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Racial/Ethnic Differences in the Association between Hospitalization and Kidney Transplantation among Waitlisted End Stage Renal Disease Patients

Kira L. Newman, BA^{1,2}, Stacey A. Fedewa, MPH¹, Melanie H. Jacobson, MPH¹, Andrew B. Adams, MD, PhD^{3,4}, Rebecca Zhang, MS⁴, Stephen O. Pastan, MD^{4,5}, and Rachel E. Patzer, PhD, MPH^{1,3,4}

¹Department of Epidemiology, Rollins School of Public Health, Atlanta, GA

²Medial Scientist Training Program, Emory University School of Medicine, Atlanta, GA

³Division of Transplantation, Department of Surgery, Emory University School of Medicine, Atlanta, GA

⁴Emory Transplant Center, Atlanta, GA

⁵Division of Renal Medicine, Department of Medicine, Emory University School of Medicine

Abstract

Introduction—Even after placement on the deceased donor waitlist, there are racial disparities in access to kidney transplant. The association between hospitalization, a proxy for health while waitlisted, and disparities in kidney transplant has not been investigated.

Methods—We used United States Renal Data System Medicare-linked data on waitlisted End-Stage Renal Disease (ESRD) patients between 2005 and 2009 with continuous enrollment in Medicare Parts A & B (n=24 581) to examine the association between annual hospitalization rate and odds of receiving a deceased donor kidney transplant. We used multi-level mixed effects models to estimate adjusted odds ratios (aOR), controlling for individual-, transplant center-, and organ procurement organization-level clustering.

Results—Blacks and Hispanics were more likely than whites to be hospitalized for circulatory system or endocrine, nutritional, and metabolic diseases ($p<0.001$). After adjustment, compared to individuals not hospitalized, patients who were hospitalized frequently while waitlisted were less likely to be transplanted (>2 vs. 0 hospitalizations/year aOR=0.57, $p<0.001$). Though blacks and Hispanics were more likely to be hospitalized than whites ($p<0.001$), adjusting for hospitalization did not change estimated racial/ethnic disparities in kidney transplantation.

Corresponding author: Kira L Newman, 1518 Clifton Rd., Atlanta, GA, 30322, Fax: 404-727-0045, Tel: 720-201-6043, Kira.newman@emory.edu.

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Conclusions—Individuals hospitalized while waitlisted were less likely to receive a transplant. However, hospitalization does not account for the racial disparity in kidney transplantation after waitlisting.

Introduction

Recent work has identified pre-kidney transplant hospitalization as a factor associated with poor transplant outcomes¹. However, the overall patterns of pre-transplant hospitalizations, particularly as they relate to whether or not end-stage renal disease (ESRD) patients receive a kidney transplant, have not been described in depth or examined with regard to racial and ethnic disparities in transplantation.

It has been consistently shown that racial and ethnic disparities exist in accessing renal transplantation. Racial and ethnic minorities are less likely to be listed for a transplant, they are more likely to be listed later, and once waitlisted, they are less likely to be transplanted and more likely to have long waiting times for receiving an organ^{2–8}. These factors and others are associated with worse health outcomes for racial/ethnic minorities following kidney transplant^{9,10}. While causes of racial and ethnic disparities prior to being waitlisted have been well studied^{11–14}, factors associated with disparities after waitlisting are less well understood⁸.

Given that racial and ethnic minorities are waitlisted later after starting dialysis than non-Hispanic whites, we hypothesized that these individuals may be sicker when waitlisted and therefore less likely to ultimately receive a transplant. We used hospitalization rate while waitlisted as a surrogate for overall health, as hospitalization rate has been previously associated with severity of illness and lower quality of life^{15–17}. However, it is possible that hospital utilization may be an indicator of poor access to primary or preventive care. The purpose of this study was to evaluate the association between hospitalization and receipt of a kidney transplant and to test whether this explained the racial/ethnic disparity in kidney transplantation. This study used a multilevel modeling approach to account for geographic variation by organ procurement organization (OPO) and transplant center.

Methods

Study population and data sources

Adults (aged 18+ years) waitlisted for first renal allograft between January 1, 2005 and December 31, 2009 who had continuous coverage by Medicare Parts A and B while waitlisted were included in this analysis. Patient data were obtained from the United States Renal Data System (USRDS). Demographic and clinical information were ascertained via the Centers for Medicare and Medicaid Services (CMS) Medical Evidence form (CMS-2728), which is completed at the start of ESRD treatment. Transplant data were obtained from the United Network for Organ Sharing forms at the time of waitlisting and transplantation. Data on hospitalizations were obtained from CMS claims data. Neighborhood poverty and education data from the American Community Survey (ACS) data (2005–2010) were linked to patients by residential zip code at the time of ESRD start. Transplant center and OPO aggregate data were obtained from the Scientific Registry of

Transplant Recipients annual reports and the Organ Procurement and Transplantation Network's National Donor Service Area Dashboard.

A total of 29 505 adults with ESRD who were waitlisted between January 1, 2005 and December 31, 2009 had continuous Medicare coverage while waitlisted and were considered for inclusion. Patients were excluded if they had received a prior transplant, were missing key information, or had invalid hospitalization data. The causes and number of exclusions are outline in Figure 1. The final study population consisted of 24 581 individuals.

Study variables

The primary outcome was receipt of a deceased donor renal transplant after being waitlisted. Study participants were identified at the date of waitlisting and followed until deceased donor transplant, death, removal from the waitlist for other reasons, or the end of the study (December 31, 2009). Individuals who received living donor transplants were considered censored at the time of transplant. Follow-up time was defined as the time from waitlisting until either deceased donor transplant or removal from the waitlist due to death, inactivation, or other causes.

All hospitalizations were counted in the hospitalization rate. The first listed ICD-9 diagnosis code for each hospitalization was regarded as the primary cause of hospitalization and was determined for up to the first 30 hospitalizations. ICD-9 codes were categorized using the Healthcare Cost and Utilization Project's Clinical Classification Software ¹⁸.

Race/ethnicity and hospitalization rate while waitlisted were the main exposures of interest in the analysis. Race/ethnicity was categorized as non-Hispanic white (referred to as white), non-Hispanic black (referred to as black), and Hispanic white (referred to as Hispanic). Hospitalization rate was measured as the number of hospitalizations per year while waitlisted up to 30 days prior to transplant, to prevent hospitalization associated with the transplant operation from inclusion. Hospitalization rates were divided into three categories: no hospitalizations per year, greater than zero to two hospitalizations per year, and more than two hospitalizations per year. Average length of stay (days) while hospitalized was also examined.

Individual-level covariates included recipient age at waitlisting, peak panel reactive antibody (PRA), sex, blood type, willingness to accept an expanded donor criteria organ, years of dialysis prior to waitlisting, ESRD cause, body mass index (BMI), history of cancer, smoking status, insurance at ESRD start, and employment at ESRD start. Peak PRA was assumed to be the PRA listed as peak, the highest PRA listed, or, if both were missing, was imputed as zero. ESRD cause was categorized as diabetes, hypertension, kidney-related causes (i.e. IgA nephropathy, polycystic kidney disease, focal segmental glomerulosclerosis, or other types of glomerular nephritis), and other causes (e.g. tumor, infection, etc.). Insurance and employment at ESRD diagnosis (i.e. ESRD start) were used as individual-level proxies of socioeconomic status (SES). Insurance and employment at ESRD start were obtained for each individual based on USRDS data. Employment was categorized as employed full-time, employed part-time, unemployed, retired, and other (included homemakers, students, medical leave of absence, and other).

Neighborhood poverty, neighborhood education, and health insurance at the time of ESRD onset were also considered proxies for SES. Neighborhood poverty was estimated by the percentage of households with an annual income below the federal poverty level in each 5-digit zip code area based on ACS data. Neighborhood education was estimated by the percentage of adults with less than a high school level education in each 5-digit zip code area based on ACS data.

Transplant center- and OPO-level covariates included facility renal transplant volume, OPO import-export status for deceased donor renal allografts, and OPO-specific median time to renal transplant. Transplant center renal transplant volume was estimated using the mean number of annual kidney transplants performed between 2005 and 2009 and was divided into tertiles. OPOs were categorized as importers or exporters based on whether they were net receivers of kidneys from other OPOs' catchment areas or net donors to other OPOs. Median time to transplant was divided into tertiles.

Data analysis

Chi-square and ANOVA tests were used to test for differences between baseline characteristics by race/ethnicity and by hospitalization rate. Chi-square tests were used to examine differences between hospitalization causes by race/ethnicity. Crude time to transplant from waitlisting was examined using Kaplan-Meier curves with log-rank tests were to examine statistical differences by race/ethnicity and hospitalization. We used multi-level logit-binomial models with robust sandwich estimators and fixed and random effects to estimate the odds ratios of receiving a deceased donor transplant, controlling for covariates and accounting for clustering by facility and OPO. The models were adjusted with fixed effects for individual-level demographic and clinical covariates, facility volume, OPO-level covariates and interaction between race/ethnicity and hospitalization rate. Random intercepts were included at the individual, facility, and OPO levels, and a random slope was included for hospitalization rate. The significance of the interaction terms was tested using the likelihood-ratio test and none were significant, thus they were excluded from all further models.

To test for differences between the effects of different types of hospitalizations, a multivariable fixed effects model of the association between hospitalization and transplant was adjusted for fixed effects of average length of hospitalization, hospitalization rate, and cause of hospitalization was constructed. It included a random slope for the effect of hospitalization rate and random intercepts at the individual, transplant center, and OPO levels.

The final multivariable mixed effects model of the association between race/ethnicity and hospitalization on transplant was adjusted for fixed effects of average length of hospitalization, age, sex, blood type, BMI, peak PRA, cause of ESRD, years on dialysis prior to waitlisting, smoking history, cancer history, insurance at time of ESRD start, neighborhood poverty, neighborhood education, transplant center volume, OPO import/export status, and OPO median time to transplant. The model had a random slope for the effect of hospitalization rate and random intercepts at the individual, transplant center, and OPO levels.

As a sensitivity analysis, Cox proportional hazard models were constructed to examine the effects of race/ethnicity on time to transplant with and without adjustment for hospitalization rate and average length of hospitalization and with and without adjustment for age, sex, blood type, BMI, peak PRA, cause of ESRD, years on dialysis prior to waitlisting, smoking history, cancer history, insurance at time of ESRD start, neighborhood poverty, neighborhood education, transplant center volume, OPO import/export status, and OPO median time to transplant. All variables were tested for the proportional hazards assumption using log-log survival curves. Hospitalization rate did not satisfy the proportional hazards assumption, so the models that included this variable were stratified by hospitalization rate.

Complete case analysis was used in all models. All analyses were performed with SAS 9.4 (Cary, NC). P-values of <0.05 were considered significant. The Emory University Institutional Review Board approved this study (IRB00038140).

Results

Characteristics of the study population

A total of 24 581 adults waitlisted for deceased donor kidney transplant were included in this analysis, of whom 8 504 received a deceased donor transplant (34.62%). Individuals were waitlisted for a median of 418 days (interquartile range (IQR): 166–817.5). During the study period, 2 900 individuals were removed from the waitlist after receiving a living donor transplant (11.81%) and 1 573 were removed from the waitlist because their condition deteriorated and they were no longer eligible or they died (6.40%). The study population was 44.33% white, 35.44% black, and 20.23% Hispanic. Study variables stratified by racial/ethnic group are presented in Table 1. While waitlisted, black individuals were the most likely group to be hospitalized at least once, followed by Hispanics and whites (52.5%, 48.5%, and 44.5%, respectively). Study variables stratified by hospitalization rate are presented in Table 2.

Overall, there were 43 484 hospitalizations for which primary diagnoses were obtained. The most common cause of hospitalization was for diseases of the circulatory system (12 191 hospitalizations, 28.0%), followed by injuries and poisonings (8 441 hospitalizations, 19.4%) and diseases of the digestive system (4 691 hospitalizations, 10.8%). Of all diagnoses, 8 621 (19.8%) were from individuals who received a transplant during the study period. The number of hospitalizations stratified by cause and transplantation are presented in Figure 3.

Causes of hospitalization varied by race/ethnicity. The greatest differences in prevalence of hospitalizations by cause were for circulatory system and endocrine, nutritional, and metabolic diseases. Black and Hispanic individuals were more likely than whites to be hospitalized for both causes (both $p<0.001$, Supplementary Table 1). There were significant differences between racial/ethnic groups in the prevalence of hospitalization for all types of causes except for diseases of the blood and blood forming organs, mental illness, diseases of the nervous system and sense organs, and diseases of the skin and subcutaneous tissue (Supplementary Table 1).

Transplant access by hospitalization cause

After controlling for hospitalization rate and length of stay in the multivariable mixed effects model with hospitalization causes as fixed effects, many hospitalization causes were associated with decreased likelihood of transplant. Hospitalization for neoplasms was associated with the greatest decrease in the odds of being transplanted (OR=0.48, 95% confidence interval (CI) 0.39–0.60), followed by hospitalization for uncategorized codes (OR=0.55, 95% CI 0.33–0.91) and diseases of the blood and blood-forming organs (OR=0.63, 95% CI 0.46–0.85). Hospitalizations for mental illness, genitourinary, digestive system, obstetric, and congenital conditions were not associated with decreased likelihood of transplant (all $p>0.10$). Full results for association between hospitalization cause and likelihood of transplant are provided in Supplementary Table 2.

Transplant access by race/ethnicity and hospitalization rate (crude analyses)

During the study period, 39.36% of white individuals received deceased donor transplants compared to 33.41% of black and 26.36% of Hispanic individuals ($p<0.001$). In crude analyses, black and Hispanic individuals who did receive transplants waited longer than white individuals ($p<0.001$, data not shown). The median waiting time for white individuals who received a transplant was 296 days (IQR: 108–593). For black individuals it was 423 days (IQR: 169–766.5). For Hispanic individuals it was 430 days (IQR: 175–776).

In crude analyses, hospitalization rate while waitlisted was negatively associated with receiving a deceased donor transplant ($p<0.001$). Never hospitalized individuals were most likely to receive a transplant, compared with those hospitalized >0 and ≤ 2 times and >2 times per year (40.27%, 32.07%, and 22.22%, respectively). In Kaplan-Meier analysis, the association between hospitalization rate and waiting time was nonlinear, though individuals who were never hospitalized spent less time on the waiting list were more likely to receive a transplant than individuals who were hospitalized (Figure 2, $p<0.001$). Of the three categories of hospitalization, individuals who were never hospitalized had the shortest median waiting time from wait listing to transplant of 210 days (IQR: 70–457), individuals hospitalized >0 and ≤ 2 times per year had the longest median waiting time of 707 days (IQR: 457–977), and individuals hospitalized more than two times per year had a median waiting time of 356.5 days (IQR: 170–619.5).

Death and inactivation or removal from the waitlist for other reasons were more common among individuals with higher hospitalization rates. Of the study population, 0.22% of individuals who were never hospitalized died while waitlisted during the study, 0.43% of individuals who were hospitalized >0 and ≤ 2 times/year died, and 2.05% of individuals hospitalized >2 times/year died while waitlisted during the study. Of individuals who were never hospitalized, 1.22% were permanently inactivated or removed from the waitlist because they were too sick to transplant, compared with 7.28% of individuals hospitalized >0 and ≤ 2 times/year and 16.90% of individuals hospitalized >2 times/year. There were no notable differences in the death rate while waitlisted for different racial/ethnic groups. Of the study population, whites had the highest proportion of individuals who died while waitlisted, followed by blacks and Hispanics (0.73%, 0.57%, and 0.38%, respectively). A similar proportion of blacks and Hispanics were removed or inactivated because they became too

sick to transplant (4.62% and 4.77%), but a larger proportion of whites were inactivated or removed from the waitlist for this reason (7.22%).

Transplant access by race/ethnicity and hospitalization rate (multivariable analysis)

The final, fully adjusted multivariable mixed effects model only accounted for some of the racial/ethnic disparity observed between black and white individuals (Table 3, adjusted OR for transplant among black vs. white=0.87, 95% CI 0.81–0.94; unadjusted OR=0.77, 95% CI 0.73–0.82). The fully adjusted model did account for the racial/ethnic disparity between Hispanic individuals and white individuals in transplant (Table 3, adjusted OR for transplant among Hispanic vs. white individuals=0.95, 95% CI 0.86–1.05; unadjusted OR=0.55, 95% CI 0.51–0.59). However, controlling for hospitalization did not change the estimated crude disparity between black individuals and white individuals or between Hispanic and white individuals or the estimated adjusted disparity between black and white individuals (Table 3).

The variables with the largest impact on the estimated racial/ethnic disparity in transplant were transplant center and OPO (Table 3). Controlling for both transplant center and OPO attenuated the estimated OR for a Hispanic individual compared to a white individual from 0.55 (95% CI: 0.51–0.59) to 0.87 (95% CI: 0.79–0.96) and for a black individual compared to a white individual from 0.77 (95% CI: 0.73–0.82) to 0.84 (95% CI: 0.78–0.91, Table 3), although Hispanics and blacks were still statistically significantly less likely to receive a transplant compared with white individuals.

The associations between other variables and transplant in the fully adjusted model are presented in Table 4. In the fully adjusted model, some variables that were associated with increased odds of transplant included having type A or AB blood (ref=type O; ORs=1.72 and 3.56, respectively; both $p<0.0001$) and willingness to accept an expanded donor criteria organ (OR=1.60, $p<0.0001$). Some factors associated with decreased odds of receiving a transplant included years spent on dialysis prior to waitlisting (one year OR=0.67, $p<0.0001$) and being listed in an OPO with a high median time to transplant (tertile OR=0.49, $p<0.0001$).

Sensitivity analysis

In the sensitivity analysis, Cox proportional hazards models indicated that controlling for hospitalization rate did not eliminate the racial/ethnic disparities in time to transplant (hazard ratio (HR) for black vs. white individuals in fully adjusted model without controlling for hospitalization rate and length of stay=0.80 [95% CI: 0.76–0.84], with hospitalization rate and length of stay=0.80 [0.76–0.84]; for Hispanics compared to whites without adjusting for hospitalization variables HR=0.75 [0.70–0.80], and with, HR=0.72 [0.67–0.77]).

Discussion

In this cohort of US adults waitlisted for deceased donor kidney transplant, the cause of hospitalization had differential effects on the likelihood of transplant and varied by race/ethnicity. Black and Hispanic individuals were more likely to be hospitalized while

waitlisted than whites and were more likely to be hospitalized for diseases of the circulatory system and for endocrine, nutritional and metabolic diseases. On average when hospitalized, blacks had longer lengths of hospitalization than whites or Hispanics. In our sample, black and Hispanic individuals were younger than whites, and younger individuals have been reported to have higher rates of hospitalization pre-transplant than older individuals ¹⁹. However the observed association between age and hospitalization was smaller than our observed association between minority race/ethnicity and hospitalization, suggesting that other factors besides age may be involved in the association between race/ethnicity and hospitalization.

This is the first study to investigate causes of hospitalization among racial/ethnic minorities waitlisted for kidney transplant. Earlier work has only considered hospitalization post-transplant ²⁰. We found that there are racial/ethnic differences in causes of hospitalization while waitlisted, consistent with differences in underlying comorbidities. Black and Hispanic individuals were more likely than whites to be hospitalized for circulatory system or endocrine, nutritional, and metabolic illnesses (Supplementary Table 1) and were more likely to have ESRD as a result of similar conditions (Table 1). Hospitalization for either of these causes was associated with a 20% decrease in the odds of receiving a transplant during the study period (Supplementary Table 2). This suggests that differential disease profiles between racial/ethnic groups may lead to differential rates of transplantation.

In prior studies, black race has been associated with higher rates of hospital readmission among Medicare beneficiaries with a variety of conditions ^{21–24} and higher rates of readmission following kidney transplant ²⁵. Yet among individuals on hemodialysis, black race and Hispanic ethnicity have been associated with lower rates of hospitalization overall, when compared to non-Hispanic whites ²⁶. Part of the discrepancy between this study and the study by Yan, et al. may be that Yan, et al. only considered hospitalization outcomes within the first year of maintenance hemodialysis for ESRD, regardless of waitlisting. There also may be discrepancies because of differences in the age distributions between their study and ours, with individuals in the Yan study being older on average than individuals in our study.

Our hypothesis that racial/ethnic disparities in transplant for waitlisted individuals was partially due to hospitalization was not supported by our results. As previously reported by other researchers, we identified racial differences in the likelihood of transplantation after waitlisting ^{8,27}, but these racial differences were not explained by higher hospitalization rates among minorities. Controlling for hospitalization in crude and adjusted analyses had little to no impact on the estimated racial/ethnic disparities in transplantation. While high rates of hospitalization while waitlisted were associated with lower likelihood of transplant, this effect was independent of race/ethnicity.

The observed racial/ethnic disparities in transplant access were largely explained by center and OPO-level effects, though they did not account for all the observed racial/ethnic disparities. Prior research has underscored the importance of geographic factors in explaining disparities in transplantation ^{27–30}. An interesting result from our study was that controlling for transplant center and OPO nearly eliminated the disparity in transplant

between Hispanic and non-Hispanic white individuals (Table 3). This dramatic effect reinforces the fact that region plays a substantial role in likelihood of receiving a transplant for Hispanic individuals and supports similar findings by Arce, et al. ²⁷. Future research should consider regional-level interventions that may make kidney transplantation more equitable across OPOs.

In contrast to the effect of controlling for transplant center and OPO on the disparities in transplant for Hispanic individuals, controlling for these factors had a much smaller impact on the disparity between blacks and whites, underscoring the important fact that racial/ethnic disparities are not homogeneous across groups. Even after full adjustment for individual-, transplant center-, and OPO-level variables, there was still a 13% difference between black individuals' and white individuals' likelihoods of transplant during the study period. This residual disparity may have been the result of SES and cultural factors that we did not control for, such as individual education level, social support, language barriers, transportation resources, or medical mistrust. These factors may complicate individuals' abilities to remain on the waitlist, such as through medical noncompliance or refusal of a transplant when one becomes available. Future work should evaluate these and other factors included in Ladin, et al.'s conceptual framework for disparities in transplantation ³¹.

In our sample, there was a significant effect of insurance at ESRD start, an indicator of individual-level SES, suggesting other unmeasured SES factors may play a role. Other variables that may explain some of the racial/ethnic disparity are matching factors, such as human leukocyte antigen (HLA), that are unaccounted for in our models even after controlling for blood type and PRA ^{32,33}. HLA is one potential driver of racial/ethnic disparities in transplant ³³, leading to gaps in the rate of transplants between whites and racial/ethnic minorities, despite greater willingness by minorities to accept poorer quality (i.e. expanded criteria donor) organs ³⁴.

This study has multiple strengths. This is the first study to examine the causes of hospitalization while waitlisted for kidney transplant and to assess the impact of hospitalization while waitlisted on transplant. We had a large study population, which allowed us to analyze multiple racial/ethnic groups and many covariates. It also allowed us to assess for interaction between race/ethnicity and hospitalization rate concurrently with other covariates. Furthermore, we were able to account for clustering by transplant center and OPO in addition to individual-level variability because of our use of hierarchical mixed models. Lastly, USRDS data have extremely high follow-up rates, making our dataset nearly complete with regard to key exposures and outcomes.

There were some limitations of this study. To assess hospitalization while waitlisted, we had to restrict our study population to individuals with continuous coverage by Medicare parts A and B. This study was observational, and there may be unmeasured variables that created residual confounding. Certain variables, such as neighborhood-level SES indicators and BMI, were only measured once and may have changed over the course of the study, which was not accounted for in analyses. In addition, using area-level SES measures to assess individual-level SES may lead to misclassification bias ³⁵. Finally, we only included individuals who were black, white, or Hispanic due to small sample sizes and heterogeneity

in the other groups, and in examining hospitalization rate, we were not able to separate out diverse factors that contribute to hospitalization rate, such as severity of illness and access to preventive care.

This study is the first that we are aware of to examine the impact of hospitalization while waitlisted on kidney transplant and its association with race/ethnicity. We report that hospitalization does not explain the racial/ethnic disparity in kidney transplantation for waitlisted individuals, even after adjusting for individual, transplant center, and OPO-level variables. Further studies are needed to identify modifiable factors associated with racial/ethnic disparities for individuals waiting for kidney transplantation and to test targeted interventions to reduce these inequities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

ACS	American Community Survey
aOR	adjusted odds ratio
BMI	body mass index
CI	confidence interval
CMS	Centers for Medicare and Medicaid Services
ESRD	end-stage renal disease
HLA	human leukocyte antigen
IQR	interquartile range
OPO	organ procurement organization
PRA	panel reactive antibody
SES	socioeconomic status
USRDS	United States Renal Data System

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Reason for exclusion	Number excluded	Number in study
Participants aged 18 or older in USRDS placed on kidney waitlist Jan 1, 2005-Dec 31, 2009, continuously enrolled in Medicare parts A & B, with valid date of removal from waitlist		29,505
Not non-Hispanic black, non-Hispanic white, or Hispanic white	2,328	27,177
Previous transplant	1,079	26,098
Missing race/ethnicity data	231	25,867
Missing comorbidity data	202	25,665
Missing prior insurance data	154	25,511
Missing neighborhood level SES variables	672	24,839
Missing facility ID	135	24,704
Missing OPO ID	122	24,582
Invalid exposure	1	24,581
Analytic dataset		24,581

Figure 1.

Flow chart of study inclusion among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

Figure 2.

Kaplan-Meier time to transplant curves by hospitalization rate among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

Figure 3.

Distribution of primary cause of hospitalization categorized according to Agency for Healthcare Research and Quality's Clinical Classifications Software for ICD-9, stratified by transplant status among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

Abbreviations and contractions: Blood: Diseases of the blood and blood-forming organs; Circulatory: Diseases of the circulatory system; Endocrine: Endocrine, nutritional, and metabolic diseases and immunity disorders; GI: Diseases of the digestive system; GU: Diseases of the genitourinary system; MSK: Diseases of the musculoskeletal system and connective tissue; OB: Complications of pregnancy, childbirth, and the puerperium; Other: Residual codes, unclassified; Symptoms/signs: Symptoms, signs, and ill-defined conditions and factors influencing health status.

Distribution of individual-, neighborhood-, transplant center-, and OPO-level study variables stratified by race/ethnicity among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

Table 1

Variable	Total N=24 581 N (%)	White non-Hispanic N=10 862 N (%)	Black non-Hispanic N=8 735 N (%)	White Hispanic N=4 984 N (%)	p-value
Mean hospitalization rate					
0 hosp/yr	12 795 (52.05)	6 006 (55.29)	4 218 (48.29)	2 559 (51.50)	<0.001
0< and 2 hosp/yr	7 441 (30.27)	2 919 (26.87)	2 917 (33.39)	1 605 (32.20)	
>2 hosp/yr	4 345 (17.68)	1 937 (17.83)	1 597 (18.28)	811 (16.27)	
Average hospitalization length (Mean, SD)	2.3 (3.9)	2.2 (4.0)	2.5 (3.9)	2.3 (3.7)	<0.001
Age at time of waitlisting (Mean, SD)	54 (13.6)	57.4 (13.4)	51.3 (13.2)	51.4 (13.2)	<0.001
Female	9 412 (38.29)	3 849 (35.44)	3 734 (42.75)	1 829 (36.70)	<0.001
Blood Type					
A	8 163 (33.21)	4 466 (41.12)	2 236 (25.60)	1 461 (29.31)	<0.001
B	3 463 (14.09)	1 179 (10.85)	1 805 (20.66)	479 (9.61)	
AB	1 007 (4.10)	430 (3.96)	457 (5.23)	120 (2.41)	
O	11 948 (48.61)	4 787 (44.07)	4 237 (48.51)	2 924 (58.67)	
BMI					
Underweight (<18.5)	10 799 (43.93)	4 345 (40.00)	4 425 (50.66)	2 029 (40.71)	<0.001
Normal (18.5–24.9)	3 710 (15.09)	1 835 (16.89)	1 002 (11.47)	873 (17.52)	
Overweight (25.0–29.9)	4 619 (18.79)	2 169 (19.97)	1 377 (15.76)	1 073 (21.53)	
Obese (≥ 30)	5 453 (22.18)	2 513 (23.14)	1 931 (22.11)	1 009 (20.24)	
Peak PRA					
PRA=0	15 516 (63.12)	7 134 (65.68)	5 043 (57.73)	3 339 (66.99)	<0.001
0<PRA<80	7 346 (29.88)	3 094 (28.48)	2 934 (33.59)	1 318 (26.44)	
PRA ≥ 80	1 719 (6.99)	634 (5.84)	758 (8.68)	327 (6.56)	
Insurance at ESRD start					
Employer/Private	5 739 (23.35)	2 830 (26.05)	2 218 (25.39)	691 (13.86)	<0.001
Medicaid	6 472 (26.33)	1 912 (17.60)	2 575 (29.48)	1 985 (39.83)	
Medicare	5 976 (24.31)	3 763 (34.64)	1 548 (17.72)	665 (13.34)	
No insurance	3 875 (15.76)	1 199 (11.04)	1 563 (17.89)	1 113 (22.33)	

Variable	Total N=24 581 N (%)	White non-Hispanic N=8 735 N (%)	Black non-Hispanic N=4 984 N (%)	White Hispanic N=4 984 N (%)	p-value
Other	2 519 (10.25)	1 158 (10.66)	831 (9.51)	530 (10.63)	
Employment at ESRD start					
Full-time	3 108 (21.71)	1 374 (20.31)	1 045 (23.32)	689 (22.44)	<0.001
Part-time	737 (5.15)	395 (5.84)	223 (4.98)	119 (3.88)	
Retired	6 566 (45.86)	3 625 (53.58)	1 787 (39.88)	1 154 (37.59)	
Unemployed	3 120 (21.79)	1 036 (15.31)	1 234 (27.54)	850 (27.69)	
Other	785 (5.48)	335 (4.95)	192 (4.28)	258 (8.40)	
Expanded criteria donor ^a	13 503 (54.93)	6 271 (57.73)	4 584 (52.48)	2 648 (53.13)	<0.001
Years on dialysis at waitlisting					
0	10 949 (44.54)	4 503 (41.46)	4 431 (50.73)	2 015 (40.43)	<0.001
1	7 047 (28.67)	3 623 (33.35)	1 935 (22.15)	1 489 (29.88)	
2	4 195 (17.07)	1 794 (16.52)	1 446 (16.55)	955 (19.16)	
3+	2 390 (9.72)	942 (8.67)	923 (10.57)	525 (10.53)	
ESRD Cause					
Diabetes	9 532 (38.78)	3 712 (34.17)	3 152 (36.08)	2 668 (53.53)	<0.001
Hypertension	6 342 (25.80)	2 219 (20.43)	3 179 (36.39)	944 (18.94)	
Kidney-related	4 670 (19.00)	2 664 (24.53)	1 251 (14.32)	755 (15.15)	
Other	4 037 (16.42)	2 267 (20.87)	1 553 (13.20)	617 (12.38)	
History of Cancer	797 (3.24)	537 (4.94)	189 (2.16)	68 (1.36)	<0.001
Cigarette smoker	1 250 (5.09)	696 (6.41)	442 (5.06)	112 (2.25)	<0.001
% households below poverty line					
<10%	206 (0.84)	100 (0.92)	76 (0.87)	30 (0.60)	0.256
10%–20%	5 338 (21.72)	2 374 (21.86)	1 866 (21.36)	1 098 (22.03)	
20%	19 037 (77.45)	8 388 (77.22)	6 793 (77.77)	3 856 (77.37)	
% adults with high school education					
<85%	11 792 (47.97)	5 174 (47.63)	4 159 (47.61)	2 459 (49.34)	0.097
85%	12 789 (52.03)	5 688 (52.37)	4 576 (52.39)	2 525 (50.66)	
Mean annual transplant center volume					
Lowest tertile	8 359 (34.01)	3 991 (36.74)	2 436 (27.89)	1 932 (38.76)	<0.001
Middle tertile	8 105 (32.97)	3 234 (29.77)	3 358 (38.44)	1 513 (30.36)	

Variable	Total N=24 581 N (%)	White non-Hispanic N=10 862 N (%)	Black non-Hispanic N=8 735 N (%)	White Hispanic N=4 984 N (%)	p-value
Highest tertile	8 117 (33.02)	3 637 (33.48)	2 941 (33.67)	1 539 (30.88)	
OPO kidney importer	7 872 (32.02)	3 287 (30.26)	3 469 (39.85)	1 103 (22.19)	<0.001
OPO median wait time to transplant					
Lowest tertile	8 322 (33.86)	4 246 (39.09)	2 768 (31.68)	1 308 (26.24)	<0.001
Middle tertile	8 011 (32.59)	3 998 (36.81)	2 939 (33.65)	1 074 (21.55)	
Highest tertile	8 248 (33.55)	2 618 (24.10)	3 028 (34.67)	2 602 (52.21)	

All values N (%) unless otherwise specified.

Abbreviations: ESRD, end-stage renal disease; OPO, organ procurement organization; hosp/yr, hospitalizations per year; SD, standard deviation; BMI, body mass index; PRA, panel reactive antibody.

^aWilling to accept expanded criteria donor organ.

Table 2

Distribution of individual-, neighborhood-, transplant center-, and OPO-level study variables stratified by hospitalization rate among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

Variable	Total N=24 581 N (%)	0 Hosp/yr N=12 795 N (%)	>0 and 2 Hosp/yr N=7 441 N (%)	>2 Hosp/yr N=4 345 N (%)	P-value
Race/ethnicity					
White non-Hispanic	10 862 (44.19)	6 006 (46.94)	2 919 (39.23)	1 937 (44.58)	<0.001
Black non-Hispanic	8 735 (35.54)	4 221 (32.99)	2 917 (39.20)	1 597 (36.75)	
White Hispanic	4 984 (20.28)	2 568 (20.07)	1 605 (21.57)	811 (18.67)	
Average hospitalization length (Mean, SD)	2.3 (3.88)	0 (0)	4.4 (4.32)	5.6 (4.4)	<0.001
Age at time of waitlisting (Mean, SD)	54 (13.61)	53.9 (13.71)	54.2 (13.43)	54.2 (13.59)	0.225
Female	9 412 (38.29)	4 475 (34.97)	3 039 (40.84)	1 898 (43.68)	<0.001
Blood Type					
A	8 163 (33.21)	4 466 (34.90)	2 290 (30.78)	1 407 (32.38)	<0.001
B	3 463 (14.09)	1 697 (13.26)	1 142 (15.35)	624 (14.36)	
AB	1 007 (4.10)	592 (4.63)	229 (3.08)	186 (4.28)	
O	11 948 (48.61)	6 040 (47.21)	3 780 (50.80)	2 128 (49.98)	
BMI					
Underweight (<18.5)	10 799 (43.93)	4 897 (38.27)	3 864 (51.93)	2 038 (46.90)	<0.001
Normal (18.5–24.9)	3 710 (15.09)	2 142 (16.74)	935 (12.57)	633 (14.57)	
Overweight (25.0–29.9)	4 619 (18.79)	2 685 (20.98)	1 165 (15.66)	769 (17.70)	
Obese (≥ 30)	5 453 (22.18)	3 071 (24.00)	1 477 (19.85)	905 (20.83)	
Peak PRA					
PRA=0	15 516 (63.12)	8 752 (68.40)	4 184 (56.23)	2 580 (59.38)	<0.001
0<PRA<80	7 346 (29.88)	3 422 (26.74)	2 576 (34.62)	1 348 (31.02)	
PRA ≥ 80	1 719 (6.99)	621 (4.85)	681 (9.15)	417 (9.60)	
% households below poverty line					
<10%	206 (0.84)	116 (0.91)	57 (0.77)	33 (0.76)	0.691
10%–20%	5 338 (21.72)	2 803 (21.91)	1 595 (21.44)	940 (21.63)	
20%	19 037 (77.45)	9 976 (77.19)	5 789 (77.80)	3 372 (77.61)	
% adults with high school education					

Variable	Total N=24 581 N (%)	0 Hosp/yr N=12 795 N (%)	>0 and 2 Hosp/yr N=7 441 N (%)	>2 Hosp/yr N=4 345 N (%)	P-value
<85%	12 789 (52.03)	6 611 (51.67)	3 881 (52.16)	2 297 (52.87)	0.381
85%	11 792 (47.97)	6 184 (48.33)	3 560 (47.84)	2 048 (47.13)	
Insurance at ESRD start					
Employer/Private	5 739 (23.35)	3 250 (25.40)	1 613 (21.68)	876 (20.16)	<0.001
Medicaid	6 472 (26.33)	2 986 (23.34)	2 094 (28.14)	1 392 (32.04)	
Medicare	5 976 (24.31)	2 944 (23.01)	1 891 (25.41)	1 141 (26.26)	
No insurance	3 875 (15.76)	2 162 (16.90)	1 139 (15.31)	574 (13.21)	
Other	2 519 (10.25)	1 453 (11.36)	704 (9.46)	362 (8.33)	
Employment at ESRD start					
Full-time	3 108 (21.71)	1 942 (23.65)	724 (19.64)	442 (18.27)	<0.001
Part-time	737 (5.15)	458 (5.58)	173 (4.69)	106 (4.38)	
Retired	6 566 (45.86)	3 634 (44.26)	1 737 (47.11)	1 195 (49.40)	
Unemployed	3 120 (21.79)	1 724 (21.00)	854 (23.16)	542 (22.41)	
Other	785 (5.48)	452 (5.51)	199 (5.40)	134 (5.54)	
Expanded criteria donor ^a	13 503 (54.93)	6 922 (54.10)	4 173 (56.08)	2 408 (55.42)	0.019
Years on dialysis at waitlisting					
0	10 949 (44.54)	5 041 (39.40)	3 888 (52.25)	2 020 (46.49)	<0.001
1	7 047 (28.67)	3 868 (30.23)	1 971 (26.49)	1 208 (27.80)	
2	4 195 (17.07)	2 370 (18.52)	1 113 (14.96)	712 (16.39)	
3+	2 390 (9.72)	1 516 (11.85)	469 (6.30)	405 (9.32)	
ESRD Cause					
Diabetes	9 532 (38.78)	4 434 (34.65)	3 039 (40.84)	2 059 (47.39)	<0.001
Hypertension	6 342 (25.80)	3 436 (26.85)	1 973 (26.52)	933 (21.47)	
Kidney-related	4 670 (19.00)	2 713 (21.20)	1 306 (17.55)	651 (14.98)	
Other	4 037 (16.42)	2 212 (17.29)	1 123 (15.09)	701 (16.16)	
History of Cancer	797 (3.24)	454 (3.55)	195 (2.62)	148 (3.41)	0.001
Cigarette smoker	1 250 (5.09)	614 (4.80)	381 (5.12)	255 (5.87)	0.021
Mean annual transplant center volume					
Lowest tertile	8 359 (34.01)	4 412 (34.48)	2 438 (32.76)	1 509 (34.73)	<0.001
Middle tertile	8 105 (32.97)	4 307 (33.66)	2 426 (32.60)	1 372 (31.58)	

Variable	Total N=24 581 N (%)	0 Hosp/yr N=12 795 N (%)	>0 and 2 Hosp/yr N=7 441 N (%)	>2 Hosp/yr N=4 345 N (%)	P-value
Highest tertile	8 117 (33.02)	4 076 (31.86)	2 577 (34.63)	1 464 (33.69)	
OPO kidney importer	7 872 (32.02)	4 155 (32.47)	2 390 (32.12)	1 327 (30.54)	0.061
OPO median wait time to transplant					
Lowest tertile	8 322 (33.86)	4 707 (36.79)	2 186 (29.38)	1 429 (32.89)	<0.001
Middle tertile	8 011 (32.59)	4 234 (33.09)	2 407 (32.35)	1 370 (31.53)	
Highest tertile	8 248 (33.55)	3 854 (30.12)	2 848 (38.27)	1 546 (35.58)	

All values N(%) unless otherwise specified.

Abbreviations: ESRD, end-stage renal disease; OPO, organ procurement organization; hosp/yr, hospitalizations per year; SD, standard deviation; BMI, body mass index; PRA, panel reactive antibody.

^aWilling to accept expanded criteria donor organ.

Table 3

Adjusted odds ratios and 95% confidence intervals for association between race/ethnicity and transplant and hospitalization and transplant among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 5 OR (95% CI)	Model 6 OR (95% CI)
Black v. white (ref.)	0.77 (0.73, 0.82)	--	0.78 (0.74, 0.83)	0.84 (0.78, 0.91)	0.87 (0.81, 0.94)	0.87 (0.81, 0.94)
Hispanic v. white (ref.)	0.55 (0.51, 0.59)	--	0.54 (0.51, 0.59)	0.87 (0.79, 0.96)	0.99 (0.89, 1.09)	0.95 (0.86, 1.05)
0 < and 2 v. 0 Hosp/yr (ref.)	--	0.70 (0.66, 0.74)	0.71 (0.67, 0.76)	--	--	1.01 (0.87, 1.16)
>2 v. 0 Hosp/yr (ref.)	--	0.42 (0.39, 0.46)	0.42 (0.39, 0.45)	--	--	0.57 (0.49, 0.65)

Abbreviations: OR, odds ratio; CI, confidence interval; black, black non-Hispanic; white, white non-Hispanic; Hispanic, white Hispanic; Hosp/yr, mean hospitalizations per year; v., versus; ref., referent; BMI, body mass index; PRA, panel reactive antibody.

Model 1: unadjusted except for fixed effect for race/ethnicity and random intercept for individual

Model 2: unadjusted except for fixed effect for hospitalization rate and random intercept for individual

Model 3: unadjusted except for fixed effects for race/ethnicity, hospitalization rate, and random intercept for individual

Model 4: unadjusted except for fixed effect for race/ethnicity and random intercepts for individual, transplant center, and OPO

Model 5: adjusted for fixed effects for race/ethnicity, age, sex, blood type, BMI, peak PRA, cause of ESRD, years on dialysis prior to waitlisting, smoking history, cancer history, insurance at time of ESRD start, willingness to accept an expanded donor criteria organ, neighborhood poverty, neighborhood education, transplant center volume, OPO import/export status, and OPO median time to transplant and random intercepts for individual, transplant center, and OPO.

Model 6: adjusted for variables in Model 5 plus fixed effects for hospitalization rate and average length of hospitalization and a random slope for hospitalization rate.

Table 4

Table of adjusted odds ratios and 95% confidence intervals for association between variables and likelihood of transplant among ESRD patients waitlisted for kidney transplant in the United States, 2005–2009.

Variable	OR (95% CI)	P-value
Mean hospitalization rate		
0 hosp/yr	Ref.	
>0 and ≤2 hosp/yr	1.01 (0.87, 1.16)	0.873
>2 hosp/yr	0.57 (0.49, 0.65)	<0.001
Average length of hospitalization (days)	0.92 (0.90, 0.93)	<0.001
Race/ethnicity		
White non-Hispanic	Ref.	
Black non-Hispanic	0.87 (0.81, 0.94)	<0.001
White Hispanic	0.95 (0.86, 1.05)	0.303
Peak PRA		
PRA=0	Ref.	
PRA >0 and <80	1.12 (1.00, 1.25)	0.045
PRA ≥80	1.14 (0.92, 1.41)	0.295
Age (years)		
18–40	Ref.	
41–55	1.12 (1.03, 1.22)	0.002
56–69	1.07 (0.95, 1.20)	0.157
70–90	1.02 (0.89, 1.18)	0.453
Sex		
Male	Ref.	
Female	0.91 (0.85, 0.98)	0.028
Blood type		
O	Ref.	
A	1.72 (1.59, 1.87)	<0.001
B	0.98 (0.87, 1.09)	0.982
AB	3.56 (3.02, 4.20)	<0.001
Neighborhood poverty	1.00 (0.94, 1.08)	0.087
Neighborhood education	1.06 (0.99, 1.14)	0.549
Insurance at ESRD start		
Private	Ref.	
Medicaid	1.01 (0.91, 1.11)	0.958
Medicare	1.00 (0.89, 1.12)	0.965
Other insurance	0.99 (0.87, 1.13)	0.831
None	1.01 (0.87, 1.17)	0.922
Willing to accept expanded criteria donor organ	1.60 (1.45, 1.76)	<0.001
Years on dialysis prior to waitlisting	0.67 (0.63, 0.73)	<0.001
ESRD cause		
Other	Ref.	

Variable	OR (95% CI)	P-value
Diabetes	0.91 (0.82, 1.01)	0.096
Hypertension	0.98 (0.87, 1.10)	0.759
Kidney-related	1.07 (0.96, 1.20)	0.221
BMI		
Normal (18.5–24.9)	Ref.	
Underweight (<18.5)	1.36 (1.12, 1.67)	0.003
Overweight (25.0–29.9)	0.90 (0.83, 0.99)	0.064
Obese (≥30.0)	0.80 (0.73, 0.88)	<0.001
History of Cancer	0.75 (0.62, 0.90)	0.005
Smoker	0.92 (0.79, 1.06)	0.386
Transplant center volume	0.98 (0.88, 1.09)	0.933
OPO kidney importer	1.09 (0.85, 1.40)	0.482
OPO median time to transplant	0.49 (0.41, 0.58)	<0.001

Abbreviations: ESRD, end-stage renal disease; OR, odds ratio; CI, confidence interval; hosp/yr, hospitalizations per year; Ref., referent group; PRA, panel reactive antibody; BMI, body mass index; OPO, organ procurement organization.