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Article

Distance to Kidney Transplant Center and Access to Early Steps in the Kidney Transplantation Process in the Southeastern United States

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Abstract

Background and objectives Access to kidney transplantation requires a referral to a transplant center for medical evaluation. Prior research suggests that the distance that a person must travel to reach a center might be a barrier to referral. We examined whether a shorter distance from patients' residence to a transplant center increased the likelihood of referral and initiating the transplant evaluation once referred.

Design, setting, participants, & measurements Adults who began treatment for ESKD at any Georgia, North Carolina, or South Carolina dialysis facility from 1/1/2012 to 12/31/2015 were identified from the US Renal Data System. Referral (within 1 year of dialysis initiation) and evaluation initiation (within 6 months of referral) data were collected from all nine transplant centers located in that region. Distance was categorized as <15, 15–30, 31–60, 61–90, and >90 miles from the center of a patient's residential zip code to the nearest center. We used multilevel, multivariable-adjusted logistic regression to quantify the association between distance with referral and evaluation initiation.

Results Among 27,250 adult patients on incident dialysis, 9582 (35%) were referred. Among those referred, 58% initiated evaluation. Although patients who lived farther from a center were less likely to be referred, distance was not statistically significantly related to transplant referral: adjusted odds ratios of 1.08 (95% confidence interval, 0.96 to 1.22), 1.07 (95% confidence interval, 0.95 to 1.22), 0.96 (95% confidence interval, 0.84 to 1.10), and 0.87 (95% confidence interval, 0.74 to 1.03) for 15–30, 31–60, 61–90, and >90 miles, respectively, compared with <15 miles (P trend =0.05). There was no statistically significant association of distance and evaluation initiation among referred patients: adjusted odds ratios of 1.14 (95% confidence interval, 0.97 to 1.33), 1.12 (95% confidence interval, 0.94 to 1.35), 1.04 (95% confidence interval, 0.87 to 1.25), and 0.89 (95% confidence interval, 0.72 to 1.11) for 15–30, 31–60, 61–90, and >90 miles, respectively, compared with <15 miles (P trend =0.70).

Conclusions Distance from residence to transplant center among patients undergoing long-term dialysis in the southeastern United States was not associated with increased likelihood of referral and initiating transplant center evaluation.

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Introduction

For most patients with ESKD on dialysis, a referral from a dialysis facility to a transplant center for a medical evaluation is required to initiate the kidney transplant process (1–3). The distance that patients with ESKD must travel to reach a transplant center may influence both the likelihood that they are referred by a provider and also, the likelihood that they present for the medical evaluation at a transplant center once referred. Patients and nephrologists, particularly those in rural locations, may view distance as a barrier (4,5). Concerns related to post-transplant medication cost and access to transportation were frequently reported by patients with ESKD when asked about barriers to initiating or completing the medical evaluation at a transplant center (6–8).

There is some indication that the 262 United States adult transplant centers may not be as geographically widespread as the >7000 dialysis facilities, and thus, they may be less accessible to referred patients on dialysis (9,10). Previous studies suggest the average one-way driving distance from a patient's home to the nearest dialysis facility is 7.9 miles (11), whereas the mean distance between a transplant patient's home and the nearest transplant center is 23 miles (12).

Unlike waitlisting and transplant receipt, early steps in the transplant process, like referral to a transplant center and initiation of the evaluation at that center, are not regularly studied outcomes because this information is not collected in national surveillance data. Examining the characteristics associated with referral and evaluation initiation is critical to the understanding

of disparities in access to kidney transplant because completion of these early steps is necessary to move forward with transplant, and these characteristics may not be the same as factors associated with placement on the waitlist or receipt of a transplant (13). We are hypothesizing that distance may be a more apparent barrier in referral and evaluation initiation because patients may be more easily discouraged from pursuing the complex transplant process at these early steps. To our knowledge, no study has examined the effect of distance on early transplant steps. The purpose of this study was to measure the association of distance to transplant center with timely transplant center referral and evaluation initiation among incident patients with ESKD in the southeastern United States, a region with the nation's lowest transplant rates (14).

Materials and Methods

Cohort Creation

The underlying cohort was identified from the US Renal Data System (USRDS) and consisted of all adults (ages 18–80 years old) with incident ESKD who began dialysis at any Georgia, North Carolina, or South Carolina dialysis facility between January 1, 2012 and December 31, 2015, with follow-up through June 30, 2017. Because patients can be referred prior to ESKD diagnosis, more than once, and to multiple centers, we restricted our population to patients' first nonpreemptive referral event during the study period. A more complete description of cohort exclusion criteria is available in Figure 1. Each transplant center sent referral and evaluation initiation data securely to ESRD Network 6, which served as the data coordinating center (15). This study was approved by the Emory Institutional Review Board (IRB79596).

Referral and Transplant Evaluation Initiation

Referral for transplant and transplant evaluation initiation were determined by transplant center–reported referral or evaluation date, respectively, to any of the nine transplant centers in Georgia, North Carolina, and South Carolina (13,15). Patient's transplant referral and evaluation date were linked with USRDS data, and referral was defined as a referral date occurring within 12 months of dialysis initiation. Among referred patients, patients were considered to initiate transplant evaluation if they presented for evaluation at a transplant center within 6 months of referral. Patient referral and evaluation start data were collected after June 30, 2017 to ensure no loss to follow-up. Specifically, patients had a minimum of 1 year following their dialysis initiation date and 6 months following their referral date to receive a referral or initiate the transplant evaluation, respectively.

Distance

Distance from the patient's residential zip code tabulation area (ZCTA) centroid to the nearest transplant center was estimated in miles as a direct route approximation. We converted each patient's residential zip code at the time of

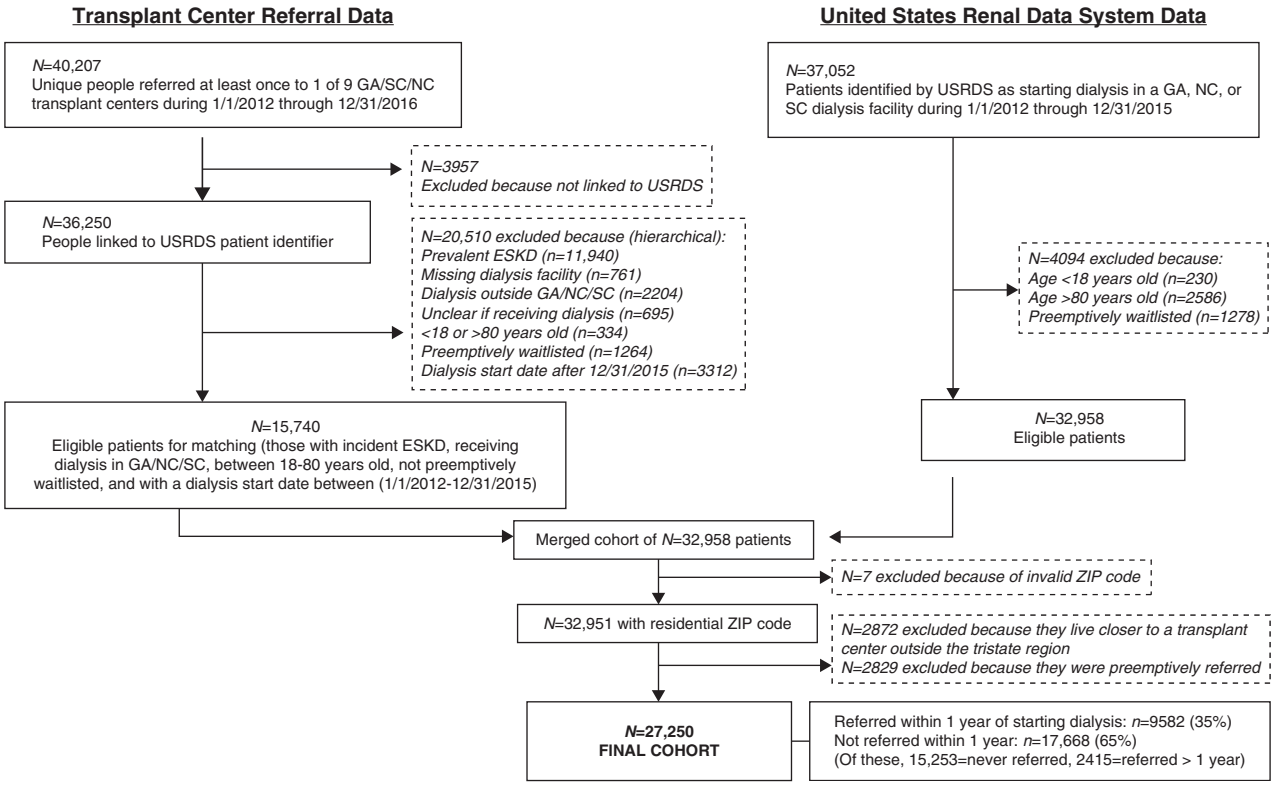

Figure 1. | Data merge and cohort selection to examine the relationship between distance from a patient's residence to the nearest transplant center and access to kidney transplantation resulted in 27,250 incident dialysis patients in the Southeastern United States (GA, NC, and SC). GA, Georgia; NC, North Carolina; SC, South Carolina; USRDS, US Renal Data System.

starting dialysis to ZCTA using a zip-ZCTA crosswalk file (16). The coordinates corresponding to the centroid of each ZCTA were taken from the US Census 2014 data file "mapping ZCTAs to centroids" (17). The US Census Geocoder (18) provided the coordinates associated with the addresses of each transplant center. We also identified coordinates for transplant centers located in neighboring states (Alabama, Tennessee, Florida, Virginia, West Virginia, and Kentucky) and used the SAS "geodist" function to calculate distance in miles from the patient's residential ZCTA centroid to each transplant center. Patients who lived closer to a transplant center outside Georgia, North Carolina, or South Carolina were excluded (n=2872) because it was possible that they could have been referred to one of these centers. Because distance was estimated and could not be assumed to be linear, distance was categorized as <15, 15–30, 31–60, 61–90, and >90 miles. Figure 2 shows the geographic distribution of southeastern dialysis facilities and transplant centers.

Covariates

Patient- and dialysis facility–level characteristics potentially associated with transplant center referral, evaluation, or distance were extracted from the USRDS. Patient-level demographic and clinical characteristics corresponded to the USRDS date on which the patient began dialysis and included age in years, sex, race/ethnicity, attributed cause of ESKD, comorbidities, and primary health insurance type. Facility-level characteristics included for-profit status, hospital based versus free standing, facility size, and number of social workers employed at the facility. The 2014 American Community Survey provided neighborhood-specific sociodemographic/economic information (19). This included the percentage of people in a patient's neighborhood who lived in poverty, had a high school diploma, and identified as black race. A measure of residential remoteness was calculated for each patient using rural-urban commuting area codes that were assigned to zip codes (20). We classified patients as residing in one of three areas: metropolitan, micropolitan, and rural (21).

Statistical Analyses

Cohort characteristics were described overall, by distance, and by referral and evaluation initiation status. Two multivariable multilevel logistic regression models assessed the effect of distance on (*1*) referral (yes/no) and (*2*) evaluation initiation (yes/no) among those referred. The multilevel regression models used facility-specific random effects with an exchangeable correlation structure and robust SEMs to account for correlations between patients from the same dialysis facility. Both models were adjusted for any variable that was significantly associated with distance and the respective outcome in unadjusted analyses. Adjusted odds ratios (aORs) and corresponding 95% confidence intervals (95% CIs) were reported.

We conducted a complete patient analysis; 1937 (7%) and 405 (4%) were excluded for missing covariates from referral and evaluation initiation models, respectively. Missing data for each covariate can be found in Tables 1 and 2. *P* values testing the trend of effect estimates across distance categories were calculated by assigning each person the midpoint/median distance in miles of each category. We assessed interactions of distance by race/ethnicity, socioeconomic status, neighborhood poverty, and rural/urban status. Sensitivity analyses examined distance continuously and categorized using different cut points, and the

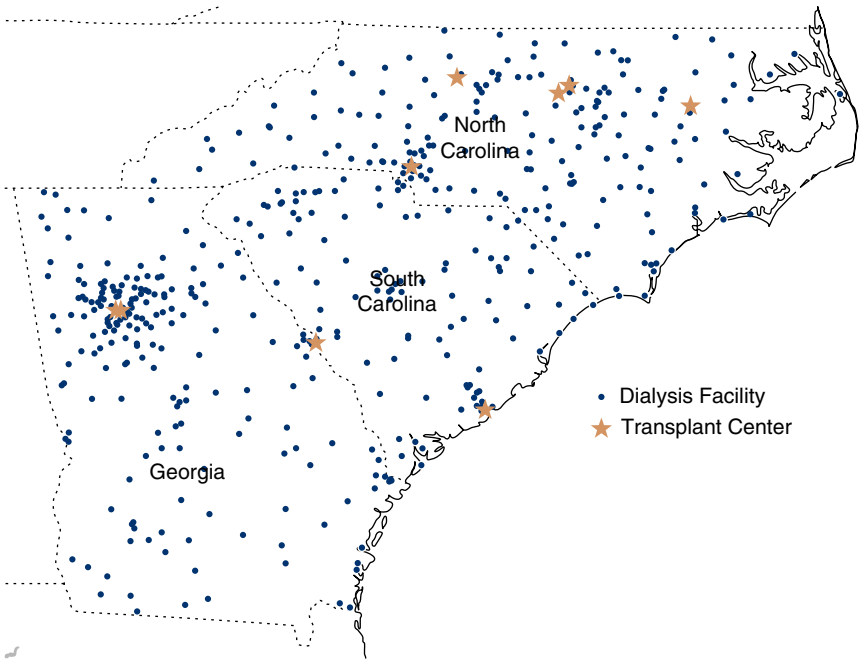

Figure 2. | Georgia, North Carolina, and South Carolina transplant centers (n=9) are not as geographically widespread as dialysis facilities (n=745) in the same Southeastern United States region. Of note, transplant center–associated satellite clinics are not shown here.

Table 1. Demographic and clinical characteristics of southeastern patients on incident dialysis at baseline by patient distance to a transplant center, 2012–2015

Characteristics	Study Population,[a] n=27,250	<15 miles, 5870 (22%)	15–30 miles, 5364 (20%)	31–60 miles, 6959 (26%)	61–90 miles, 6330 (23%)	>90 miles, 2727 (10%)
Selected patient characteristics at the start of dialysis						
Age, yr, mean (SD)	60 (13)	58 (14)	59 (13)	60 (13)	60 (13)	60 (13)
Age category, yr, *N* (%)						
18–29	754 (3)	179 (3)	158 (3)	198 (3)	156 (3)	63 (2)
30–39	1637 (6)	433 (7)	313 (6)	395 (6)	340 (5)	156 (6)
40–49	3572 (13)	860 (15)	727 (14)	838 (12)	771 (12)	376 (14)
50–59	6116 (22)	1342 (23)	1174 (22)	1551 (22)	1430 (23)	619 (23)
60–69	8234 (30)	1726 (29)	1608 (30)	2092 (30)	1990 (31)	818 (30)
70–80	6937 (26)	1330 (23)	1384 (26)	1885 (27)	1643 (26)	695 (26)
Sex, *N* (%)						
Men	15,096 (55)	3282 (56)	3005 (56)	3876 (56)	3457 (55)	1476 (54)
Women	12,154 (45)	2588 (44)	2359 (44)	3083 (44)	2873 (45)	1251 (46)
Race/ethnicity, *N* (%)						
White, non-Hispanic	10,507 (39)	1507 (26)	2334 (44)	3206 (46)	2483 (39)	980 (36)
White, Hispanic	590 (2)	153 (3)	168 (3)	155 (2)	74 (1)	40 (2)
Black, non-Hispanic	15,488 (57)	4022 (69)	2699 (51)	3481 (50)	3634 (58)	1652 (61)
Other race/ethnicity	581 (2)	168 (3)	144 (3)	85 (1)	134 (2)	50 (2)
Attributed cause of ESKD, *N* (%)						
Diabetes	12,098 (46)	2396 (43)	2330 (45)	3148 (47)	2932 (48)	1292 (49)
Hypertension	9856 (38)	2317 (41)	1902 (37)	2419 (36)	2329 (38)	889 (34)
GN	1747 (7)	379 (7)	413 (8)	458 (7)	331 (5)	166 (6)
Other	2504 (10)	546 (10)	506 (10)	696 (10)	487 (8)	269 (10)
Comorbidities, *N* (%)						
BMI≥35 kg/m^2	6747 (25)	1389 (24)	1346 (26)	1793 (26)	1540 (25)	679 (25)
Congestive heart failure	7385 (28)	1558 (27)	1437 (27)	1937 (28)	1714 (28)	739 (27)
Atherosclerotic heart disease	2576 (10)	465 (8)	491 (9)	708 (10)	603 (10)	309 (12)
Other cardiac disease	4585 (17)	749 (13)	900 (17)	1329 (19)	1073 (17)	534 (20)
Cerebrovascular disease (stroke)	2425 (9)	481 (8)	485 (9)	654 (10)	519 (8)	286 (11)
Peripheral vascular disease	2310 (9)	422 (7)	398 (8)	650 (10)	544 (9)	296 (11)
Hypertension	23,927 (89)	5130 (89)	4714 (90)	6118 (89)	5548 (89)	2417 (90)
Diabetes	15,992 (60)	3245 (56)	3111 (59)	4236 (62)	3780 (61)	1620 (60)
Chronic obstructive pulmonary disease	2304 (9)	382 (7)	462 (9)	689 (10)	532 (9)	239 (9)
Cancer	1655 (6)	296 (5)	385 (7)	456 (7)	338 (5)	180 (7)
Tobacco use	2442 (9)	420 (7)	438 (8)	746 (11)	546 (9)	292 (11)
Drug dependence	445 (2)	122 (2.)	85 (2)	117 (2)	83 (1)	38 (1)
Alcohol dependence	497 (2)	101 (2)	98 (2)	132 (2)	112 (2)	54 (2)
Functional status, *N* (%)						
Inability to ambulate	1592 96)	286 (5)	302 (6)	434 (6)	390 (6)	180 (7)
Inability to transfer	777 (3)	122 (2)	158 (3)	223 (3)	185 (3)	89 (3)
Needs assistance with daily activities	2930 (11)	512 (9)	594 (11)	796 (11)	732 (12)	296 (11)
Institutionalized	1648 (6)	357 (6)	328 (6)	432 (6)	371 (6)	160 (6)
Primary health insurance provider, *N* (%)						
Medicare	8474 (32)	1614 (28)	1696 (32)	2306 (34)	1966 (32)	892 (33)
Medicaid	6775 (25)	1441 (25)	1151 (22)	1756 (26)	1699 (27)	728 (27)
Employer group	4824 (18)	1160 (20)	1044 (20)	1135 (17)	1101 (18)	384 (14)
Other coverage	3889 (15)	846 (15)	823 (16)	1022 (15)	822 (13)	376 (14)
No coverage	2841 (11)	690 (12)	545 (10)	642 (9)	645 (10)	319 (12)
Received pre-ESKD nephrology care, *N* (%)	16,753 (71)	3255 (67)	3354 (72)	4434 (72)	4029 (73)	1681 (70)
Patient informed of transplant options, *N* (%)	23,398 (86)	5182 (88)	4561 (85)	5930 (85)	5420 (86)	2305 (85)
Reasons that patient was not informed of transplant options, *N* (%)						
Patient has not been assessed	2126 (8)	359 (6)	442 (8)	588 (8)	558 (9)	179 (7)
Medically unfit	820 (3)	130 (2)	134 (3)	214 (3)	167 (3)	175 (6)
Unsuitable due to age	323 (1)	47 (1)	86 (2)	95 (1)	58 (1)	37 (1)
Other[b]	310 (1)	58 (1)	60 (1)	107 (2)	64 (1)	21 (1)
Selected neighborhood characteristics						
Neighborhood poverty (zip code residents below poverty), *N* (%)						
0%–19% below poverty (versus ≥20% below poverty)	18,126 (67)	3538 (61)	4467 (84)	5019 (73)	3691 (59)	1411 (52)

Table 1. (Continued)

Characteristics	Study Population,[a] n=27,250	<15 miles, 5870 (22%)	15–30 miles, 5364 (20%)	31–60 miles, 6959 (26%)	61–90 miles, 6330 (23%)	>90 miles, 2727 (10%)
Average % black, mean (SD)	36 (24)	49 (28)	32 (20)	28 (20)	36 (22)	39 (21)
Average % high school graduates, mean (SD)	83 (7)	85 (8)	85 (6)	81 (6)	82 (7)	81 (8)
Selected dialysis facility characteristics						
For profit, *N*, %	23,243 (87)	4608 (81)	4546 (87)	6129 (90)	5838 (95)	2122 (79)
Free-standing facility, *N* (%)	26,521 (98)	5674 (97)	5241 (99)	6807 (98)	6183 (99)	2616 (97)
Facility size (no. of patients), *N* (%)						
<25	753 (3)	166 (3)	88 (2)	162 (2)	216 (4)	121 (5)
26–54	5552 (21)	1173(20)	1019 (19)	1703 (25)	1192 (19)	465 (17)
55–78	6191 (23)	1129 (19)	1551 (29)	1274 (18)	1436 (23)	801 (30)
79+	14,532 (54)	3365 (58)	2665 (50)	3790 (55)	3397 (54)	1315 (49)
Patient-to-social worker ratio by quartile, *N* (%)[c]						
<39:1 (quartile 1)	1155 (5)	244 (5)	257 (5)	361 (6)	222 (4)	71 (3)
40:1–74:1 (quartile 2)	5649 (23)	1252 (24)	1333 (26)	1356 (21)	1000 (18)	708 (29)
75:1–102:1 (quartile 3)	7798 (31)	1713 (33)	1412 (27)	1835 (29)	1963 (35)	875 (36)
>102:1 (quartile 4)	10,380 (42)	2016 (39)	2183 (42)	2870 (45)	2506 (44)	805 (33)
Selected geographic measures and characteristics						
Distance in miles to center, mean (SD)	46 (33)	8 (4)	23 (4)	44 (9)	75 (9)	109 (20)
Distance in miles to center, median	38	8	23	43	75	99
Distance in miles to center, (IQR)	(18–69)	(5–11)	(19–26)	(36–52)	(66–82)	(95–114)
Distance in miles to center, (range)	(1–169)	(1–15)	(15–30)	(30–60)	(60–90)	(90–169)
Urban/rural classification, *N* (%)[d]						
Metropolitan	18,643 (68)	5841 (100)	4442 (83)	3171 (46)	3511 (56)	1678 (62)
Micropolitan/rural	8597 (32)	29 (0.5)	912 (17)	3788 (54)	2819 (44)	1049 (38)

BMI, body mass index; IQR, interquartile range.
[a]A total of 84 (0.3%) patients were missing data on race/ethnicity, 1045 (4%) were missing attributed cause of disease, 647 (2%) were missing BMI, 455 (2%) were missing comorbidity information, 447 (2%) were missing primary health insurance provider, 3611 (13%) were missing pre-ESKD nephrology care, 451 (2%) were missing patient informed of transplant options (percentage varies by reason), 606 (2%) were missing for-profit status, 222 (0.8%) were missing facility type (free standing versus hospital based), 222 (1%) were missing total number of patients within facility, 2268 (8%) were missing facility social worker information (or facility has no social workers), and 10 (0.0004%) were missing urban/rural.
[b]Includes psychologically unfit, patient declines information, and other reasons.
[c]Number of patients for every one social worker. This number was calculated only among those facilities that have social workers.
[d]Variable presented descriptively as two categories due to cell counts n<11 to maintain patient confidentiality. Urban/rural classification variable was categorized into three groups (metropolitan, micropolitan, and rural) in both adjusted models presented in Table 3.

main association among a cohort including patients who lived closest to a transplant center outside of the tristate area, excluding patients who died within 12 months of beginning dialysis and including patients representative of an ideal kidney transplant candidate (excluding patients age >65 years old; diagnosed with peripheral vascular disease, coronary heart failure, or cerebrovascular disease; or reported by dialysis facility staff not to be assessed for transplantation due to medical reasons).

Results

Cohort Description

There were 37,052 patients identified by the USRDS as beginning dialysis in a Georgia, North Carolina, or South Carolina dialysis facility between 1/1/2012 and 12/31/2015 (Figure 1). Our final analytic cohort contained 27,250 patients, and over half were men (55%) and black (57%) (Table 1). Average age at dialysis start was 60 years old (SD: 13). Two thirds of the cohort resided in a metropolitan area (68%). The median distance from patient residence to the nearest transplant center was 38 miles (interquartile range [IQR], 18–69). One fifth of patients (22%) lived <15 miles from a transplant center, whereas one tenth (10%) lived >90 miles away. Among the cohort, n=9582 (35%) were referred to a Georgia, North Carolina, or South Carolina transplant center within 1 year of beginning dialysis (Table 2). Among those referred, n=5536 (58%) initiated a transplant evaluation within 6 months of being referred.

Unadjusted Analyses

In unadjusted analyses, patient characteristics varied by distance (Table 1). Over two thirds of patients living <15 miles of a transplant center were black (69%); 26% were white. In general, the percentage of patients with comorbidities was higher with farther distance (*e.g.*, 56% of patients living <15 miles from a center had diabetes versus 60% of patients living >90 miles away).

Similarly, compared with not referred patients, referred patients were more likely to be younger (average age 54 [SD: 13] versus 62 [SD: 12] years old), be men (59% versus 53%), be black (63% versus 54%), have private

Table 2. Demographic, clinical, and dialysis facility characteristics of patients with ESKD who started dialysis at a Georgia, North Carolina, or South Carolina dialysis facility during 2012–2015, whether they were referred to a transplant center in any of the three states within 1 year of beginning dialysis, and whether they initiated a transplant evaluation at a transplant center within 6 months of referral

Selected Patient Characteristics	Study Population,[a] n=27,250	Referred to Center within 1 yr of Dialysis Start among Total Population, n=9582/27,250 (35%)	Evaluated within 6 mo of Referral among Those Referred, n=5536/9582 (58%)
Distance in miles to center, mean (SD)	46 (33)	44 (33)	42 (33)
Distance in miles to center, median	38	36	32
Distance in miles to center, (IQR)	(18–69)	(19–67)	(15–64)
Distance in miles to center, (range)	(1–169)	(1–162)	(1–162)
Distance in miles to nearest transplant center, *N* (%)			
<15	5870 (22)	2206 (23)	1375 (25)
15–30	5364 (20)	2022 (21)	1270 (23)
31–60	6959 (26)	2376 (25)	1359 (25)
61–90	6330 (23)	2075 (22)	1070 (19)
>90	2727 (10)	903 (9)	462 (8)
Urban/rural classification, *N* (%)			
Metropolitan	18,643 (68)	6677 (70)	3975 (72)
Micropolitan	4981 (18)	1674 (18)	894 (16)
Rural	3616 (13)	1229 (13)	667 (12)
Selected patient characteristics at the start of dialysis			
Age, yr, mean (SD)	60 (13)	54 (13)	52 (13)
Age category, yr, *N* (%)			
18–29	754 (3)	451 (5)	327 (6)
30–39	1637 (6)	964 (10)	624 (11)
40–49	3572 (13)	1917 (20)	1223 (22)
50–59	6116 (22)	2517 (26)	1473 (27)
60–69	8234 (30)	2713 (28)	1481 (27)
70–80	6937 (26)	1020 (11)	408 (7)
Sex, *N* (%)			
Men	15,096 (55)	5674 (59)	3368 (61)
Women	12,154 (45)	3908 (41)	2168 (39)
Race/ethnicity, *N* (%)			
White, non-Hispanic	10,507 (39)	3059 (32)	1743 (32)
White, Hispanic	590 (2)	265 (3)	183 (3)
Black, non-Hispanic	15,488 (57)	6003 (63)	3436 (62)
Other race/ethnicity	581 (2)	234 (3)	156 (3)
Attributed cause of ESKD, *N* (%)			
Diabetes	12,098 (46)	4125 (44)	2216 (41)
Hypertension	9856 (38)	3635 (39)	2132 (40)
GN	1747 (7)	835 (9)	561 (11)
Other	2504 (10)	696 (8)	444 (8)
Comorbidities, *N* (%)			
BMI≥35 kg/m^2	6747 (25)	2418 (26)	1316 (24)
Congestive heart failure	7385 (28)	2082 (22)	1050 (19)
Atherosclerotic heart disease	2576 (10)	638 (7)	310 (6)
Other cardiac disease	4585 (17)	1206 (13)	626 (12)
Cerebrovascular disease (stroke)	2425 (9)	601 (6)	285 (5)
Peripheral vascular disease	2310 (9)	571 (6)	249 (5)
Hypertension	23,927 (89)	8572 (91)	4933 (90)
Diabetes	15,992 (60)	5373 (57)	2953 (54)
Chronic obstructive pulmonary disease	2304 (9)	481 (5)	189 (4)
Cancer	1655 (6)	308 (3)	167 (3)
Tobacco use	2442 (9)	838 (9)	399 (7)
Drug dependence	445 (2)	128 (1)	48 (1)
Alcohol dependence	497 (2)	131 (1)	64 (1)
Functional status, *N* (%)			
Inability to ambulate	1592 96)	186 (2)	63 (1)
Inability to transfer	777 (3)	64 (1)	22 (0.4)
Needs assistance with daily activities	2930 (11)	441 (5)	180 (3)

Table 2. (Continued)

Selected Patient Characteristics	Study Population,[a] n=27,250	Referred to Center within 1 yr of Dialysis Start among Total Population, n=9582/27,250 (35%)	Evaluated within 6 mo of Referral among Those Referred, n=5536/9582 (58%)
Institutionalized	1648 (6)	149 (2)	52 (1)
Primary health insurance provider, *N* (%)			
Medicare	8474 (32)	2364 (25)	1228 (23)
Medicaid	6775 (25)	2185 (23)	1119 (21)
Employer group	4824 (18)	2355 (25)	1605 (29)
Other coverage	3889 (145)	1149 (12)	645 (12)
No coverage	2841 (11)	1420 (15)	867 (16)
Received pre-ESKD nephrology care, *N* (%)	16,753 (71)	5926 (71)	3391 (70)
Patient informed of transplant options, *N* (%)	23,398 (86)	8593 (90)	4989 (90)
Reasons that patient was not informed of transplant options, *N* (%)			
Patient has not been assessed	2126 (8)	739 (8)	408 (7)
Medically unfit	820 (3)	75 (1)	30 (1)
Unsuitable due to age	323 (1)	19 (0.2)	7 (0.1)
Other[b]	310 (1)	62 (1)	34 (1)
Selected neighborhood characteristics			
Neighborhood poverty (zip code residents below poverty), *N* (%)			
0%–19% below poverty (versus ≥20% below poverty)	18,126 (67)	6418 (68)	3761 (69)
Average % black, mean (SD)	36 (24)	37 (24)	38 (25)
Average % high school graduates, mean (SD)	83 (7)	83 (7)	84 (7)
Selected dialysis facility characteristics			
For profit, *N* (%)	23,243 (87)	8178 (87)	4702 (86)
Free-standing facility, *N* (%)	26,521 (98)	9423 (99)	5440 (99)
Facility size (no. of patients), *N* (%)			
<25	753 (3)	260 (3)	175 (3)
26–54	5552 (21)	1996 (21)	1194 (22)
55–78	6191 (23)	2314 (24)	1305 (24)
79+	14,532 (54)	4960 (52)	2830 (51)
Patient-to-social worker ratio by quartile, *N* (%)[c]			
<39:1 (quartile 1)	1155 (5)	403 (5)	246 (5)
40:1–74:1 (quartile 2)	5649 (23)	2054 (24)	1265 (25)
75:1–102:1 (quartile 3)	7798 (31)	2653 (30)	1555 (30)
>102:1 (quartile 4)	10,380 (42)	3628 (42)	2048 (40)

[a]A total of 84 (0.3%) patients were missing data on race/ethnicity, 1045 (4%) were missing attributed cause of disease, 647 (2%) were missing BMI, 455 (2%) were missing comorbidity information, 447 (2%) were missing primary health insurance provider, 3611 (13%) were missing pre-ESKD nephrology care, 451 (2%) were missing patient informed of transplant options (percentage varies by reason), 606 (2%) were missing for-profit status, 222 (0.8%) were missing facility type (free standing versus hospital based), 222 (0.8%) were missing total number of patients within facility, 2268 (8%) were missing facility social worker information (or facility has no social workers), and 10 (0.0004%) were missing urban/rural.
[b]Includes psychologically unfit, patient declines information, and other reasons.
[c]Number of patients for every one social worker. This number was calculated only among those facilities that have social workers.

health insurance (25% versus 14%), and live closer to a transplant center (median distance, 36 [IQR, 17–67] versus 40 [IQR, 19–70] miles) (Table 2). Referred patients were less likely to have certain comorbidities, including heart and cerebrovascular disease–related issues, diabetes, cancer, and chronic obstructive pulmonary disease. Among referred patients, those who initiated a transplant evaluation within 6 months of referral tended to be younger (52 [SD: 13] versus 56 [SD: 13] years) and live closer to a transplant center (median distance, 32 [IQR, 15–64] versus 41 [IQR, 19–73] miles). Patients living <15 miles from a transplant center had higher proportions of referral compared with those who lived >90 miles away (38% versus 33%). There is a more pronounced decrease in the proportion of referred patients initiating evaluation living <15 miles from a center compared with those who live >90 miles away (62% versus 51%) (Table 3).

Multivariable Analyses

In adjusted analyses, the distance that a patient lived from the nearest transplant center was not statistically significantly associated with referral or evaluation initiation; trends for each of these early steps were also not statistically significant (referral: aORs of 1.08 [95% CI, 0.96 to 1.22], 1.07 [95% CI, 0.95 to 1.22], 0.96 [95% CI, 0.84 to 1.10], and 0.87 [95% CI, 0.74 to 1.03] for 15–30, 31–60, 61–90, and >90 miles, respectively, compared with <15 miles; P trend =0.05; evaluation initiation: aORs of 1.14 [95% CI, 0.97 to 1.33], 1.12 [95% CI, 0.94 to 1.35], 1.04 [95% CI, 0.87 to 1.25], and 0.89 [95% CI, 0.72 to 1.11] for 15–30, 31–60, 61–90, and >90 miles, respectively, compared with <15 miles; P trend =0.70]. The association of distance did not vary by patient race/ethnicity, insurance type, poverty level of the patient's neighborhood, or urban/rural classification.

Sensitivity Analyses

Results from adjusted models that used different distance categorizations were similar to reported results. Cut-point selections for sensitivity models included (*1*) <20, 20–45, and >45 miles; (*2*) <15, 15–30, 31–60, and >60 miles; and (*3*) <20, 20–50, 51–90, and >90 miles. When adjusted models were run with distance as a continuous variable, results were similar to the reported trend test P values found by using the midpoint/median of each distance category (per 10-mile increment: aOR, 0.88 per 10-mile increment; 95% CI, 0.76 to 1.00; P value =0.08 for referral and for evaluation initiation: aOR, 0.99 per 10-mile increment; 95% CI, 0.97 to 1.01; P value =0.23). The association of distance on referral and evaluation was also similar after excluding patients who died (n=1993) within 12 months of beginning dialysis from the analysis and excluding patients who did not meet ideal kidney transplant criteria (n=15,265). Within the subset of nonpreemptively referred patients who were excluded for living closer to a transplant center outside of the tristate area (n=2705), the majority of the patients lived >90 miles from the nearest Georgia, North Carolina, or South Carolina transplant center (<15 miles: 112 [4%]; 16–30 miles 160 [6%]; 31–60 miles 582 [22%]; 61–90 638 [24%]; and >90 miles 1213 [45%]). The association of distance on referral and evaluation was also similar to reported results.

Discussion

In this study of southeastern United States patients on dialysis, we did not find an association between distance from patient zip code to the nearest transplant center and

Table 3. Results from adjusted models showing effect of distance on patient with ESKD referral and transplant center evaluation initiation, 2012–2015

Distance, miles	N (%)	Odds of Referral within 1 yr of Dialysis Start, n=27,250[a]		
		aOR (95% CI)	P Value	Test for Trend
Proportion of patients referred by distance category				
<15	2206 (38)	1.00 (reference)		0.05
15–30	2022 (38)	1.08 (0.96 to 1.22)	0.19	
31–60	2376 (34)	1.07 (0.95 to 1.22)	0.28	
61–90	2075 (33)	0.96 (0.84 to 1.10)	0.57	
>90	903 (33)	0.87 (0.74 to 1.03)	0.12	
Proportion of patients initiating evaluation by distance category among those referred		Odds of initiating evaluation within 6 mo of referral among those referred, n=9598[b]		
<15	1375 (62)	1.00 (reference)		0.70
15–30	1270 (63)	1.14 (0.97 to 1.33)	0.11	
31–60	1359 (57)	1.12 (0.94 to 1.35)	0.21	
61–90	1070 (52)	1.04 (0.87 to 1.25)	0.67	
>90	462 (51)	0.89 (0.72 to 1.11)	0.31	

aOR, adjusted odds ratio; 95% CI, 95% confidence interval.
[a]Model was adjusted for age, race, attributed cause of ESKD, atherosclerotic heart disease, other cardiac disease, cerebrovascular disease, peripheral vascular disease, diabetes, chronic obstructive pulmonary disease, cancer, insurance type, facility for-profit status, neighborhood race, neighborhood education, urban/rural, and state (model n=25,321).
[b]Model was adjusted for age, race, attributed cause of ESKD, atherosclerotic heart disease, other cardiac disease, cerebrovascular disease, peripheral vascular disease, diabetes, chronic obstructive pulmonary disease, insurance type, neighborhood race, neighborhood education, neighborhood poverty, urban/rural, and state (model n=9179).

referral for kidney transplant evaluation or evaluation initiation at a transplant center. Although the farthest (>90 miles) compared with the shortest (<15 miles) distances were associated with 13% and 11% lower likelihood of referral and evaluation initiation, respectively, the associations were not statistically significant, and the trend analyses did not support a dose-response relationship between distance and these early steps.

We found these results surprising given the previous qualitative studies that cited distance as a barrier to referral (4,5) for patients with ESKD. Our findings also generally contradict other literature demonstrating associations between distance and reduced access to both primary care and specialized medical services for chronic conditions (22–25). Transportation cost and access are more important barriers to referral and evaluation initiation compared with distance. Populations of patients with ESKD report transportation concerns as barriers to transplant access (6–8), and other studies among general populations have shown that transportation barriers (including lack of transportation in the form of car or mass transit and transportation cost) are important impediments to health care access in the United States (26–28). Furthermore, studies have shown that, although transportation is often more expensive for people living farther from clinics compared with those living closer, transportation is often reported as a concern equally among both rural and urban residents (28,29), suggesting that transportation barriers affect patients regardless of distance. Similarly, it could be that travel time rather than distance is a more important measure when examining disparities in kidney transplant access (30). For example, a person living in an urban area <15 miles from a transplant center who must coordinate bus schedules with medical appointment times may spend more time in transit than a person living 40 miles away who is transported in a car. Alternatively, other factors, like access to childcare or elderly care and time off from work, may be more important predictors of referral or evaluation initiation than distance.

Previous research has examined patient travel distance in relation to waitlist placement and kidney transplantation access. However, associations of distance with these later steps in the transplantation process across prior studies are inconsistent, and it is unclear whether this could be due to differences in study populations (*i.e.*, pediatric versus adult patients with ESKD), time periods, geographic locations (Canada versus the United States), or other factors. Two studies reported that patients living farther from the nearest transplant center had a reduced likelihood of receiving a transplant (31,32), whereas two other studies reported no association of distance with transplantation or placement on the waitlist (33,34), and one study indicated that adults living farther from a transplant center were more likely to receive a transplant than adults living closer (35). One study analyzed the association between distance to transplant center and waitlist placement in the same three states as our study (Georgia, North Carolina, and South Carolina) but during the years 1998–2002, and found no association with distance (33). A separate but similar study also used USRDS data but examined the entire United States adult population with incident ESKD during 1995–2007 (n=699,751) (35). Receipt of a kidney transplant was the primary outcome. A study using USRDS data from 1995 to 2007 examined the association of receipt of a kidney transplant and longer distances (0–15, 16–50, 51–100, 101–136, 137–231, 232–310, and >310 miles) compared with our study (<15, 15–30, 31–60, 61–90, and >90 miles), and it found that patients living farther (>15 miles) from a transplant center were more likely to receive a transplant compared with patients living within 15 miles of a transplant center (35). The authors speculated that this could happen if patients with ESKD living farther from a transplant center were (*1*) more motivated to pursue transplantation, (*2*) less likely to originally initiate dialysis, or (*3*) completed transplant evaluation faster with the assistance of physicians who may be aware of the potential logistical barriers incurred by living farther from a center.

Distance to a transplant center may be more likely to have an effect on earlier steps in the kidney transplant process, indicating a need to examine the outcomes of referral and evaluation initiation. For example, one study found that black patients with ESKD were more likely to be referred to a transplant center compared with white patients but were less likely placed on the waitlist (13). Our results suggested a slightly more notable effect of distance and a decreased likelihood of referral compared with the lack of association between distance and evaluation initiation among patients referred, indicating that factors associated with referral may differ from those associated with evaluation. The decision to refer a patient may be directed more by the nephrologist's perceptions, whereas evaluation initiation may be more dependent on a patient's resources, perceptions, and motivations. Explaining the role that distance may play on timely referral and evaluation initiation can elucidate and inform intervention efforts required to improve equity in access to transplantation, particularly with respect to geographic disparities.

Our study has limitations. First, our results may not be generalizable to other United States regions where a higher proportion of patients live >100 miles from a transplant center because 95% of our cohort lived within 100 miles of a transplant center. Second, we may have misclassified distance estimates due to the use of the centroid of patients' residential ZCTA; however, we broadly categorized distance in our analyses to minimize any effect of this imprecision. Third, residential zip code was defined by the patient's home residence location at the time of beginning dialysis, and patients could have moved after beginning dialysis. However, any resulting distance misclassification may not be severe because only 11% of Americans moved between 2015 and 2016, and of Americans who moved, over two thirds stayed within the same county (36). Fourth, our data did not capture facility referrals or center evaluations that occurred outside the three states. We thus excluded patients who lived closest to a transplant center outside the tristate region because they may have been more likely referred to one of these outside transplant centers. Because these excluded patients were more likely to live the farthest from a Georgia, North Carolina, or South Carolina transplant center, including these patients in the study cohort would have made it impossible to discern whether any lack of referral was due to distance or instead, because a referral occurred at an outside transplant center, and this exclusion may have attenuated the

effects that we saw. Fifth, four of the nine centers in the southeastern United States offer at least one satellite location where patients living far away from the center can be evaluated. We are unable to discern whether a patient was evaluated at a transplant center or an associated satellite clinic in our transplant center–reported data, which also may have tempered the examined associations.

We found that distance from patient zip code to the nearest transplant center was not associated with the likelihood of referral or transplant evaluation initiation in Georgia, North Carolina, or South Carolina. Results suggest that distance to a transplant center may be a barrier for a subset of patients living >90 miles from the nearest transplant center in the southeastern United States, and those patients may benefit from additional transplant center–associated satellite locations or a more streamlined evaluation process that reduces the number of visits that a patient needs to make to a center to complete the evaluation. However, these results suggest that distance is not the primary driving force in accessing these early steps in the transplant process. Other unmeasured factors in the same genre as distance, such as travel time or transportation options, may have a larger effect on these early steps and should be more robustly explored. Future studies outside of the southeastern United States examining the association between distance and access to early steps in the kidney transplant process should be conducted to observe whether there is heterogeneity in this association across geographic regions.

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