Geographic Differences in Population Health and Expected Organ Supply in the Gulf Coast Region of the United States Compared to Non-Gulf States

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Background. The Final Rule aimed to reduce geographic disparities in access to transplantation by prioritizing the need for transplant over donor proximity. However, disparities in waiting times persist for deceased donor kidney transplantation. The kidney allocation system implemented in 2014 does not account for potential local supply based on population health characteristics within a donation service area (DSA). We hypothesized that regions with traditionally high rates of comorbid disease, such as the states located along the Gulf of Mexico (Gulf States), may be disadvantaged by limited local supply secondary to poor population health. **Methods.** Using data from the Robert Wood Johnson Foundation County Health Rankings, the United States Renal Data System, and the Scientific Registry of Transplant Recipients, we compared population-level characteristics and expected kidney donation rates by Gulf States location. **Results.** Prevalence of African American ethnicity, end-stage renal disease, diabetes, fair/poor self-rated health, physical inactivity, food insecurity, and uninsurance were higher among Gulf State DSAs. On unadjusted analyses, Gulf State DSAs were associated with 3.52 fewer expected kidney donors per 100 eligible deaths than non-Gulf States. After adjustment, there was no longer a statistically significant difference in expected kidney donation rate. **Conclusions.** Although Gulf State DSAs have lower expected donation rates, these differences appear to be driven by the prevalence of health factors negatively associated with donation rate. These data suggest the need to discuss population health characteristics when examining kidney allocation policy, to account for potential lower supply of donors and to further address geographic disparities in access to kidney transplantation.

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J.E.L. and R.D.R. had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analyses. R.D.R. conceived and designed the study, with oversight from J.E.L. and P.A.M. B.A.S., M.N.M., and D.S. participated in interpretation of the data and revision of the article, and all authors gave final approval of the manuscript. R.D.R. drafted the article and was responsible for the statistical analyses.

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INTRODUCTION

The Final Rule was proposed by Health and Human Services Secretary Donna Shalala in 1998, in response to criticism that the United States deceased donor organ allocation system at that time favored regions with a larger supply of transplantable organs. The legislation that was passed in 2000 was designed to create a more equitable nationwide system of organ transplantation and to reduce geographic disparities in access to transplantation by prioritizing a patient's need for transplant over proximity to the donor.[1] Despite passage of the Final Rule, persistent geographic disparities in waiting times and transplantation have been well-described. Donation service areas (DSAs) are 58 geographic units designated by the Centers for Medicare and Medicaid Services that are served by Organ Procurement Organizations (OPOs) and one or more donor hospitals. Davis et al[2] reported a wide range of waiting times for deceased donor kidney transplantation across DSAs, with a greater prevalence of African American race/ethnicity, lower prevalence of college education, and lower kidney procurement rates in the DSAs with the longest waiting time. Mathur et al[3] reported lower waitlist and transplant rates in DSAs with higher incidence of end-stage renal disease (ESRD).

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The kidney allocation system (KAS) was updated in 2014 to attempt to equitably and efficiently allocate kidneys based on dialysis time and estimated longevity matching between donor and recipient.[4] However, the current KAS does not account for potential limited supply based on population health characteristics within a DSA and does not explicitly address geographic disparities. Therefore, regions with traditionally high rates of comorbid disease may be disadvantaged if local supply is limited. In fact, geographic disparities have persisted post-KAS implementation. The Access to Transplant Score is generated by the Organ Procurement and Transplantation Network (OPTN) and provides evidence of disparities post-KAS in the form of a wide range of median waiting times, ranging from 2 to 7.6 years.[5] Six of the 15 DSAs with the worst Access to Transplant scores serve the US Gulf States region, which encompasses Texas, Louisiana, Mississippi, Alabama, and Florida, states that are located along the Gulf of Mexico. A recent article by Zhou et al demonstrated that OPTN regions 3 and 4 (serving the Gulf States) have deceased donor kidney transplant rates that rank among the lowest in the country.[6] These persistent disparities have been attributed to candidate blood type and calculated panel reactive antibody but also to unmeasured differences in the DSA where the transplant candidate is listed, which may include underlying population health.

The population of the US Gulf States region has grown by 109% since 1970,[7] compared to 52% nationally, and the population in this region is projected to grow to 74.8 million by 2030.[8] The region has a higher proportion of individuals 65 or older and more African Americans than the national average,[7] as well as a high prevalence of economically disadvantaged individuals, including 142 counties with 20% or more residents living in poverty.[9] These demographics, combined with the dramatic growth in population size, confer high levels of health vulnerability in this region. Rates of comorbid diseases (diabetes, hypertension, obesity) have increased in the United States over the past decade, with the prevalence of diabetes increasing from 4% to 7%[10] and the prevalence of obesity from 30.5% to 37.7%.[11] These rates are highest in the Southeast,[12,13] which is comprised primarily of the Gulf States. Thus, population health may contribute to the observed disparities in organ supply, with fewer donors from whom at least one organ is procured and ultimately fewer transplants performed in the presence of increased population comorbid disease in a given DSA. However, it is unknown whether there is an association between population health and kidney supply. We hypothesize that the prevalence of population-level factors is associated with expected donation rates within DSAs and that differences in population factors between the US Gulf and non-Gulf States will explain this disparity.

METHODS

Data Sources

This study is a secondary data analysis at the DSA level, utilizing data from several sources. The County Health Rankings and Roadmaps are produced through a collaboration between the Robert Wood Johnson Foundation and the University of Wisconsin Population Health Institute. The rankings are published annually, with the goals of building awareness of health factors and assisting communities in identifying opportunities for improving the health of the public. The rankings include measurements of health factors such as obesity, education, diabetes, and smoking from more than 20 data sources, captured at the Federal Information Processing Standard code level. The County Health Rankings from 2016 were used to describe population-level factors within DSAs and include census population estimates from 2014.[14]

The United States Renal Data System (USRDS) is a national data system that collects, analyzes, and distributes information about ESRD in the United States and is funded by the National Institute of Diabetes and Digestive and Kidney Diseases, in conjunction with the Centers for Medicare and Medicaid Services.[15] Information on population burden of ESRD by county census population in 2016 was obtained from USRDS, as the County Health Rankings do not capture these data.

This study also used data from the Scientific Registry of Transplant Recipients (SRTR), which collects data submitted by members of the OPTN on all donors, waitlisted candidates, and transplant recipients in the United States. The Health Resources and Services Administration of the US Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors. Data from the publicly available January 2017 release of the OPO specific reports were used to obtain expected and observed rates of kidney donation from the observation period between July 1, 2015, and June 30, 2016.[16] This study received Institutional Review Board approval (protocol 161212003).

Dataset Construction

County Health Rankings data included information on 3140 counties (after excluding Bedford County, VA, which was not included in the SRTR OPO reports). Additionally, the Puerto Rico DSA was excluded, as population-level variables are not captured in the County Health Rankings, resulting in a total of 57 DSAs included in the analysis. A DSA was classified as being located in a US Gulf State if it served any counties located in Alabama, Florida, Louisiana, Mississippi, or Texas. Missing data on county-level factors were as follows: primary care physician (PCP) ratio (136 counties), household income (1 county), uninsured prevalence (1 county), unemployed prevalence (1 county), average daily particulate matter (33 counties), motor vehicle mortality rate (410 counties), injury death rate (117 counties), violent crime rate (167 counties), and drug overdose mortality rate (1558 counties). Missingness was explored by DSA location and was found not to be differentially missing by Gulf State versus non-Gulf State. As such, multiple imputation with fully conditional specification was utilized to impute missing values for these variables, with 20 imputations. The pooled mean estimate of all 20 imputed values for a variable was obtained for each county that was originally missing that variable and was assigned to the county.

County-level population characteristics were assigned to DSAs as follows: the proportion of county population to total 2014 census population of all counties within a DSA was calculated, and that proportion was multiplied by the county prevalence of each population factor (ie, if County "A" represented 15% of the total census population of

DSA "A" and the prevalence of obesity in that county was 20%, 0.15 was multiplied by 0.2). These prevalence measures accounting for county size were then summed for all counties within the DSA, to obtain a weighted prevalence measure representative of all counties in the DSA.

Outcome Measures

Organ supply was defined as expected kidney donation rate per 100 eligible deaths, provided in the OPO-specific reports. SRTR calculates the expected donation rate using a logistic regression model fit to all eligible deaths in all OPOs, adjusting for age, race, sex, and cause of death and accounting for national performance.

Statistical Analysis

County-level population characteristics thought to be associated with organ supply were chosen from the County Health Rankings and USRDS a priori. Distribution of county-level measures aggregated to the DSA level by Gulf State location was described and compared using Wilcoxon rank sum tests as appropriate given the distribution. After assessing the distribution of the outcomes, multivariable linear regression was used to examine the association between location in a US Gulf State and prevalence measures with expected kidney donation rate, adjusting for all factors significantly associated with expected donation rate on unadjusted analyses. Population characteristics related to age, sex, and race/ethnicity (demographics) were not considered for multivariable analyses, as these factors are already accounted for in SRTR's calculation of the expected donation rate. All analyses were performed using SAS 9.4 (Cary, NC).

Sensitivity Analyses

Multiple models were built controlling for groups of variables (health factors only, socioeconomic factors only, societal/environmental factors only). As our inferences remained consistent with the model containing all factors significant on univariate analyses, we present that model as the primary model. We explored Poisson regression modeling but opted to present the linear regression results, given that there was no offset and the outcomes were normally distributed and bounded by 0 and 100. We also explored the metrics proposed by Goldberg et al.[17] While these analyses confirmed the adjusted findings of the primary analyses, these metrics are measures of OPO performance rather than organ supply, and as such these analyses are not presented.

RESULTS

Prevalence measures summed and weighted to the DSA level are presented in Table 1, by whether the DSA serves a US Gulf State. The prevalence of African American race/ethnicity was higher in DSAs in Gulf States versus non-Gulf States (18.6% versus 8.2%, $P = 0.003$), while the prevalence of non-Hispanic White race/ethnicity was higher in non-Gulf States (56.1% versus 72.6%, $P = 0.007$). Regarding health/comorbid factors, the prevalence of diabetes (11.2% versus 10.0%, $P < 0.001$), fair/poor self-rated health (18.6% versus 15.2%, $P < 0.001$), and physical inactivity (25.0% versus 23.4%, $P = 0.03$) were all higher in Gulf State DSAs. Additionally, the PCP ratio of residents per one physician was higher in Gulf States (1938.8 versus 1533.0, $P = 0.03$), indicating that there are more residents per PCPs in these areas. The rate of ESRD per 100 000 population was also higher in DSAs in the Gulf States (214.4 versus 187.1, $P = 0.003$).

When examining socioeconomic factors, the food environment index was lower in the Gulf States (6.6 versus 7.5, $P < 0.001$), consistent with a higher prevalence of food insecurity (16.9% versus 14.0%, $P = 0.003$), demonstrating poorer access to healthy food in this region. Household income was lower ($47 011 versus $53 036 [US dollars] annually, $P = 0.003$) and income inequality ratio was higher (4.9 versus 4.6, $P = 0.02$) in Gulf States, with a lower prevalence of some college education (58.4% versus 65.7%, $P < 0.001$) and higher prevalence of uninsurance (22.7% versus 14.9%, $P < 0.001$) in DSAs in the Gulf States. The prevalence of several environmental factors differed by Gulf State location, with higher rates of motor vehicle mortality per 100 000 population (14.3 versus 10.8, $P = 0.001$) and violent crime per 100 000 (513.6 versus 349.2, $P = 0.008$) seen among DSAs in the Gulf States. The crude expected rate of kidney donation per 100 eligible deaths was lower among Gulf States (66.0 versus 69.5, $P = 0.02$), with a national average of 69.1 per 100 eligible deaths.

On unadjusted simple linear regression analysis, there were 3.52 fewer expected kidney donors per 100 eligible deaths in the Gulf States compared to non-Gulf States (95% confidence interval [CI]: −6.42 to −0.60, $P = 0.02$) (Table 2). For every 10 additional cases of ESRD per 100 000 population, there were 0.59 fewer expected donors per 100 eligible deaths (95% CI: −0.76 to −0.41, $P < 0.001$). For every 5% increase in the prevalence of diabetes, there were 4.57 fewer expected donors per 100 eligible deaths (95% CI: −9.11 to −0.03, $P = 0.049$), and for every 5% increase in the prevalence of fair/poor self-rated health, there were 2.24 fewer expected kidney donors per 100 eligible deaths. For a 1-unit increase in the income inequality ratio (indicating a greater disparity between the highest 20% and lowest 20% income), there were 4.51 fewer expected donors per 100 eligible deaths. Greater prevalence of unemployment was associated with lower expected donation rate, while greater prevalence of rurality was associated with a higher expected donation rate. Greater violent crime rate was associated with 0.02 fewer expected donors per 100 eligible deaths (95% CI: −0.03 to −0.008, $P < 0.001$), while higher drug overdose death rate was associated with 0.38 more expected donors per 100 eligible deaths (95% CI: 0.13–0.62, $P = 0.004$).

On adjusted analyses, the association between US Gulf State location and expected kidney donation rate was no longer significant (estimate: 1.52, 95% CI: −1.22 to 4.26, $P = 0.27$). The only DSA-aggregated factors that remained significantly associated with expected donation rate were ESRD burden per 100 000 population, which had a negative association, and prevalence of rurality and drug overdose death rate, which were positively associated with the outcome (Table 3).

DISCUSSION

In this cross-sectional study, the first to explore the association between population-level factors and kidney

TABLE 1.

Descriptive table of county data summed and weighted to DSA level, by whether the DSA serves a Gulf State

	Gulf State (N = 11)	Non-Gulf State (N = 46)	
Factor	**Median (IQR)**	**Median (IQR)**	***P***
Demographics, %			
Race/ethnicity			
African American	**18.6 (13.3–32.1)**	**8.2 (4.7–13.9)**	**0.003**
American Indian/Alaska native	0.7 (0.5–1.0)	0.7 (0.5–1.6)	0.59
Asian	2.6 (1.6–3.5)	2.9 (2.1–4.9)	0.25
Hispanic	17.4 (4.4–33.2)	9.2 (4.8–15.9)	0.35
Native Hawaiian/Pacific Islander	0.1 (0.07–0.14)	0.1 (0.06–0.18)	0.90
Non-Hispanic White	**56.1 (44.7–66.2)**	**72.6 (56.2–81.3)**	**0.007**
Age 65+	14.5 (12.0–18.0)	14.8 (14.1–15.8)	0.82
Female	51.1 (50.4–51.4)	50.8 (50.3–51.2)	0.15
Health/comorbidities, %			
Diabetes	**11.2 (10.8–12.3)**	**10.0 (9.1–10.8)**	**< 0.001**
Excessive drinking	17.7 (13.9–18.6)	17.7 (16.4–19.5)	0.48
Fair/poor health	**18.6 (16.2–21.1)**	**15.2 (13.2–16.8)**	**< 0.001**
Obesity	28.6 (26.9–34.3)	28.3 (24.8–30.6)	0.21
Smoking	16.8 (14.7–20.2)	16.3 (14.9–18.9)	0.44
Physical inactivity	**25.0 (23.8–30.2)**	**23.4 (20.6–25.4)**	**0.03**
Primary care physician ratio (ratio of residents to primary care physicians)	**1938.8 (1508–2114)**	**1533.0 (1357–1851)**	**0.03**
Rate of ESRD per 100 000 population	**214.4 (209.9–271.1)**	**187.1 (162.3–210.0)**	**0.003**
Socioeconomic			
Food environment index	**6.6 (6.3–6.9)**	**7.5 (7.0–7.8)**	**< 0.001**
Food insecurity, %	**16.9 (15.3–18.1)**	**14.0 (13.1–16.2)**	**0.003**
Household income in US$	**47,011 (44406–50247)**	**53,036 (50100–61025)**	**0.003**
Income inequality ratio	**4.9 (4.6–5.1)**	**4.6 (4.3–4.8)**	**0.02**
Some college, %	**58.4 (57.7–60.7)**	**65.7 (61.9–67.1)**	**<0.001**
Unemployment, %	6.3 (5.4–6.9)	6.1 (5.6–6.7)	0.53
Uninsured, %	**22.7 (19.2–24.8)**	**14.9 (12.2–17.1)**	**<0.001**
Rural, %	16.6 (7.2–30.1)	23.1 (12.0–30.6)	0.64
Societal/environmental			
Average daily density of fine particular matter (air pollution)	10.9 (9.8–12.1)	11.9 (10.4–12.8)	0.23
Injury death rate per 100 000	74.0 (55.6–75.5)	62.5 (52.7–68.7)	0.16
Motor vehicle mortality rate per 100 000	**14.3 (13.6–18.5)**	**10.8 (8.5–12.8)**	**0.001**
Violent crime rate per 100 000	**513.6 (374.2–537.5)**	**349.2 (274.0–428.3)**	**0.008**
Drug overdose death rate per 100 000	13.7 (10.1–14.0)	14.0 (12.3–19.4)	0.08

Bold indicates significance <0.05.
DSA, Donation Service Area; ESRD, end-stage renal disease; IQR, interquartile range.

donation rate, we found that DSAs located in US Gulf States have a higher prevalence of population-level factors that were negatively associated with donation rate, as well as an expected kidney donation rate per 100 eligible donors that was lower than DSAs not serving the Gulf States. However, this lower rate was no longer observed when adjusting for various population-level characteristics.

Our unadjusted data show lower rates of expected kidney donation per 100-eligible deaths in the US Gulf States compared to non-Gulf States. In conjunction with known disparities in waiting times, these findings indicate an inability to meet the local need for transplantation. Moreover, the finding that the expected donation rate did not differ by Gulf State location after adjustment for population health suggests that the difference in expected donation rate appears to be driven by the prevalence of various health factors that are negatively associated with kidney donation rate. These findings also support the hypothesis that some of the persistent geographic disparities seen in the Access to Transplant score may be due to unmeasured disease burden within a DSA, as population health measures that were negatively associated with kidney donation rates were also more prevalent in the Gulf States. Extending beyond disparities observed in the US Gulf States region, there is much criticism of the current US KAS and the inconsistencies created by the use of DSAs as the unit of distribution, including disparate geographic area and population sizes across DSAs. In their analysis of geographic disparities in deceased donor kidney transplantation, Zhou et al[6] draw attention to the modeled geographic redistricting that has already been discussed for liver allocation but has not yet been proposed for kidney. Examining redistricting within KAS may be beneficial, to address the persistent disparities in access to kidney transplantation. In fact, OPTN/UNOS is currently seeking public comments regarding alternative models for kidney and pancreas allocation.[18]

TABLE 2.

Unadjusted linear regression estimates of expected kidney donation rate per 100 eligible deaths by population-level characteristics

	Estimate	Lower CI	Upper CI	*P*
Gulf State	**−3.52**	**−6.42**	**−0.60**	**0.02**
Health/comorbidities				
ESRD burden per 100 000 population[a]	**−0.59**	**−0.76**	**−0.41**	**<0.001**
Prevalence of diabetes[b]	**−4.57**	**−9.11**	**−0.03**	**0.049**
Prevalence of heavy alcohol use[b]	0.91	−1.47	3.29	0.45
Prevalence of poor health[b]	**−2.24**	**−4.27**	**−0.20**	**0.03**
Prevalence of obesity[b]	1.44	−0.18	3.06	0.08
Prevalence of smoking[b]	1.79	−0.30	3.88	0.09
Prevalence of physical inactivity[b]	0.20	−1.21	1.62	0.77
Socioeconomic				
PCP ratio[c]	0.07	−0.31	0.45	0.71
Prevalence of food insecurity[b]	−0.96	−3.57	1.66	0.47
Income inequality ratio	**−4.51**	**−7.74**	**−1.27**	**0.007**
Prevalence of some college education[b]	0.66	−0.68	2.00	0.33
Prevalence of unemployment[b]	**−6.44**	**−12.08**	**−0.81**	**0.03**
Prevalence of uninsurance[b]	−1.20	−2.40	0.001	0.05
Prevalence of rurality[b]	**0.74**	**0.29**	**1.18**	**0.002**
Societal/environmental				
Average daily density of fine particular matter (air pollution)	**0.76**	**0.02**	**1.50**	**0.045**
Injury death rate	**0.10**	**0.003**	**0.20**	**0.04**
Motor vehicle mortality rate	0.02	−0.29	0.32	0.91
Violent crime rate	**−0.02**	**−0.03**	**−0.008**	**<0.001**
Drug overdose death rate	**0.38**	**0.13**	**0.62**	**0.004**

Bold indicates significance <0.05.
[a]For every 10 additional cases of ESRD/100 000 population.
[b]Per 5% increase.
[c]For every 100 additional residents per primary care physician.
CI, confidence interval; ESRD, end-stage renal disease; PCP, primary care physician.

The finding that the prevalence of ESRD is negatively associated with kidney donation rates is consistent with previous research. Mathur et al[3] demonstrated that increasing incidence of ESRD within a DSA was associated with lower transplant rates, after adjusting for organ supply (donation rate per million population), and kidney yield declined with ESRD incidence. Furthermore, the negative association between ESRD and expected kidney donation rate persisted after adjustment, suggesting that despite similar supply, the need is not met in areas with higher disease burden. The negative association between prevalence of diabetes and donation rate may reflect an unwillingness to use kidneys from deceased donors with diabetes, based on recent work showing inferior long-term allograft outcomes when compared to donors who were nondiabetic.[19] However, Cohen et al[20] have also demonstrated a significant survival benefit conferred for many candidates from the use of these donors, and given that the demand for organs continues to exceed the supply, enhanced utilization of these kidneys should be supported.

The negative association between fair/poor self-rated health and expected kidney donation rate seen on univariate analysis is supported by the 2012 National Survey of Organ Donation Attitudes and Behaviors, which reported that 10.5% of respondents indicated that they were not willing to sign up to become an organ donor because they believed they were not in good health, and 18.2% stating they could not donate for medical reasons.[21] Similarly, a cross-sectional study in 2015 found higher odds of registering as an organ donor among individuals with fewer comorbid conditions[22]; this same study reported a higher odds of donor registration for those at higher income levels and among those who were employed, consistent with the findings in our study that greater prevalence of unemployment was associated with lower rates of kidney donation, while greater income inequality was negatively associated with donation rate at the DSA level.

We found a positive association between prevalence of rurality in a DSA and expected kidney donation rate per 100 eligible deaths. This result is supported by a finding from a study of all US transplants from 2000 to 2003, which showed that families of rural deceased donors were significantly more likely than urban families to be aware of their loved one's wish to donate their organs.[23] That study also found that rural residents were 1.25 times more likely to donate than to receive solid organs, and donated organs from rural residents were mostly transplanted at urban centers. This finding is also consistent with SRTR data, which demonstrated that more populous areas tended to have lower rates of kidney recovery.[24] Rural disparities in access to transplant have been shown, with urban residents waitlisted and transplanted at higher rates than their rural counterparts[25] and transplant rates lowest for African American and Native American dialysis patients in rural areas.[26] With nearly all transplant centers located in urban areas, it is not surprising that urban residents have improved access. However, the Final Rule necessitates a further investigation of strategies to increase access to transplantation for rural residents.

Based on data from the OPTN as of January 2018, there has been a 144% increase over the past 5 years in the number of deceased donors whose mechanism of death was drug intoxication. Therefore, the positive association between drug overdose death rate and expected kidney donation rate is not surprising. However, Goldberg et al[27] demonstrated a significantly lower mean number of organs transplanted per donor for donors who died from a drug overdose versus gunshot wound, asphyxiation, and blunt injury, a difference attributed to concerns about possible transmission of infection and organ ischemia. The authors stress the need for communication of evidence-based data on the low risk of disease transmission, to encourage the optimal use of organs from these donors.

This study is not without limitations. While the imputed values were pooled to create one summary measure for each variable missing for a county, these pooled estimates do not account for the variability arising from the imputed datasets. However, the imputed values overlapped with the observed values, and data were not missing differentially by the Gulf State region. It is likely that there are unmeasured DSA performance-specific factors (organ acceptance practices, such as aggressiveness of OPOs at pursuing marginal donors, etc.) that influence donation rates. However, we explored other measures of organ supply that have been proposed as sensitivity analyses and found the associations to be consistent. The County Health Rankings

TABLE 3.

Multivariable linear regression models for expected kidney donation rate per 100 eligible deaths

	Model I (adj. R squared = 0.08)			Model II (adj. R squared = 0.65)			Model III (adj. R squared = 0.23)			Model IV (adj. R squared = 0.37)			Model V (adj. R squared = 0.68)		
	Est.	95% CI	*P*	Est.	95% CI	*P*	Est.	95% CI	*P*	Est.	95% CI	*P*	Est.	95% CI	*P*
Gulf State DSA	**–3.52**	**–6.42 to –0.60**	**0.02**	0.13	–2.41 to 2.67	0.92	–2.90	–6.52 to 0.72	0.11	–0.81	–4.00 to 2.37	0.61	1.52	–1.22 to 4.26	0.27
Health															
ESRD per 100 000				**–0.74**	**–0.95 to –0.53**	**<0.01**							**–0.65**	**–0.90 to –0.40**	**<0.01**
Diabetes				4.04	–3.09 to 11.17	0.26							2.69	–3.81 to 9.20	0.41
Heavy alcohol use				–1.16	–3.39 to 1.08	0.30									
Poor health				–1.30	–4.48 to 1.89	0.42							–0.77	–4.42 to 2.89	0.68
Obesity				**2.29**	**0.23 to 4.34**	**0.03**									
Smoking				2.23	–0.29 to 5.75	0.08									
Physical inactivity				–1.79	–4.03 to 0.45	0.11									
Socioeconomic															
PCP ratio							–0.30	–0.88 to 0.28	0.30						
Food insecurity							0.22	–3.75 to 4.20	0.91						
Income inequality							–2.04	–5.95 to 1.87	0.30				0.01	–3.18 to 3.20	0.99
College education							–0.03	–2.17 to 2.11	0.98						
Unemployment							–3.48	–10.54 to 3.58	0.33				2.17	–2.61 to 6.94	0.37
Uninsurance							0.69	–1.26 to 2.64	0.48				0.59	–1.02 to 2.20	0.46
Rurality							**0.93**	**0.24 to 1.62**	**0.009**				**0.75**	**0.12 to 1.39**	**0.02**
Societal/environmental															
PM density										0.30	–0.39 to 0.94	0.39	0.18	–0.41 to 0.78	0.54
Injury death rate										0.18	–0.04 to 0.40	0.10	–0.07	–0.21 to 0.07	0.31
MV mortality rate										–0.24	–0.82 to 0.34	0.42			
Violent crime rate										**–0.02**	**–0.03 to –0.009**	**<0.01**	–0.01	–0.01 to 0.003	0.19
Overdose death rate										0.09	–0.30 to 0.47	0.65	**0.38**	**0.06 to 0.71**	**0.02**

Bold indicates significance <0.05.
CI, confidence interval; DSA, Donation Service Area; ESRD, end-stage renal disease; PCP, primary care physician.

are population-level data, and as such, we cannot attribute our findings to be causally related to donation rates. However, this is the first study to our knowledge using this data source to examine the cross-sectional association of population characteristics with donation rates.

In summary, we identified several population health factors that were negatively associated with expected kidney donation rate, and after adjusting for the prevalence of these factors, there was no longer a statistically significant difference in the donation rate by DSA Gulf State location. These data suggest the need to discuss population health characteristics when examining kidney allocation policy, to account for potential lower supply of donors and to further address geographic disparities in access to kidney transplantation.

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