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Kidney Transplantation and the Intensity of Poverty in the Contiguous United States

Sumit Mohan^{1,7}, Richard Mutell², Rachel E. Patzer^{3,4}, James Holt⁵, David Cohen¹, and William McClellan^{4,6}

¹Department of Medicine, Division of Nephrology, Columbia University College of Physicians & Surgeons, New York, NY.

²Apex Health Innovations, Simi Valley, CA.

³Department of Surgery, Division of Transplantation, Rollins School of Public Health, Emory University, Atlanta, GA.

⁴Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA.

⁵Centers for Disease Control and Prevention, Atlanta, GA.

⁶Renal Division, Emory University School of Medicine, Atlanta, GA.

Abstract

Background—Geographic variation in kidney transplantation rates in the United States has been described previously but remains unexplained by age, race, sex, or socioeconomic status differences. Geographic variations in the concentration of poverty appear to impact end-stage renal disease care and potentially access to transplantation.

Methods—We studied the impact of how spatial topography of poverty across geographical regions in the contiguous United States is associated with kidney transplantation in the 48 contiguous U.S. states.

Results—We found considerable geographic variation in transplantation rates across the country that persisted across quartiles of county-level median household income and percentage minority population. Higher transplant rates were seen with increasing median household income and decreasing minority populations but were not influenced by education level. Transplantation rates

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⁷Address correspondence to: Department of Medicine, Division of Nephrology, Columbia University College of Physicians & Surgeons, 622 W 168th Street, PH4-124, New York, NY 10032. sm2206@columbia.edu.

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S.M. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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in counties with poverty rates above the national average had low transplant rates, but these rates were influenced by the poverty level in the surrounding counties. Similarly, wealthy counties had higher transplant rates but were lowered in counties of relative wealth that were surrounded by less wealthy counties.

Conclusions—Our results underline the geographical heterogeneity of kidney transplantation in the United States and identify regions of the country most likely to benefit from interventions that may reduce disparities in transplantation.

Keywords

Spatial topography; Geographical variation; Healthcare disparities; Poverty; Renal transplantation

Geographic variation in access to kidney transplantation in the United States has been described previously but remains unexplained by age, race, sex, or differences in socioeconomic status (SES) (1–5). Neighborhood poverty has been shown to adversely impact both the incidence of end-stage renal disease (ESRD) and patient access to renal transplantation, particularly among minorities (3, 6). Geographic variations in poverty and the concentration of poverty in the United States have been described previously and shown to impact the care of patients with ESRD, such as incident arteriovenous fistula placement (7, 8).

The reasons why access to kidney transplantation varies across patient racial and socioeconomic groups and geographical regions are unclear. Axelrod et al. recently reported the positive influence of shorter distance to the local transplant center and higher socioeconomic status on renal transplantation—particularly for live donations (9). The impact of these factors was probably exaggerated by the movement of patients—particularly those of higher socioeconomic status and those living far from local transplant centers—from donor service areas with long wait times to other areas or regions of the country (9). However, considering merely distance to the transplant center without considering other local social and economic environmental factors may not provide a complete understanding of the causes of disparities in renal transplantation across the United States. We hypothesized that spatial poverty across geographical regions may contribute to variations in rates of kidney transplantation in the United States. The purpose of this study was to examine the associations of geographical variation in the intensity of poverty in the contiguous 48 states on the rate of kidney transplantation from 1992 through 2008.

RESULTS

The STAR file contained ZIP code information for a total of 245,195 deceased and living transplant recipients living in 2,935 counties in the contiguous 48 states and the District of Columbia for the 15 years included in our analysis. There was significant variation in the annualized transplant rate across the states, with the lowest kidney transplant rates observed in the District of Columbia and states in the South (Fig. 1A). The highest rates of transplant were observed among states in the Northeast region (Fig. 1A, $P<0.001$)—a variation that persisted between individual organ procurement regions as well (Fig. 2 and Figure S1, SDC, <http://links.lww.com/TP/A969>; $P<0.001$).

There is considerable geographic variation in renal transplantation rates at the county level (Fig. 1B), and these variations in the annualized transplant rate persist across quartiles of counties based on the median household income and percentage minority population (Fig. 3). A clear trend of higher transplant rates was noted with increasing median household income (Fig. 3, $P<0.001$) and decreasing minority (non-white) county populations (Fig. 3, $P<0.001$). However, high school graduation rates did not have a significant impact on transplantation rates (Fig. 3, $P=0.065$).

We found a small negative correlation between the total number of patients receiving transplants in a county over a 15-year period with the prevalence of ESRD at the county level ($r=-0.31$, $P<0.0001$). The county prevalence of ESRD in 2000 correlated positively with the county median household income ($r=0.37$, $P<0.0001$) and the percentage of minority population ($r=0.47$, $P<0.0001$) and negatively with high school graduation rate ($r=-0.29$, $P<0.001$). The annual transplant rate correlated positively with the median household income ($r=0.33$, $P<0.0001$) and negatively with the percentage minority population within a county ($r=-0.44$, $P<0.001$) but did not correlate significantly with the high school graduation rate ($r=-0.0033$, $P=0.85$).

We compared transplantation rates by poverty level and concentration. An increasing level of poverty at the county was associated with significantly lower transplantation rates (Fig. 4, $P=0.001$). However, when each of these categories was further divided into counties that were concentrated areas (contiguous areas of similar levels of poverty) and spatial outliers (isolated areas surrounded by areas with contrasting levels of poverty), the influence of the poverty levels of the surrounding counties was apparent. Counties with high rates of poverty had kidney transplantation rates below the national median that were positively impacted when surrounded by counties of relative wealth (spatial outliers). Similarly, counties with low rates of poverty had transplantation rates above the national median that were negatively impacted when surrounded by counties of relative poverty.

The median transplant rate in counties with extremely high, very high, and high poverty rates was below the national median annualized transplantation rate of 0.064 (Fig. 4). However, those counties of extremely high, very high, and high poverty rates that were surrounded by counties with similar poverty rates had significantly lower transplantation rates than counties with similar levels of poverty that had more affluent surrounding counties (Fig. 5, $P=0.001$, $P=0.0019$, and $P<0.0001$, respectively). Similarly, the median transplant rates for counties with low and very low poverty rates were higher than the median national transplant rate. However, counties with low and very low rates of poverty that were surrounded by relatively less wealthy counties had significantly lower transplant rates than their counterpart counties that were surrounded by other affluent counties (Fig. 5, $P<0.0001$ and $P=0.024$, respectively).

DISCUSSION

Our analysis demonstrates that counties with poverty rates higher than the national average were more likely to have lower rates of kidney transplantation. In addition, the results also demonstrate the influence of the poverty rates in the adjoining counties suggesting that the

influence of county-level economic prosperity on renal transplantation rates extends beyond the immediate county. The relationship between poverty and transplant rates in a county was ameliorated by the presence of lower rates of poverty in the surrounding counties. Similarly, counties of relative wealth had significantly higher rates of transplantation than the national mean. In addition, counties of relative wealth, when surrounded by similarly prosperous counties, had higher rates of transplantation than similarly wealthy counties that were isolated pockets of wealth surrounded by areas of relative poverty. These results help identify areas at the greatest disadvantage with respect to renal transplantation rates and the counties where interventions such as satellite transplant clinics are likely to have the greatest impact.

The increase in renal transplantation rates associated with lower rates of poverty in surrounding counties suggests that access to renal transplantation is not merely a facet of an individual patients' socioeconomic status but perhaps also a function of geographical proximity to more affluent areas with better healthcare resources including perhaps transplant centers. However, mere proximity to larger healthcare centers with the requisite expertise and resources for renal transplantation would not facilitate access in the absence of affordability that is provided by Medicare coverage for patients with ESRD. Renal transplantation remains the therapy of choice for renal failure, and as a limited resource its utilization receives considerable scrutiny. The reasons for the lower transplant rates in the more affluent counties surrounded by poorer counties were not immediately apparent. The vast majority of these affluent counties were located in the South census region, suggesting that the social and racial factors such as lower rates of donation among minorities may be partly responsible for this apparent effect. These geographical variations may also be reflective of the cultural demographics of the region. For example, donation rates among Hispanic Americans are adversely impacted by low acculturation, religious beliefs, perception that the wealthy are more likely to receive organs, and the impact of organ donation on the appearance at funerals. Similar cultural barriers and distrust of the medical community by African Americans coupled with an increased burden on illness have also been described previously (10–12).

In our study, lower rates of renal transplantation were observed in areas of higher minority populations. Racial disparities in access to renal transplantation have been described previously, and some of these findings have prompted changes in organ allocation in an attempt to lower these disparities without adversely impacting outcomes (3, 5, 13–15). Our analysis underlines the differential impact of minority populations on the prevalence of ESRD and the rate of renal transplantation and the inherent racial disparity in access to renal transplantation that this reflects. The opposing impact of a rising ESRD prevalence in minority populations and the reduced rates of kidney transplantation underscores racial differences and cultural barriers to renal transplantation among minority populations that must be addressed if there is to be racial parity in access to kidney transplantation.

In 2003, the United Network for Organ Sharing (UNOS) changed the kidney sharing algorithm, removing HLA-B matching to decrease disparate access to organs between whites and non-whites (15, 16). The persistence of racial disparities in access to transplantation, despite policy modifications aimed at addressing the problem, is concerning

and suggests that factors other than biology play a role. More research is necessary to determine if neighboring counties influence racial disparities. Our results demonstrate the significant variation in the annualized transplant rates across the 11 organ procurement regions (Fig. 2 and Figure S1, SDC, <http://links.lww.com/TP/A969>)—a phenomena that has been previously described (17). Finally, we found that county-level education rates had little influence on kidney transplantation rates.

These trends, taken together, reveal a more complex model of resource allocation than many previous authors have suggested. They indicate that resources are being allocated among regions across socioeconomic barriers, but that racial disparities persist. Poverty and race continue to be driving factors in both rates of ESRD and access to renal transplantation, and must continue to be considered when designing policy or programs to readjust or expand organ utilization. A factor that must also be considered is competition for specialty care *within* localities where there are economic disparities. Relative poverty must be accounted for when looking at outcomes for ESRD and transplantation, and when reevaluating allocation of resources and services.

Indeed, with the reduced emphasis on HLA matching, organ allocation procedures have been moving toward more race- and SES-neutral policies. Efforts upstream of the allocation process, such as community interventions and patient education, must be targeted to continue to reduce disparities.

Our study had several limitations. First, we were unable to calculate the number of patients eligible for a renal transplant by county. We used the total ESRD population in individual counties to estimate the population that might receive renal transplantation. Although this may overestimate the demand for renal transplantation, an estimate using only waitlisted patients would underestimate this demand by excluding patients who were seeking living donor transplants and those who may have been eligible for transplantation but were never referred or evaluated for renal transplantation. Using only the population waitlisted would likely be an underestimate of transplant access for minority and poor patients because black patients and those with low SES have decreased access to earlier steps in the renal transplant process before waitlisting (18, 19). A third limitation of this study was our ability to study racial disparities because downloads in the Renal Data and Extraction Reference (RenDER) database are restricted when there were fewer than 10 patients for any race at the level of geographical detail being studied. Finally, our analysis assumed both a relatively stable ESRD prevalence and stable rates of poverty for the time interval being studied. The last assumption allowed us to use the ESRD prevalence in the midpoint (8th) year and socioeconomic parameters from the 2000 census data.

We found significant geographical and spatial heterogeneity in rates of kidney transplantation in the United States, such that kidney transplantation is associated with both a county's poverty level and the poverty of surrounding counties. The results of this study suggest that the spatial topography of poverty should be considered when planning interventions or resource allocations to reduce racial and socioeconomic disparities in access to renal transplantation in the United States. Future research should examine how the

interplay of race, spatial poverty, and individual-level SES impacts disparities in kidney transplantation.

MATERIALS AND METHODS

Study Population and Data Sources

The ZIP code of residence for patients who have undergone a deceased or living donor renal transplant was obtained from the standard transplant research and analysis (STAR) files based on data from the organ procurement and transplantation network (OPTN) data as of November 27th 2009 that were obtained from the UNOS. The ESRD prevalence for individual counties was obtained from the RenDER database from the United States Renal Data System for the year 2000. County demographic data, including population counts, race and ethnicity, household income, and education rates, were obtained from the 2000 Census.

We limited our analysis to the contiguous 48 states and excluded patients who did not have ZIP codes listed (approximately 7.5% of all patients) in the STAR files for kidney transplantation for a 15-year period from January 1, 1992 through December 31, 2008.

Finally, we used a previously described index calculated from 2000 U.S. Census poverty data to characterize the geographic concentration of poverty of the county in which each transplant center was located (7). Unlike simple county poverty percentages, this index took into account both the magnitude of each county's poverty rate (as measured by the percentage of individuals living below the federal poverty line in 1999) compared to the national county-level mean poverty rate, as well as the clustering of counties with similar or dissimilar poverty rates. Counties whose poverty rates fell between 1 and 2 standard deviations (SD) above the mean were classified as "high" poverty counties, counties whose rates fell between 2 and 3 SD above the mean were classified as "very high" poverty counties, and counties whose rates equaled or exceeded 3 SD above the mean were classified as "extremely high" poverty counties. Conversely, counties whose rates fell between 1 and 2 SD below the mean were classified as "low" poverty counties, and counties whose rates fell between 2 and 3 SD below the mean were classified as "very low" poverty counties. There were no counties whose rates exceeded at least 3 SD below the mean; thus, there were no "extremely low" poverty counties. Spatial clustering was determined through the use of local Moran *I* scores, a type of local indicator of spatial association previously published (20, 21). Counties were considered to be part of a spatial "concentration" if their poverty rates were significantly ($P < 0.05$) positively correlated with those of nearby or surrounding counties. This characterization of "highly correlated" was based on having a standardized local Moran *I* greater than 2. Counties were considered to be "spatial outliers" if their poverty rates were significantly ($P < 0.05$) negatively correlated with those of nearby or surrounding counties; in this case, the inclusive definition was having a standardized local Moran *I* score less than or equal to -2 .

Thus, the combination of poverty rates and spatial clustering yields geographic insights into contiguous counties of wealth and poverty and areas of isolated wealth and poverty—what we refer to as spatial outliers. Each county was categorized to one of the following 10 poverty categories: extremely high poverty (concentrated), very high poverty (concentrated),

high poverty (concentrated), low poverty (concentrated), very low poverty (concentrated), extremely high poverty (outlier), very high poverty (concentrated), high poverty (outlier), low poverty (outlier), or very low poverty (outlier).

Statistical Analysis

The estimated average annual transplant rate for each county in the contiguous United States was calculated by dividing the 15-year transplant rate for each county by 15. The 15-year rate of transplantation for each county was determined by dividing the total number of transplants over the 15-year period studied by the ESRD prevalence in the midpoint (8th) year, i.e., in 2000 for each county. Patients living outside of the 48 contiguous states and the District of Columbia were excluded from our analysis. Comparison of transplantation rates across quartiles of median household income, high school graduation rates, percentage minority race (i.e., non-white) population, population density, and county poverty was performed using the nonparametric Kruskal-Wallis rank test. The median transplant rates between spatial outliers and concentrated areas in each strata of poverty were compared using the Wilcoxon–Mann–Whitney test. Similarly, variations in the transplant rates across the 11 organ procurement regions were also compared. Correlations were examined using Spearman rank correlation coefficient because of the non-normal distribution of the transplant rates. Results were considered statistically significant at the $P < 0.05$ level. All P values were two-sided.

Statistical analysis was performed using Stata 11.1 and spatial analysis including generation of maps was performed using ArcGIS ArcMap 10.0. Database management was performed using Oracle 11g.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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FIGURE 1.

A, statewise median annual transplant rates (calculated by dividing the 15-year transplant rate for each state by 15. The 15-year rate of transplantation for each county was determined by dividing the total number of transplants over the 15-year period studied by the ESRD prevalence in the midpoint [8th] year, i.e., in 2000 for each state). B, county-level distribution of annualized transplant rates (calculated by dividing the 15-year transplant rate for each county by 15. The 15-year rate of transplantation for each county was determined by dividing the total number of transplants over the 15-year period studied by the ESRD prevalence in the midpoint [8th] year, i.e., in 2000 for each county).

FIGURE 2.

Variation in transplantation rates across organ procurement regions. Map showing boundaries for each of the 11 regions (please see Figure S1, SDC, <http://links.lww.com/TP/A969> for cartographical depiction of this data).

FIGURE 3.
Influence of county-level socioeconomic factors on the rate of kidney transplantation.

FIGURE 4.
Impact of county poverty level on the median transplant rate.

FIGURE 5.

Influence of spatial topography of poverty on kidney transplantation rates. (The number of counties in each category is listed at the base of the corresponding bar. The average category included 1,242 counties.)