Association between Longer Travel Distance for Transplant Care and Access to Kidney Transplantation and Graft Survival in the United States

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ABSTRACT

Background Transplant candidates may gain an advantage by traveling to receive care at a transplant center that may have more favorable characteristics than their local center. Factors associated with longer travel distance for transplant care and whether the excess travel distance (ETD) is associated with access to transplantation or with graft failure are unknown.

Methods This study of adults in the United States wait-listed for kidney transplantation in 1995–2015 used ETD, defined as distance a patient traveled beyond the nearest transplant center for initial waiting list registration. We used linear regression to examine patient and center characteristics associated with ETD and Fine–Gray models to examine the association between ETD (modeled as a spline) and time to deceased or living donor transplantation or graft failure.

Results Of 373,365 patients, 11% had an ETD ≥ 50 miles. Traveling excess distance was more likely among patients who were of non-Black race or those whose nearest transplant center had lower annual living donor transplant volume. At an ETD of 50 miles, we observed a lower likelihood of deceased donor transplantation (subhazard ratio [SHR], 0.85; 95% confidence interval [95% CI], 0.84 to 0.87) but higher likelihood of living donor transplantation (SHR, 1.14; 95% CI, 1.12 to 1.16) compared with those who received care at their nearest center. ETD was weakly associated with higher risk of graft failure.

Conclusions Patients who travel excess distances for transplant care have better access to living donor but not deceased donor transplantation and slightly higher risk of graft failure. Traveling excess distances is not clearly associated with better outcomes, especially if living donors are unavailable.

Kidney transplantation rates and outcomes vary considerably across transplant centers in the United States.1–4 Some patients may derive advantages in terms of their access to transplantation and post-transplantation outcomes if they are wait-listed at a center that is located farther away from their residence but has more favorable wait time or other center-related characteristics. This could contribute to disparities in transplantation rates across different subgroups of patients, as not all patients may have the means to travel to transplant centers farther away from their residence.

Several factors may influence the selection of a transplant center, including patient preference (which could be affected by center waiting time and outcomes, center reputation, and practical considerations, such as transportation and center location), provider referral patterns, and insurance

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network considerations. Current Organ Procurement and Transplantation Network (OPTN) policy allows patients to register at one or multiple transplant programs of their choice. This policy has been a source of controversy. Proponents argue that it allows for patient autonomy and access to treatments (such as desensitization) that may not be available locally. Additionally, for patients who have been declined as candidates at one center, it allows for re-evaluation at another center where risk thresholds and eligibility for transplantation may differ. However, the ability of patients to receive care at the center of their choice may be limited by their means to travel, and therefore, inequities could arise from the current policy. Understanding predictors of traveling longer distances beyond the nearest transplant center for care and the association with transplant access and graft outcomes could inform whether additional systematic changes should be considered to improve equity in access to kidney transplantation in the United States.

Our objectives were to examine patient and transplant center characteristics associated with traveling longer distances (beyond the distance to the nearest transplant center) for care and to determine if there was an association between the excess distance traveled and subhazard of transplantation or graft failure. We focused on the relationship between excess distance traveled for the initial waiting list registration and kidney transplantation events in our analyses. We hypothesized that patients who traveled longer distances would be less likely to be racial/ethnic minorities. We also hypothesized that patients who traveled excess distances for transplant care would be more likely to undergo kidney transplantation but potentially would have worse graft outcomes (due to greater geographic barriers to follow-up care).

METHODS

Study Population
We included adults (18–80 years) who were wait-listed for kidney transplantation for the first time from January 1995 to December 2015 using data from the United States Renal Data System (USRDS), the national ESKD registry that includes all patients treated with dialysis or kidney transplantation in the United States. Patients were excluded if they had a missing residential zip code at the time of their initial waiting list registration or if they were living or deceased donor transplants. We also included the median time to first de- ceased donor transplantation and the annual number of first living or deceased donor transplants. We also included the proportion of first transplants that failed (death censored) and the proportion of patients who died within the first year following transplantation.

We used excess travel distance (ETD; defined as the additional distance that a patient traveled beyond the distance to their nearest active transplant center for initial waiting list registration) as our outcome. Patients who received transplant care at the nearest active transplant center were assigned an ETD of zero. We defined “active” transplant centers as centers that completed at least 25 waiting list registrations for kidney transplantation in patients aged ≥18 years within the same 5-year interval that the patient’s waiting list registration occurred, thereby accounting for changes in the activity of transplant centers over time.

We determined the zip code of the patient’s residence at initial waiting list registration and the zip code of the transplant center where the patient was first registered on the waiting list using the “RESIDENC” and “FACILITY” files, respectively, in USRDS. We used zip code coordinates (from US Census Zip Code Tabulation Area data and commercial

Significance Statement
Kidney transplantation rates and outcomes vary across transplant centers. Some patients may gain an advantage by traveling to a center with characteristics more favorable than those of the center nearest their residence. The authors examined patient and center characteristics associated with longer travel distance and the latter’s association with receipt of kidney transplantation and graft survival in the United States. Patients were more likely to travel farther if they were of non-Black race or if the nearest center had a lower volume of living donor surgeries. Longer travel distance was associated with higher likelihood of living donor transplantation but lower likelihood of deceased donor transplantation, and it was weakly associated with higher graft failure risk. These findings provide insights into advantages (or lack thereof) of traveling beyond the nearest center for transplant care.

Characteristics Associated with Traveling Excess Distances for Transplant Care
We examined patient and transplant center characteristics that were associated with traveling excess distances past the nearest transplant center for care. At the patient level, we considered demographic factors (age, sex, and race/ethnicity), comorbidity count, distance from the patient’s residence to the nearest transplant center, having a living donor (defined as receipt of living donor transplantation), neighborhood median income by zip code of patient residence, and insurance category as predictors. For comorbidity count, we considered heart failure, cerebrovascular disease, diabetes, drug or alcohol dependence, ischemic heart disease, inability to ambulate, peripheral artery disease, and smoking status at the time of initiation of RRT. At the center level, we considered characteristics of the nearest transplant center in the year that waiting list registration occurred. These included the median time to first deceased donor transplantation and the annual number of first living or deceased donor transplants. We also included the proportion of first transplants that failed (death censored) and the proportion of patients who died within the first year following transplantation.
Primary Analysis: Subhazard of Transplantation
We used ETD as the predictor in our primary analysis of the subhazard of transplantation. We used log-transformed values of ETD modeled as a restricted cubic spline to assess for potential nonlinear relationships, but we also used ETD as a categorical predictor in sensitivity analysis.

Our primary outcome was time to deceased and living donor transplantation (defined as time from initial waiting list registration to first kidney transplantation). We examined times to deceased and living donor transplantation as separate outcomes of interest, treating death and living or deceased donor transplantation, respectively, as competing risks.

Secondary Analysis: Subhazard of Graft Failure
For our analysis of graft outcomes, we included all patients who underwent first kidney transplantation in the United States during the study period (January 1995 to December 2015). We updated our computation of the primary predictor (ETD) using the zip code of the patient residence at the time of first transplantation and the zip code of the transplant center that performed the first kidney transplantation. We used time to graft failure (from time of first kidney transplantation) as our secondary outcome of interest.

Statistical Analyses
We compared the characteristics of patients by the magnitude of ETD using chi-squared and Kruskal–Wallis tests as appropriate.

We constructed maps of median ETD at the county and state levels from patient zip codes using US Census Bureau cartographic boundary shape files and the spmap function in STATA. Patients with a zip code in more than one county were assigned to the county with the highest proportion of patient residences for that zip code.

To examine factors associated with ETD to the transplant center, we used a multivariable linear regression model. We assessed patient- and center-level factors in the year that first waiting list registration occurred as described above as predictors of ETD (log transformed due to non-normality of residuals) as the outcome. We translated the associations in our multivariable linear regression model into percentage shorter or longer ETD compared with the baseline for ease of interpretation.

Primary Analyses
We used log-transformed ETD modeled as a restricted cubic spline as our primary predictor in Fine and Gray models for the outcome of time to transplantation and used separate models for the outcomes of deceased and living donor transplantation, but we also examined the outcome of any kidney transplantation (deceased or living donor). We accounted for competing risk of living and deceased donor transplantation, respectively, in addition to the competing risk of death, and we censored follow-up at transplantation or administratively on December 31, 2015. Any patients who had their initial waiting list registration and kidney transplantation on the same day were assigned a time of 0.1 days. Spline knots were placed at the 25th, 50th, and 75th percentiles and additionally, at the 95th percentile (which corresponds to ETD 140 miles) of log-transformed ETD.

We performed unadjusted and adjusted analyses. In model 1, which we considered our main model, we adjusted for age, sex, race/ethnicity, United Network for Organ Sharing (UNOS) region, rural/urban category of patient residence, and year of waiting list registration or comorbidity count for outcomes of living and deceased donor transplantation. We evaluated for differences in the spline association differed substantially after an ETD of 30–55.1 miles (tertiles) to define the other categories of ETD in this alternative deﬁnition of our predictor.

We repeated our primary analysis using ETD as a categorical predictor for the outcome of time to transplantation. The spline association differed substantially after an ETD of 30 miles in our primary analysis, so we chose ETD<30 miles as the reference category for our categorical predictor. We then divided patients with ETD≥30 miles into 30–55.1, 55.1–117.1, and >117.1 miles (tertiles) to deﬁne the other categories of ETD in this alternative deﬁnition of our predictor.

We evaluated for presence of interactions between ETD and race/ethnicity for the outcome of time to living and deceased donor transplantation given known disparities in transplantation rates across different racial/ethnic groups. We also assessed for interaction between ETD and year of waiting list registration or comorbidity count for outcomes of living and deceased donor transplantation. We evaluated for differences on the basis of rural/urban category of patient residence.

Lastly, in exploratory analysis, we examined the relation between ETD category and time to any transplant among those who were wait-listed at more than one transplant center, including those who may have switched centers.

Secondary Analyses
In our secondary analyses, we included all patients who underwent first kidney transplantation in the United States during the study period and used the same unadjusted and adjusted models described above with additional adjustment for donor type (living or deceased) for the outcome of time to graft failure from date of transplantation. We accounted for...
the competing risk of death and censored follow-up at graft failure, at death, or administratively on December 31, 2015. We performed these secondary analyses using ETD as a spline and categorical variable where ETD was categorized using the same method as above. Lastly, we assessed for interactions between ETD, race/ethnicity, and donor type for the outcome of time to graft failure.

We used Stata 15 (StataCorp LLC, College Station, TX) in all analyses.

RESULTS

Study Population
In total, 373,365 patients were wait-listed during the study period and had zip code data for their residence and transplant center. Details surrounding cohort inclusion and exclusion criteria are shown in Figure 1. Median age when first wait-listed was 52.9 years, and 60% were men (Table 1). Forty-two percent of the study cohort received care at their nearest transplant center (ETD = 0), 36% of the cohort had an ETD ≤ 5 miles, and 11% of the cohort had an ETD ≥ 50 miles. There were statistically significant differences in age, sex, race/ethnicity, UNOS region and rural/urban category of patient residence, insurance type, and neighborhood median income across ETD categories (Table 1). Median ETD at the county level varied considerably across the United States (Figure 2), with variation also evident at the state level (Supplemental Figure 1).

Notably, 12% of the cohort was wait-listed at more than one transplant center prior to receiving their first kidney transplant, but for the vast majority of these individuals, there was no change in ETD category.

Characteristics Associated with Traveling Excess Distances for Transplant Care
The patient-level factors that were most strongly associated with ETD in our adjusted model included race/ethnicity, distance from the patient’s residence to the nearest transplant center, having a living donor, and insurance type (Figure 3). Black patients were less likely to travel excess distances to their transplant center (11.8%; 95% confidence interval [95% CI], 10.8 to 12.8 lower ETD) compared with non-Hispanic White patients (Figure 3). Patients who lived farther from their nearest transplant center were more likely to travel excess distances (16.3%; 95% CI, 16.2 to 16.4 higher ETD per 25-mile increase in distance). Patients with a living donor were more likely to travel excess distances (6.5%; 95% CI, 5.2 to 7.9 higher ETD) compared with those without a living donor (Figure 3). Furthermore, patients with Medicaid or no insurance were less likely to travel excess distances (3.4%; 95% CI, 1.5 to 5.3 and 9.3%; 95% CI, 7.3 to 11.2 lower ETD, respectively) compared with patients with Medicare (Figure 3).

Of the center-level factors we assessed, lower annual volume of living donor transplant surgeries at the nearest transplant center was most strongly associated with higher ETD (23.9%; 95% CI, 23.2 to 24.7 higher ETD per 25 fewer first living donor transplants per year) (Figure 3). Median time to deceased
Primary Analysis: Subhazard of Transplantation

As ETD increased, marked differences in the subhazard ratio of deceased donor transplantation compared with living donor transplantation were noted (Figure 4). As ETD increased, the subhazard ratio for any transplantation increased gradually, but for deceased donor transplantation, the subhazard ratio was consistently below one (Figure 4). At an ETD of 50 miles, the subhazard ratio for deceased donor transplantation was 0.85 (95% CI, 0.84 to 0.87). In contrast, as ETD increased, the subhazard ratio of living donor transplantation increased and was consistently above one (Figure 4). At an ETD of 50 miles, the subhazard ratio for living donor transplantation was 1.14 (95% CI, 1.12 to 1.16). A magnified image of the association between ETD (at distances of 0–250 miles) and the subhazard ratio of any transplantation, living donor transplantation, and deceased donor transplantation is shown in Figure 5.

Table 1. Patient characteristics for the overall population and by ETD category

<table>
<thead>
<tr>
<th>% (Unless Otherwise Specified)</th>
<th>Overall</th>
<th>ETD Category, Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;30</td>
</tr>
<tr>
<td>N</td>
<td>373,365</td>
<td>314,056</td>
</tr>
<tr>
<td>Age when first wait-listed, yr, median (IQR)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.9 (42.6–61.3)</td>
<td>52.9 (42.7–61.3)</td>
</tr>
<tr>
<td>Men&lt;sup&gt;b&lt;/sup&gt;</td>
<td>60.3</td>
<td>60.2</td>
</tr>
<tr>
<td>ETD, miles, median (IQR)</td>
<td>1.4 (0.0–11.5)</td>
<td>0.1 (0.0–4.5)</td>
</tr>
<tr>
<td>Race/ethnicity&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>47.7</td>
<td>45.8</td>
</tr>
<tr>
<td>Black</td>
<td>30.1</td>
<td>31.4</td>
</tr>
<tr>
<td>Hispanic White</td>
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<td>14.8</td>
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<td>Asian</td>
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<td>5.4</td>
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<tr>
<td>Other/unknown</td>
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</tr>
<tr>
<td>UNOS region&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Rural/urban&lt;sup&gt;e&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Insurance type&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
<td>None</td>
<td>10.5</td>
<td>10.7</td>
</tr>
<tr>
<td>Medicare</td>
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<td>8.8</td>
</tr>
<tr>
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<td>18.3</td>
</tr>
<tr>
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<td>62.1</td>
</tr>
<tr>
<td>Income&lt;sup&gt;g&lt;/sup&gt;</td>
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<td></td>
</tr>
<tr>
<td>Median income, $1000, median (IQR)</td>
<td>49.5 (38.7–65.1)</td>
<td>50.0 (38.8–66.2)</td>
</tr>
<tr>
<td>Transplant during study&lt;sup&gt;h&lt;/sup&gt;</td>
<td></td>
<td></td>
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<tr>
<td>Transplant (any)</td>
<td>56.9</td>
<td>56.8</td>
</tr>
<tr>
<td>Living donor transplant</td>
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<tr>
<td>Deceased donor transplant</td>
<td>39.4</td>
<td>39.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>IQR, interquartile range.
<sup>b</sup>P<sup>+</sup><0.05 for difference across ETD categories using chi-squared or Kruskal–Wallis tests.

<sup>**</sup>donor transplantation at the nearest transplant center was only weakly associated with ETD. With regard to center-level performance, a higher proportion of deaths within the first year of transplantation at the nearest center was weakly associated with higher ETD (2.0%; 95% CI, 1.3 to 2.6 higher ETD per 5% more deaths), but the proportion of graft failures within the first year at the nearest center was not (Figure 3).
and outcomes is shown in Supplemental Figure 2. We observed similar results when ETD was treated as a categorical variable (Supplemental Table 1).

There was an interaction between race and ETD for the outcomes of both living and deceased donor transplantation ($P<0.05$). All racial/ethnic groups had lower subhazard ratio for deceased donor transplantation with longer ETD, but the effect size was more prominent in Black patients compared with the other racial/ethnic groups (Figure 5, Supplemental Table 2). In contrast, as ETD increased, non-Hispanic Whites and Blacks both had subhazard ratios greater than one for living donor transplantation, with the largest effect size observed in non-Hispanic Whites (Figure 5). However, this association was not observed in Hispanic White or Asian patients.

There was no interaction between categorized year of waiting list registration and ETD for outcomes of living or deceased donor transplantation. We tested for interaction between ETD and comorbidity count and did not find an interaction for the outcome of either living or deceased donor transplantation ($P>0.05$). We observed a similar association between ETD and outcomes of living and deceased donor transplantation whether patients lived in metropolitan, micropolitan, or rural areas (Supplemental Figure 3).

In our exploratory analysis, ETD at the time of first waiting list registration was associated with higher hazard of transplantation among the subgroup of patients who went on to have subsequent waiting list events at other transplant centers as compared with those who did not have subsequent waiting list events (Supplemental Table 3).

**Secondary Analysis: Subhazard of Graft Failure**

In total, 242,786 patients underwent first kidney transplantation during the study period and had available zip code data for their residence and the center that performed the transplant procedure. The inclusion and exclusion criteria are shown in Supplemental Figure 4. We found statistically significant differences in age, sex, race/ethnicity, UNOS region and rural/urban category of patient residence, insurance type, and neighborhood median income across different ETD categories at time of first transplant (Supplemental Table 4).

ETD was not strongly associated with the subhazard ratio of graft failure, with a statistically significant association observed only when ETD exceeded several hundred miles (Figure 4, Supplemental Table 1). There were also no statistically significant interactions between ETD and race/ethnicity or donor type for the outcome of graft failure.

**DISCUSSION**

Our study identified several patient-level (living a farther distance from the nearest transplant center, having a living donor, and private health insurance) and center-level (lower living donor transplant volume at the nearest center) factors associated with traveling a longer distance for care. Patients who traveled farther for transplant care were also less likely to be Black, which was consistent with our hypothesis. We found that traveling excess distance for waiting list registration was associated with higher hazard of living donor but not deceased donor transplantation. We did not find substantial differences in the risk of graft failure within the range of ETD that most patients traveled. However, patients with very long ETD values were more likely to have graft failure. Although we had expected that traveling farther for transplant care would be associated with increased deceased donor transplantation rates, our observations were not consistent with our hypotheses. Our
A recent survey of patients with kidney disease sought to identify factors that patients valued when selecting a transplant center. Patients most often ranked the waiting list as the most important factor for selecting a transplant center, ahead of post-transplant outcomes and practical considerations (such as geography or availability of accommodation). Our study identified only a weak association between the median waiting time for deceased donor transplantation at the nearest transplant center and traveling beyond the nearest transplant center for care. However, our study suggests that those who ultimately received living donor transplantation and those who were not of Black race were more likely to travel excess distances. Smaller annual volume of living donor transplants at the nearest transplant center was also strongly associated with longer ETD. Interestingly, when Black patients did travel excess distance, the subhazard of living donor transplantation increased and was comparable to non-Hispanic White patients, particularly at lower ETD values. This suggests that Black patients may have barriers to accessing transplant centers with a large volume of living donor transplants, but their hazard of living donor transplantation is similar if they do receive care at these centers located farther away.

Most of the research to date evaluating geographic determinants of transplantation have focused on patients who live a longer distance from the nearest transplant center, live in rural versus urban areas, or travel to transplant centers across different Donation Service Areas (DSAs). Our study is novel in its focus on examining whether travel beyond the nearest transplant center for care associates with better pre- or post-transplantation outcomes. Our findings indicate that longer travel distance was only associated with higher hazard of living donor transplantation (regardless of whether there was a change in the DSA). Indeed, the observed differences in the hazard of deceased or living donor transplantation were evident at even small ETDs that would not be associated with a change in DSA, suggesting that important differences are present even between transplant centers located in the same DSA.

OPTN policy allows patients to register at the transplant program or multiple transplant programs of their choice.

Figure 3. Patient- and center-level characteristics were associated with traveling excess distances for transplant care. The figure shows the results of a multivariable linear regression model with patient- and center-level characteristics as predictors and ETD as the outcome. Race/ethnicity, distance the patient lives from the nearest transplant center, having a living donor, and insurance type were the patient-level characteristics most strongly associated with ETD. Annual volume of living donor transplant surgeries at the nearest transplant center was the center-level characteristic most strongly associated with ETD.
Previous studies have shown that a minority of patients register on the waiting list concurrently at multiple programs or “multiple list,” which is associated with higher rates of transplantation compared with listing at a single center.\textsuperscript{7,28–30} Our study found that patients with longer ETD actually had a lower likelihood of deceased donor transplantation. Although current OPTN policy could have potentially led to disparities in deceased donor transplantation rates, our data do not support the presence of any observed benefit in deceased donor transplantation access when patients travel farther for waiting list registration.

Interestingly, longer ETD was associated with higher living donor transplantation rates, although this observation varied by race/ethnicity. It is possible that the ability to travel farther is a marker of higher socioeconomic status or knowledge surrounding transplantation and likelihood of finding a living donor. It is also possible that highly motivated living donors who were turned down at a transplant center were accepted at a transplant center farther away, although we do not have data with sufficient granularity to examine this issue. Additionally, the reasons why non-Hispanic Whites had a higher hazard of living donor transplantation compared with other racial/ethnic groups with higher ETD is unclear but warrants further investigation. Further studies are needed to understand the drivers of ETD for transplant care, and policy makers and insurers may wish to consider whether offering the option of choosing to travel to transplant centers farther away may lead to disparities in transplantation access or adds to the cost of health care without providing clear benefit, at least as it relates to deceased donor transplantation.

The strengths of our study include the use of a large and nationally representative population and the focus on ETD, which is novel. In addition, our results have good precision as evidenced by the narrow 95% CIs of our results. However, some limitations should be noted. Given that our study is observational, residual confounding may be present. We do not have granular information as to why a patient was waitlisted at a transplant center farther away from his or her home,

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Subhazard ratio of transplantation, deceased donor transplantation, living donor transplantation, and graft failure by ETD modeled as a cubic spline. ETD was associated with lower subhazard of deceased donor transplantation, higher subhazard of living donor transplantation, and was weakly associated with higher subhazard of graft failure. Fine–Gray competing risk models adjusted for age, sex, race/ethnicity, UNOS region and rural/urban category of patient residence, and year of waiting list registration (or year of transplantation for outcome of graft failure) accounting for competing risks (model 1). Model for graft failure was additionally adjusted for living or deceased donor type. Horizontal bars show 95% CIs.}
\end{figure}
Figure 5. Subhazard ratio of (A) deceased and (B) living donor transplantation in race/ethnicity subgroups by ETD modeled as a restricted cubic spline. Fine-Gray competing risk models adjusted for adjusted for age, sex, race/ethnicity, UNOS region and rural/urban category of patient residence, and year of waiting list registration (model 1) accounting for competing risks. Horizontal bars show 95% CIs.
which could be due to personal preference, insurance-related limitations or requirements to seek care at a Center of Excellence, prior history of being declined at a transplant center, or other considerations. However, as ETD increases, we expect that transplant center selection would be driven more by patient preference rather than insurer policies. We do not have data on whether candidates had living donors who were not eligible to donate or who may not have remained committed to donation or whether recipient ineligibility for transplantation was the reason for nonattainment of living donor transplantation. Lastly, patients who were wait-listed but were never treated with dialysis or transplantation were excluded as they are not in USRDS.

In conclusion, patients were more likely to travel past the nearest transplant center for care if they were non-Black race, if they had a living donor or private health insurance, and if the nearest transplant center had lower living donor surgery volume. Patients who traveled excess distances beyond their local transplant center for waiting list registration had higher access to living but not deceased donor transplantation, and they also had slightly higher risk of graft failure (especially at very long ETDs); however, variations by race/ethnicity were noted. Further studies are needed to understand these observations and ensure equity in organ access and outcomes.

DISCLOSURES

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E. Ku and A.M. Whelan designed the study; B. Grimes, E. Ku, C.E. McCulloch, and A.M. Whelan developed the analysis plan; B. Grimes, E. Ku, and A.M. Whelan were involved in analysis of the data; A.M. Whelan wrote the first draft of the manuscript; A.M. Whelan made the figures; D.B. Adey, S. Brar, K.L. Johansen, E. Ku, C.E. McCulloch, G.R. Roll, and A.M. Whelan revised the manuscript; and all authors approved the final version of the manuscript.

SUPPLEMENTAL MATERIAL

This article contains the following supplemental material online at https://jasn.asnjournals.org/lookup/suppl/doi:10.1681/ASN.2020081242/-/DCSupplemental.

Supplemental Table 1. Subhazard ratio (95% CI) for time to transplantation, deceased donor transplantation, living donor transplantation, and allograft failure by ETD using <30-miles ETD (reference) and tertiles of ETD >30 miles.

Supplemental Table 2. Subhazard ratio (95% CI) for time to deceased donor transplantation and living donor transplantation by excess distance categories in different racial/ethnic groups.

Supplemental Table 3. Subhazard ratio (95% CI) for time to any transplantation among individuals who were registered at more than one facility at any point in time prior to receipt of a kidney transplant.

Supplemental Table 4. Characteristics of patients who received transplantation included for secondary analysis for the outcome of graft failure.

Supplemental Figure 1. Median ETD category by state in the continental United States.

Supplemental Figure 2. Expanded view of the relationship between ETD and access to transplant at distances ranging from 0 to 250 miles.

Supplemental Figure 3. Subhazard ratio of (A) deceased and (B) living donor transplantation in rural/urban subgroups across ETD modeled as a restricted cubic spline.

Supplemental Figure 4. Cohort derivation for secondary outcome of graft failure.

REFERENCES


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