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Impacts of Geographic Distance on Peritoneal Dialysis Utilization: Refining Models of Treatment Selection

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Impacts of Geographic Distance on Peritoneal Dialysis Utilization: Refining Models of Treatment Selection

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ABSTRACT

Objective: To examine the relationship between distance to dialysis provider and patient selection of dialysis modality, informed by the absolute distance from a patient's home and relative distance of alternative modalities.

Data Sources: US Renal Data System

Study Design: 70,131 patients initiating chronic dialysis and 4,795 dialysis facilities in 2006. The primary outcome was patient utilization of peritoneal dialysis (PD). Independent variables included absolute distance between patients' home and the nearest hemodialysis (HD) facility, relative distance between patients' home and nearest PD versus nearest HD facilities, and their interaction. Logistic regression was used to model distance on PD use, controlling for patient and market characteristics.

Principal Findings: 9% of incident dialysis patients used PD in 2006. There was a positive, non-linear relationship between absolute distance to HD services and PD use ($p<0.0001$), with the magnitude of the effect increasing at greater distances. In terms of relative distance, odds of PD use increased if a PD facility was closer or the same distance as the nearest HD facility ($p=0.006$). Interaction of distance measures to dialysis facilities was not significant.

Conclusions: Analyses of patient choice between alternative treatments should model distance to reflect all relevant dimensions of geographic access to treatment options.

Key Words: dialysis, geographic distance, treatment selection

INTRODUCTION

Patient distance to medical care services has been shown to influence receipt of timely care and outcomes (Bello et al. 2012; Burgess and DeFiore 1994; Harmon et al. 2013; Hayton et al. 2013), particularly for vulnerable patients who require ongoing care. Close proximity to chronic dialysis services may ease the travel burden on patients with end-stage renal disease (ESRD) who require renal replacement therapy for the remainder of their life. In these patients, travel distance to care has been associated with patient-reported quality of life, willingness to comply with treatment regimen, and risk of complications and death (Chao et al. 2015; Diamant et al. 2010; Maheswaran et al. 2003; Mehrotra et al. 2012; Moist et al. 2008; O'Hare, Johansen, and Rodriguez 2006; Organ and MacDonald 2014; Tonelli et al. 2007; Willis et al. 1998).

Patients who are newly diagnosed with kidney failure must choose between hemodialysis (HD) and peritoneal dialysis (PD), which have different implications for patient travel due to different in-center treatment requirements. HD is primarily performed as a center-based treatment modality performed by clinical staff in dialysis facilities at least three times weekly for about 4 hours per treatment. Among home-based dialysis treatment options (including hemodialysis), PD is a modality in which patients are trained to perform daily self-treatment, requiring patients to visit dialysis facilities monthly for maintenance. In-center HD is the most common form of renal replacement therapy and offered by almost all dialysis facilities, while PD represents the overwhelming majority of home-based dialysis utilization in the US and is used less often and offered by roughly half of dialysis providers in the US (O'Hare et al. 2006; US Renal Data System (USRDS) 2014; Wang et al. 2011; Wang et al. 2010). Home hemodialysis is not considered further in this study.

Research shows that patient choice of dialysis modality is driven by a myriad of clinical factors (e.g., suitability for self-care, vascular or abdominal heath) and non-clinical factors (e.g., physician and patient preference, patients’ employment status, social support at home) (Ahlmen, Carlsson, and Schonborg 1993; Golper et al. 2011; Hirth et al. 2003; Maaroufi et al. 2013; McLaughlin et al. 2003; Stack 2002). Patients’ education, awareness and understanding of these dialysis modalities has also been shown to influence modality choice (Blake, Quinn, and Oliver 2013; Golper et al. 2011; Kurella Tamura et al. 2014; Kutner et al. 2011; McLaughlin et al. 2003; Ribitsch et al. 2013). The availability of treatment services in local facilities may play a role in patient awareness of and exposure to different modalities, but has received less attention.

Limited availability and access to PD services has been a purported barrier to broad under-utilization of PD in the US (Wang et al. 2011; Wang et al. 2010). Prevalent PD use peaked at 12% in 1994 and declined to a current rate of 6% in the US, compared to 18-73% PD use in other North American, Asian, and European countries (USRDS 2014). The few studies that examined the role of geographic distance to dialysis in patient utilization of PD found mixed results. In this paper, we augment data and methods of prior research to reassess the relationship between patients' distance to dialysis treatment and modality choice. Our results can inform methodological approaches to examining the relationship between geographic distance and utilization of health services in other contexts.

PREVIOUS RESEARCH AND HYPOTHESES

Recent research found that patients' distance to facilities offering HD was negatively associated with PD initiation and distance to PD facilities was positively associated with PD initiation (Prakash et al. 2014). These findings contrast earlier observations of higher PD use among patients living in rural areas, despite less PD availability in rural areas (O'Hare et al. 2006; Tonelli et al. 2007). The mixed findings may arise from varying analytic approaches used across studies. Earlier analyses did not directly assess patient distance to dialysis clinics, but rather approximations based on degree of rurality (O'Hare et al. 2006) or distance to physician's practice (Tonelli et al. 2007). Multivariable modeling of patient distance in Prakash and colleague's (2014) analysis included separate variables for distance to nearest home-based and in-center facility and their interaction as well as distance to center actually attended; however, multicollinearity and confounding of the influence of providers' treatment availability arise when including the distance to attended facility (i.e., not an exogenous predictor of choice).

Appropriate modeling of patients' geographic access to PD and HD can be informed by behavioral, economic, and travel distance approaches applied in prior health services research. Traditional distance or gravity models posit that patient interest in a treatment decreases as distance to the treatment increases (Congdon 2001; Cromley and McLafferty 2002). Behavioral approaches account for patients' predisposing, need and enabling characteristics as contributing factors of treatment choice (Andersen and Newman 1973), which may modify the impact of distance on patient choice of treatments. Economic approaches (e.g., conditional choice models) consider the tradeoffs between travel costs and value of provider's service options in determining treatment preferences (Duan et al. 1983; Garnick et al. 1989), such that patients may be willing to travel further for a high value service. Common among these approaches is that any provider offers all alternative treatments, which is not the case in PD and HD offerings by dialysis facilities.

This analysis of geographic access to alternative dialysis modalities contributes to the literature because of three key differences from prior work. First, distance is the explanatory variable of interest in this analysis instead of being modeled as a control variable or in the context of instrumental variables for outcomes assessment (McClellan, McNeil, and Newhouse 1994; Xian et al. 2011). Second, most literature has examined distance in the context of acute inpatient care (Burns and Wholey 1992; Garnick et al. 1989; Lee and Cohen 1985; McClellan et al. 1994), where patient choice is time-sensitive. As a result, absolute distance from a patient's home to a treatment setting may be the most important aspect of geographic access. In this study, however, we assess the role of distance on patient choice of dialysis modality in the context of chronic outpatient treatment (Burgess and DeFiore 1994). Third, accounting for regional treatment use in the prior year likely avoids a spurious correlation between distance and utilization and reflects many unobserved influences on treatment choice.

We expect to find three significant relationships between geographic distance and dialysis treatment choice. First, we expect the relationship between patients' absolute distance to a dialysis facility and PD utilization to be non-linear or even non-monotonic. For patients who live far from any dialysis facility (e.g., have large absolute distance), absolute distance to care may not be a substantial barrier to access for PD. Rather, PD's self-treatment at home and monthly visits for dialysis maintenance may make PD an appealing alternative to thrice weekly HD. Roughly 20 percent of ESRD patients live far from the majority of dialysis facilities that tend to be located in urban areas (O'Hare et al. 2006; Wang et al. 2010). Patients with small absolute distances (e.g., living close to a dialysis facility) may also be less sensitive to the absolute distance to dialysis treatment (Osterlund et al. 2014).

Second, all dialysis modalities are not available from all providers, so patient choice of less available PD is constrained. As a result, the relative distance (between a patient's home and the nearest PD provider versus a patient's home and the nearest HD provider) is an important aspect of geographic access and patient choice, in addition to absolute distance. The cumulative travel distance differs markedly between HD and PD treatment because PD patients only have a monthly visit to a dialysis facility, but HD patients have to visit 12-13 times per month. Thus, patients may be quite sensitive to large differences in the cumulative monthly travel distance between HD and PD modalities. Patients with a short relative distance, whose nearest HD facility also offers PD or whose nearest PD facility is in close proximity to the nearest HD facility, may be indifferent to distance in their modality selection but have greater "exposure" to PD (i.e., awareness that the same or nearby facilities offer PD) that may increase uptake of PD. Patients whose relative distance to PD is high may face barriers to learning about PD and initiate PD at lower rates than patients with smaller relative distances. Since only half of dialysis facilities offer both HD and PD and few facilities only offer PD alone, nearly all patients live closer to an HD facility than a PD facility. Further, modeling patient choice as a function of relative distance avoids the potential co-linearity of absolute distance to PD and absolute distance to HD given that PD is commonly co-located with HD.

Third, the impact of relative distance on patient choice of HD or PD may also vary depending on patients' absolute distance to their nearest dialysis facility. Therefore, full exploration of the relationship of geographic access to dialysis facility and PD initiation should consider interaction of absolute distance and relative distance to reflect the conditions of patients' choice set of provider location *and* service offerings (Figure 1). Finally, controlling for prior regional utilization avoids a reverse causality issue, whereby patients in markets with more PD use (arising from these other factors) have shorter average distances due to the presence of more PD providers.

In sum, our model considers the functional form of the relationship between absolute distance and PD use, the significance of relative distance, whether the relationships between absolute distance and PD use differs when the relative distance between HD and PD facilities is near or far (i.e., interaction), and controls for prior year PD use at the market-level. These methodological considerations are applicable to ongoing policy evaluations of dialysis payment reforms and, more broadly, to analyses of treatment or provider choice (e.g., elective outpatient surgery, cancer treatments, provider ownership type).

METHODS

Sample

We conducted a cross-sectional retrospective study of a cohort of 70,131 newly diagnosed patients with ESRD initiating chronic dialysis treatment in 2006. Inclusion criteria were: 1) surviving the first 90-days of dialysis; 2) having a residence zip code in the US; 3) receiving dialysis primarily in outpatient-based dialysis facilities (i.e., non-institutionalized patients); 4) having complete demographic and clinical information in the patient registry data; and 5) receiving either in-center hemodialysis or peritoneal dialysis in 2006; 6) aged >19 and <90; and 7) distance to nearest in-center HD facility ≤60 miles. We excluded children because the pediatric ESRD population represents a small % of incident ESRD patients whose treatment decisions are largely age-dependent (e.g., limited access to facilities accepting pediatric patients, children with ESRD are more likely to receive kidney transplant or PD treatment). The oldest patients and those living >60 miles from the nearest dialysis facility represented a very small minority of incident ESRD patients (<0.01%), whose treatment decisions may be driven by different mechanisms compared to the general adult ESRD population. Our sample of dialysis facilities included the 4,795 facilities in the US that treated patients with either in-center HD, PD, or both throughout 2006. Patients receiving home hemodialysis were excluded, as this modality was rare and not reliably assessed in our study year (USRDS 2009).

Data and Variables

The principal source of data was the US Renal Data System (USRDS), the repository of CMS data on ESRD providers and patients. Patient characteristics were obtained from the Medical Evidence Report (Form CMS-2728), which contains information on all patients initiating, re-entering, or changing ESRD services (e.g., modality, treating provider). Additional patient information sources included the PATIENTS file (containing information on patients' first date of ESRD service and demographic information) and the RESIDENC file (providing the zip code of patient residence at the start of ESRD service).

We used the patient treatment history file (RXHIST60) to assess the binary outcome of PD treatment, based on patients' treatment modality indicating PD (USRDS 2009). This inclusive definition considers any use of PD during the patient's first calendar year (2006) of dialysis. Dialysis facility's location, structural characteristics, treatment service offerings, and operating statistics came from the Annual Facility Survey (Form CMS-2744). General market demographic data came from the Area Resource File. We defined markets as hospital referral regions (HRR), which approximate the geographic extent of healthcare markets for tertiary care (Wennberg and Cooper 1999) and appear to better reflect PD service areas than municipal designations because PD patients commonly travel outside county boundaries for monthly PD maintenance visits.

Independent variables of interest included two distance measures, calculated as straight-line distances from patients' and dialysis facilities' zip code centroids. First, we ascertained the absolute distance between each patient's home at dialysis initiation and the nearest facility offering HD. Absolute distance references HD services because virtually all dialysis units offer HD. Because absolute distance to closest HD facility was skewed with a significant percentage with a distance of 0 (38%) we included both 1) a continuous distance variable to closest HD facility and 2) a dichotomous variable for distance to closest HD facility of zero vs. greater than zero to improve model fit (Hosmer and Lemeshow 2000). Second, we calculated the relative distance between patients' nearest facilities offering PD and HD services, defined as the difference of patients' absolute distance to their closest PD facility versus HD facility. By reflecting patients' differential distance to facilities that offer HD or PD or both, this second measure implicitly accounts for patients' absolute distance to PD provider in a way that is interpretable and reduces the problem of co-linearity in regression models. Approximately 47% of patients had a relative distance of zero (where closest PD and HD facilities were in the same facility or zip code), and over 45% had a relative distance >20 miles. Because only 0.6% of patients had a negative value of relative distance a results of few facilities offering only PD, we dichotomized relative distance: "1" if the nearest PD facility was closer or the same distance as the nearest HD facility and "0" if PD was farther than HD service.

Analyses controlled for other characteristics of patients, facilities, and regional markets that may influence treatment choice (Ahlmen et al. 1993; Kutner et al. 2011; Stack 2002). Patient demographic characteristics at dialysis initiation included age, gender, race (White, Black, other), full- or part-time employment status at onset of ESRD, and urban/rural residence. Patient-level clinical covariates included receipt of pre-ESRD nephrologist care, diabetes as the cause of ESRD, BMI, and comorbidity indicators (e.g., diabetes, hypertension, heart disease). Market characteristics for patient's region included market-level PD prevalence in 2005 (numbers of patients receiving PD per 1,000 ESRD prevalent population per HRR), proportion of dialysis facilities affiliated with a large chain organization, the percentage of facilities in urban locations, and overall market size (population density). Market-level PD prevalence in 2005 was included to account for patient exposure to PD services that may influence its uptake and to reduce the risk that the distance coefficients were biased due to a correlation between high market level use and low distance to PD providers.

Analysis

A logistic regression model of PD use was fit to examine the relationships of continuous absolute distance to closest HD facility and dichotomized relative distance between closest HD facility and PD facility, adjusting for patient and market characteristics. An interaction term between absolute distance to closest HD facility and relative distance was also included.

We examined the assumption of linearity of the logit for all continuous variables, including absolute distance to closest HD, using fractal polynomial models (Hosmer and Lemeshow 2000). Fractal polynomial models are a general family of parametric models based on one or two terms of the form X^p, where the exponents (p) are chosen from a predefined set providing a class of possible functional forms that lead to satisfactory fit to the data in many situations (Sauerbrei et al. 2006). The SAS macro MFP (Multivariable Fractal Polynomial) was implemented to determine appropriate transformations.

Model fit was poor when assuming linearity (Hosmer-Lemeshow goodness-of-fit statistic p=0.02), while model fit for the final model including fractal polynomial transformations for all continuous predictors was improved (p=0.32). Transformation of absolute distance to closest HD with inverse square root ($X^{-0.5}$) and quadratic (X^2) terms optimized the predictive value of absolute distance on PD use, which avoided underestimation of the slope for smaller distances and overestimation of the slope for larger distances by allowing the rate of change in the odds of PD use to vary across the continuum of distance. The final logistic model had reasonable predictive power with a C-statistic of 0.75.

To interpret the relationship of distance to closest HD facility and relative distance between HD and PD facilities, predicted odds ratios of PD utilization and associated 95% confidence intervals were calculated for different values of absolute and relative distances. The study was approved by the Institutional Review Board of Duke University Health System.

RESULTS

Descriptive Statistics

Of the 70,131 who initiated dialysis in 2006, 9% used PD in 2006 (Table 1). PD patients were younger and more likely to be white, employed, and have pre-ESRD nephrology care compared to HD patients. The majority of patients resided in urban locations, with slightly less urbanicity among those on PD (75% on PD versus 80% on HD). Patients on PD lived in regions with higher PD prevalence and a greater proportion of facilities offering PD. Mean (median) absolute distance to the nearest dialysis facility of both types of modality was greater for PD patients than those on HD -- 5.9 (3.0) miles versus 4.1 (1.9) miles to nearest HD facility and 10.8 (5.3) miles versus 9.4 (4.2) miles to nearest PD facility. Mean (median) relative distance between nearest dialysis facilities offering PD and HD services 4.9 (0.0) miles for PD and 5.4 (0.4) miles HD patients.

Figure 2 illustrates PD utilization by discrete categories of absolute distance to nearest HD facility by category of relative distance. For distances greater than 0 as categories of distance increased, PD use generally increased. In general, PD use was higher when PD was located closer or the same distance as the patients' nearest facility offering HD (relative distance <=0) compared to when PD was located farther away.

Logistic Model Results

Absolute distance to the closest HD facility (χ^2_3=81.9, p<0.0001), dichotomized absolute distance to closest HD of zero miles ($\chi^2_1 = 11.7$, p=0.0006) and relative distance between PD and HD facilities (χ^2_1=7.5, p=0.006) were significantly associated with PD use. The interaction between absolute and relative distance was not significant (p=0.13, Figure 3).

Figure 3 illustrates the relationships between PD utilization and different absolute distances compared to a reference of zero miles. Absolute distances of 1-3 miles were not associated with greater PD use, and only became a significant predictor of PD use for absolute distances >3 miles. The odds of PD initiation were greater (odds ratio (OR)=1.3; 95% CI 1.2, 1.4) when the absolute distance from home to the closest HD facility increased from zero to 5 miles. The odds of PD initiation increased roughly three-fold when the absolute distance from home to the closest HD facility increased from zero to 50 miles (OR=3.2; 95% CI 2.1, 4.6).

Estimated odds of PD use were somewhat greater if PD was closer or the same distance as the nearest HD (i.e., relative distance ≤0). Although the interaction was not statistically significant, the estimated odds of PD use were slightly lower if patients' nearest PD facility was located further than the nearest HD facility (i.e., relative distance >0) at absolute distances of 3-35 miles. The effect of relative distance flips at farther distances, which may be due to non-linearity of distance to nearest HD in PD use and/or the sparseness of data at larger distances to nearest HD.

DISCUSSION

This study examined the influence of geographic access to dialysis facilities on patient selection of peritoneal dialysis in terms of absolute and relative distance. To our knowledge, this is the first study that considers more fully the conditions of patients' choice of service and provider locations in determining utilization of dialysis modalities. Findings from this analysis have implications on conceptualizing and understanding the impacts of dialysis service supply.

We found that 9% of incident dialysis patients used PD in 2006 and that patients' absolute distance to care is an important factor in initiation of PD, particularly for those living farther away from more commonly offered HD services. Absolute distance to HD services was a significant predictor of PD use in distances >3 miles and its effects increased in magnitude at absolute distances of 35-50 miles, confirming a non-linear relationship between absolute distance to dialysis facilities and modality choice. Our results contrast with a more recent analysis, which found longer absolute distance to patients' nearest HD associated with decreased odds of PD use (Prakash et al. 2014). These differences are likely due to the ways in which distance and patients' choice set was modeled to account for non-mutually exclusive treatment service availability at potential providers. This is an important consideration because dialysis facilities may offer a range of treatment options, from exclusive provision of HD or exclusive PD (rarely) or both. Instead of including an additional measure of absolute distance to PD provider, we included relative distance to simultaneously represent patients' differential distance and treatment service availability (HD vs. PD) to nearest providers. Our analysis confirmed the significance of modeling absolute distance to HD and differential distance between PD and HD.

Altogether, our results indicate that proximity is an important factor for patients considering dialysis care, but not in the ways that policymakers and researchers traditionally think about access to care. Instead of distance acting only as a barrier to treatment services in a monotonic fashion, longer absolute distances are associated with different choices in treatment.

If we accept the premise that PD is underutilized on average, then greater distance might "nudge" the dialysis population closer to an ideal mix of treatment modalities even if it represents a barrier to some individuals. This is consistent with earlier studies that found higher rates of PD use in rural regions, which typically have less PD supply than urban areas (O'Hare et al., 2006) as well as commonly noted logistical advantages and appeal of PD for patients in remote areas or lacking adequate transportation. This relationship is influenced in part by the home-based, self-management of PD and the less frequent visits to providers (Osterlund et al. 2014).

Distance to dialysis facilities was associated with PD uptake among patients living moderate to longer distances from dialysis facilities, but patients residing close by dialysis units (0-3 miles) were relatively indifferent to distance. This is particularly interesting because the majority of dialysis patient and dialysis facilities are located in urban locations. The significance of relative distance (i.e., when patients' nearest PD facility was closer or the same distance as the nearest facility) and regional PD prevalence (Technical Appendix) indicates that the availability of PD services and utilization may play a role in patient awareness and exposure to PD to influence its use but, for the majority of dialysis markets with a high population and density of providers, other factors influence modality choice besides PD supply and distance.

For policy and planning, Medicare's 2011 ESRD bundled payment reform for dialysis services that is expected to induce greater demand for and access to PD services (GAO 2009; Hirth et al. 2013; Hornberger and Hirth 2012) may have limited impacts on increasing new supply and access to PD for patients in micropolitan and rural areas. Findings from prior work and this analysis, conducted before the current era of the ESRD bundle, suggest a strategy of locating PD in urban locations that do not preclude patients traveling from afar for less frequent PD visits than HD while, at the same time, allowing urban facilities to benefit from their proximity to most HD and PD patients (Wang et al., 2011). The results presented here may serve as a benchmark to examine where policy has the greatest impact in PD utilization and patient access.

Results from this analysis also have important implications for health services research focused on patient travel distance more broadly. The concepts and methods from this analysis may inform similar studies examining patient selection of providers and alternative modalities of treatment that are not equally available across providers, such as elective procedures, new surgical techniques, or advanced imaging technologies. For example, patients facing longer travel distances to breast cancer treatment have higher rates of mastectomy than frequently administered radiotherapy treatment, compared to patients who travel shorter distances for treatment (Canadian Institute for Health Information 2012). Analyses of utilization must appropriately model access to reflect logistical implementation of treatment options and the service options available to patients. In addition, absolute or relative distance has been used as an instrumental variable (IV) in analyses of other outcomes. Distance strongly predicts choice of provider in various clinical contexts (Brooks et al. 2006; Grabowski et al. 2013; Hirth et al. 2003; Hirth et al. 2014; McClellan et al. 1994; Shugarman and Brown 2006; Zwanziger, Mukamel, and Indridason 2002). In the dialysis context, Brooks and colleagues (2006) found the relative proximity to for-profit and nonprofit dialysis facilities to be the strongest predictor of the type of facility chosen, and that use of this measure as an IV eliminated the relationship between ownership and patient survival that existed in observational data. Similarly, Hirth et al. (2006) used differential distance to predict PD use, which was then used to predict patient employment status, showing that PD facilitated employment, but to a lesser extent than would be indicated by the observational correlation. The current study demonstrates that more complex relationships between distance and provider choice (e.g., using indicators of both absolute and relative distance as well as interactions; accounting for market-level variations in treatment use that could arise from non-distance factors) could enhance the performance of distance as an instrumental variable in other contexts.

Our study has several limitations. First, patient distances of 0 miles to nearest dialysis units in our study are not realistically feasible and the considerable proportion of patients living in the same zip code as their nearest dialysis facility (i.e., many ESRD patients live in urban locales, where dialysis facilities are typically located) affected our model specification. Location data in the USRDS were limited to zip code and distance measures, based on zip code centroids, inhibited precise measurement of distance. This adds some measurement error, particularly at small distances, so the 0-3 mile results should be interpreted cautiously. Second, our construction of distance measures was based on straight line distance instead of travel distance (based on actual road and traffic patterns) or travel time that may mask true impacts of distance and relative distance. However, analysis of hospital choice has demonstrated a high correlation between straight-line and travel distance (Boscoe, Henry, and Zdeb 2012; Phibbs and Luft 1995). Third, the 2006 data used for this study may not reflect current rates of PD use and did not allow for examining initiation of home-based HD, which, although still far less common than PD as a home therapy modality, has become increasingly popular in recent years. This heuristic study sample contained the most recent patient and provider data available to the authors and suitable for analysis. However, our findings may suggest similar relationships between distance and home-based HD, which can be formally tested when more recent data that also contain more reliable assessment of home HD become available. Last, while our analysis controlled for regional use of PD among patients, we were not able to account directly for physician supply or physician practice patterns, which may explain variation in PD use. Future research may consider incorporating additional physician-level data to examine the extent to which physician referral modifies the relationship between distance and treatment selection.

In this paper, we refined measurement and modeling of patient distance to care to assess the extent to which and for whom distance to dialysis services influenced choice of dialysis modality. The methodological considerations underlying the inclusion of absolute and relative distance to different treatment options are important to forthcoming policy evaluations of dialysis payment reforms to inform efforts to promote increased utilization of an often preferred and effective modality of treatment for patients with kidney failure that has been historically underutilized. More broadly, our methodological approach in assessing patient distance to care will be useful in the study of other healthcare services that are not equally available and accessible to all patients.

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Table 1. Incident ESRD Patient Characteristics, 2006

N= 70,131	Overall sample	By dialysis modality	
	Mean (SD) or %	PD N=6,099	HD N=64,032
Patient characteristics			
Age	62.0 (14.9)	57.8 (14.6)	62.4 (14.8)
Male (%)	55.9	55.1	56.0
Race: White (%)	64.7	72.8	63.9
Black	29.8	21.1	30.6
Other	5.5	6.1	5.5
Employed (full-time or part-time) (%)	12.3	25.5	11.1
Urban residence (%)	79.6	75.0	80.0
Pre-ESRD nephrologist care (%)	68.8	87.7	67.0
Cause of ESRD: Diabetes (%)	48.3	44.7	48.7
BMI	28.9 (1.6)	28.8 (6.7)	28.9 (7.7)
Comorbid conditions			
Diabetes	54.1	48.5	54.6
Hypertension	85.9	87.5	85.8
Coronary artery disease	22.6	17.2	23.1
Cerebrovascular disease	9.1	6.1	9.4
Peripheral vascular disease	14.4	10.5	14.7
Other cardiac disease	14.7	11.1	15.1
Congestive heart failure	32.8	19.8	34.0
Chronic obstructive pulmonary disease	8.3	4.8	8.6
Cancer	7.0	5.1	7.2
Distance			
Absolute distance to closest HD	4.2 (6.6)	5.9 (8.3)	4.1 (6.4)
Absolute distance to closest PD	9.6 (15.8)	10.8 (15.7)	9.4 (15.8)

Relative distance: closest PD - HD	5.3 (13.9)	4.9 (12.5)	5.4 (14.0)
Relative distance: nearest PD is closer or the same distance as nearest HD (%)	47.8	51.1	47.2
Market characteristics (HRR)			
PD prevalence in prior year	61.6 (24.3)	71.9 (27.2)	60.7 (23.8)
% facilities in urban location	78.8 (16.7)	75.7 (16.9)	79.1 (16.6)
% facilities: chain affiliated	67.2 (24.8)	68.5 (25.2)	67.1 (24.7)
Population density	1169.4 (566.6)	594.7 (813.4)	1124.1 (685.8)

Figure 1. Hypothesized relationships of patient distance to dialysis services and related influences on PD utilization

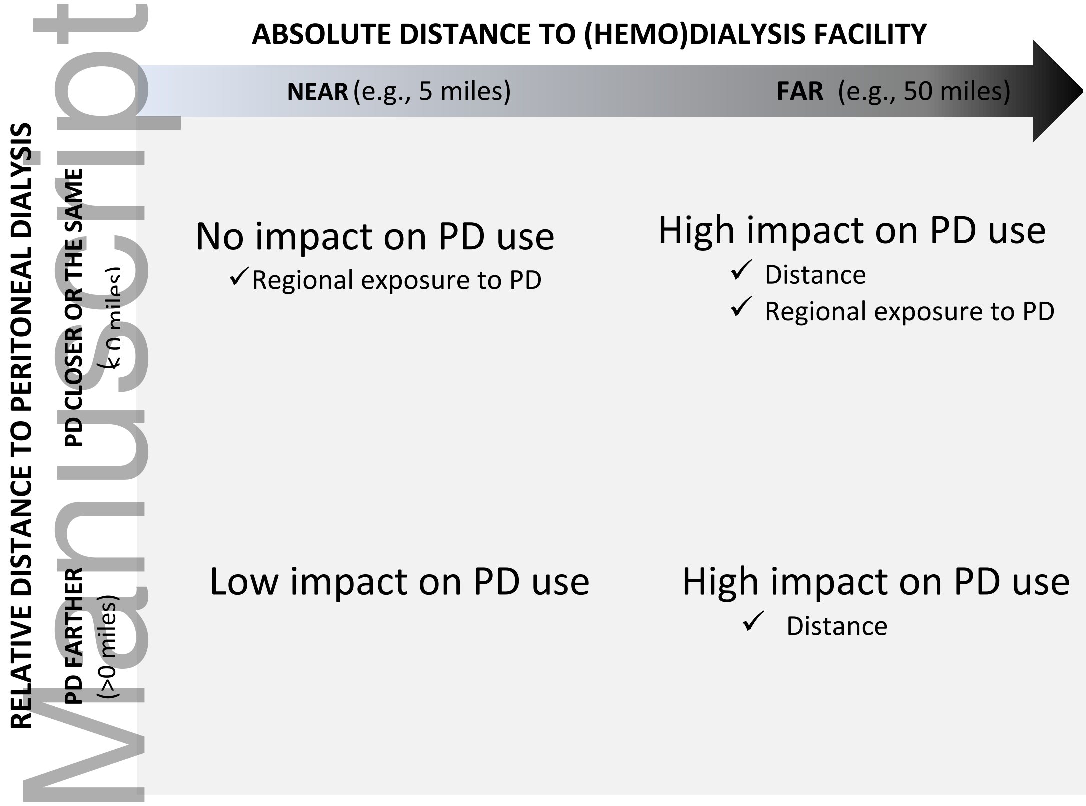


Figure 2. Unadjusted rates of PD utilization, by discrete categories of patients' absolute distance to nearest hemodialysis facility and relative distance category (number of patients for each of the two categories of relative distance shown on top and below bars)

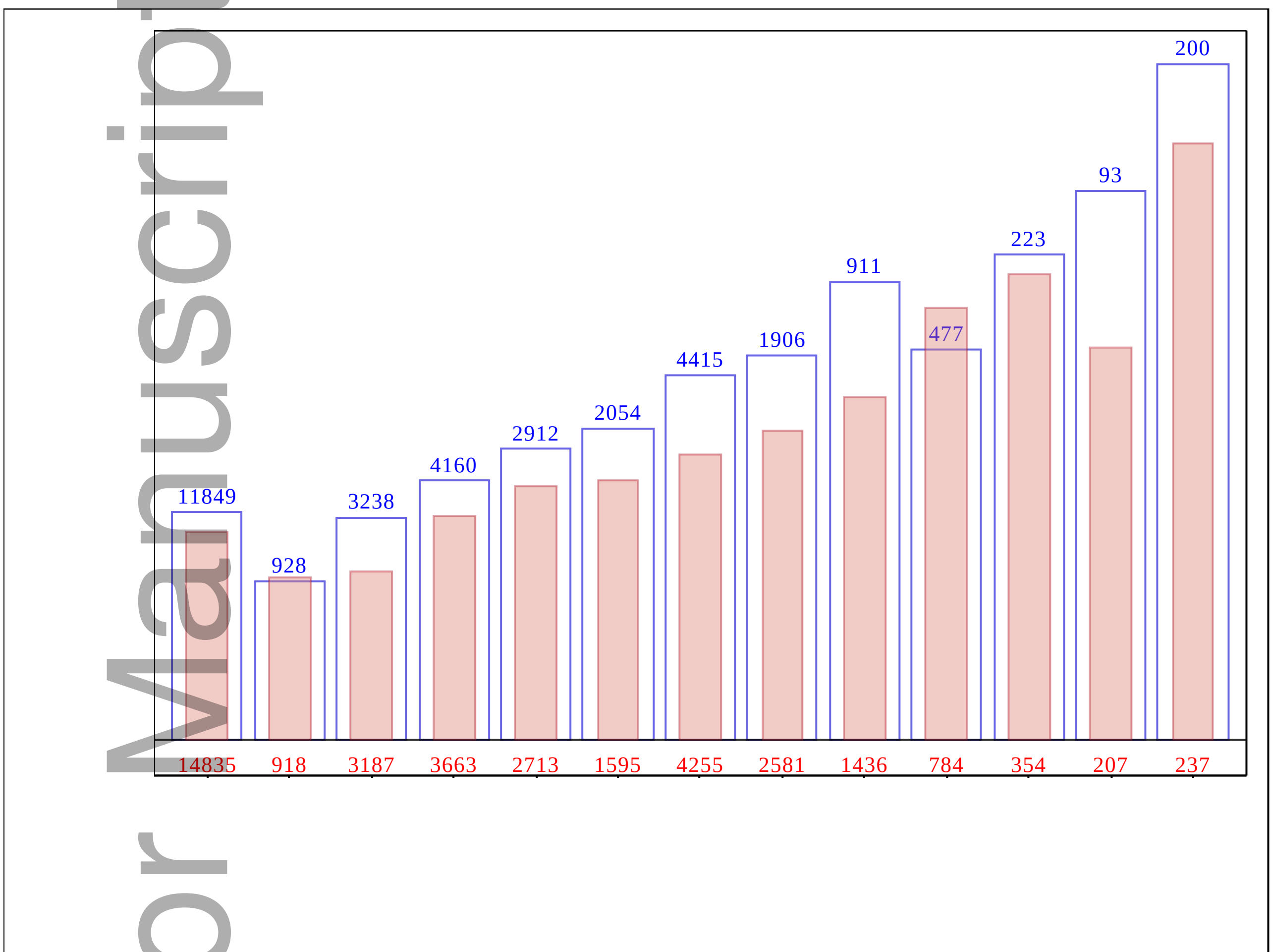
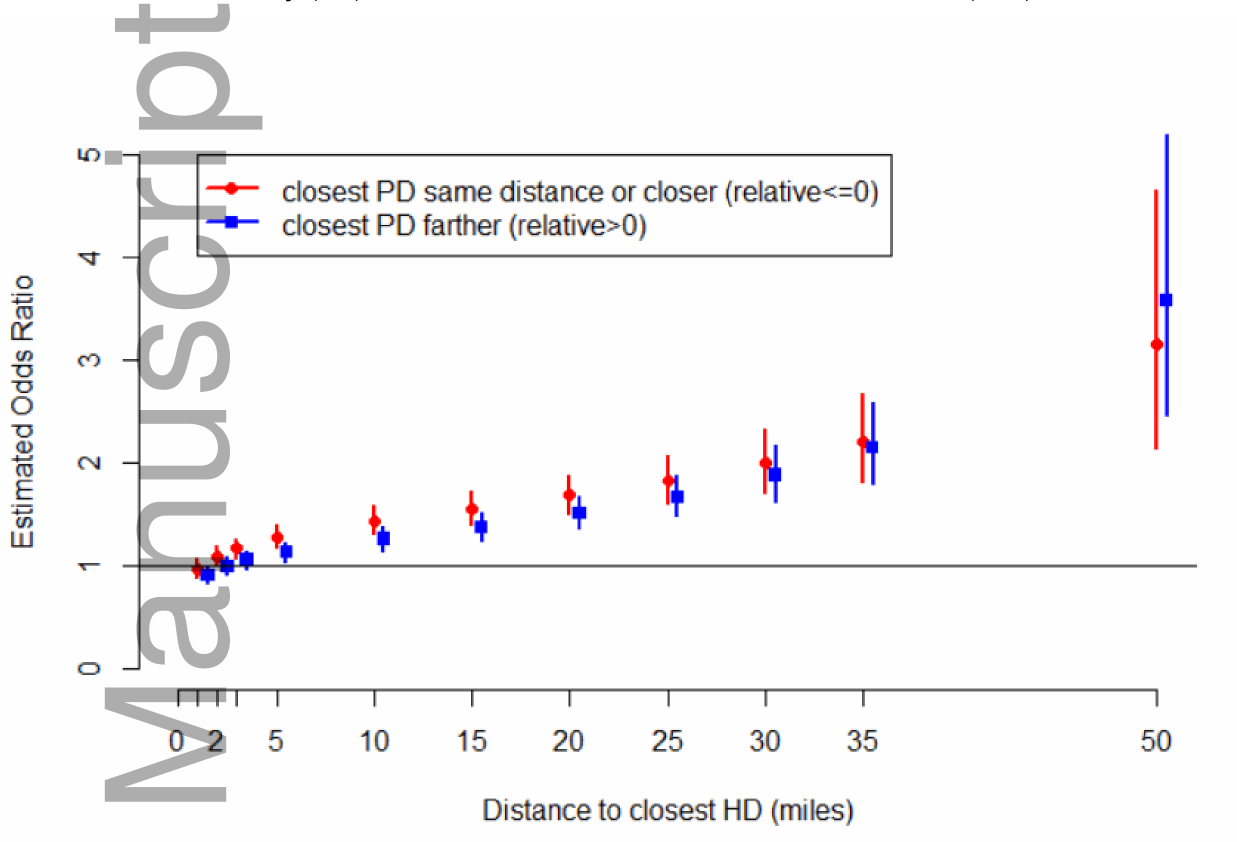


Figure 3. Adjusted Results: Predicted Odds of PD Utilization

Estimated odds ratio and 95% confidence limits comparing distance to closest HD facility from 1-50 to 0 miles to closest HD facility (in the same zip code) when distance to closest PD facility is either the same or closer than HD facility (red) or distance to closet PD is farther than closest HD (blue).



Notes:

1. Although the interaction (absolute distance * relative distance) is not statistically significant (*p* =0.13), we present results within the structure of our formal hypothesis tests.
2. Adjusted model also controlled for patient characteristics: age, gender, race, employment status, urban/rural residence, receipt of pre-ESRD nephrology care, body mass index comorbid conditions and cause of ESRD as well as market-level characteristics: PD prevalence rate in prior year, dialysis facility composition and general population density (fractal polynomial transformations results for other continuous predictors not shown). Estimates from the full model are available in the Technical Appendix.