)	1818	915	1907	881	1349	836
White (%)	80.9	84.9	70.7	75.3	66.5	70.7
African American (%)	12.2	9.2	18.4	14.1	16.1	17.0
Hispanic/Latino (%)	5.3	4.8	8.8	8.9	13.3	10.5
Asian (%)	1.0	0.4	1.4	1.1	3.0	1.2
Pancreas ⁴ (N)	359	439	836	603	474	437
White (%)	87.5	92.3	85.9	88.4	80.6	80.6
African American (%)	7.2	3.9	6.7	5.1	11.2	11.4
Hispanic/Latino (%)	3.9	3.4	6.6	5.5	6.8	6.4
Asian (%)	1.1	0.2	0.4	0.7	0.6	1.1

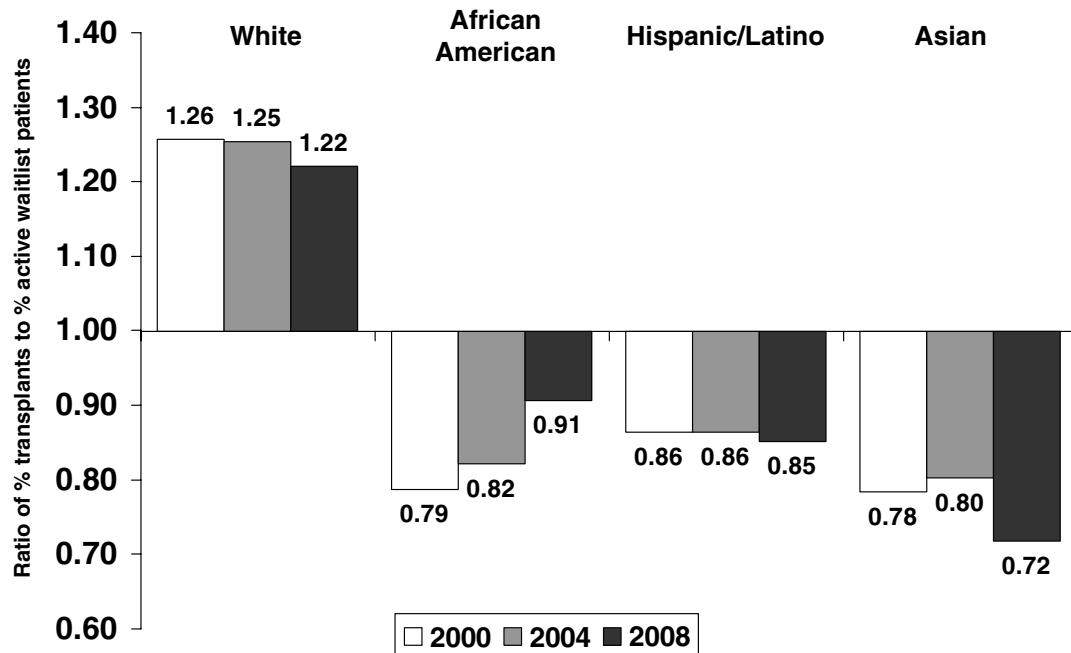
Source: OPTN/SRTR special analysis, September 2009; data as of May 2009. Reference Tables 5.1a, 5.4, 6.1a, 6.4, 7.1a, 7.4, 8.1a, 8.4, 9.1a, 9.4, 10.1a, 10.4, 11.1a, 11.4, 12.1a and 12.4.

¹Patients with active waiting list status at the end of the prior year.

²Transplants performed during the given year.

³Simultaneous pancreas and kidney transplants.

⁴Includes pancreas-transplant-alone (PTA) and pancreas-after-kidney (PAK) transplants.



Source: OPTN/SRTR Special Analysis, September 2009; data as of May 2009

Figure 1: Ratio of percent of kidney transplants and percent on active waiting list at end of prior year, 2000–2008.

would approximate the proportions of the same groups on the waiting list. In such a system, the ratio of the proportion transplanted to the proportion wait-listed would approach one. Significant deviations from a value of one would suggest the presence of barriers or advantages in access to transplantation for a particular group. To evaluate racial/ethnic access to kidney transplantation, the proportion of DD transplant recipients from each of the reported racial/ethnic groups (white, African American, Hispanic/Latino and Asian) during three representative years (2000, 2004 and 2008) was divided by the proportion of patients on the waiting list from the same group on December 31 of the preceding year. The results are expressed as ratios and are shown for kidney transplantation in Figure 1. Similar results are presented for the other organ types later in this paper. A value over 1.0 indicates that more patients of a racial/ethnic group received DD organs than would be expected from that group's proportion of the waiting list. Conversely, a value below 1.0 signifies that the group has received DD transplants at a rate below its prevalence on the waiting list. Among kidney transplant recipients, whites were transplanted at a rate greater than their representation on the waiting list. In contrast, African Americans, Hispanic/Latinos and Asians were transplanted at rates lower than expected from their waiting-list prevalence. The difference between the ethnic/racial composition of the waiting list and the distribution of kidney transplant recipients appears to be narrowing over time for whites and African Americans; it is stable among Hispanics/Latinos but may be increasing for Asians.

Kidney transplant trends: Between 1999 and 2006, the total number of kidney transplants increased for all race/ethnicity groups. However, between 2006 and 2008, the number of white recipients of standard criteria donor (SCD) transplants declined from 4180 in 2006 to 4017 in 2008; the number of white recipients also declined for expanded criteria donor (ECD) transplants from 905 in 2006 to 867 in 2008 and for living donor (LD) transplants from 4463 in 2004 to 3995 in 2008 [Tables 5.4a, 5.4b and 5.4d]. The numbers of SCD and LD kidney transplants performed in the other racial/ethnic groups, in general, remained more stable or increased slightly; the number of ECD kidney transplants continued to increase for African Americans and Hispanic/Latinos, perhaps as a consequence of the OPTN policy that largely allocates ECD kidneys based upon waiting time alone.

Kidney graft and recipient survival: Graft outcomes varied by racial/ethnic group irrespective of donor type, and the differences tended to increase with time after transplant. As shown in Figure 2, adjusted DD 3-month graft survival was very similar among the four race/ethnicities. One-year adjusted DD graft survival ranged from 89% to 94%; the percentages for 5- and 10-year adjusted DD graft survival were from 62% to 76% and 32% to 54%, respectively. At each of these timepoints, Asian kidney recipients enjoyed the highest adjusted and unadjusted (not shown) graft survival, followed by Hispanic/Latinos, and then whites. African American recipients had the lowest graft survival at each interval shown.

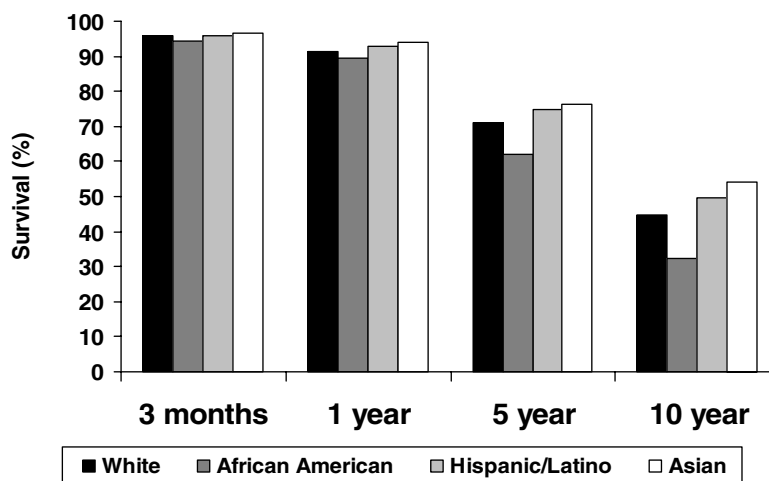


Figure 2: Adjusted deceased donor kidney graft survival by race/ethnicity.

Source: 2009 OPTN/SRTR Annual Report, Table 5.8c

*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Graft survival after LD transplantation followed a similar pattern. The adjusted LD kidney transplant graft survival at 3 months was 98% overall, ranging from 98% to 99% [Table 5.10d]. One-year adjusted LD graft survival was 96% overall, ranging from 95% to 98%; 5-year adjusted LD graft survival was 81% overall, ranging from 73% to 89% and 10-year adjusted LD graft survival was 59% overall, ranging from 45% to 70% [Table 5.10d]. Although LD graft survival was excellent for all groups at 3 months, differences developed by 1 year. As with DD kidney transplantation, Asian recipients enjoyed the highest adjusted LD graft survival, followed by Hispanic/Latinos, and then whites, with African Americans displaying the poorest outcomes.

Notably, the gap between DD graft survival for African Americans and other racial/ethnic groups appeared to be narrowing. Both DD and LD (LD, not shown) graft survival improved more rapidly for African Americans than for other racial/ethnic groups. Table 2 shows outcomes among kidney transplant recipients for 1996–2001 and 2002–2007. The overall 5-year adjusted DD kidney transplant graft survival improved by 6% for African Americans (from 56% to 62%); likewise, improvement was 4% for Hispanic/Latinos (71% to 75%), 2% for Asians (74% to 76%) and 3% for whites (68% to 71%).

Long-term, adjusted DD patient survival among African Americans and whites were similar with both groups, lagging behind the 10-year survival rates seen for Hispanic/Latino and Asian transplant recipients (Figure 3). In the first year following kidney transplant, adjusted recipient survivals were tightly grouped from 96% to 98% for the four ethnic groups considered. By the fifth year post-transplant, Hispanic/Latino and Asian recipients demonstrate superior patient survivals when compared with either white or African American recipients at 89% and 87%

versus 82% and 82%, respectively. By 10 years posttransplant, this difference increased as whites and African Americans had 60% and 57% patient survival, respectively, compared with Asians at 71% and Hispanic/Latinos at 68%.

Receipt of an LD kidney was associated with an almost 100% 3-month and 99% 1-year patient survival for each racial/ethnic group. At 5 and 10 years after transplantation, the adjusted patient survivals among African American (91% and 73%, respectively) and white recipients (92% and 77%, respectively) were inferior to the patient survival seen for Hispanic/Latino (95% and 83%, respectively) and Asian recipients (95% and 84%, respectively) [Table 5.12d].

Comparing 5-year trends (1996–2001 vs. 2002–2007) in adjusted DD kidney recipient survival, 3% improvements were seen for African Americans (79% to 82%) and Hispanic/Latinos (85% to 88%), whereas Asians improved by 2% (86% to 88%) and whites by 1% (81% to 82%) (Table 2).

In summary, among kidney transplant recipients, several trends are evident. First, the disparity in access to DD kidney transplantation between wait-listed white and minority patients appears to be narrowing significantly for African Americans, but less so for Hispanic/Latinos and Asians. Asian and Hispanic/Latino recipients demonstrated consistently superior long-term DD and LD graft and patient survivals compared with white recipients. African American recipients have consistently inferior long-term LD and DD graft survival relative to other racial/ethnic groups. Factors contributing to differences in posttransplant graft survival will be examined in detail later in this paper. Finally, DD kidney graft and patient survival is improving more rapidly for African Americans and Hispanic/Latinos than for whites and Asians.

Table 2: Adjusted deceased donor graft and patient survival at 5 years by organ and race/ethnicity for transplant recipients from 1996 to 2001 and 2002 to 2007

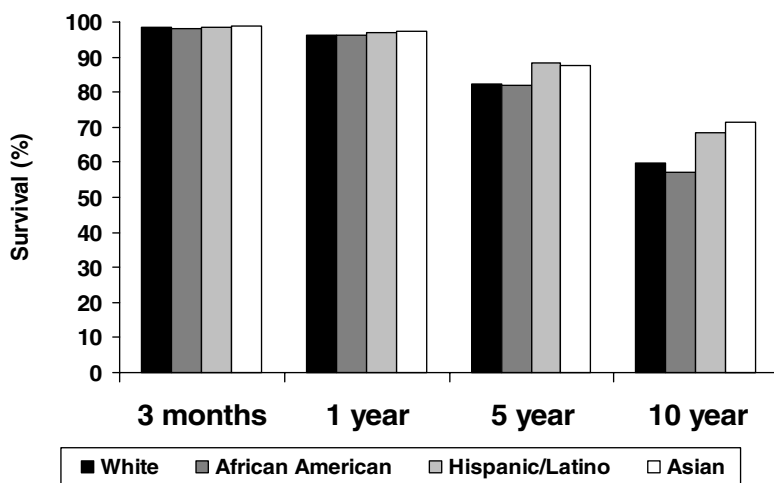
Organ	Race/ethnicity	1996–2001		2002–2007	
		N	5-year survival (%)	N	5-year survival (%)
Kidney graft	Overall	47 073	65.5	55 513	69.2
	White	25 912	68.3	26 726	70.9
	African American	13 253	56.4	17 022	62.2
	Hispanic/Latino	5115	70.8	7740	75.0
	Asian	2313	73.7	3265	76.3
Kidney patient	Overall	40 516	81.0	48 242	83.5
	White	21 612	80.8	22 388	82.4
	African American	11 829	79.0	15 242	82.1
	Hispanic/Latino	4502	85.2	6932	88.4
	Asian	2124	86.0	2997	87.6
Liver patient	Overall	22 667	72.0	29 604	73.8
	White	17 117	72.6	21 269	74.1
	African American	1942	64.8	2778	66.8
	Hispanic/Latino	2583	72.5	3860	75.2
	Asian	868	73.3	1445	78.1
Heart patient	Overall	12 915	72.8	11 991	75.2
	White	10 129	74.8	8478	77.7
	African American	1697	61.9	2062	64.8
	Hispanic/Latino	773	71.6	1016	75.1
	Asian	259	75.0	339	75.9
Lung patient	Overall	5228	44.5	7199	53.5
	White	4670	45.3	6194	53.2
	African American	357	33.9	558	57.5
	Hispanic/Latino	155	46.8	326	49.4
	Asian	30	56.2	77	61.4

Source: OPTN/SRTR special analysis, September 2009; data as of May 2009.

Liver transplant trends and outcomes

Access to liver transplantation: Different patterns were seen in access to liver transplantation among wait-listed candidates than those observed for kidney transplantation (Figure 4). Among liver transplant recipients, whites were transplanted at a rate commensurate with their pro-

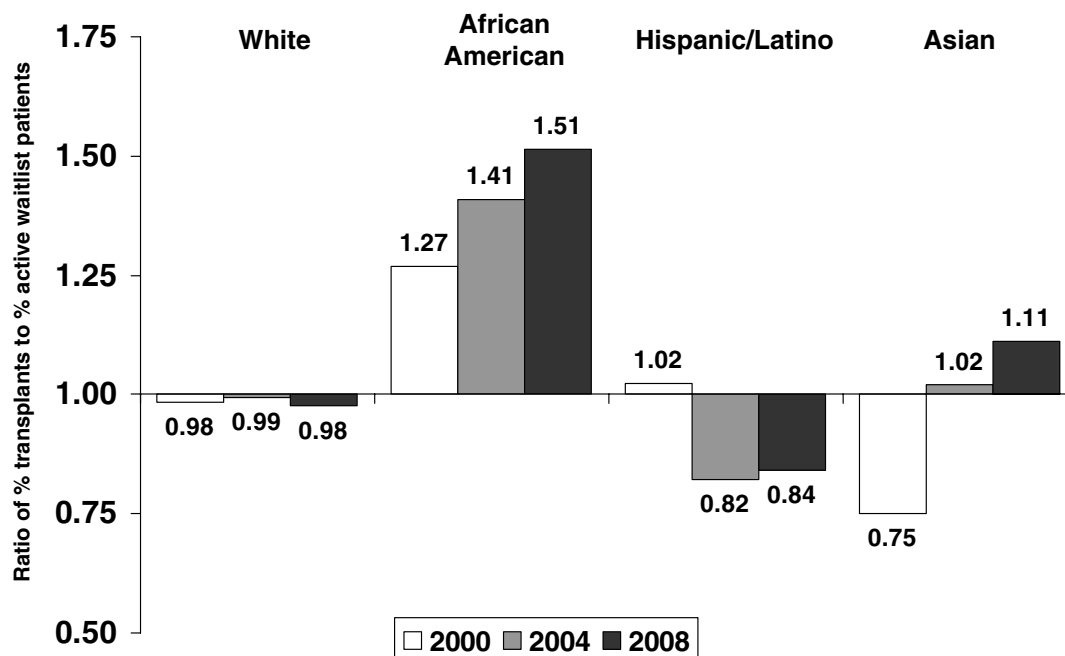
portion on the waiting list. However, African Americans and, most recently, Asians were transplanted at rates above their representation on the waiting list. Furthermore, liver transplantation rates relative to whites and Hispanic/Latinos appeared to be increasing for Asians and particularly for African Americans. In contrast, the rate



*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Source: 2009 OPTN/SRTR Annual Report, Table 5.12c

Figure 3: Adjusted deceased donor kidney patient survival by race/ethnicity.



Source: OPTN/SRTR Special Analysis, September 2009; data as of May 2009

Figure 4: Ratio of percent of liver transplants and percent on active waiting list at end of prior year, 2000–2008.

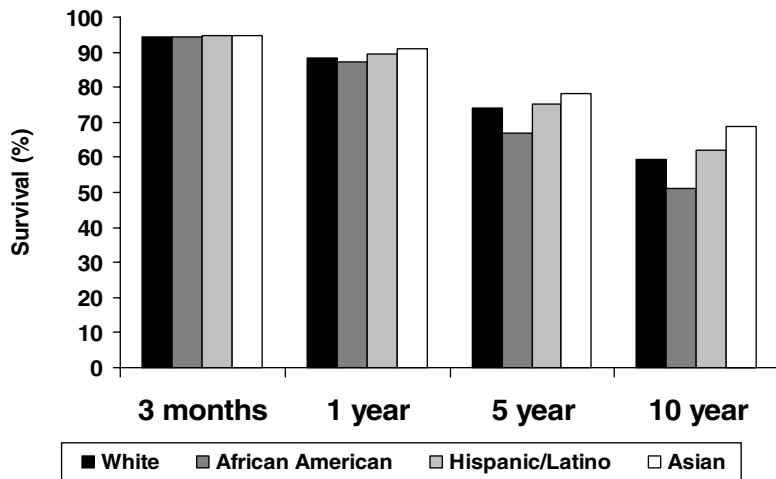
at which Hispanic/Latinos received liver transplants decreased between 2000 and 2008 relative to their representation on the waiting list. In 2008, the liver transplant rate deficit was 16% for Hispanic/Latinos and 2% for whites in comparison with their waiting-list representation, whereas African Americans and Asians received 51% and 11% more liver transplants, respectively, than would be predicted based upon their waiting-list prevalence. Importantly, these results were not adjusted for patient characteristics including MELD scores.

Liver transplantation trends: The total number of liver transplants (DD and LD) gradually increased from 4751 in 1999 to a peak of 6651 in 2006, but declined slightly over the past 2 years, falling to 6318 in 2008 [Tables 9.4a and 9.4b]. This decrease principally reflected a drop in the number of liver transplants for whites, as the number of liver transplants going to the other race/ethnicities remained relatively stable. As a consequence, the ethnic/racial distribution of DD liver transplant recipients has changed, with a decline in white recipients from 76% in 1999 to 70% in 2008 balanced by modest increases in the percentage transplanted for African Americans, Asians and Hispanic/Latinos [Table 9.4a]. The number of LD liver transplants declined from a peak of 524 in 2001 to a low of 249 in 2008 [Table 9.4b]. LD liver transplants now comprise less than 4% of liver transplants performed nationally, with the preponderance in 2008 going to whites (189, [76%]), and very few to African Americans (20, [8%]), Hispanic/Latinos (26, [10%]) and Asians (14, [6%]).

Liver transplant recipient survival: As seen with kidney transplantation, patient survival varied by racial/ethnic group (Figure 5). The adjusted 3-month patient survival for DD liver transplants in 2006–2007 was 94%, with little difference between racial/ethnic groups [Table 9.12a]. Patient survival for white recipients was 88% at 1 year and 74% at 5 years; African American recipients had similar 1-year, but lower 5-year patient survival (87% and 67%, respectively) (Figure 5). In contrast, Asian and, to a lesser extent, Hispanic/Latino recipients had superior outcomes. One- and five-year patient survival was 89% and 75%, respectively, for Asians and 91% and 78% for Hispanic/Latinos. By 10 years, patient survival was 68% for Asians, 62% for Hispanic/Latinos, 59% for whites and 51% for African Americans.

As with kidney transplantation, there was a trend toward improved 5-year adjusted overall DD patient survival when transplants from 1996 through 2001 (66%) were compared with those performed in the interval of 2002–2007 (69%) (Table 2). The largest increments in liver transplant patient survival occurred with Asians (73–78%), with lesser improvements in Hispanic/Latinos (73–75%) and African Americans (65–67%), whereas little improvement was observed in recipient survival for whites (73–74%).

In summary, access to DD liver transplantation for African Americans and Asians was above and access for Hispanic/Latinos was below their proportional representation on the waiting list. The numbers of DD liver



*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

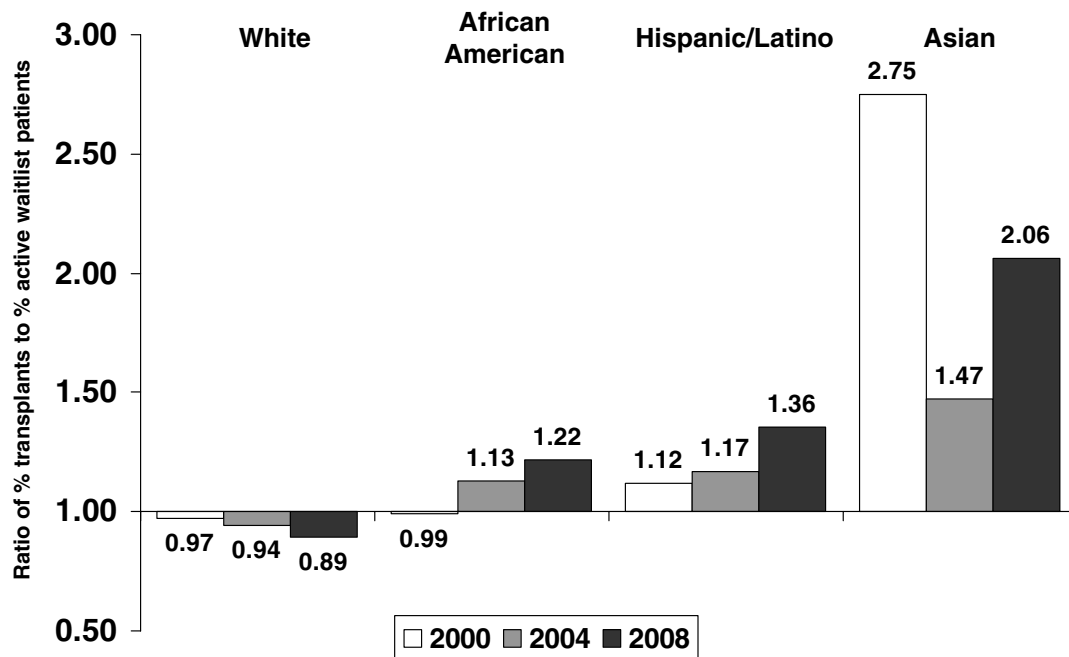
Source: 2009 OPTN/SRTR Annual Report, Table 9.12a

Figure 5: Adjusted deceased donor liver patient survival by race/ethnicity.

transplants declined for whites, but remained stable for other racial/ethnic groups. The overall number of LD liver transplants decreased. Few racial/ethnic minorities received LD liver transplants. Similar to kidney transplantation, DD patient survival differed between racial/ethnic groups, and the differences increased over time. African Americans demonstrated the poorest and Asians the best DD posttransplant survival. DD Liver transplant results are improving, more so for Asians and Hispanic/Latinos than for whites and African Americans.

Heart transplant trends and outcomes

Access to heart transplantation: Access to cardiac transplantation appears different from both kidney and liver transplantation (Figure 6). Asians, Hispanic/Latinos and African Americans were all transplanted at rates above their representation on the waiting list. Conversely, whites were transplanted less often than their frequency on the waiting list, and the rate for whites declined during the study period. These results were not adjusted for recipient severity of illness at listing.



Source: OPTN/SRTR Special Analysis, September 2009; data as of May 2009

Figure 6: Ratio of percent of heart transplants and percent on active waiting list at end of prior year, 2000-2008.

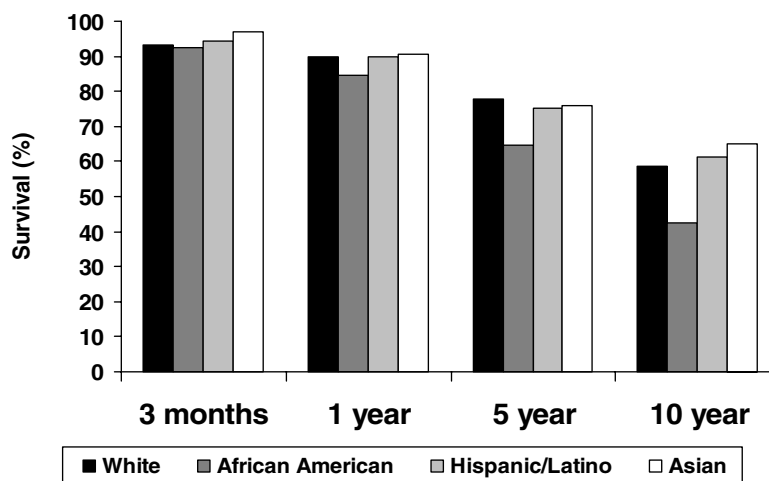


Figure 7: Adjusted heart patient survival by race/ethnicity.

Source: 2009 OPTN/SRTR Annual Report, Table 11.12

*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Heart transplant trends: As shown in Table 1, the number of cardiac transplants declined slightly, from 2199 in 2000 to 2163 in 2008. The proportion among whites declined, whereas the proportion among African Americans, Hispanic/Latinos and Asians increased during this time. Accordingly, the racial/ethnic distribution of the recipients changed, with white patients receiving 79% of cardiac transplants in 2000 and 66% in 2008. In contrast, the percentage of African American, Asian and Hispanic/Latino cardiac transplant recipients all increased. African Americans comprised 13% of the recipients in 2000 and 20% in 2008. Cardiac transplants to Asian patients increased from 2% to 3%, whereas Hispanic/Latino recipients increased from 7% to 10%.

Heart transplant recipient survival: Overall adjusted cardiac patient survival at 1 and 5 years was 88% and 75%, respectively [Table 11.12]. Again, there were differences in patient outcomes between racial/ethnic groups that increased over time (Figure 7). Short-term patterns were similar to those seen with kidney and liver transplantation. Among transplant recipients in 2006–2007, adjusted patient survival at 3 months and 1 year was highest among Asians, followed by Hispanic/Latinos, whites and then African Americans. Outcomes at 10 years followed this trend, with patient survival 65% for Asians, 61% for Hispanic/Latinos, 59% for whites and 42% for African Americans. Interestingly, at 5 years, white recipients had the best patient survival (77%), followed by Asians (75%), Hispanic/Latinos (75%) and African Americans (65%).

As with kidney and liver transplantation, there was a trend toward improved 5-year adjusted overall patient survival when transplant survival for recipients from the interval of 1996–2001 (73%) was compared with survival for recipients in the interval from 2002 to 2007 (75%); this is

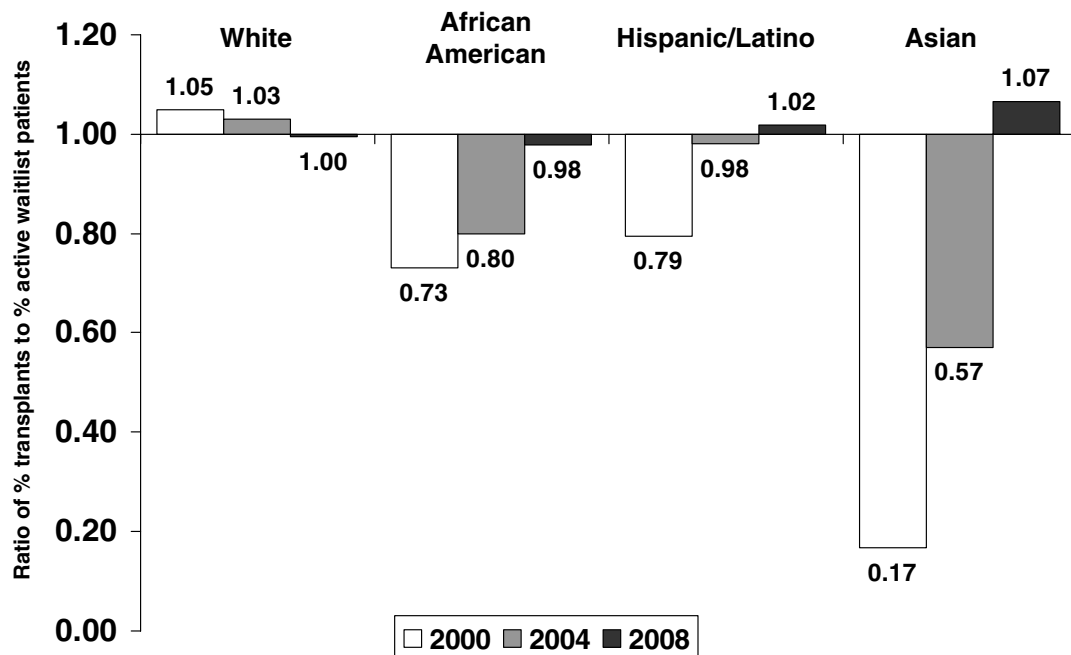
shown in Table 2. The largest improvements were seen with whites (75–78%), African Americans (62–65%) and Hispanic/Latinos (72–75%).

In summary, African Americans, Asians and Hispanic/Latinos all received heart transplants at rates that exceeded their proportion of the waiting list. Although the total number of heart transplants performed has been stable, the percentage of heart transplants going to minorities has increased. Five-year patient survival was best for whites and better for Hispanic/Latinos and Asians than for African Americans. Ten-year patient survival was highest for Asians and Hispanics, and intermediate for whites. The biggest improvements in 5-year graft survival were seen for whites, African Americans and Hispanic/Latinos.

Lung transplant trends and outcomes

Nationally, there were very few minority lung transplant recipients from 1999–2008 (ranging from 10% to 17%) (Table 12.4). The small numbers limit opportunities for analysis of access to transplant, transplant trends and differences in graft and patient survival between racial/ethnic groups. By 2008, gaps in access seen earlier in the decade for racial/ethnicity minorities resolved (Figure 8). Of the 1478 lung recipients in 2008, 83% were white, 9% African American, 6% Hispanic/Latino and 2% Asian; these percentages closely approximated the racial/ethnic composition of the active waiting list (Table 1).

DD lung transplant patient survival outcomes also differed by race/ethnicity (Figure 9). Adjusted patient survival was similar at 1-year among whites and African Americans (84% and 84%, respectively), intermediate among Hispanic/Latinos (82%) and lowest for Asians (78%). At 5 years, adjusted patient survival was 53% for whites, 57% for African Americans, 49% for Hispanic/Latinos and 61%



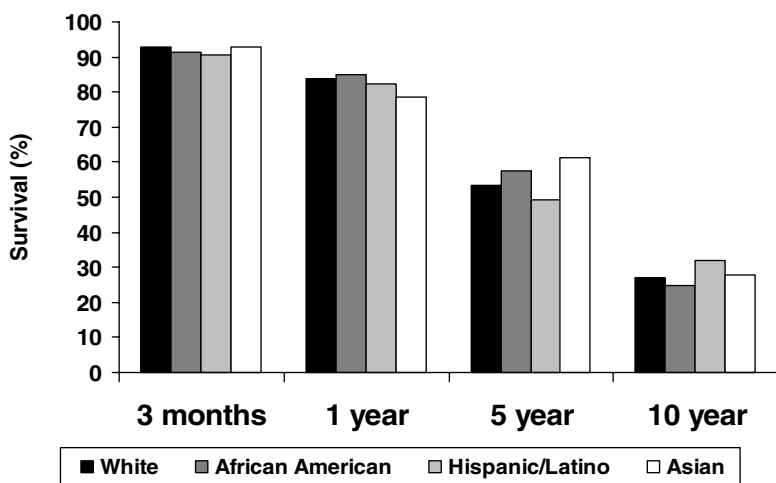
Source: OPTN/SRTR Special Analysis, September 2009; data as of May 2009

Figure 8: Ratio of percent of lung transplants and percent on active waiting list at end of prior year, 2000-2008.

for Asians. Ten-year adjusted transplant survival ranged from 32% for Hispanic/Latinos to 25% for African Americans. Table 2 shows that comparisons in adjusted five-year patient survival between the 1996-2001 and 2002-2007 cohorts demonstrated large improvements for whites (45-54%) and African Americans (34-58%). Improvements were more modest among Hispanic/Latinos (47-49%) and Asians (56-61%).

Pancreas transplant alone, pancreas after kidney and simultaneous kidney and pancreas transplant trends and outcomes

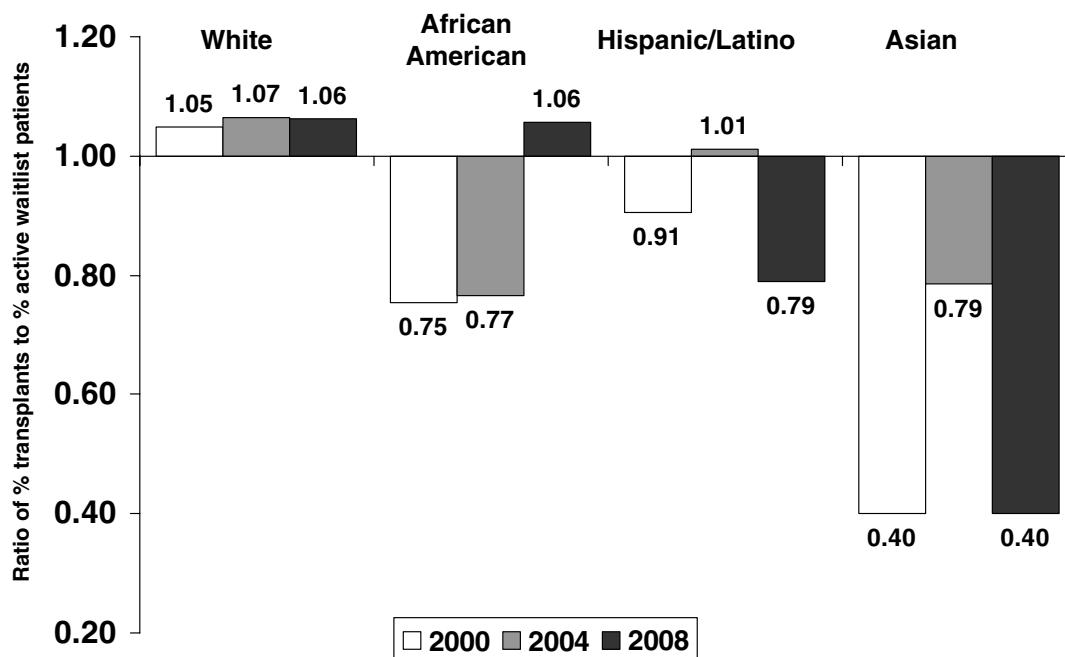
In 2008, 223 pancreas transplants alone (PTA), 214 pancreas after kidney (PAK) and 836 simultaneous kidney-pancreas (SPK) transplants were performed [Tables 6.4, 7.4, 9.4]. These small samples produce uncertainty in the interpretation of racial/ethnicity trends in access to



*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Source: 2009 OPTN/SRTR Annual Report, Table 12.12

Figure 9: Adjusted deceased donor lung patient survival by race/ethnicity.



Source: OPTN/SRTR Special Analysis, September 2009; data as of May 2009

Figure 10: Ratio of percent of SPK transplants and percent on active waiting list at end of prior year, 2000–2008.

transplant and patient survival, particularly for PTA and PAK transplants and for Asian recipients. For PTA in 2008, 80% went to whites, 10% to African Americans, 2% to Asians and 7% to Hispanic/Latinos. The racial/ethnic distribution of PAK in 2008 was very similar to PTA, as 81% of the PAK recipients were white, 13% African American, 1% Asian and 6% Hispanic/Latino [Tables 6.4, 7.4, 8.4]. For both PTA and PAK, the racial/ethnic distribution of recipients appeared to parallel the active waiting list (not shown). Few minorities received SPK transplants (Table 1); on a percentile basis, 71% of recipients were white, 17% African American, 1% Asian, and 11% were Hispanic/Latino (Table 1). Most recently, whites and African Americans appeared to be transplanted at a slightly higher rate, and Hispanic/Latinos and Asians minorities at substantially lower rates than expected by their prevalence on the waiting list (Figure 10).

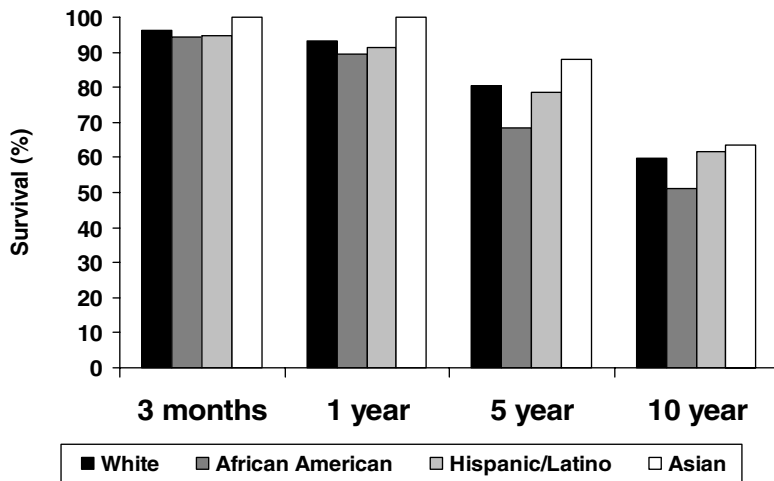
PTA and PAK survival for different racial/ethnic groups were not compared, given the very small number of minority recipients. One-year adjusted SPK kidney graft survival was 93% for whites, 89% for African Americans, 100% for Asians (although the number of recipients was only 23) and 91% for Hispanic/Latinos (Figure 11). The 1-year SPK pancreas graft survival was lower, at 85% for whites, 83% for African Americans, 91% for Asians and 87% for Hispanic/Latinos (Figure 12). At 5 years, the adjusted SPK kidney graft survival ranged from 88% for Asians to 68% for African Americans. Whites and Hispanic/Latinos were at

81% and 78%, respectively. Five-year SPK pancreas graft survival varied from 84% for Asians to 66% for African Americans, with whites at 74% and Hispanic/Latinos at 77%. At 10 years, SPK kidney graft survival was very similar for Hispanic/Latinos (61%), Asians (63%) and whites (60%), but only 51% for African Americans. SPK pancreas graft survival varied from 59% for Asians, 57% for Hispanic/Latinos and 56% for whites, to 49% for African Americans.

One-year adjusted SPK patient survival was 96% for whites, 95% for African Americans and Hispanic/Latinos, and 100% for Asians (Figure 13). Five-year adjusted patient survival was 94% for Asians, 89% for Hispanic/Latinos, 88% for whites and 83% for African Americans. Ten-year adjusted patient survival ranged from 77% for Asians, 74% for Hispanic/Latinos and 72% for whites, to 67% for African Americans.

Intestine transplant trends and outcomes

There were only 168 intestine candidates on the intestine waiting list at the end of 2008, and only 185 intestinal transplants were performed nationally in 2008 (Table 1). Among these candidates, 61% were white, 23% were African American, 2% Asian and 13% Hispanic/Latino. Of these recipients, 67% were white, 17% were African American, 3% Asian and 11% Hispanic/Latino. Adjusted patient survival, especially for Asians, are based upon very small numbers. At 1 year, adjusted patient survival was 80% for



*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Figure 11: Adjusted deceased donor SPK kidney graft survival by race/ethnicity.

Source: 2009 OPTN/SRTR Annual Report, Table 8.8

whites, 79% for Hispanic/Latinos, 78% for African Americans and 72% for Asians. Patient survival at 5 years was 65% for Hispanic/Latinos, 57% for whites, 58% for Asians and 55% for African Americans. At 10 years, survival was 48% for Asians, 45% for whites, 44% for Hispanic/Latinos and 40% for African Americans (Figure 14).

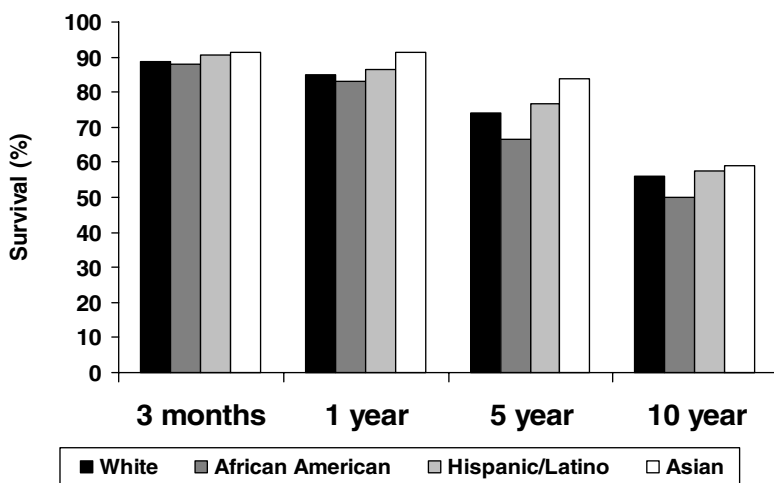
solitary DD kidney transplants performed between January 1, 2000 and December 31, 2007. Data were recorded at the time of transplant. Recipients were excluded from analysis if they were younger than 18 years of age at transplantation, had previously received a kidney or extra-renal transplant, or underwent an LD or multiorgan transplant.

Kidney Transplant Outcomes: Special Analysis

Methods

To identify and quantify factors contributing to racial and ethnic differences in kidney transplant outcomes, the relative risks (RRs) of DD kidney graft failure at 5 years post-transplant were examined using multiple Cox proportional hazards regression models for adult recipients of primary

Graft failure was defined as the earliest date of graft failure (as determined by OPTN/SRTR or CMS data) or death (as determined by OPTN/SRTR, CMS or SSDMF data). Individuals were censored at the earliest of the date of 5 years posttransplant, last follow-up, or the end of the study (December 31, 2008). The RR of graft failure for three racial/ethnic groups (African American, Hispanic/Latino and Asian) were determined and referenced to the RR for whites. The RR for Other racial/ethnic group is not shown due to the small population size.



*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Figure 12: Adjusted deceased donor SPK pancreas graft survival by race/ethnicity.

Source: 2009 OPTN/SRTR Annual Report, Table 8.8

Access and Outcomes Among Minority Transplant Patients

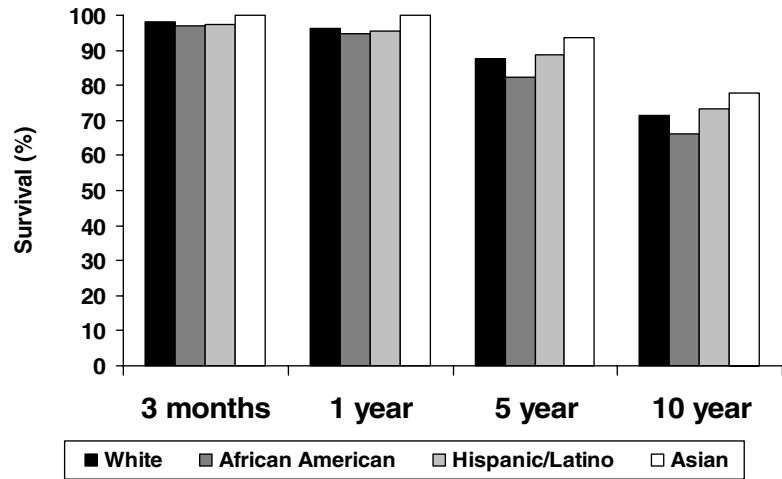


Figure 13: Adjusted deceased donor SPK patient survival by race/ethnicity.

Source: 2009 OPTN/SRTR Annual Report, Table 8.12

*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

The main analyses focus on the RR of graft failure for the racial/ethnic groups of white, African American, Hispanic/Latino and Asian kidney transplant recipients, comparing an unadjusted model and several adjusted models. Each adjusted model includes combinations of categories of variables as described in Table 3. To better understand the differential effects of patient- and center-related characteristics on kidney transplant outcomes, variables were categorized and ranked, from those that were most associated with the characteristics of the transplant center and most removed from the individual characteristics of patients to those that were most specific to individual patients and distant from the characteristics of the transplant center. Accordingly, variables were arranged in ordered categories as: center factors, OPO factors, organ factors, transplant factors, treatment protocols, socioeconomic factors, dialysis time, disease burden and patient

demographics. The variables that are included in each category are collected by the OPTN at the time of transplantation. The RR of graft failure at 5 years and the number and percentage of DD kidney transplant recipients by racial/ethnic group for selected factors related to graft failure are shown in Table 4. The individual effects of adjustment for each category of variables are shown in Table 5. To quantify the incremental effect of different categories of factors, RRs were sequentially analyzed using unadjusted models and then models that adjusted for specific categories of variables beginning with center characteristics and progressing to patient characteristics (Table 6). Finally, the models were rerun in reverse sequence, from those most patient-specific to those most center-specific to determine whether the order by which variables were added would influence the direction and magnitude of each category of variables captured in the model

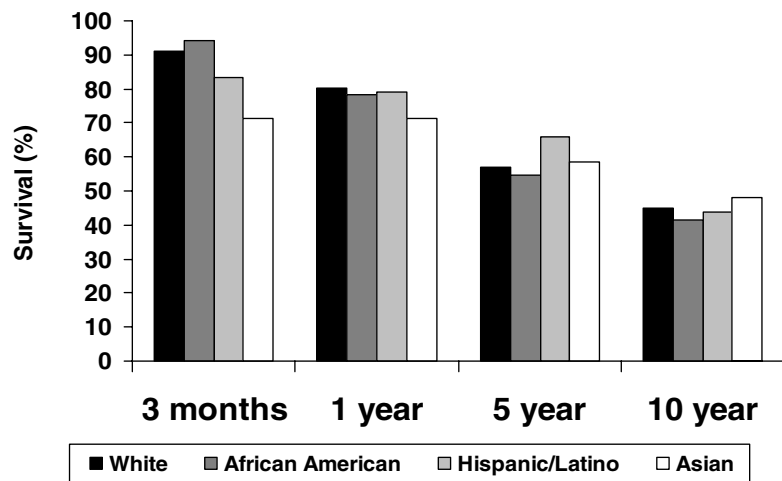


Figure 14: Adjusted deceased donor intestine patient survival by race/ethnicity.

Source: 2009 OPTN/SRTR Annual Report, Table 10.12

*Transplants 2006-2007 used to calculate 1 year survival, 2002-2007 for 5 year survival, and 1997-2007 for 10 year survival.

Table 3: Factors used in the graft outcome models

Center factors
Median waiting time (<2 years, ≥2 years, not yet reached)
Average length of stay (<7 days, ≥7 days)
Volume (in quartiles <59 transplants, 59–99 transplants, 100–165 transplants, ≥166 transplants)
Age distribution (% age 0–17, % age 18–34, % age 35–49, % age 50–64, % age 65+)
Race/ethnicity (% White, % African American, % Hispanic/Latino, % Asian, % Other)
PRA (% 0–9, % 10–79, % 80+, % missing)
Diagnosis (% glomerulonephritis, % diabetes, % hypertension, % other/missing)
Percent deceased donor transplants among all kidney transplants
OPO
OPO (58 organ procurement organizations)
Organ factors
Donor age (<40 years, 40–49 years, 50–59 years, ≥60 years)
Donor race (White, Non-White)
Donor sex (male, female)
Donor hepatitis B (yes/no)
Donor hepatitis C (yes/no)
Donor positive CMV (yes/no)
ECD (yes/no)
DCD (yes/no)
Donor cause of death (anoxia, CVA/stroke, head trauma, CNS tumor, other)
Transplant factors
HLA mismatch A (0, 1, 2, missing)
HLA mismatch B (0, 1, 2, missing)
HLA mismatch DR (0, 1, 2, missing)
Donor-recipient weight ratio (<0.75, 0.75–0.89, 0.90–1.14, ≥1.15, missing)
Transplant year (2000–2007)
Cold ischemia time hours (0–6, >6–12, >12–18, >18–24, >24–30, >30–36, >36, missing)
Shared (yes/no)
Pumped (yes/no)
Treatment protocols at hospital discharge
Induction (yes/no)
Cyclosporine (yes/no)
Tacrolimus (yes/no)
Sirolimus (yes/no)
Mycophenolate (yes/no)
Corticosteroid (yes/no)
Other maintenance immunosuppression (yes/no)
Socioeconomic factors
Recipient insurance (Medicare only, Medicaid only, Medicare primary + other secondary, private only, private only + other, other source of payment, missing)
Education (less than high school, high school, college, other)
Average income in zip code (<\$20K, \$20–29K, \$30–39K, \$40–59K, ≥\$60K)
Dialysis time
Time on dialysis (preemptive, ≤1 year, >1–2 years, >2–3 years, >3–5 years, >5–7 years, >7 years)
Disease burden
Diagnosis (glomerulonephritis, diabetes, hypertension, other, missing)
PRA (0–9, 10+, missing)
Cancer (yes/no)

Continued

Table 3: Continued

CVA (yes/no)
COPD (yes/no)
Diabetes with insulin (yes/no)
Diabetes (yes/no)
Albumin (<35, ≥35, missing)
Hepatitis B (yes/no)
Hepatitis C (yes/no)
Positive CMV (yes/no)
Age
Recipient age (18–34, 35–49, 50–64, 65+)
Demographic factors
Sex and previous pregnancies (male, female never pregnant, female previously pregnant)
Blood type (A, AB, B, O)
BMI (<18.5, 18.5–24, 25–30, ≥30, missing)
Employment (yes/no)

(Table 7). All statistical analyses were performed using SAS 9.2.

Results

Table 4 summarizes the number and percentage of 58 978 kidney transplant recipients by racial/ethnic group for selected categories of statistically important variables (age, duration of ESRD, diagnosis, hepatitis C status and insurance type at transplant), and reports the overall RR of graft failure associated with subcategories of these factors. Whites were, on average, older and all other racial/ethnic groups younger, than the average age of the entire kidney transplant recipient population. The best outcomes were seen among transplant patients between 35 and 49 years of age; lesser and greater age was associated with higher rates of graft failure. There was a dose-related effect of duration of ESRD as measured by dialysis time, with an overall twofold difference in the RR of graft loss at 5 years between those receiving a preemptive kidney transplant and those who undergo transplantation after seven or more years of dialysis. In general, whites were far more likely to receive a preemptive kidney graft and less likely to be exposed to greater than 3 years of dialysis before transplantation. Also of significant importance were primary ESRD diagnosis, hepatitis C status and insurance. Compared with the reference group of recipients with glomerulonephritis, those with ESRD from diabetes had an increased RR of graft loss of 1.11; those with hypertension had an RR of 1.08; and patients with other causes of ESRD had a slightly reduced RR of 0.94. Asians were most likely to have ESRD from glomerulonephritis, African Americans from hypertension and whites from other causes. Hepatitis C was also associated with an increased RR of 1.37, and African Americans were far more likely to be hepatitis C antibody positive at the time of transplant than recipients of the other racial/ethnic groups. Finally, in comparison with private insurance only, all other types of insurance were associated with increased RR of graft loss. Medicare-only insurance was most common in African Americans, Medicaid-only in

Table 4: Relative risk of deceased donor graft failure at 5 years and number and percentage of deceased donor kidney transplant recipients by racial/ethnic group for selected factors related to graft failure, 2000–2008

Factor	RR ¹	Recipient race/ethnicity group									
		All		White		African American		Hispanic/Latino		Asian	
		N	%	N	%	N	%	N	%	N	%
All		58 978	100	28 245	100	18 603	100	7 772	100	3 578	100
Recipient age		51.8 years		54.0 years		49.5 years		49.6 years		51.3 years	
Mean age		51.8 years		54.0 years		49.5 years		49.6 years		51.3 years	
18–34 years	1.25*	7 218	12.2	2 597	9.2	2 755	14.8	1 318	17.0	464	13.0
35–49 years (ref)	1.00	17 049	28.9	7 188	25.4	6 253	33.6	2 333	30.0	1 060	29.6
50–64 years	1.14*	25 099	42.6	12 479	44.2	7 611	40.9	3 136	40.3	1 507	42.1
65+	1.56*	9 612	16.3	5 981	21.2	1 984	10.7	985	12.7	547	15.3
Recipient years of ESRD		3.5 years		2.7 years		4.5 years		4.1 years		3.9 years	
Mean ESRD years		3.5 years		2.7 years		4.5 years		4.1 years		3.9 years	
Preemptive	0.68*	3 653	6.2	2 701	9.6	414	2.2	351	4.5	166	4.6
0–1 years	0.85*	5 232	8.9	3 722	13.2	823	4.4	406	5.2	246	6.9
1–2 years (ref)	1.00	9 741	16.5	5 996	21.2	2 147	11.5	1 018	13.1	474	13.2
2–3 years	1.06*	10 292	17.5	5 408	19.1	2 940	15.8	1 274	16.4	546	15.3
3–5 years	1.11*	16 106	27.3	6 702	23.7	5 702	30.7	2 339	30.1	1 079	30.2
5–7 years	1.29*	8 448	14.3	2 469	8.7	3 711	19.9	1 446	18.6	683	19.1
>7 years	1.39*	5 506	9.3	1 247	4.4	2 866	15.4	938	12.1	384	10.7
Recipient diagnosis		12 477 21.2		6 224 22.0		3 400 18.3		1 600 20.6		1 106 30.9	
Glomerulonephritis (ref)	1.00	12 477	21.2	6 224	22.0	3 400	18.3	1 600	20.6	1 106	30.9
Diabetes	1.11*	15 069	25.6	7 101	25.1	4 178	22.5	2 573	33.1	807	22.6
Hypertension	1.08*	15 026	25.5	4 441	15.7	7 921	42.6	1 721	22.1	846	23.6
Other	0.94*	16 312	27.7	10 453	37.0	3 059	16.4	1 864	24.0	810	22.6
Hepatitis C		55 799 94.6		27 360 96.9		16 785 90.2		7 448 95.8		3 452 96.5	
No (ref)	1.00	55 799	94.6	27 360	96.9	16 785	90.2	7 448	95.8	3 452	96.5
Yes	1.37*	3 179	5.4	885	3.1	1 818	9.8	324	4.2	126	3.5
Recipient insurance		6 595 11.2		2 712 9.6		2 685 14.4		876 11.3		254 7.1	
Medicare only	1.17*	6 595	11.2	2 712	9.6	2 685	14.4	876	11.3	254	7.1
Medicaid only	1.28*	2 216	3.8	523	1.9	790	4.2	607	7.8	263	7.4
Medicare (primary) + other	1.25*	30 309	51.4	13 219	46.8	10 322	55.5	4 501	57.9	1 800	50.3
Private only (ref)	1.00	9 532	16.2	5 810	20.6	2 184	11.7	826	10.6	643	18.0
Private (prime) + other	1.12*	8 574	14.5	5 240	18.6	1 987	10.7	748	9.6	507	14.2
Other source	1.08	1 744	3.0	736	2.6	633	3.4	213	2.7	111	3.1

*p < 0.05.

¹Adjusted for all factors in Table 3 and race/ethnicity. Source: OPTN/SRTR special analysis, August 2009; data as of February 2009.

Hispanic/Latinos, and private-only and private-primary insurance in whites.

The RRs of graft failure at 5 years are shown in Tables 5–7 by race/ethnicity for one unadjusted and several adjusted models. In each table, the RR of graft failure for African Americans, Hispanic/Latinos and Asians are compared with the RR for whites (RR = 1.00). Without adjustments, the RR of graft failure at 5 years when compared with whites was 1.35 for African Americans, 0.83 for Hispanic/Latinos and 0.75 for Asians. All comparisons in Tables 5–7 between the RR of graft failure for whites and other race/ethnicities are statistically significant with a p-value < 0.05.

Table 5 shows the independent effect of adjustment for each category of variables. When compared with the unadjusted results, adjustments for age, disease burden, so-

cioeconomic status, time on dialysis prior to transplantation and treatment factors modified the differences in the RR of graft failure compared with whites among each of the other racial/ethnic groups. Surprisingly, adjustments for center factors and demographic characteristics (without age) had little or no effect on the rates of graft failure. Transplant factors and center-alone adjustments affected relative survival for African Americans and Asians, and organ factors influenced outcomes for Asians.

Adjustment for age alone resulted in an apparent increase in the RR of graft failure for minorities in comparison with whites (Table 5). Because white recipients were older, on average, than recipients from other racial/ethnic groups (Table 4), adjustment for age likely increased the expected number of graft failures for whites relative to minorities and, therefore, resulted in higher RRs for African

Table 5: Relative risk of graft failure at 5 years by race/ethnicity among deceased donor kidney transplant recipients, 2000–2008 (single factors into model)

Factor ¹	White RR	African American RR*	Hispanic/Latino RR*	Asian RR*
No adjustment	1.00	1.35	0.83	0.75
Center alone	1.00	1.31	0.83	0.75
Center factors alone	1.00	1.29	0.82	0.74
OPO alone	1.00	1.33	0.86	0.76
Organ factors alone	1.00	1.33	0.82	0.71
Transplant factors alone	1.00	1.27	0.82	0.71
Treatment protocol alone	1.00	1.38	0.87	0.79
Socioeconomic factors alone	1.00	1.28	0.77	0.73
Dialysis time alone	1.00	1.22	0.76	0.69
Disease burden alone	1.00	1.26	0.79	0.74
Age alone	1.00	1.45	0.88	0.78
Demographic factors alone	1.00	1.33	0.82	0.77

*p < 0.05, each row versus white.

¹See Table 3 for the list of variables included in each category of variables.

Source: OPTN/SRTR special analysis, August 2009; data as of February 2009.

Table 6: Relative risk of graft failure at 5 years by race/ethnicity among deceased donor kidney transplant recipients, 2000–2008

Factor ¹	White RR	African American RR*	Hispanic/Latino RR*	Asian RR*
No adjustment	1.00	1.35	0.83	0.75
+Center factors	1.00	1.29	0.82	0.74
+OPO factors	1.00	1.30	0.83	0.75
+Organ factors	1.00	1.29	0.84	0.73
+Transplant factors	1.00	1.23	0.84	0.72
+Treatment protocol	1.00	1.24	0.84	0.73
+Socioeconomic factors	1.00	1.19	0.79	0.73
+Dialysis time	1.00	1.13	0.77	0.71
+Disease burden	1.00	1.07	0.74	0.71
+Age	1.00	1.11	0.77	0.73
+Demographic factors	1.00	1.12	0.77	0.74

*p < 0.05, each row versus white.

¹See Table 3 for the list of variables included in each category of variables.

Source: OPTN/SRTR special analysis, August 2009; data as of February 2009.

Table 7: Relative risk of graft failure at 5 years by race/ethnicity among deceased donor kidney transplant recipients, 2000–2008 (reverse factor entry into model)

Factor ¹	White RR	African American RR*	Hispanic/Latino RR*	Asian RR*
No adjustment	1.00	1.35	0.83	0.75
+Demographic factors	1.00	1.33	0.82	0.77
+Age	1.00	1.43	0.87	0.80
+Disease burden	1.00	1.33	0.83	0.79
+Dialysis time	1.00	1.22	0.76	0.74
+Socioeconomic factors	1.00	1.21	0.75	0.74
+Treatment protocol	1.00	1.22	0.78	0.77
+Transplant factors	1.00	1.17	0.78	0.75
+Organ factors	1.00	1.15	0.77	0.73
+OPO	1.00	1.12	0.78	0.74
+Center factors	1.00	1.12	0.77	0.74

*p < 0.05, each row versus white.

¹See Table 3 for the list of variables included in each category of variables. Source: OPTN/SRTR special analysis, August 2009; data as of February 2009.

Americans, Hispanic/Latinos and Asians. In contrast, whites had less pretransplant exposure to dialysis than did minority recipients. Because longer time on dialysis is associated with poorer graft survival, adjustment for time on dialysis increased the number of expected graft failures for African Americans, Asians and Hispanic/Latinos and decreased the RR of graft failure for these minority groups relative to whites. Therefore, adjusting for age tends to increase and, for duration of dialysis exposure, to decrease the RR of graft failure for each minority in comparison with whites.

It is also notable that adjustment for the center factors included in these models closely parallels the results of an adjustment for center alone. In contrast, adjustment for age alone does not mimic the effect of adjustment for additional demographic factors among African Americans and Hispanic/Latinos. Therefore, center-alone is not maintained as a separate category in the stepwise analyses displayed in Tables 6 and 7, whereas age in these analyses continues to be analyzed separately from other demographic factors.

The RR of graft failure by race/ethnicity at 5 years is shown for 11 models (1 unadjusted model and 10 models adjusted for an increasing number of factors) in Tables 6 and 7. These tables demonstrate a different method of comparison of graft failure rates than that used in Table 5. As in Table 5, unadjusted, or crude rates for African Americans, Hispanic/Latinos and Asians were compared with the rates for whites (1.00). However, unlike Table 5, the unadjusted models were followed, not by separate, stand-alone adjusted models, but by models with stepwise adjustments for the sets of variables under consideration. In these stepwise models, each subsequent model incorporates all of the adjustments preceding it, as summarized in the row immediately above. For example, in Table 6, the model for OPO factors also includes the adjustments for center factors, and the model for organ factors includes the adjustment factors for center and OPO, etc.

In Table 6, adjustment for center factors alone reduced the difference in the RR of graft failure observed in the unadjusted models between African Americans and whites. Stepwise adjustments for OPO factors and organ characteristics had little incremental effect. Further stepwise adjustment for transplant factors demonstrated additional effects only for African Americans, but no additive effect was demonstrated through adjustment for treatment protocol. With progressive adjustments for socioeconomic factors, dialysis time and disease burden, differences in the RR of graft failure between the unadjusted and adjusted results for Hispanic/Latinos and Asians when compared with whites increased; differences between whites and African Americans decreased. Taking all of the preceding adjustments into account, further adjustments for age modestly increased the differences observed between whites and

African Americans and modestly decreased the differences between whites and other groups. Surprisingly, once all of the other stepwise adjustments in these models are performed, the addition of demographic factors, per se, exerted no incremental effects on graft survival. In the final complete model that accounts for all of the variables listed in Table 3, the overall adjusted RR of graft failure was 1.12 for African Americans, 0.77 for Hispanic/Latinos and 0.74 for Asians compared with whites.

As discussed earlier, the sequentially adjusted models were tested in reverse order. These results are shown in Table 7, and were in general similar to those seen in Table 6. Adjustment for demographic factors had little impact on the relationships seen in the unadjusted models. Adjustment for age increased the differences observed between whites and African Americans and decreased the differences between whites and other groups. Sequential adjustments for disease burden, dialysis time, socioeconomic factors, treatment protocols and transplant factors reduced differences between whites and African Americans, but increased differences between whites and the other race/ethnicity groups. Incremental adjustment for OPO slightly decreased differences in RR of graft failure between whites and African Americans. When all other adjustments were taken into account, there was no discernible incremental effect for center factors.

These analyses show that African Americans have graft failure rates at 5 years that are higher than those of all other racial/ethnic groups, even after adjusting for the variables listed in Table 3. The adjusted RR of graft failure for African Americans compared with whites varied from 1.07 to 1.45, depending upon the manner in which variables were incorporated into the adjusted models (Tables 5–7). The RR for Hispanic/Latinos and Asians compared with whites varied much less across the models considered (Hispanic/Latino: unadjusted RR = 0.83, adjusted RR range 0.74–0.88; Asian: unadjusted RR = 0.75, adjusted RR range 0.69–0.81). Adjustments for demographic characteristics, other than age, and for center factors explain few of these differences. In general, those categories (age, disease burden, duration of pretransplant dialysis exposure, socioeconomic factors and treatment protocols) that are more closely associated with individual patients have a greater effect on the RR of graft failure than do organ or transplant-related factors or variables that are more closely associated with the transplant center or OPO.

Overall, graft survival at 5 years was best for Asians and Hispanic/Latinos, intermediate for whites and poorest for African Americans. These differences were not explained in their entirety by the data from the time of transplant currently available in the OPTN/SRTR database. The range of RRs when compared with whites in the unadjusted analyses ranged from an RR of 0.75 for Asians to an RR of 1.35 in African Americans (first line of Tables 6 and 7). In the fully adjusted models, this range is compressed to an RR of 0.74

for Asians and 1.12 in African Americans (last line of Tables 6 and 7). Thus, the covariates explain a greater portion of the differences observed between African Americans and whites than between whites and Hispanic/Latinos or between whites and Asians (Tables 6 and 7). Age and duration of pretransplant dialysis exposure seem to exert the greatest effect on differential outcomes (Table 5).

Discussion

Sizeable differences in DD kidney transplant outcomes remain unaccounted for despite adjustments for the baseline variables included in these models. It is possible that inclusion of additional baseline variables, such as more complete information on existing medical comorbidities, socioeconomic factors, histocompatibility or measures of new or posttransplant variables (e.g. assays of metabolic pathways for immunosuppressive medications, immune competence, adherence to medical regimen or quality indicators for posttransplant follow-up) might improve the predictive value of these analyses and explain more of the observed differences. For example, the prevalence of gene polymorphisms associated with hypertension (9) and increased inflammation or drug metabolism (10) vary across racial and ethnic groups. In addition, adjusting for posttransplant variables may have the potential to identify factors that account for some of these racial/ethnic differences and perhaps identify appropriate posttransplant intervention. It is also possible that, even with more extensive data collection, some differences may remain unexplained.

Although much of the difference in outcomes between racial/ethnic groups can be accounted for by adjusting for patient differences, the observed unadjusted differences remain important. Although the adjustments facilitate understanding of the factors that contribute to the observed outcome disparities, the differences between racial/ethnic groups in important variables may themselves reflect inequities in the kidney transplant system and merit further evaluation. For example, the disparities in age and pretransplant dialysis time between whites and minority transplant recipients may reflect different listing practices or inequalities in access to transplantation. If so, efforts to mitigate these inequities may, in turn, reduce the gap in outcomes between racial/ethnic groups.

In summary, access to transplantation differs between racial/ethnic groups, but the pattern of these differences varies by organ type. In unadjusted analyses, minority patients demonstrate persistent decreased access to kidney transplantation, and whites to cardiac transplantation. Regarding liver transplants, African American and Asians appear to have increased and growing access, whereas Hispanic/Latinos have decreased access. Findings of differences in access to transplant by race among those

wait-listed for different types of solid organ transplants should be interpreted with caution. Although ratios above or below 1.0 quantify differences in access according to race/ethnicity, specific thresholds that might constitute clinically meaningful disparities remain undefined. Further, analyses assessing difference in access did not account for potential confounders (e.g. severity of illness at time of presentation or allocation) that could affect interpretation of these observations on access to transplant.

Graft and patient outcomes also differ between racial/ethnic groups. The pattern of these differences is similar for patient survival across organs and for kidney graft survival. In general, Asians followed by Hispanic/Latinos have the best outcomes. Whites have intermediate outcomes, superior to those of African Americans, but lagging behind those observed for Asians and Hispanic/Latinos. This trend is apparent at multiple time-points after transplant and is seen with nearly all organ types.

In our analysis of kidney transplant graft loss, adjustment for a number of demographic factors could not fully explain the differences observed between racial/ethnic groups. Compared with the rates observed for white kidney transplant recipients, adjustments partially accounted for much of the increased risk of graft loss observed for African Americans, but explained much less of the superior graft survival noted for Asians and Hispanic/Latinos. Finally, the analysis demonstrated differences in the race/ethnicity composition of the waiting list by a number of categories of variables and quantified the contribution of these variables to the outcome disparities seen between racial/ethnic groups. In the multivariate models, patient-related factors were, in general, more explanatory than center-related variables in explaining observed differences in graft survival. Further initiatives to resolve these inequities may narrow the racial/ethnic differences in outcomes after organ transplantation.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

References

1. Epstein AM, Ayanian JZ, Keogh JH et al. Racial disparities in access to renal transplantation—Clinically appropriate or due to underuse or overuse? *N Engl J Med* 2000; 343: 1537–1544.
2. Isaacs RB, Lobo PI, Nock SL, Hanson JA, Ojo AO, Pruett TL. Racial disparities in access to simultaneous pancreas-kidney transplantation in the United States. *Am J Kidney Dis* 2000; 36: 526–533.
3. Eckhoff DE, McGuire BM, Young CJ et al. Race: A critical factor in organ donation, patient referral and selection, and orthotopic liver transplantation? *Liver Transpl Surg* 1998; 4: 499–505.
4. Press R, Carrasquillo O, Nickolas T, Radhakrishnan J, Shea S, Barr RG. Race/ethnicity, poverty status, and renal transplant outcomes. *Transplantation* 2005; 80: 917–924.
5. Mehra MR, Uber PA, Scott RL, Park MH. Ethnic disparity in clinical outcome after heart transplantation abrogated using tacrolimus and mycophenolate mofetil-base immunosuppression. *Transplantation* 2002; 74: 1568–1573.
6. Rogers J, Baliga PK, Chavin KD et al. Effect of ethnicity on outcome of simultaneous pancreas and kidney transplantation. *Am J Transplant* 2003; 3: 1278–1288.
7. Levine GN, McCullough KP, Rodgers AM, Dickinson DM, Ashby VB, Schaubel DE. Analytical methods and database design: Implications for transplant researchers, 2005. *Am J Transplant* 2006; 6: 1228–1242.
8. http://www.ustransplant.org/annual_reports/current/Tech_Notes_AR_CD.htm2004. In: Annual Report of the U.S. Organ Procurement and Transplantation Network and the Scientific Registry of Transplant Recipients: Transplant Data 1994–2003. Department of Health and Human Services, Health Resources and Services Administration, Healthcare Systems Bureau, Division of Transplantation, Rockville, MD; United Network for Organ Sharing, Richmond, VA; Arbor Research Collaborative for Health, Ann Arbor, MI. Accessed November 4, 2009.
9. Israni AK, Li N, Sidwani S et al. Association of hypertension genotypes and decline in renal function after kidney transplantation. *Transplantation* 2007; 84: 1240–1247.
10. Girnita DM, Webber SA, Ferrell R et al. Disparate distribution of 16 candidate single nucleotide polymorphisms among racial and ethnic groups of pediatric heart transplant patients. *Transplantation* 2006; 82: 1774–1780.