Trends in Kidney Transplantation Rates and Disparities

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Objective: To examine the likelihood of transplantation and trends over time among persons with end-stage renal disease (ESRD) in Wisconsin.

Methods: We examined the influence of patient- and community-level characteristics on the rate of kidney transplantation in Wisconsin among 22,387 patients diagnosed with ESRD between January 1, 1982 and October 30, 2005. We grouped patients by the year of ESRD onset in order to model the change in transplantation rates over time.

Results: After multivariate adjustment, all other racial groups were significantly less likely to be transplanted compared with whites, and the racial disparity increased over calendar time. Older patients were less likely to be transplanted in all periods. Higher community income and education level and a greater distance from patients' residence to the nearest dialysis center significantly increased the likelihood of transplantation. Males also had a significantly higher rate of transplantation than females.

Conclusion: These results demonstrate a growing disparity in transplantation rates by demographic characteristics and a consistent disparity in transplantation by socioeconomic characteristics. Future studies should focus on identifying specific barriers to transplantation among different subpopulations in order to target effective interventions.

Key words: end-stage renal disease ■ health disparities ■ kidney

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BACKGROUND

The incidence of end-stage renal disease (ESRD) has increased over threefold from 1982 to 2003 in the United States.[1] As a result of the rapid rise in ESRD, the demand for dialysis and transplantation has dramatically increased, which has led to concerns about the availability and equitable allocation of kidneys for transplantation. Transplantation is currently the best treatment option for patients with ESRD. Compared to dialysis, transplantation is associated with an increase in life expectancy, an increase in quality of life and a decrease in healthcare costs.[2-4] However, waiting times for deceased donor transplants, as well as the number of patients on the waiting list, have been steadily rising in recent years.[5] The increase in waiting times is a potential concern, not only because a lower proportion of patients are receiving kidneys but also because graft outcomes worsen as the duration of ESRD before transplantation increases.[6]

Inequalities in kidney transplantation rates have been documented for minorities, women and low-income groups.[7-11] Although Wisconsin has one of the highest rates of transplantation in the United States,[12] it is uncertain how racial and sociodemographic characteristics influence transplantation rates in the state. Further, previous studies have focused on disparities in transplantation in the Unites States but have not addressed how the independent effects of race, ethnicity and socioeconomic factors have affected transplantation rates over time. This analysis is important in order to highlight the potential benefits or shortcomings of recent changes in clinical practices and policies regarding transplantation. Therefore, we examined the independent effect of age, sex, race, community-level education, community-level income, primary cause of ESRD and distance from patients' residence to the nearest dialysis center on the time from ESRD onset to transplantation among Wisconsin ESRD patients diagnosed between 1982 and 2005 and explored whether racial and socioeconomic differences in transplantation rates have changed significantly over time.

METHODS

Study Design and Data Source

We conducted a cohort study of incident ESRD patients who began kidney replacement therapy between January 1, 1982 and October 30, 2005. We obtained deidentified data from the Renal Network of the Upper Midwest (Network 11), which encompasses Wisconsin, Minnesota, Michigan, North Dakota and South Dakota. Network 11 is one of 18 renal networks in the United States that collects and provides data on patients with ESRD to the Centers for Medicare and Medicaid Services.[13]

All Wisconsin residents who received treatment for ESRD in Network 11 were included in our study. Patients were excluded if they initiated dialysis following the rejection of a kidney transplant or if they had preexisting ESRD before moving into the Network 11 region. Data used in our analysis included the patient's age at ESRD onset, race/ethnicity (white, African American, American Indian/Alaska native, Asian/native Hawaiian/Pacific Islander and Hispanic/Latino), sex, primary cause of ESRD, donor type (deceased, living related, living unrelated), selected comorbidities for patients with an ESRD onset between 1996 and 2005, and month and year of first dialysis treatment or kidney transplant. The duration from ESRD onset to either death, transplantation, loss to follow-up or the end of the study period was calculated for each patient.

The primary causes of ESRD were grouped into the following five categories: diabetes; glomerulonephritis; hypertension and large vessel disease; cystic, hereditary, and congenital diseases; and other. The fifth category (other) comprised a small number of patients with secondary glomerulonephritis or vasculitis, interstitial nephritis or pyelonephritis, neoplasms or tumors, and miscellaneous conditions as the primary cause of ESRD.

Table 1. Distribution of cases of end-stage renal disease (ESRD) in Wisconsin by demographic and socioeconomic characteristics by calendar period

Characteristic	1982–1985 (n=1,290)	1986–1990 (n=3,106)	1991–1995 (n=4,728)	1996–2000 (n=6,071)	2001–2005 (n=7,192)	P Value*
Mean Age (Standard Deviation)	51.3 (± 17.9)	57.3 (± 17.5)	59.5 (± 17.2)	62.6 (± 16.7)	64.1 (± 16.5)	<0.0001
Race (%)						<0.0001
White (n=17,979)	1,125 (87.2)	2,588 (83.3)	3,859 (81.6)	4,842 (79.8)	5,565 (77.4)	
African American (n=3,060)	129 (10.0)	372 (12.0)	660 (14.0)	831 (13.7)	1,068 (14.9)	
American Indian/ Alaska native (n=474)	28 (2.2)	65 (2.1)	100 (2.1)	133 (2.2)	148 (2.1)	
Hispanic/Latino (n=574)	2 (0.2)	52 (1.7)	65 (1.4)	180 (3.0)	275 (3.8)	
Asian/native Hawaiian/ Pacific Islander (n=300)	6 (0.5)	29 (0.9)	44 (0.9)	85 (1.4)	136 (1.9)	
Sex (%)						0.6760
Males (n=12,663)	723 (56)	1,745 (56.2)	2,641 (55.9)	3,471 (57.2)	4,083 (56.8)	
Females (n=9,724)	567 (44.0)	1,361 (43.8)	2,087 (44.1)	2,600 (42.8)	3,109 (43.2)	
Primary Cause of ESRD (%)						<0.0001
Diabetes (n=8,920)	410 (31.8)	1,122 (36.1)	1,915 (40.5)	2,550 (42.0)	2,923 (40.6)	
Glomerulonephritis (n=2889)	314 (24.3)	512 (16.5)	703 (14.9)	689 (11.4)	671 (9.3)	
Hypertension (n=5,538)	204 (15.8)	742 (23.9)	1142 (24.2)	1497 (24.7)	1953 (27.2)	
Cystic/hereditary (n=1,186)	100 (7.8)	214 (6.9)	245 (5.2)	289 (4.8)	338 (4.7)	
Other† (n=3,854)	262 (20.3)	516 (16.6)	723 (15.3)	1,046 (17.2)	1,307 (18.2)	
Community-Level Median Household Income (Standard Deviation)	28,417 (± 8667)	28,275 (± 8742)	28,718 (± 8773)	29,113 (± 9026)	29,199 (± 8927)	<0.0001
Community-Level Education‡ (%)	40.8 (± 13.9)	39.8 (± 13.5)	40.2 (± 13.2)	40.8 (± 13.3)	40.4 (± 13.0)	0.0212
Distance to Nearest Dialysis Center (Miles) (Standard Deviation)	12.5 (± 17.3)	11.9 (± 15.9)	11.6 (± 15.5)	11.7 (± 15.4)	12.1 (± 15.3)	0.1986

* Differences in characteristics by calendar period; † Other includes: secondary glomerulonephritis/vasculitis, interstitial nephritis/pyelonephritis, neoplasms/tumors, and miscellaneous conditions; ‡ Education level was defined as the percent of the ZIP-code level population with at least some college education

Data on comorbid conditions were available only for patients with an ESRD onset between 1996 and 2005. Although Network 11 collects data on 22 comorbidities, in our analysis we included only those comorbidities that were present in ≥10% of patients or were known to be associated with the risk of transplantation. These included congestive heart failure, cerebrovascular disease, peripheral vascular disease, history of hypertension, diabetes (currently on insulin), chronic obstructive pulmonary disease and malignant neoplasm (cancer).

Previous studies have explored the relationship between patients' residence and the likelihood of transplantation.[14,15] We explored the relationship between distance to the nearest dialysis center and transplantation rates because the amount of travel associated with dialysis may be an important factor in patient preference, physician reference, or both for transplantation. To calculate the distance from the nearest dialysis center to the centroid of each patient's ZIP code of residence, the geometric centroid of each ZIP code was determined using ArcGIS 9.0.[16] The mailing address for all of the dialysis centers in Wisconsin, Minnesota, Iowa and Illinois were obtained from the Nephron Information Center[17] and geocoded (assigned latitude and longitude coordinates). Euclidean distance from the center of each ZIP code to the nearest dialysis center was calculated. Distances were grouped into four categories (<10, 10–19, 20–39 and ≥40 miles).

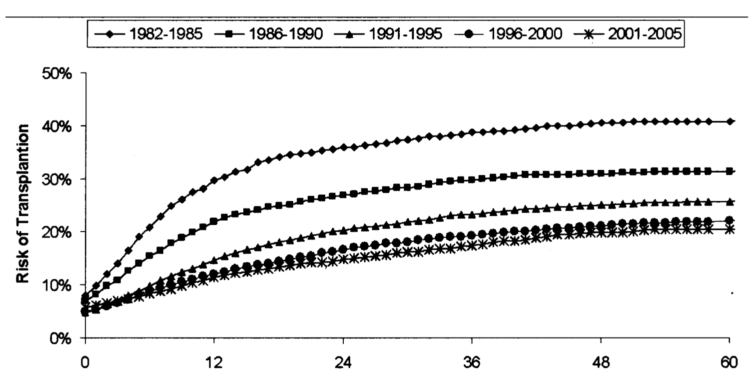
In addition to individual-level patient characteristics, we obtained data from the 1990 U.S. Census on the median household income and percentage of the population with at least some college education in the patient's ZIP code of residence at the time of ESRD diagnosis. Median ZIP code income and education were not calculated for 988 patients (4% of the sample) because their ZIP codes did not exist at the time of the 1990 U.S. Census. For the analysis, patients were grouped into quartiles of their ZIP-code-level median household incomes (≤$24,000, $24,001–$30,000, $30,001–$36,000 and >$36,000) and into tertiles of the percentage of ZIP code residents with at least a college education (<45%, 45%–49% and ≥50%). To ensure confidentiality of patient information and to maintain deidentified data, Network 11 merged the ZIP-code-level characteristics using the predefined categories with the individual level data and then stripped the patient's address information, including the patient's residential ZIP code, from the file before providing the data. The study was approved by the University of Wisconsin–Madison institutional review board.

Statistical Methods

We compared baseline characteristics of the overall study population (both transplant and nontransplant recipients) by year using the Chi-squared test for dichotomous variables and the F test for continuous variables. We used a two-step nonparametric procedure to calculate the cumulative incidence of kidney transplant by a given time while accounting for the occurrence of death, a competing risk event.[18] More traditional methods to estimate cumulative risk, such as the method of Kaplan-Meier,[19] rely on the assumption that the survival time of an individual is independent of any mechanism that causes that individual to be censored. This premise is not tenable in our case, because patients who died before receiving a transplant cannot experience the event under study (i.e., receiving a transplant). The competing risk method adjusts for the fact that death is not independent of the event of interest (i.e., receiving a transplant) and gives an unbiased estimate of the cumulative incidence of transplantation.[18]

Cox proportional hazards regression[20] was used to quantify the independent relationship between patient characteristics at ESRD onset and the risk of kidney transplantation. Separate models for living and deceased transplants were explored. We used crude and adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) to estimate the effects of the study variables on kidney transplantation. Censored events occurred at death, loss

Figure 1. Cumulative incidence of kidney transplantation by calendar year



to follow-up or at the end of the study period. Interactions between income and race, income and sex, and primary diagnosis and race were also tested. We tested these interactions because they were either found to be significant in other studies[8] or were deemed biologically plausible a priori. The assumption of proportional hazards was tested for each of the variables in the final model. All analyses were performed using SAS (8.1) statistical software (SAS®, Cary, NC). A previously published SAS macro was used to compute the cumulative incidence accounting for competing events.[21]

RESULTS

Baseline Characteristics

There were 23,797 patients diagnosed with ESRD between January 1, 1982 and October 30, 2005, in Wisconsin, and 22,387 (94%) were included in our analysis. We excluded 1,096 patients with missing information for income, education, race, distance, primary diagnosis and four multiracial patients. Patients were also excluded if they recovered before receiving a kidney transplant (n=310), as they were most likely receiving treatment temporarily and were therefore not eligible for kidney transplant. Patients who were excluded were similar to those remaining in the study with regard to sex, mean age (62 vs. 61 years), prevalence of glomerulonephritis (13% vs. 12%) and prevalence of hypertension (25% vs. 26%), but were more likely to be have diabetes (40% vs. 31%).

In order to assess differential effects in the rate of transplantation over time, we divided the study population into five calendar periods according to the year of ESRD onset: 1982–1985, 1986–1990, 1991–1995,

Table 2. Age-adjusted cumulative incidence of transplantation by two years after end-stage renal disease (ESRD) onset (1982–2005)

Characteristic	Overall 1982–2005	1982–1985	1986–1990	1991–1995	1996–2000	2001–2005	P Value*
Total Number of Transplants	5,310	546	1003	1286	1394	1081	
Overall (%)	19.5	21.5	22.1	18.7	18.3	17.4	<0.0001
Race (%)							
White	23.4	22.1	24.2	22.3	23.4	22.9	0.1875
African American	7.6	16.8	13.6	6.6	5.9	5.7	<0.0001
American Indian/Alaska native	12.7	21.8	12.2	18.7	10.5	9.5	0.0087
Hispanic/Latino	12.1	22.9	14.1	16.2	11.1	10.1	<0.0001
Asian/native Hawaiian/ Pacific Islander	15.8	7.6	27.0	12.1	10.7	16.5	0.0004
Sex (%)							
Male	20.5	23.6	23.7	20.6	19.0	17.6	<0.0001
Female	18.1	18.5	20.4	16.2	17.6	17.0	0.0040
Primary Cause of ESRD (%)							
Diabetes	18.0	20.5	33.6	18.6	15.0	13.9	<0.0001
Glomerulonephritis	25.2	24.6	32.0	22.7	24.8	22.8	0.0001
Hypertension	14.0	19.2	17.1	12.4	13.1	9.3	<0.0001
Cystic/hereditary	35.0	25.3	32.5	34.6	37.0	35.8	0.0329
Other†	18.0	29.7	19.1	15.7	16.6	19.0	<0.0001
Community-Level Median Household Income (%)							
≤$24,000	15.0	18.8	17.4	14.5	12.7	14.1	<0.0001
$24,001–$30,000	19.8	22.8	23.3	18.6	19.3	16.5	<0.0001
$30,001–$36,000	22.1	21.3	24.4	22.7	21.1	20.1	<0.0001
>$36,000	23.2	23.6	25.2	21.2	23.4	22.0	0.2419
Community-Level Education‡ (%)							
<45%	18.5	20.9	21.3	17.6	17.6	16.1	<0.0001
45–49%	20.2	24.1	24.2	21.3	17.5	17.2	0.0018
≥50%	22.5	22.3	23.8	21.7	21.7	22.0	0.7754

* The p value is for the change in cumulative incidence from 1982–1985 through 2001–2005; † Other includes: secondary glomerulonephritis/vasculitis, interstitial nepritis/pyelonephritis, neoplasms/tumors, and miscellaneous conditions; ‡ Education level was defined as the percent of the ZIP-code level population with at least some college education

1996–2000 and 2001–2005. The number of incident cases of ESRD increased throughout the study period, from 315 in 1982 to 1,640 in 2004. Average age at ESRD onset increased from 51 years in 1982–1985 to 64 years in 2001–2005. Also, the proportion of ESRD caused by diabetes increased from 32% to 41%, and the proportion caused by hypertension increased from 16% to 27% during the same period. In contrast, ESRD caused by glomerulonephritis and by cystic or hereditary disease decreased from 24% to 9% and from 8% to 5%, respectively (Table 1).

Cumulative Incidence of Transplantation

The overall crude cumulative incidence of transplantation decreased significantly from 1982–1986 to 2001–2005, at all durations after ESRD onset (Figure 1). The likelihood of receiving a transplant was also greater for men than women at all time points after ESRD onset (Figure 2). Up to one year after ESRD onset, whites had the highest crude incidence of transplantation, after which Asian/native Hawaiian/Pacific Islanders had a significantly higher incidence of transplantation than all other races (Figure 3). The likelihood of receiving a transplant was consistently lower in older age groups than in younger age groups (Figure 4).

The likelihood of receiving a transplant sharply increased during the first two years after ESRD onset and increased little thereafter (Figure 1). Therefore, we used the cumulative incidence up to two years of follow up to describe the univariate relationships between the study variables and the risk of transplantation by calendar period (Table 2). Overall, 20% of the patients in our study had not died and had received a kidney transplant by two years after ESRD onset. However, the age-adjusted probability of transplantation within two years decreased progressively and significantly with calendar time, from 22% in 1982–1985 to only 17% in 2001–2005. While the age-adjusted incidence of transplantation among whites remained relatively constant over time, the likelihood of receiving a transplant within two years dropped significantly over the same time period for African Americans, American Indians/Alaska natives and Hispanic/Latinos (Table 2).

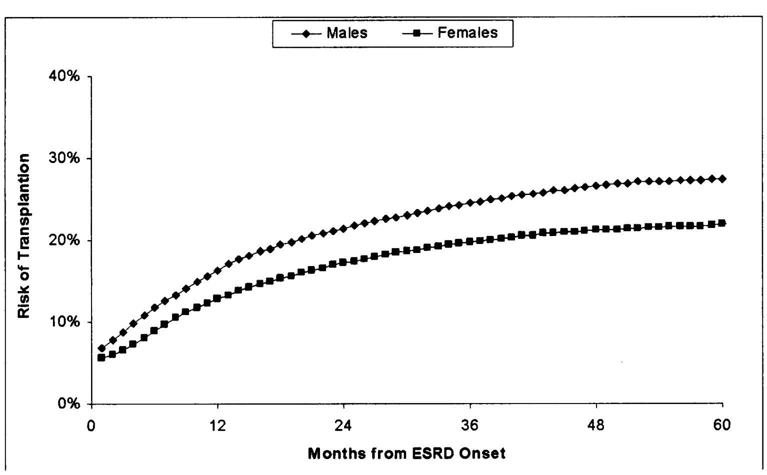
The age-adjusted cumulative incidence of transplantation was greater for males than for females in all calendar periods, although the gap seemed to disappear in 2001–2005 (Table 2). The overall age-adjusted incidence was higher in communities with higher levels of income and education, and the trends over time show that the incidence in the lowest income and education groups decreased significantly relative to the highest group. The incidence of transplantation decreased in all primary causes of ESRD, except for cystic and hereditary diseases, where the age-adjusted incidence increased from 25% in 1982–1985 to 36% in 2001–2005 (Table 2). The likelihood of receiving a transplant also decreased over time for all distance categories, except for those that lived ≥40 miles from the nearest dialysis center, where the age-adjusted incidence increased from 17% in 1982–1985 to 26% in 2001–2005 (data not shown).

Multivariate Analysis: Cox Proportional Hazards Analysis

After adjustment for age, race, primary diagnosis, community-level income, community-level education and distance to the nearest dialysis center, men were 13% more likely to receive a kidney transplant compared to females (Table 3). Those in the highest community-level income and community-level education groups were also significantly more likely (12% and 19%, respectively) to receive a transplant than the lowest groups. Distance from the nearest dialysis center was also predictive of transplantation, with those living furthest away being 23% more likely to receive a transplant, compared to those living <10 miles from a dialysis center. The effects of these variables on kidney transplantation did not change significantly with calendar time (data not shown).

Race and age were also significantly associated with transplantation, after adjustment for sex, community-level income, community-level education, distance from the nearest dialysis center and primary diagnosis (Table 4). The effect of these variables did change significantly with calendar time. African Americans diagnosed with ESRD in 1982–1985 were 35% (HR=0.65; 95% CI: 0.49–0.86) less likely to receive a transplant than whites.

Figure 2. Cumulative incidence of kidney transplantation by sex



This discrepancy increased with calendar time, with African Americans diagnosed with ESRD in 2001–2005 being 74% (HR=0.26; 95% CI: 0.21–0.32) less likely to receive a transplant than whites. Similar trends in the time to transplantation over time also occurred among American Indians/Alaska natives, Hispanic/Latinos and Asian/Native Hawaiian/Pacific Islanders. By 2001–2005, these racial groups were all significantly less likely to receive a transplant compared to whites (Table 4).

The rate of kidney transplantation also significantly differed by age, with older patients receiving transplants at a significantly lower rate compared to the youngest age group (<20 years) in all time periods (Table 4). However, this age disparity decreased progressively with calendar time for all age groups. For instance, among patients 40–49 years old, those who were diagnosed with ESRD in 1982–1985 were 67% (HR=0.33; 95% CI: 0.23–0.46) less likely to receive transplants, while those 40–49 who were diagnosed with ESRD in 2001–2005 were only 44% (HR=0.56; 95% CI: 0.42-0.75) less likely to receive transplants, as compared to patients <20 years old from the same time periods.

Multivariate Analysis: Cox Proportional Hazards Analysis—Living Donor Transplantation and Comorbid Conditions

A separate analysis for living donor transplants yielded similar results to a model with all transplants (living and deceased, data not shown). The risk of a living donor transplant for African Americans was significantly lower compared to whites, and the likelihood of transplantation decreased over time (1982–1985, HR=0.34; 95% CI: 0.18–0.63; 2001–2005, HR=0.16; 95% CI: 0.11–0.24). However, contrary to what was observed with all transplants, the likelihood of a living donor transplant was similar in women and men (HR=0.97; 95% CI: 0.88–1.06).

We also ran a separate analysis among patients diagnosed between 1996 and 2005 in order to adjust for comorbid conditions (because data on comorbidities before 1996 were not available). Similar hazard ratios to those reported in Tables 3 and 4 were obtained for all variables after adjusting for comorbidities (1996–2000 and 2001–2005). Interactions between community-level income and race, community-level income and sex, and race and primary cause of ESRD were not statistically significant.

DISCUSSION

The Medicare End-Stage Renal Disease Program, established in 1973, entitles people of all ages with a diagnosis of ESRD to receive medical coverage. This federal program was initiated in order to ensure equity in the availability of dialysis and transplantation by removing financial barriers to care.[22] The United Network for Organ Sharing and the Organ Procurement and Transplantation Network (UNOS/OPTN) implemented a point system for the allocation of deceased donor kidneys in 1987; the system uses an algorithm designed to maximize graft outcomes and promote equal access to trans-

Table 3. Overall multivariate adjusted hazard ratios of kidney transplantation for demographic and socioeconomic variables

Characteristics	Hazard Ratio* (95% CI)	P Value
Sex		<0.0001
Male	1.00	
Female	0.88 (0.83–0.93)	
Community-Level Median Household Income		<0.0001
≤$24,000	1.00	
$24,001–$30,000	1.17 (1.08–1.26)	
$30,001–$36,000	1.14 (1.05–1.24)	
>$36,000	1.12 (1.02–1.23)	
Community-Level Education†		<0.0001
<45%	1.00	
45–49%	1.06 (0.97–1.17)	
≥50%	1.19 (1.10–1.28)	
Distance to Nearest Dialysis Center (Miles)		<0.0001
<10	1.00	
10–19	1.06 (0.99–1.14)	
20–39	1.26 (1.17–1.37)	
≥40	1.23 (1.08–1.39)	

* Adjusted for all variables in the table plus age, race and primary cause of end-stage renal disease (ESRD); † Education level was defined as the percent of the ZIP-code level population with at least some college education

plantation.[23] Despite the laudable goals of the existing systems, we found differences and increasing disparities over time in the rate of transplantation among ESRD patients in Wisconsin by demographic and socioeconomic characteristics.

Our study found a significant difference in kidney transplantation between African Americans and whites, consistent with previous work.[8-11,24] Several reasons for this disparity have been suggested. First, patient preferences for transplantation may be different between African Americans and whites.[25] However, Alexander and Sehgal[8] reported that once patients are fully informed of ESRD treatment options, African Americans prefer transplantation as often as whites. Consequently, the suggested difference in preference may be due in part to physician bias. In fact, Ayanian et al.[26] found that physicians were less likely to believe that transplantation improved survival for African Americans, and a smaller proportion of African-American patients reported that their physician had discussed transplantation with them, compared to white patients. Survival on dialysis for African Americans is greater than that for whites,[27] and this may bias judgments on the benefit of transplantation for African Americans, particularly for older ESRD patients.

Another potential factor in the differential likelihood for a transplant may be that African Americans are more likely to receive a lower score for a deceased donor transplant based on the UNOS/OPTN kidney allocation point system.[28] Points are awarded, in part, according to the number of human leukocyte antigen (HLA) mismatches; the more mismatches, the lower the score.[29] White candidates typically have less HLA polymorphism compared to African Americans and therefore receive higher scores for potential organ match.[28] In 2003, UNOS/OPTN decreased the points awarded for better HLA matching with the goal of reducing the racial imbalance in the allocation of kidneys. UNOS/OPTN also changed the allocation system by dropping the points for HLA-B matched antigens. Both of these changes were also driven by research suggesting that the more stringent HLA matches were less predictive of transplantation success than was originally thought.[28,30] Additional work is ongoing to refine an allocation schema that might achieve greater equity among racial groups.

Our results are consistent with those from Gaston,[23] who reported that the time from wait-listing to transplantation increased 32% among whites and 66% among African Americans from 1992–1997. Efforts to minimize waiting list time for nonwhites have been overshadowed by the overall increase in ESRD and concomitant expansion of the waiting list.[22] Certainly, this has affected transplant programs in Wisconsin. The median waiting list times at two large transplant programs in Wisconsin are less than the national median waiting list times (15 and 31 months vs. 38 months).[31,32] Still, there is a lack of transplantation among African Americans, and the difference in transplantation rates between African Americans and whites is increasing. This suggests either

Table 4. Multivariate adjusted hazard ratios of kidney transplantation for demographic and socioeconomic characteristics by calendar period

Characteristic	1982–1985	1986–1990	1991–1995	1996–2000	2001–2005	P Value
Race	HR*	HR*	HR*	HR*	HR*	<0.0001
White	1.0	1.0	1.0	1.0	1.0	
African American	0.65 (0.49–0.86)	0.48 (0.39–0.58)	0.33 (0.27–0.39)	0.31 (0.26–0.37)	0.26 (0.21–0.32)	
American Indian/Alaska native	0.86 (0.44–1.66)	0.62 (0.38–1.01)	0.57 (0.36–0.90)	0.53 (0.36–0.77)	0.40 (0.25–0.65)	
Hispanic/Latino	3.75 (0.93–15.21)	0.59 (0.37–0.95)	0.56 (0.37–0.86)	0.55 (0.43–0.72)	0.38 (0.27–0.54)	
Asian/native Hawaiian/ Pacific Islander	0.85 (0.31–2.29)	0.81 (0.53–1.26)	0.62 (0.42–0.92)	0.66 (0.47–0.92)	0.62 (0.43–0.90)	
Age						<0.0001
<20	1.0	1.0	1.0	1.0	1.0	
20–29	0.70 (0.50–0.97)	0.98 (0.75–1.29)	0.83 (0.64–1.08)	0.66 (0.49–0.88)	0.89 (0.64–1.23)	
30–39	0.46 (0.33–0.64)	0.74 (0.57–0.96)	0.63 (0.49–0.82)	0.67 (0.52–0.87)	0.77 (0.56–1.04)	
40–49	0.33 (0.23–0.46)	0.54 (0.42–0.70)	0.46 (0.35–0.59)	0.47 (0.37–0.60)	0.56 (0.42–0.75)	
50–59	0.14 (0.10–0.19)	0.25 (0.19–0.33)	0.22 (0.17–0.29)	0.28 (0.22–0.36)	0.37 (0.28–0.50)	
60–69	0.03 (0.02–0.05)	0.07 (0.05–0.10)	0.08 (0.06–0.11)	0.11 (0.08–0.14)	0.17 (0.13–0.24)	
≥70	0.00 (0.00–0.00)	0.01 (0.00–0.01)	0.01 (0.00–0.01)	0.01 (0.01–0.02)	0.02 (0.01–0.03)	

* Hazard ratios and 95% confidence intervals adjusted for all other variables in the table plus primary diagnosis, sex, education, income and distance; † Education level was defined as the percent of the ZIP-code level population with at least some college education

that the aforementioned factors are overwhelming the capacity of the programs to provide transplantation to African Americans or that increasing educational efforts must be directed at living donation, organ donation and transplantation in general, in order for both patients and transplant centers to address this healthcare disparity.

We also found a significant difference in transplantation between whites and American Indians/Alaska natives. This finding is consistent with published data that show American Indians wait three times longer than whites to receive a transplant.[33] Also, in agreement with previous studies, we found significant differences in transplantation between whites and Asian/native Hawaiian/Pacific Islanders.[34] Similarly, we found differences in transplantation between males and females, with no significant change in relative transplantation rates over time. Other studies have found significant differences by sex in activation on the transplant waiting list and the time to transplantation once on the waiting list.[35,36]

Age was strongly associated with transplantation rates in Wisconsin. The likelihood of receiving a transplant is inversely related to age,[24] although kidney transplants performed in older recipients confer similar healthcare and quality-of-life benefits.[37] The issue of how best to ration the precious resource of deceased donor organs could theoretically disadvantage older individuals with ESRD. The Eurotransplant program that designates older, deceased donor kidneys to older recipients has been successful in overcoming some of these challenges and avoiding concerns about misappropriation of organs.[38] Fortunately, our results suggests that the difference in transplantation rates by age has narrowed somewhat over time.

Although we found that higher community income and education levels were associated with a higher likelihood of transplantation, these findings were not as striking as in other studies. Garg et al.[7] found that increasing ZIP-code-level income was associated with an increased likelihood of placement on the transplant waiting list; each $10,000 increase in ZIP-code-level income was associated with a 14% higher likelihood of activation for kidney transplantation. Alexander and Sehgal[8] also found that persons of lower income were less likely to be interested in transplantation, and were less likely to complete a pretransplant workup. However, once patients were on the waiting list, income level did not affect the acquisition of a transplant. In the present study, the effects of community-level income and community-level education might be mitigated by the fact that we assessed overall acquisition of a kidney transplant. Income and education levels might more strongly affect the steps leading to placement on the waiting list but might have a limited effect on receiving a transplant once patients are on the list. The difference between our study and others might also be the regional variation in transplantation, as all of the patients in our study lived in Wisconsin at the time of ESRD onset. In addition, the effects of education and income were population averages rather than individual values. This would result in random error and dilution of the effects of income and education level on transplantation.

Figure 3. Cumulative incidence of kidney transplantation by race

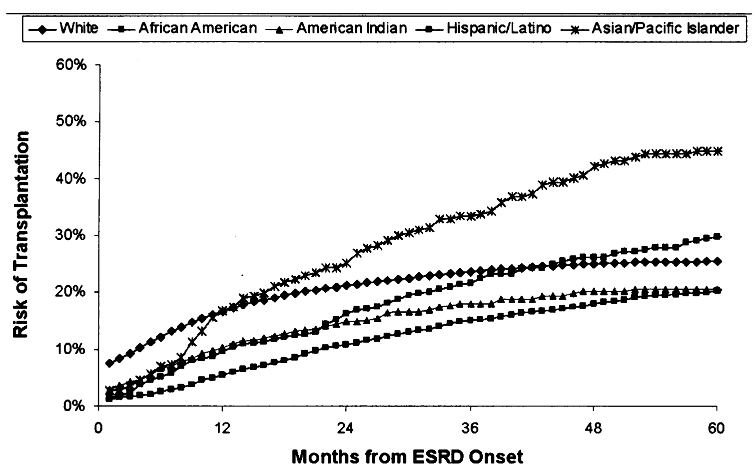
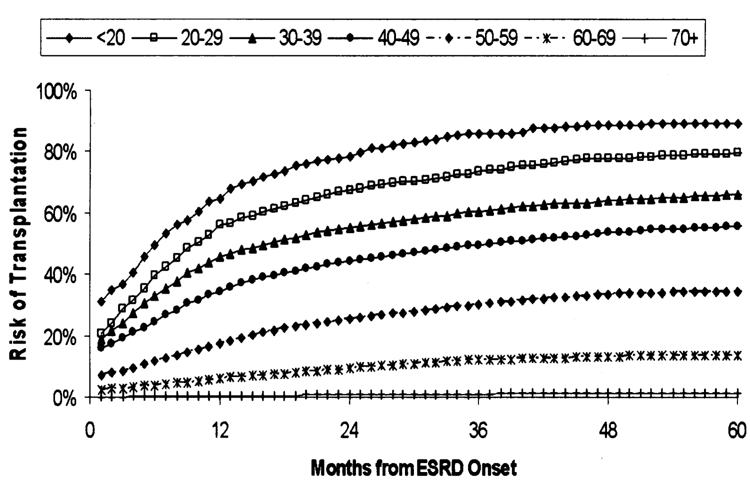


Figure 4. Cumulative incidence of kidney transplantation by age



The strength of our study is aided

by the adjustment for numerous demographic and socioeconomic characteristics, as well as the ability to assess changes in transplantation over time. The data set that was used for this study was comprehensive—all Wisconsin ESRD patients who initiated dialysis treatment or received a kidney transplant in Network 11 were identified and were subsequently included in the study population. This data set is an unbiased sample of ESRD patients; therefore, the results of this study are not because of selection bias. Also, the results are not likely caused by chance because of our large sample size. In addition, we used a competing risk method to calculate the cumulative incidence of transplantation. This method provided an unbiased estimate of the incidence of transplantation while adjusting for death before transplantation—an outcome that occurred in >50% of our study population. Previous studies have compared estimates of the cumulative incidence using the Kaplan-Meier approach to those estimates obtained using the competing risk approach. The findings show that estimates obtained using the Kaplan-Meier approach are numerically larger than those accounting for competing risk events.[18,39]

Some limitations must be considered when evaluating this work. Patient characteristics such as race were not self-reported. This might introduce misclassification error that is likely independent of transplantation, as racial data are collected at the time of entry to the ESRD program. Under these conditions, the hazard ratios that we observed for each racial group should be smaller than they actually are, as the racial groups should be more homogenous in the presence of misclassification. We also used community-level income and education as proxies for individual level characteristics. The association of health outcomes with aggregate (ZIP-code-level) measures might be substantially weaker than with individual level measures.[40] Therefore, the actual effects of income and education levels are likely larger than those estimated in our study. In addition, our study focused on ESRD patients in Wisconsin; consequently, the results may not be generalizable to other states or the United States as a whole. Finally, we were not able to assess differences in transplantation by different stages in the transplant process (i.e., patient preferences for transplant, pretransplant work-up and time from placement on the waiting list to transplantation). Nonetheless, we were able to demonstrate that overall disparities in transplantation exist. Further studies will be required in order to identify specific stages in the transplantation process that might be particularly relevant for different subpopulations.

The growing incidence of ESRD has created an unprecedented demand for kidney transplants. It is estimated that by 2010, the median waiting time for a kidney transplant will be 10 years.[21] In Wisconsin, as well as nationally, it will be increasingly important to allocate kidneys equitably. Further studies are needed to elucidate the specific barriers to transplantation among different subpopulations and target effective interventions.

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