

SDC, Materials and Methods

Data sources

The primary data source was the 2015 Behavioral Risk Factor Surveillance System (BRFSS) State Prevalence and Trends Data at the Centers for Disease Control and Prevention. BRFSS is the largest continuously conducted telephone health survey system in the world, completing more than 400,000 adult interviews in the United States every year. These data include health-related risk behaviors, chronic health conditions, and use of preventive services from all 50 states, the District of Columbia, and 3 United States territories.¹⁴

The second data source was the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donors, wait-listed candidates, and transplant recipients in the United States; these data are submitted by the members of the OPTN. The Health

Resources and Services

Administration of the United States Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors. The study was approved by the University of Alabama at Birmingham Institutional Review Board.

Study population

The unit of analysis was kidney transplant center. All United States kidney transplant centers that performed at least 10 transplants in 2015 were eligible for inclusion. One center performed more than 10 transplants in 2015 but did not list anyone in 2013-2014 and thus was excluded from the analysis, resulting in a final cohort of 213 kidney transplant centers.

Categorization of exposures

BRFSS prevalence measures are reported by the CDC at the state level and are weighted to account for the complex survey sampling design. To create prevalence measures that best reflected the population characteristics of a transplant center, we defined each center's "catchment area" as the list of states from which patients were added to the waiting list at that center. We utilized a kidney-only candidate's first waiting-list addition between January 1, 2013 and December 31, 2014 to account for the lag time between listing and transplantation. Of the 72,266 unique individuals listed in that time frame, 172 did not have a zip code available, and 502 were listed at centers that did not perform 10 transplants in 2015 and thus were excluded. After these exclusions, 71,592 candidates contributed geographic information.

Center demographic and SES indicator prevalence measures were weighted by multiplying a given state's prevalence measure by the proportion of waitlisted patients from that state (e.g., if 80% of transplant candidates at Center A were from State A and 20% were from State B, the prevalence of obesity in State A was multiplied by 0.8 and added to the prevalence of obesity in State B multiplied by 0.2, and the resulting prevalence was assigned to the center). This was done to make a transplant center's prevalence measures look more like the patient population of the center and to account for heterogeneity within a state that was not captured by a state-level summary measure in BRFSS. A summary of the within-state variation created using this weighting measure is presented in Table S1. The following population demographic and SES indicators hypothesized to be associated with rate of LDKT were considered for analysis: prevalence of age ≥ 65 years, male sex, minority race/ethnicity defined as non-White (African American, Asian, Hispanic, American Indian, Native Hawaiian, other, or multiracial), less than college education, lack of health insurance (defined as report of "no health care coverage"),

annual household income < \$15,000, unemployment (collapsed responses for “no work for < 1 year” and “no work for > 1 year”), no internet use in past 30 days, and not married / no partner. We considered the following population health indicators for analysis, as they are absolute and relative contraindications to living kidney donation: history of cardiovascular disease (CVD), diabetes mellitus (DM), hypertension, kidney disease, depression, poor self-rated health, obesity, and current smoking.

For center-level characteristics, we examined the absolute number of living donor transplants performed in 2015 and whether the transplant center performed incompatible kidney transplants (either blood group incompatible or donor exchange programs).¹⁵

Outcome ascertainment

Center rate of living donation was defined as the proportion of all kidney transplants performed at a center in 2015 that were from living donors.

Statistical analyses

Using measures of central tendency and spread, we explored the distribution of center prevalence measures by OPTN region. Given that some states only have 1 active transplant center, we chose to present the rate of LDKT in a heat map at the OPTN region rather than the state level, so as not to identify unique transplant centers. Prevalence measures were also described at the region level for consistency. Spearman’s correlation was used to generate the correlation coefficient between covariates to assess the potential for collinearity. We also investigated the variance inflation factor (VIF) for each covariate and obtained VIFs > 10 for CVD, DM, minority prevalence, and smoking and VIFs approaching 10 for obesity, lower

education, unemployment, and no internet use. As such, we chose to collapse SES and health factors into 2 indices.

To create the indices, prevalence measures were dichotomized into whether the center's weighted prevalence was greater than or equal to the national median of that factor (Table S2). The relationship between the dichotomous factor and rate of LDKT was explored. We performed principal component factor analyses using measures with p-values ≤ 0.1 on unadjusted analyses, to confirm the communality of the measures and obtain the factor loadings for each measure to calculate weighted factor-based scores.^{16,17} If a center's prevalence was greater than or equal to the national median, the factor loading was added to the total score for each index, such that a center could have a maximum score of 4.101 for the disease index and a maximum score of 3.291 for the SES index. To test internal consistency of the indices, we calculated Cronbach's alpha for each index. Given that health and SES are correlated and to determine whether there was an additive effect, the indices were cut at the median and categorized as low vs. high and further collapsed into a single measure, with the number of centers falling into each category presented in Table S3.

Living donation rate was examined for normality, and model diagnostics assessed the appropriateness of the assumption of linearity, with both assumptions confirmed. Given the presence of more than 1 transplant center in some states and the potential for lack of independence of these centers, we utilized a linear mixed effects model with a random intercept for state accounting for within-state correlation to assess the association between population health and SES factors and center rate of living donation. The most parsimonious model was chosen by minimizing the Akaike's Information Criterion. All analyses were conducted with SAS version 9.4 (SAS Institute, Inc., Cary, NC).

Sensitivity analyses

To account for other factors of center performance that may influence volume of living donors at a center, we ran several sensitivity analyses. Given the concerns by Matar et al that proportion of all kidney transplants done that are from living donors may not accurately measure center performance of LDKT,¹⁸ we ran a Poisson model to estimate the rate ratio of living donor transplants per individuals on the waiting list as of January 1, 2015, as a function of population characteristics. Inferences were consistent and are reported in Table S4. We also explored the inclusion of deceased donor organs available per waiting list population and median center waiting time as covariates, and our findings were confirmed.

Additional sensitivity analyses included excluding Children's Hospitals and generating a linear model with robust standard errors clustering at the state. Finally, we explored different definitions of catchment area, based on distribution of donor zip code and 200-mile radius around the transplant center. All inferences were consistent.

Table S1. Summary of within-state variation created by weighting methodology

| Factor | Average within-state variation (percentage points) | Range |
|-------------------------|---|--------------|
| Age 65+ | 0.71 | 0.005-3.92 |
| Male sex | 0.22 | 0.00-1.60 |
| Minority race/ethnicity | 4.39 | 0.09-23.85 |
| Less than college | 1.59 | 0.01-18.9 |
| Lack of insurance | 1.11 | 0.05-5.02 |
| Low income | 1.1 | 0.03-6.47 |
| Unemployment | 0.41 | 0.01-5.08 |
| No internet use | 1.09 | 0.03-4.28 |
| Not married | 1.09 | 0.007-19.71 |
| Cardiovascular disease | 0.32 | 0.02-1.45 |
| Diabetes | 0.44 | 0.01-1.80 |
| Hypertension | 0.98 | 0.02-3.81 |
| Depression | 0.84 | 0.03-8.68 |
| Kidney disease | 0.14 | 0.001-0.63 |
| Obesity | 1.01 | 0.01-6.77 |
| Poor self-rated health | 0.36 | 0.008-1.49 |
| Smoking | 0.87 | 0.004-2.84 |
| Living donor rate | 27.99 | 0.00-57.73 |

Table S2. National median of prevalence measures

| Factor | National median | % of centers in areas above national median |
|---------------------------------|------------------------|--|
| Cardiovascular disease | 6.1% | 54.5% |
| Diabetes mellitus | 10.0% | 60.1% |
| Hypertension | 30.9% | 47.9% |
| Kidney disease | 2.7% | 45.5% |
| Poor self-rated health | 4.1% | 56.8% |
| Depression | 18.9% | 36.6% |
| Obesity | 29.8% | 48.8% |
| Smoking | 17.5% | 34.3% |
| Less than college education | 75.3% | 38.0% |
| Income < \$15,000/yr | 10.3% | 60.1% |
| No health insurance | 10.8% | 51.6% |
| Unemployed | 5.6% | 62.9% |
| No internet use in past 30 days | 17.0% | 62.4% |
| Unmarried / not partnered | 56.4% | 67.6% |
| Age 65+ years | 20.0% | 41.8% |
| Male | 48.7% | 41.8% |
| Minority (non-White) | 26.5% | 60.6% |

Table S3. Categorization of centers based on combined health and SES scores

| Category | N | % of centers analyzed |
|-----------------------------------|----------|------------------------------|
| Low health score, low SES score | 69 | 32.4 |
| Low health score, high SES score | 32 | 15.0 |
| High health score, low SES score | 36 | 16.9 |
| High health score, high SES score | 76 | 35.7 |

Table S4. Adjusted analyses of Poisson regression model with offset for waitlist burden

| Characteristic | Rate Ratio | 95% CI | p-value |
|---|-------------|------------------|-------------------|
| | Adjusted | | |
| <i>Demographic</i> | | | |
| High prevalence of 65 years and older | 0.89 | 0.67-1.20 | 0.46 |
| High prevalence of males | 0.98 | 0.73-1.31 | 0.88 |
| High prevalence of minorities (non-White) | 0.61 | 0.49-0.76 | < 0.001 |
| | | | |
| <i>SES and Disease Combined</i> | | | |
| Low disease score, low SES score | Ref | | |
| Low disease score, high SES score | 0.73 | 0.45-1.19 | 0.21 |
| High disease score, low SES score | 0.83 | 0.62-1.10 | 0.19 |
| High disease score, high SES score | 0.79 | 0.65-0.97 | 0.02 |
| | | | |
| <i>Center-specific</i> | | | |
| Incompatible transplant program | 1.80 | 1.54-2.11 | < 0.001 |