County-Level Dialysis Facility Supply and Distance Traveled to Facilities among Incident Kidney Failure Patients

Alexis F. Velázquez,1 Rebecca Thorsness2,3 Amal N. Trivedi,3,4 and Kevin H. Nguyen3

Key Points
- The number of county-level dialysis facilities has increased between 2012 and 2019.
- Patients in counties with no dialysis facilities traveled further to start treatment than those in counties with three or more facilities.

Abstract
Background The availability of dialysis facilities and distance traveled to receive care can impact health outcomes for patients with newly onset kidney failure. We examined recent changes in county-level number of dialysis facilities between 2012 and 2019 and assessed the association between county-level dialysis facility supply and the distance incident kidney failure patients travel to receive care.

Methods We conducted a cross-sectional study of 828,427 adult patients initiating in-center hemodialysis for incident kidney failure between January 1, 2012, and December 31, 2019. We calculated the annual county-level number of dialysis facilities, and counties were categorized as having zero, one, two, or three or more dialysis facilities at the time of treatment initiation. We then measured the distance traveled between a patient’s home address and dialysis facility at treatment initiation (in miles) and evaluated the association between county-level number of dialysis facilities and distance traveled to initiate treatment.

Results The average annual county-level number of facilities increased from 1.8 to 2.3 between 2012 and 2019. In our study period, 5% of incident adult kidney failure patients resided in a county that had zero dialysis facilities between 2012 and 2019. Compared with counties with three or more dialysis facilities, patients living in counties with no facilities in our study period traveled 14.3 miles (95% CI, 13.4 to 15.2) further for treatment.

Conclusions Kidney failure patients in counties that had no dialysis facilities traveled further, limiting their access to dialysis. Counties with no dialysis facilities at the end of the study period were more rural and had higher poverty than other counties.

Introduction
Kidney failure is the stage of CKD at which point a patient requires kidney transplantation or maintenance dialysis, most commonly hemodialysis, for survival. Maintenance hemodialysis, which is provided at certified dialysis facilities and is typically delivered to patients in multihour sessions up to three times a week, is the primary treatment modality for kidney failure patients. Therefore, availability of and proximity to a dialysis facility is critical for maintaining access to this life-saving therapy. Peritoneal dialysis and home hemodialysis are alternative, less prominent treatment modalities for kidney failure. These treatments are administered at home, and some studies suggest that their use increases as travel distance increases; however, they offer their own sets of challenges, including more stringent medical and social requirements.

According to the US Renal Data System, total incident kidney failure has increased over the last decade, and along with it, there has been a gradual increase in the number of facilities that provide dialysis (1,2). However, the availability of dialysis facilities throughout the United States may vary geographically (3). Understanding whether there are disparities in dialysis facility availability is important, particularly considering the disproportionate impact of kidney failure in socially vulnerable populations and wide geographic variation of kidney failure incidence, access to nephrology care, and transplantation rates (4–6). More
granular, county-level estimates can inform local policy decisions, resource allocation, or targeted interventions. Although studies have described the health effects of increased travel distance in other care settings, such as transplant outcomes, emergency room utilization, and progression of cancer staging, less focus has been placed on the country-wide, county-level supply of dialysis facilities and distance traveled (7–9). One study examining geographic disparities in dialysis patient travel suggests that rural patients travel longer distances than dialysis patients in urban areas (10). Despite its potential impact on access to care and health outcomes for kidney failure patients, the disparity in travel caused by county-level dialysis facility supply has not been adequately studied.

In this study, we described national and county-level trends in the number of dialysis facilities available between 2012 and 2019 in the United States. We then compared patient-level sociodemographic and clinical characteristics on the basis of county-level number of dialysis facilities. Lastly, we calculated the distance between patients’ home addresses and the dialysis facility at the time they initiated treatment.

Materials and Methods

Data Sources and Study Population

The study sample included adults aged ≥18 years who developed incident kidney failure and were treated with in-center hemodialysis between January 1, 2012, and December 31, 2019. Incident patients were identified using data from the Renal Management Information System Medical Evidence Form (CMS 2728) (11), which collects sociodemographic and clinical information at treatment initiation, and information about the dialysis facility where treatment was initiated. Using the dialysis facility provider number, we linked patient-level CMS 2728 data to publicly available data from Dialysis Facility Compare, which includes information on all dialysis facilities nationwide certified by the Medicare program (2). Characteristics reported include facility address, for-profit status, chain ownership (e.g., DaVita, Fresenius), total number of dialysis stations, date of certification, measures of clinical quality and patient experience, and indicators for whether the facility offers in-center hemodialysis, peritoneal dialysis, or home hemodialysis training. Although data are collected and reported quarterly, we used each dialysis facility’s first submission of each year to obtain our facility characteristics. To describe county-level variation further, we incorporated county-level population characteristics (age composition, sex composition, racial and ethnic composition, rurality, educational attainment, proportion living below the federal poverty level, and uninsured rate; Supplemental Table 1). Using previously described methods (12,13), we used mailing addresses obtained from the CMS 2728 to geolocate both patients and facilities using ArcGIS spatial software v10.5.1 (ESRI). We excluded a small proportion of patients (2%) who were either missing a dialysis facility provider number or received care at a Veterans Health Administration dialysis facility, which are not included in Dialysis Facility Compare. Because our study focused on distance traveled, we also excluded patients receiving home dialysis, which was approximately 10% of the incident kidney failure population in our study period (Supplemental Figure 1).

Measures

We calculated the county-level number of dialysis facilities and county-level number of dialysis facilities per 1000 incident adult kidney failure patients for each year from 2012 to 2019. We then estimated the association between county-level dialysis facility supply and distance traveled to initiate treatment. On the basis of the distribution of annual county-level number of facilities, we developed the following four categories: zero, one, two, and three or more facilities. To approximate patient travel distance, we then calculated the straight-line distance in miles between a patient’s mailing address at the time of initiation and the dialysis facility where they initiated treatment, hereafter referred to as “distance to dialysis facility” using the Stata package geodist (14). In our main analysis, we excluded a small proportion (0.4%) of incident patients for whom the distance was >200 miles.

Statistical Analyses

We used Pearson’s chi-squared tests and ANOVA to examine differences in patient- and county-level characteristics by county-level dialysis facility supply. We then used multivariable linear regression models to estimate the association between county-level supply and distance to dialysis facility, where our unit of analysis was the patient. We adjusted for patient-level factors (age, sex, race and ethnicity, health insurance type, primary cause of kidney failure) variables that influence a patient’s need to travel for dialysis initiation. Additionally, we adjusted county-level factors (unemployment rate, unemployment rate, proportion of the county living below the federal poverty level, and urban/rural status) that may impact a patient’s distance from their dialysis facility. Standard errors were clustered at the county level. All analyses were performed using Stata v15.0 (StataCorp, College Station, TX). The study protocol was approved by the Institutional Review Board at Brown University and CMS Privacy Board. The study met the STROBE standards for observational studies.

Sensitivity Analyses

We present county-level and facility-level characteristics (e.g., number of stations, chain ownership) by county-level dialysis facility supply. To assess the robustness of our analyses, we included alternative definitions of county-level dialysis facility supply. Specifically, we assessed differences in distance to dialysis facility on the basis of whether patients resided in a county with zero facilities at the time of treatment initiation, whether patients crossed county lines to initiate treatment, and whether patients crossed state lines to initiate treatment (Supplemental Table 4). In other sensitivity analyses, we measured facility supply as annual county-level facilities per capita and county-level facilities per 1000 incident kidney failure patients (Supplemental Table 5 and 6) (15). In these analyses we divided counties into quartiles and compared distance traveled for patients residing in counties in the lowest quartile with those residing in the highest quartiles. To assess the role of population density on our results, we measured differences in travel distance on the basis of a county’s urban/rural continuum code (Supplemental Table 7). Lastly, to contextualize our results further, we also calculated the
change in distance traveled before versus after a county lost all its dialysis facilities (Supplemental Table 8).

**Results**

**Changes in County-Level Dialysis Facility Supply**

From 2012 to 2019, there was a net increase in the average county-level number of dialysis facilities from 1.8 to 2.3 among all counties. Additionally, there was an increase in the county-level number of dialysis facilities per 1000 incident patients from 70.3 to 76.7 between 2012 and 2019 (Figure 1).

**Characteristics of Incident Kidney Failure Patients**

Our population included 828,427 adults who developed incident kidney failure and initiated in-center hemodialysis treatment between 2012 and 2019 ($M_{age}$=63.6 years [SD 14.6 years], 43% women, 27% Black, 15% Hispanic; Table 1). Just over three-quarters (78%) of the patient population were covered by Medicare, Medicaid, or both, and 6% were uninsured. Just over three-quarters (77%) of all incident kidney failure was attributed to either hypertension or diabetes, and 61% of all patients had some form of pre–kidney failure nephrology care. The mean eGFR, a measure of kidney function, was 9.6 ml/min per 1.73 m² (SD 5.1 ml/min per 1.73 m²) for the overall population. The mean eGFR of patients residing in counties that had zero dialysis facilities during the study period was 10.1 ml/min per 1.73 m² (SD 5.1 ml/min per 1.73 m²) compared with 9.4 ml/min per 1.73 m² (SD 5.1 ml/min per 1.73 m²) among patients residing in counties that had three or more dialysis facilities during the study period. County-level characteristics are presented in Supplemental Table 2.

**County Characteristics**

Our study included a total of 25,128 county-years in the 50 states in the United States and District of Columbia (Supplemental Table 2). Approximately 40% of counties had zero dialysis facilities during our study period. Nationally, the median number of facilities per county was one (interquartile range 0–2 facilities per county). On average, counties with zero facilities or one facility were more rural and had lower annual average populations and slightly higher rates of individuals living below poverty and uninsurance rates compared with three or more facilities. Among all dialysis facilities in our study, 25% offered home hemodialysis training, 47% offered peritoneal dialysis, and counties with only one dialysis facility were more likely to offer home hemodialysis or peritoneal dialysis than counties with three or more facilities. Additionally, counties with fewer dialysis facilities had lower average numbers of stations per facility: counties with one dialysis facility had

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**Figure 1.** Trends in County-Level Dialysis Facility Supply. (A) Average county-level number of dialysis facilities. (B) Average county-level number of dialysis facilities per 1000 incident adult patients.
an average of 8.7 (SD 28.2) stations per facility, and counties with three or more facilities had 19 (SD 21.3) stations per facility (Supplemental Table 3). Inversely, counties with one dialysis facility had 132.9 (SD 160.1) dialysis facilities per 1000 incident patients, whereas counties with three or more dialysis facilities had 70.8 (SD 51.9) dialysis facilities per 1000 incident patients (Supplemental Table 2).

Distance to Dialysis Facility at Treatment Initiation

Patients in counties that had no facilities traveled 25.2 miles (SD 20.5 miles) at treatment initiation, those in counties with one facility traveled 12.1 miles (SD 16.5 miles), and those in counties with two facilities traveled 8.6 miles (SD 12.7 miles; Table 2). Comparatively, the distance traveled at dialysis initiation for patients living in counties with three or more facilities traveled an average of 5.5 miles (SD 9 miles) In unadjusted models, patients who lived in counties that had no facilities traveled significantly further (19.3 miles; 95% confidence interval [CI], 18.4 to 20.2 miles) than patients in counties that had three or more facilities. Interestingly, patients in counties that had one (6 miles; 95% CI, 5.6 to 6.5 miles) or two facilities (2.8 miles; 95% CI, 2.4 to 3.1 miles) traveled further than patients in counties with three or more facilities.

In adjusted models, the associations between change in county-level dialysis facility supply and distance to a dialysis facility were comparable with unadjusted analyses, although attenuated in magnitude. Compared with incident patients in counties with three or more facilities, those in counties with no facilities traveled further (14.3 miles; 95% CI, 13.4 to 15.2 miles) after adjusting for demographics and county-level socioeconomic factors. This suggests that the difference in travel distance among the patients in counties with few dialysis facilities can be partially explained by patient demographics and county-level socioeconomic factors. Further, incident patients in counties with one facility (2.7 miles; 95% CI, 2.1 to 3.3 miles) and

### Table 1. Characteristics of patients with incident kidney failure by county-level number of dialysis facilities 2012–2019

| Characteristic | Overall | County-Level Number of Dialysis Facilities |
|---------------|---------|--------------------------------------------|
|               | n (% of incident patients) | 0 | 1 | 2 | 3 or More |
|               | 828,427 (100) | 39,322 (5) | 94,594 (11) | 71,729 (9) | 622,782 (75) |
|               | Age, mean (SD) | 63.6 (14.6) | 64.5 (13.8) | 64.2 (14.1) | 64.2 (14.2) | 63.4 (14.8) |
| Age, yr, %    | 11     | 9    | 10   | 10   | 11   |
| 18–44         | 38     | 37   | 37   | 37   | 38   |
| 45–64         | 27     | 29   | 29   | 28   | 26   |
| 65–75         | 25     | 25   | 25   | 25   | 25   |
| 75+           | 43     | 42   | 43   | 43   | 42   |
| Women         | 52     | 76   | 72   | 68   | 46   |
| Race and ethnicity, % | 49     | 56   | 55   | 55   | 47   |
| White, non-Hispanic | 14     | 10   | 10   | 11   | 15   |
| Black, non-Hispanic | 11     | 9    | 9    | 10   | 11   |
| Hispanic      | 6      | 3    | 4    | 3    | 7    |
| Other, non-Hispanic | 15     | 6    | 6    | 7    | 18   |
| Insuranc type at treatment initiation, % | 15     | 14   | 15   | 14   | 15   |
| Dual eligible | 49     | 56   | 55   | 55   | 47   |
| Medicare      | 14     | 10   | 10   | 11   | 15   |
| Medicaid      | 11     | 9    | 9    | 10   | 11   |
| Employer      | 6      | 5    | 5    | 5    | 6    |
| Other         | 6      | 5    | 5    | 5    | 6    |
| Uninsured     | 6      | 5    | 5    | 5    | 6    |
| Primary cause, % | 48     | 50   | 49   | 49   | 48   |
| Diabetes      | 28     | 25   | 25   | 26   | 30   |
| Hypertension  | 23     | 26   | 26   | 25   | 23   |
| Other         | 61     | 64   | 67   | 66   | 59   |
| Received pre-dialysis nephrology care, % | 24     | 24   | 23   | 22   | 24   |
| Yes           | 15     | 12   | 11   | 12   | 17   |
| No            | 23     | 26   | 26   | 25   | 23   |
| Unknown       | 81     | 82   | 79   | 80   | 81   |
| Vascular access type, % | 16     | 16   | 18   | 17   | 16   |
| Catheter      | 3      | 2    | 3    | 3    | 3    |
| AVF           | 9.6 (5.1) | 10.1 (5.1) | 9.8 (5.0) | 9.9 (5.1) | 9.4 (5.1) |
eGFR at treatment initiation, mean (SD)b

\[\text{AVF, arteriovenous fistula.}\]

\[\text{a} P < 0.001 \text{ for all comparisons using Pearson’s chi-squared tests or ANOVA (continuous age and eGFR), with the exception of women, where } P = 0.001.\]

\[\text{b} \text{GFR used the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. eGFR was calculated using serum creatinine levels from CMS 2728 and did not correct for race.}\]
Discussion

We estimated national and county-level trends in the number of dialysis facilities in the United States. In recent years, there has been a net increase in the number of dialysis facilities in the United States; however, approximately 40% of counties had zero dialysis facilities during our study period. Counties that did not have dialysis facilities or only had one facility over the study period tended to be smaller, rural counties with higher rates of uninsurance, and slightly higher levels of poverty. Additionally, patients with zero facilities in their county traveled further to initiate dialysis treatment when compared with patients in counties with three or more facilities. Although smaller in magnitude, counties with one or two facilities also had to travel further than counties with larger dialysis facility supply. Dialysis facilities continue to be concentrated in more populated areas. However, there appeared to be an inverse relationship between the number of dialysis facilities per county and the number of facilities per 1000 incident kidney failure patients: counties with three or more facilities had fewer county-level facilities per 1000 incident kidney failure patients than counties with one facility. This could be interpreted in a few ways. First, this could reflect more incident kidney failure patients in more urban areas. Alternatively, it could suggest a greater need for more dialysis facilities in more urban areas. However, it is important to note that counties with three or more facilities also had a higher average number of stations than counties with one or two facilities; therefore, it is difficult to draw a conclusion (Supplemental Table 3).

Our study adds three important novel findings to the literature. First, to the authors’ knowledge, this is the first known study assessing changes in county-level dialysis facility availability in the last ten years, with prior studies focusing on national estimates. Second, we described characteristics of counties that have zero dialysis facilities, and found that these counties, which were rural, had higher uninsurance rates and higher percentages of the county living below the poverty line. Third, we calculated the distance a patient travels to initiate dialysis on the basis of county-level facility supply, which builds upon prior work that has explored the association between distance to dialysis facilities on kidney failure patients’ health outcomes (10,16). Although several studies have evaluated the impact of limited dialysis facility access, few studies have investigated the distribution and patient-level characteristics on the basis of availability of dialysis facilities. Limited availability of dialysis facilities may limit the access to maintenance dialysis for kidney failure patients and could ultimately impact their health outcomes, such as ability to receive a kidney transplant (7). Additionally, other work has found that longer travel times among kidney failure

Sensitivity Analyses

County-level and facility-level characteristics by county-level supply of dialysis facilities are presented in Supplemental Tables 2 and 3, respectively. Compared with counties with at least one dialysis facility, patients residing in counties with no dialysis facilities at treatment initiation traveled 13 miles further (95% CI, 12 to 13.9 miles) in adjusted models (Supplemental Table 4). In adjusted models, 19% of patients traveled across county lines to access their dialysis facility and, on average, traveled 13.2 miles further (95% CI, 12.5 to 13.9 miles) than patients who did not cross county lines. Additionally, about 2% of patients traveled across state lines to initiate treatment and, compared with those who did not cross state lines, traveled 14.7 miles further (95% CI, 12.4 to 16.9 miles) in adjusted models. Estimates were robust to other alternate specifications of facility-level supply (Supplemental Tables 5 and 6). Analyses assessing variation by population density suggest that patients residing in noncore counties, or counties with the lowest population density, traveled nearly 18 miles more than patients residing in large central metropolitan counties (Supplemental Table 7). Among patients living in counties that lost all of their facilities in the study period, the distance traveled to dialysis facilities before versus after all closures increased by 2.9 miles (95% CI, 0.4 to 6.14 miles; Supplemental Table 8).

Table 2. Association between county-level dialysis facility supply and distance to dialysis facility at treatment initiation among incident kidney failure patients, 2012–2019

| County-Level Number of Facilities | Average Distance (Miles), Mean (SD) | Unadjusted Difference (95% Confidence Interval) | Adjusted Difference (95% Confidence Interval) |
|----------------------------------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Reference group: ≥3 facilities in county | 5.5 (9) | Ref. | Ref. |
| 0                                | 25.2 (20.5)* | 19.3 (18.4 to 20.2)* | 14.3 (13.4 to 15.2)* |
| 1                                | 12.1 (16.5)* | 6 (5.6 to 6.5)* | 2.7 (2.1 to 3.3)* |
| 2                                | 8.6 (12.7)* | 2.8 (2.4 to 3.1)* | 0.8 (0.4 to 1.3)* |

Models estimate the association between county-level number of facilities and distance to dialysis facility in miles. The reference group has three or more facilities in a county, and differences are measured in miles. Adjusted model covariates include patient age, sex, race and ethnicity, health insurance type, primary cause of kidney failure, county-level employment rate, county-level uninsurance rate, county-level proportion of the population living below the poverty level, and urban/rural status. Models also include a linear time trend and standard errors are clustered at the county level. Ref., reference.

P<0.001.

two facilities (0.8 miles; 95% CI, 0.4 to 1.3 miles) traveled slightly further to initiate treatment than patients residing in counties with three or more facilities. Our study design and findings are presented in Supplemental Figure 2.

Reference group: ≥3 facilities in county

0 | 25.2 (20.5)* | 19.3 (18.4 to 20.2)* | 14.3 (13.4 to 15.2)* |
1 | 12.1 (16.5)* | 6 (5.6 to 6.5)* | 2.7 (2.1 to 3.3)* |
2 | 8.6 (12.7)* | 2.8 (2.4 to 3.1)* | 0.8 (0.4 to 1.3)* |
Patients are associated with greater adjusted relative risk of death and lower perceived quality of life (17).

Our findings also have important implications for kidney care delivery. Only 25% of dialysis facilities in our study offered home hemodialysis training, and 47% offered peritoneal dialysis, leaving patients with limited care options. Without access to dialysis facilities that support those modalities, patients living in counties with zero dialysis facilities are likely to travel long distances to receive support for home-based dialysis treatments. In our study, we found that patients who have no dialysis facilities in their county of residence started dialysis at a higher average eGFR than patients in counties with three or more dialysis facilities during the study period, even after removing patients on home dialysis. This does differ from some prior studies, which suggested that patients with a longer distance to a dialysis facility tended to wait longer to initiate dialysis, and this warrants further exploration (18–20). Past studies have suggested that dialysis facilities in more heavily populated urban areas are more likely to offer peritoneal dialysis. Additionally, studies have suggested that in metropolitan areas, the farther the distance a patient needs to travel for treatment, the more likely they are to use home hemodialysis or peritoneal dialysis (21). Increasing the availability of home hemodialysis treatments and peritoneal dialysis, when medically viable, should be considered for patients living in counties with no dialysis facility or limited dialysis facility access.

In addition to distance and facility supply, the coronavirus disease 2019 (COVID-19) pandemic presented new obstacles for kidney failure patients on hemodialysis because dialysis facilities attempted to identify strategies that maintained continuity of care while mitigating risk of within-facility infection. Studies have suggested that during the COVID-19 pandemic, patients undergoing in-facility hemodialysis had higher risk of mortality during the pandemic than patients undergoing home hemodialysis or peritoneal dialysis (22). Hemodialysis treatment requires patients to leave their homes to travel to a dialysis facility and receive treatment in a room of providers and other patients, thereby increasing their risk of infection. Many patients are dependent on public transportation to travel to their treatments, presenting potential for risk (23). Therefore, it is possible that inequities in access to hemodialysis were exacerbated by the COVID-19 pandemic, particularly in smaller, poorer, and more rural counties. Similarly, racial and ethnic disparities in incidence of kidney failure in Black and Hispanic populations likely exacerbated the impact that COVID-19 had on minority kidney failure patients (24,25).

Our study includes several limitations. First, although we attempted to be comprehensive in the patient- and county-level characteristics included in the study, there may be some that are unaccounted for in our analysis. Patient-level factors in our analysis are limited to incident patients who received treatment; nevertheless, our analysis still provides novel results about distance between a patient’s home address and distance to the dialysis facility where they initiate treatment. Second, travel distance does not take into account variation in frequency of dialysis sessions. Third, there is potential misclassification in the CMS 2728 data. Fourth, it is possible that patients changed their dialysis facility after treatment initiation, which we were unable to account for in our data. Further, it is likely that other measures of distance, such as travel time, may more accurately reflect travel burden for patients than linear distance (23). Although patients in an urban area may appear to be closer to the dialysis facility, we are unable to determine a patient’s mode of transportation, such as driving versus public transportation. The objective of our study was to assess dialysis facility supply as measured by county-level number of facilities; however, there may be other measures that further contextualized supply (such as number of stations per incident patient) and warrant further exploration. Finally, there is a wide heterogeneity in county size and characteristics; therefore, it may be difficult to generalize counties to one another, even if they fall into the same county subgroup or population quartile. Future work may need to examine more granular geographic areas such as neighborhoods or zip codes.

In conclusion, although there has been a net increase in dialysis facility supply and a net decrease in kidney failure incidence in the United States, there is an inequity in the counties that have a lack of dialysis facilities. Our results suggest that poorer and more rural counties were more likely to have fewer dialysis facilities, and individuals in these counties are more likely to travel further to receive dialysis treatment. This limited access to dialysis facilities has the potential to impact the health outcomes of kidney failure patients, quality of life, and rates of kidney transplants. Increasing the availability that rural and poor counties have to dialysis, home hemodialysis, and peritoneal dialysis may help address geographic and socioeconomic disparities in outcomes after kidney failure.

Disclosures
All authors have nothing to disclose.

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Author Contributions
K.H. Nguyen was responsible for the formal analysis and for supervision; K.H. Nguyen, A.N. Trivedi, and A.F. Velázquez were responsible for conceptualization; A.N. Trivedi was responsible for data curation and funding acquisition; A.F. Velázquez wrote the original draft of the manuscript; and all authors were responsible for the investigation and methodology and reviewed and edited the manuscript.

Data Sharing Statement
CMS 2728 data involves human subjects and cannot be shared. Dialysis Facility Compare data are publicly available.
Supplemental Material

This article contains supplemental material online at http://kidney360.asnjournals.org/lookup/suppl;doi:10.34067/KID.0000312022/-/DCSupplemental.

Supplemental Table 1. Data sources.

Supplemental Table 2. County-level characteristics by county-level number of dialysis facilities 2012–2019.

Supplemental Table 3. Facility characteristics by county-level number of dialysis facilities 2012–2019.

Supplemental Table 4. Alternative measures of access to dialysis facility at treatment initiation among incident kidney failure patients, 2012–2019.

Supplemental Table 5. Association between facilities per capita and distance to dialysis facility at treatment initiation among incident kidney failure patients, 2012–2019.

Supplemental Table 6. Association between annual number of facilities per 1000 incident kidney failure patients and distance to dialysis facility at treatment initiation, 2012–2019.

Supplemental Table 7. Association between urban/rural designation and distance traveled to dialysis facility.

Supplemental Table 8. Unadjusted changes in distance to dialysis facility before versus after all facilities in county close, 2012–2019 (N = 2075).

Supplemental Figure 1. Study sample construction.

References

1. United States Renal Data System: 2019 USRDS Annual Data Report: Epidemiology of Kidney Disease in the United States. Bethesda, MD, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2019. Available at: https://www.usrds.org/media/2371/2019-executive-summary.pdf. Accessed April 11, 2022

2. Centers for Medicare and Medicaid Services: Dialysis Facility Compare Datasets. Available at: https://data.medicare.gov/data/dialysis-facility-compare. Accessed August 28, 2020

3. Mathur AK, Ashby VB, Sands RL, Wolfe RA: Geographic variation in end-stage renal disease incidence and access to deceased donor kidney transplantation. Am J Transplant 10:1069–1080, 2010 https://doi.org/10.1111/j.1600-6143.2010.03043.x

4. Yip G, Cheung AK, Ma JZ, Yu AJ, Greene T, Oliver MN, Yu W, Norris KC: The associations between race and geographic area and quality-of-care indicators in patients approaching ESRD. Clin J Am Soc Nephrol 8:610–618, 2013 https://doi.org/10.2215/CJN.07780812

5. Saunders MR, Lee H, Alexander GC, Tak HJ, Thistlethwaite JR Jr, Ross LF: Racial disparities in reaching the renal transplant waitlist: Is geography as important as race? Clin Transplant 29:531–538, 2015 https://doi.org/10.1111/ctr.12347

6. Nguyen KH, Thorsness R, Swaminathan S, Mehrotra R, Patzer RE, Lee Y, Kim D, Rivera-Hernandez M, Trivedi AN: Despite national declines in kidney failure incidence, disparities widened between low- and high-poverty US counties. Health Aff (Millwood) 40:1900–1908, 2021 https://doi.org/10.1377/hlthaff.2021.00458

7. Whelan AM, Johansen KL, McCulloch CE, Adelmann D, Nie-mann CU, Roll GR, Siyahan S, Grimes B, Ku E: Longer distance from dialysis facility to transplant center is associated with lower access to kidney transplantation. Transplant Direct 6:e602, 2020 https://doi.org/10.1097/TXD.0000000000001048

8. Hsia RY, Kanzaria HK, Srebrotnjak T, Maselli J, McCulloch C, Auerbach AD: Is emergency department closure resulting in increased distance to the nearest emergency department associated with increased inpatient mortality? Ann Emerg Med 60:707–715.e4, 2012 https://doi.org/10.1016/j.annemergmed.2012.08.025

9. Massarweh NN, Chiang YJ, Xing Y, Chang GI, Haynes AB, You YN, Feig BW, Cormier JN: Association between travel distance and metastatic disease at diagnosis among patients with colon cancer. J Clin Oncol 32:942–948, 2014 https://doi.org/10.1200/JCO.2013.52.3845

10. Stephens JM, Brotherton S, Dunning SC, Emerson LC, Gilbertson DT, Harrison DJ, Kochever JJ, McClellan AC, McClellan WM, Wan S, Gillin M: Geographic disparities in patient travel for dialysis in the United States. J Rural Health 29:339–348, 2013 https://doi.org/10.1111/jrph.12022

11. US Department of Health and Human Services: End Stage Renal Disease Medical Evidence Report Medicare Entitlement and/or Patient Registration: Form CMS-2728-U3. Available at: https://www.cms.gov/Medicare/CMS-Forms/CMS-Forms-downloads/cms2728.pdf. Accessed April 11, 2022

12. Swaminathan S, Sommers BD, Thorsness R, Mehrotra R, Lee Y, Trivedi AN: Association of medical expansion with 1-year mortality among patients with end-stage renal disease. JAMA 320: 2242–2250, 2018 https://doi.org/10.1001/jama.2018.16504

13. Thorsness R, Swaminathan S, Lee Y, Sommers BD, Mehrotra R, Nguyen KH, Kim D, Rivera-Hernandez M, Trivedi AN: Medical aid expansion and incidence of kidney failure among nonelderly adults. J Am Soc Nephrol 32:1425–1435, 2021 https://doi.org/10.1681/ASN.2020101511

14. Picard R: GEODIST: Stata Module to Compute Geographical Distances, 2019. Available at: https://ideas.repec.org/c/boc/bocode/s457147.html. Accessed April 11, 2022

15. Kim KM, Oh HJ, Choi HY, Lee H, Ryu DR: Impact of chronic kidney disease on mortality: A nationwide cohort study. Kidney Res Clin Pract 38:382–390, 2019 https://doi.org/10.23876j.krcp.18.0128

16. Saunders MR, Lee H, Maene C, Schuble T, Cagney KA: Proximity does not equal access: Racial disparities in access to high quality dialysis facilities. J Racial Ethn Health Disparities 1:291–299, 2014 https://doi.org/10.1007/s40615-014-0036-0

17. Moist LM, Bragg-Gresham JL, Pisoni RL, Saron R, Akita T, Jacobson SH, Fukuhara S, Mapes DL, Rayner HC, Saito A, Port FK: Travel time to dialysis as a predictor of health-related quality of life, adherence, and mortality: The Dialysis Outcomes and Practice Patterns Study (DOPPS). Am J Kidney Dis 51;641–650, 2008 https://doi.org/10.1053/j.ajkd.2007.12.021

18. Slinin Y, Ishani A: What drives early dialysis initiation and how do we optimize timing of RRT? Clin J Am Soc Nephrol 9:1671–1673, 2014 https://doi.org/10.2215/CJN.08350814

19. Paththaranitima P, El Shamy O, Chauhan K, Saha A, Wen HH, Sharma S, Uribarri J, Chan L: The association between prevalence of peritoneal dialysis versus hemodialysis and patients’ distance to dialysis-providing facilities. Kidney360 2:1908–1916, 2021 https://doi.org/10.34067/KID.0004762021

20. Adler JT, Husain SA, Xiang L, Rodrigue JR, Waikar SS: Initial home dialysis is increased for rural patients by accessing urban facilities. Kidney360 3:488–496, 2022 https://doi.org/10.34067/KID.0006932021

21. Prakash S, Coffin R, Schold J, Lewis SA, Gunzler D, Stark S, Howard M, Rodgers D, Einsd Adt D, Sehgal AR: Travel distance and home dialysis rates in the United States. Perit Dial Int 34:24–32, 2014 https://doi.org/10.3779/pdi.2012.00234

22. Hsu CM, Weiner DE, Aweh G, Salenger P, Johnson DS, Lacson E Jr: Epidemiology and outcomes of COVID-19 in home dialysis patients compared with in-center dialysis patients. J Am Soc Nephrol 32:1569–1573, 2021 https://doi.org/10.1681/ASN.2020111653

23. Iacono S: Transportation issues and their impact upon in-center hemodialysis. J Nephrol Soc Work 23:60–63, 2004

24. Novick TK, Rizzolo K, Cervantes L: COVID-19 and kidney disease disparities in the United States. Adv Chronic Kidney Dis 27:427–433, 2020 https://doi.org/10.1053/j.ackd.2020.06.005

25. Nguyen KH, Thorsness R, Hayes S, Kim D, Mehrotra R, Swami-nathan S, Baramwal N, Lee Y, Rivera-Hernandez M, Trivedi AN: Evaluation of racial, ethnic, and socioeconomic disparities in initiation of kidney failure treatment during the first 4 months of the COVID-19 pandemic. JAMA Netw Open 4:e2127369, 2021 https://doi.org/10.1001/jamanetworkopen.2021.27369

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