Physician access and early nephrology care in elderly patients with end-stage renal disease

Yongming Zhao[1], John M Brooks[2], Michael J Flanigan[3], Elizabeth A Chrischilles[4], Jane F Pendergast[5] and Lawrence G Hunsicker[6]

[1]DxCG Inc., Boston, Massachusetts, USA; [2]Program in Pharmaceutical Socioeconomics, College of Pharmacy, The University of Iowa, Iowa City, Iowa, USA; [3]Marshfield Clinic Lakeland Center, Minocqua, Wisconsin, USA; [4]Department of Epidemiology, The University of Iowa, Iowa City, Iowa, USA; [5]Department of Biostatistics, The University of Iowa, Iowa City, Iowa, USA; and [6]Department of Internal Medicine, The University of Iowa, Iowa City, Iowa, USA

Early nephrology care may improve treatment outcomes of patients with end-stage renal disease. We sought to examine if physician access affects early nephrology care defined as visiting a nephrologist 12 to 4 months before initiating dialysis. The study population consisted of elderly patients starting hemodialysis whose demographic characteristics and initial dialysis therapy were derived from form 2728 files of the Centers for Medicare & Medicaid Services. Early nephrology care, chronic kidney disease and co-morbidities along with access to local non-nephrologist physicians and nephrologists were identified based on Medicare claims and/ or United States 2000 Census data. About one-third of elderly patients received early nephrology care prior to initiating dialysis. Patients living in an area with a large number of non-nephrologist physicians or living relatively far away from a nephrologist had a lower likelihood of getting early nephrology care prior to initiating dialysis while those in an area with more practicing nephrologists were more likely to get early nephrology care. The study shows that physician access significantly influences the use of early nephrology care among elderly patients progressing to end-stage renal disease in the United States.

Correspondence: Y Zhao, DxCG Inc, 99 Summer Street, Suite 520, Boston, Massachusetts 02110, USA. E-mail: yongming.zhao@dxcg.com

Early care provided by nephrologists prior to dialysis initiation may improve treatment outcomes of patients who approach end-stage renal disease (ESRD). Early nephrology care may attenuate or control complications of reduced kidney function, which are significant risk factors for morbidity and mortality among patients progressing to ESRD and later initiating dialysis.[1] Patients receiving early nephrology care prior to dialysis initiation may also get timely counseling about dialysis modality and receive dialysis access placement, which may bring better dialysis outcomes.[2,3] Previous studies suggest that ESRD patients receiving nephrology care late may have higher mortality after starting the dialysis.[4,5]

A large number of ESRD patients, however, do not receive early nephrology care defined as visiting a nephrologist more than 3 or 4 months prior to dialysis initiation.[6,7] Little research has examined factors affecting early nephrology care among patients who lose kidney function progressively and later start dialysis therapy. Two studies have investigated factors associated with late nephrology care. One study indicated that patients first visiting a nephrologist less than 4 months before starting dialysis tended to be black, uninsured, or have severe comorbid conditions.[8] Another study investigated 3014 Medicare/Medicaid patients in New Jersey who started dialysis in the early 1990s. Patients older in age or of a race other than white or black were more likely to visit a nephrologist first less than 90 days prior to dialysis initiation, whereas patients having hypertension and diabetes were less likely to get late referral.[9] Thus, demographic factors and chronic conditions appear to contribute to patients' seeking and receiving early specialty care from nephrologists.

However, factors related to local access to physicians may also have a significant influence on whether patients with progressive kidney disease visit a nephrologist well before initiation of ESRD care, and few studies have explored the impact of these physician access variables. This study was designed to investigate if physician access factors influence early nephrology care prior to hemodialysis initiation among elderly ESRD patients, the fast-growing part of the US ESRD population.

RESULTS

We identified 66,021 patients who were $67+$ years old upon dialysis initiation in the years 1996–1999 in the United States and who received physician services for disease evaluation and management between 24 and 4 months prior to dialysis initiation. Among the study subjects, approximately 32.17% of patients received early nephrology care defined as visiting a nephrologist between 12 and 4 months prior to dialysis initiation. Male patients accounted for 48.96% of the study sample whose median age was 75.95 years. Nearly 59.25% of patients were diagnosed with chronic kidney disease identified from Medicare claims between 24 and 4 months prior to dialysis initiation. On the basis of Medicare claims data, the majority of these elderly patients were treated for at least 1 of the 10 comorbidities of chronic kidney disease during the period between 24 and 13 months prior to dialysis initiation. The common comorbidities and their prevalence in the study cohort were hypertension (74.75%), diabetes (61.90%), congestive heart failure (43.72%), anemia (39.44%), peripheral vascular disease (17.62%), cancer (16.15%), cerebrovascular disease (12.16%), myocardial infarction (5.75%), chronic obstructive pulmonary disease (3.58%), and paralysis (1.83%). There was significant variation in patients' access to practicing non-nephrologist physicians and nephrologists in a local area defined as 30 miles within the centroid of a patient's residence Zone Improvement Plan (ZIP) code, the postal code used by the US Postal Service. Patients' access to local physicians was measured with three variables, non-nephrologist physicians per 10,000 population and nephrologists per 1000 prevalent elderly ESRD patients in a local area as well as the distance to the nearest nephrologist.

There were significant variations in patient characteristics between the group receiving early nephrology care and the group not receiving early nephrology care. Univariate analyses showed that patients who were male or who had 1 of the 10 common comorbidities except myocardial infarction, chronic obstructive pulmonary disease, and paralysis were more likely to visit a nephrologist for disease evaluation and management between 12 and 4 months prior to dialysis initiation than were females or patients without preexisting comorbid conditions. Patients having suffered from chronic kidney disease had a greater chance of receiving early nephrology care. Patients older than 76 years were less likely to receive early nephrology care compared with patients aged 67–76 years. χ^2 tests also indicated that there were substantial variations in the use of early nephrology care among patient groups defined by race, non-nephrologist physician visits, hospitalization between 24 and 13 months prior to dialysis initiation, patients' residence area characteristics, and three physician access-related variables, non-nephrologist physicians per 10,000 population, and nephrologists per 1000 prevalent elderly ESRD patients in a local area as well as the distance to the nearest nephrologist (Table 1).

Multivariate logistic regressions were developed to examine if physician access factors influence the use of early nephrology care prior to dialysis initiation. Table 2 lists the major results of a logistic regression model in which patients were grouped based on the quintiles of non-nephrologist physicians per 10,000 population and nephrologists per 1000 prevalent elderly ESRD patients in the study sample as well as other covariates. Patients living in an area with a greater number of non-nephrologist physician density per 10,000 population were less likely to receive early nephrology care compared with patients living in areas with a small number of non-nephrologist physicians. Patients residing further away from a nephrologist tended to have a lower odds ratio of receiving early nephrology care. Compared with patients whose residence was less than 4 miles away from a nephrologist, patients living from 10 to 20 miles, from 20 to 30 miles, from 40 to 50 miles, and more than 60 miles away from a nephrologist had a significantly smaller odds ratio of receiving early nephrology care. Patients residing in areas with more nephrologists per 1000 prevalent elderly ESRD patients had a significantly greater odds ratio of receiving early nephrology care prior to dialysis initiation (Table 2).

The associations between control variables and the use of early nephrology care were also explored. Male patients had a greater odds ratio of receiving early nephrology care. Patients who were black or older than 76 years had a lower likelihood of receiving early nephrology care, compared with white patients or patients aged 67–76 years. Patients with chronic kidney disease or suffering hypertension, anemia, or peripheral vascular disease were at a greater chance for early nephrology care, compared with patients without chronic kidney disease or any of the comorbidities. Patients who had congestive heart failure or myocardial infarction, received more non-nephrologist physician visits or got hospitalized between 24 and 13 months prior to dialysis initiation, were less likely to receive early nephrology care, compared with patients who had no comorbidities and who received no non-nephrologist physician visit or hospital admission. Comparison with patients living in rural areas or areas with very low median household income, patients living in a freestanding Metropolitan Statistical Area (MSA) with a population between 50,000 and 1 million or areas with higher median household income were more likely to receive early nephrology care prior to dialysis initiation (Table 2).

Two more logistic regression models defined using the deciles or semideciles of non-nephrologist physicians per 10,000 population and nephrologists per 1000 prevalent elderly ESRD patients, respectively, as well as other covariates were constructed. The main results of the two models were similar to those of the first model. However, in the patient groups classified using the distance to the nearest nephrologist in the two models, only patients living from 10 to 20 miles and from 20 to 30 miles away from a nephrologist had a significantly lower odds ratio of receiving early nephrology care compared with patients living less than 4 miles away from a nephrologist.

Table 1 | Characteristics of patient groups receiving and not receiving early nephrology care

Patients' characteristics	Percentage of patients not receiving early nephrology care (%)	Percentage of patients receiving early nephrology care (%)	P-value
Age (>76 years)	51.49	45.96	<0.0001*
Male	48.25	50.44	0.0001*
Race			
White	76.31	74.89	0.0003*
Black	20.70	22.16	
Asian	1.17	1.18	
Other	1.82	1.77	
Chronic kidney disease	46.18	86.80	<0.0001*
Comorbidities			
Hypertension	72.12	80.30	<0.0001*
Diabetes	59.96	66.00	<0.0001*
Congestive heart failure	42.26	46.82	<0.0001*
Anemia	36.30	46.05	<0.0001*
Peripheral vascular disease	16.64	19.67	<0.0001*
Cancer	15.40	17.73	<0.0001*
Cerebrovascular disease	11.78	12.94	<0.0001*
Myocardial infarction	5.71	5.84	0.4878
Chronic obstructive pulmonary disease	3.54	3.67	0.3758
Paralysis	1.85	1.77	0.5060
Non-nephrologist physician visits between 24 and 13 months prior to dialysis initiation			
No visits	10.58	13.11	<0.0001*
1–4 visits	41.74	38.14	
5–9 visits	21.91	20.71	
≥10 visits	25.76	28.04	
Hospital admission between 24 and 13 months prior to dialysis initiation			
Admission	32.35	34.15	<0.0001*
Non-nephrologist physicians per 10,000 population			
<9.68	19.50	20.42	<0.0001*
9.68–12.50	19.50	21.27	
12.50–15.04	19.93	20.47	
15.04–17.31	20.38	18.93	
≥17.31	20.68	18.92	
Nephrologists per 1000 prevalent elderly ESRD patients			
<22.90	21.06	17.46	<0.0001*
22.90–38.76	20.45	20.11	
38.76–51.23	20.29	19.32	
51.23–64.13	19.74	19.81	
≥64.13	18.46	23.30	
Distance to the nearest nephrologist			
<4 miles	50.17	51.30	<0.0001*
4–10 miles	18.76	20.63	
10–20 miles	13.73	13.72	
20–30 miles	8.22	7.33	
30–40 miles	4.12	3.64	
40–50 miles	2.19	1.54	

Table 1 | Continued

Patients' characteristics	Percentage of patients not receiving early nephrology care (%)	Percentage of patients receiving early nephrology care (%)	P-value
50–60 miles	1.02	0.77	
≥60 miles	1.80	1.07	
Residence area[a]			
Rural area	25.29	22.48	<0.0001*
MSA	43.00	48.01	
Primary MSA	31.71	29.51	
Median household income			
<$30,105	24.62	23.93	0.0117*
$30,105–36,769	25.18	24.62	
$36,769–46,592	24.86	25.90	
≥$46,592	25.34	25.55	
Percentage population below the poverty level			
<6.97%	25.42	25.82	0.4358
6.97–12.09%	25.26	25.45	
12.09–19.43%	25.07	24.55	
≥19.43%	24.25	24.18	
Observations (N)	44,780	21,241	

ESRD, for end-stage renal disease; MSA, Metropolitan Statistical Area.
*P<0.05.
[a]A rural area was defined as an area that was neither a MSA nor a primary MSA with more than 1 million people living nearby.

DISCUSSION

A patient's choice of visiting a nephrologist prior to dialysis initiation is a complex decision process involving the patient, the nephrologist, and/or the non-nephrologist physician. In a fee-for-service system like Medicare Part A and Part B coverage in the United States, a patient can visit a nephrologist directly or make a decision after being referred by a non-nephrologist physician. Self-referral may also be an approach for seeking nephrology care in the fee-for-service system. To better define the specialty care provided by nephrologists for evaluating and managing patients' chronic conditions, we recommend using nephrology care instead of nephrology referral, which may not account for all the cases of nephrologist visits in the fee-for-service system. We used early nephrology care to denote a nephrologist's visit during an early time period prior to dialysis initiation instead of early nephrology referral, which was often used in previous literature.[6,7,10–12]

Little consensus on specific referral criteria regarding early nephrology care for patients approaching ESRD exists.[12] A patient's clinical condition and other characteristics may prompt him/her to visit a nephrologist instead of a non-nephrologist physician during an early time period prior to dialysis initiation. Physician access factors may also impact the patient's choice of seeking early nephrology care. Limited access to nephrologists may be a cause of not receiving early nephrology care prior to dialysis initiation. A visit to a nephrologist may involve excess traveling and waiting time due to the limited number of nephrologists practicing within

Table 2 | A logistic regression predicting the use of early nephrology care

Independent variable	Parameter	Standard error	P-value	Odds ratio (95% CI)
Age (years)				
67–76				1.000 (referent)
>76	−0.199	0.019	<0.0001*	0.820 (0.790–0.851)
Gender				
Female				1.000 (referent)
Male	0.108	0.019	<0.0001*	1.114 (1.073–1.156)
Race				
White				1.000 (referent)
Black	−0.104	0.027	<0.0001*	0.901 (0.855–0.950)
Asian	−0.082	0.089	0.358	0.922 (0.774–1.097)
Other	−0.168	0.071	0.018*	0.846 (0.736–0.972)
CKD				
No CKD				1.000 (referent)
CKD	2.155	0.024	<0.0001*	8.631 (8.234–9.047)
Comorbidities				
No comorbidity				1.000 (referent)
Hypertension	0.237	0.026	<0.0001*	1.267 (1.204–1.334)
Diabetes	0.016	0.022	0.467	1.016 (0.973–1.061)
Congestive heart failure	−0.061	0.021	0.004*	0.940 (0.902–0.980)
Anemia	0.169	0.021	<0.0001*	1.184 (1.137–1.234)
Peripheral vascular disease	0.050	0.025	0.045*	1.051 (1.001–1.104)
Cancer	0.050	0.025	0.050	1.051 (1.000–1.105)
Cerebrovascular disease	−0.001	0.030	0.981	0.999 (0.943–1.059)
Myocardial infarction	−0.100	0.040	0.013*	0.905 (0.836–0.979)
Chronic obstructive pulmonary disease	−0.038	0.049	0.439	0.963 (0.874–1.060)
Paralysis	−0.136	0.070	0.053	0.873 (0.761–1.002)
Non-nephrologist physician visits between 24 and 13 months prior to dialysis initiation				
No visits				1.000 (referent)
1–4 visits	−0.398	0.032	<0.0001*	0.672 (0.631–0.715)
5–9 visits	−0.567	0.037	<0.0001*	0.567 (0.528–0.609)
≥10 visits	−0.608	0.037	<0.0001*	0.544 (0.506–0.586)
Hospital admission between 24 and 13 months prior to dialysis initiation				
No admission				1.000 (referent)
Admission	−0.468	0.024	<0.0001*	0.626 (0.598–0.656)
Non-nephrologist physicians per 10,000 population				
<9.68				1.000 (referent)
9.68–12.50	−0.053	0.033	0.108	0.949 (0.889–1.012)
12.50–15.04	−0.109	0.038	0.004*	0.897 (0.833–0.966)
15.04–17.31	−0.175	0.042	<0.0001*	0.839 (0.774–0.911)
≥17.31	−0.299	0.044	<0.0001*	0.741 (0.681–0.807)
Nephrologists per 1000 prevalent elderly ESRD patients				
<22.90				1.000 (referent)
22.90–38.76	0.217	0.038	<0.0001*	1.242 (1.153–1.338)
38.76–51.23	0.224	0.040	<0.0001*	1.251 (1.157–1.353)
51.23–64.13	0.211	0.042	<0.0001*	1.235 (1.136–1.342)
≥64.13	0.352	0.042	<0.0001*	1.422 (1.310–1.543)
Distance to the nearest nephrologist				
<4 miles				1.000 (referent)
4–10 miles	−0.020	0.026	0.437	0.980 (0.931–1.031)
10–20 miles	−0.094	0.031	0.003*	0.911 (0.856–0.968)
20–30 miles	−0.120	0.042	0.004*	0.887 (0.817–0.963)
30–40 miles	−0.018	0.062	0.771	0.982 (0.870–1.108)
40–50 miles	−0.286	0.081	0.0004*	0.751 (0.641–0.880)
50–60 miles	−0.164	0.109	0.131	0.848 (0.685–1.050)
≥60 miles	−0.381	0.098	0.0001*	0.683 (0.564–0.828)
Residence area[a]				
Rural area				1.000 (referent)

Table 2 | Continued

Independent variable	Parameter	Standard error	P-value	Odds ratio (95% CI)
MSA	0.131	0.032	<0.0001*	1.140 (1.071–1.213)
Primary MSA	−0.042	0.041	0.306	0.959 (0.885–1.039)
Median household income				
<$30,105				1.000 (referent)
$30,105–36,769	0.085	0.034	0.013*	1.088 (1.018–1.163)
$36,769–46,592	0.132	0.042	0.002*	1.141 (1.050–1.240)
⩾$46,592	0.153	0.053	0.004*	1.165 (1.050–1.292)
Percentage population below the poverty level				
<6.97%				1.000 (referent)
6.97–12.09%	−0.057	0.033	0.080	0.945 (0.886–1.007)
12.09–19.43%	−0.072	0.041	0.076	0.930 (0.859–1.008)
⩾19.43%	−0.079	0.052	0.131	0.924 (0.835–1.024)

CKD, Chronic kidney disease; CI, confidence interval; ESRD, end-stage renal disease; MSA, Metropolitan Statistical Area.
*$P<0.05$.
[a]A rural area was defined as an area that was neither a MSA nor a primary MSA with more than 1 million people living nearby. The dependent variable was dummy early nephrology care prior to dialysis initiation. Other binary independent variables included the year initiating hemodialysis (97, 98, 99) and 47 states plus Washington, DC (reference state: Wyoming).

a local area. Patients living in areas with fewer nephrologists have to weigh the decision of visiting a nephrologist for the surrogate care owing to the access-related costs incurred from obtaining an appointment with the specialist. The more nephrologists there are in a local area, the greater will be the probability that an elderly patient will have visited the specialist.

Non-nephrologist physicians may also play a significant role in patients' choices to seek early nephrology care. It has been suggested that non-nephrologist physicians of whom primary care physicians are the major part may be concerned about losing patients as well as potential income when making a nephrology referral, especially if they practice in areas with a high physician density.[6,13] Patients in an area with more non-nephrologist physicians may be less likely to get a referral from the doctors who face more competitive pressure and thus may worry about losing further patient visits as patients' deteriorating conditions approach ESRD for potential nephrology care, as suggested by other scholars.[13]

Geographic distance to a nephrologist may be a determinant for the use of early nephrology care.[14] Patients living in an area far away from a nephrologist have to spend more traveling time to visit a nephrologist's office. Patients residing much further away from a nephrologist may be reluctant to spend even more time for a nephrologist appointment. Conversely, they may have a higher likelihood of being referred by local non-nephrologist physicians who may not treat a nephrologist practicing much far away as a competitor in the local physician service market. This may explain why only patients who reside relatively far away from a nephrologist in this study are less likely to receive early nephrology care prior to dialysis initiation.

Some limitations of the study need to be discussed. Three physician access variables in the study were computed with Medicare claims of elderly ESRD patients. Because it is not possible to count all prevalent ESRD patients in a local area

with Medicare claims data, the number of prevalent elderly ESRD patients was taken as a denominator to measure the availability of nephrologists in the local areas, especially in areas where a number of nephrologists practiced. In some areas where elderly ESRD patients were not the major portion of the prevalent ESRD population, the availability of nephrologists in the areas might be overestimated with the number of nephrologists per 1000 prevalent elderly ESRD patients. In the late 1990s, the number of elderly ESRD patients was growing fast and becoming the major part of the ESRD population. The number of nephrologists per 1000 prevalent elderly ESRD patients may still capture to a large degree the availability of nephrologists practicing in the local areas.

Similarly, the number of non-nephrologist physicians per 10,000 population in a local area was taken to measure the availability of non-nephrologist physicians competing with nephrologists for patients. The number of non-nephrologist physicians was also identified with Medicare claims of elderly ESRD patients. Non-nephrologist physicians who did not examine elderly ESRD patients but practiced in a local area were not counted. In some areas where only a small number of elderly ESRD patients visited non-nephrologist physicians, the number of non-nephrologist physicians in those areas might be underestimated. However, this study aims to explore the impact of non-nephrologist physicians competing with nephrologists for elderly patients. The non-nephrologist physicians examining elderly ESRD patients are more likely to be doctors who are competing with nephrologists for patients with chronic kidney disease. Thus, the underestimated problem of non-nephrologist physicians in local areas might have little impact on the estimation of early nephrology care.

Confounding factors associated with both early nephrology care and physician access factors may not be fully addressed in the research. Even though chronic kidney

disease and its common comorbidities were controlled in the study, patients' disease severity, one of the important confounders, may not be measured accurately from claims data. Identifying chronic kidney disease on the basis of International Classification of Diseases, Ninth Revision codes is only a complementary approach when glomerular filtration rate cannot be generated from claims data. Chronic kidney disease in this study may be underestimated from Medicare claims.[15] The same limitation may also exist in identifying comorbidities from claims data.[16] Even if comorbidities of chronic kidney disease could be identified reliably from Medicare claims, patient groups receiving and not receiving early nephrology care may differ significantly in other clinical conditions that cannot be observed. For example, in patients suffering from anemia, the common complication of chronic kidney disease, may have varied hematocirt/hemoglobin levels and other related conditions, which may affect their likelihood of receiving early nephrology care. In addition, non-nephrologist physician visits and hospitalization may be significantly correlated with physician access factors and early nephrology care. Controlling those variables in the regression models may not sufficiently reduce the confounding problem in the study estimating the effects of physician access factors on early nephrology care. Moreover, three area-level control variables including the median household income level, percentage population below the poverty level, and residence area characteristics may not sufficiently capture variations in patients' individual income and other socioeconomic status that may influence the use of early nephrology care. The results of this study based on the data in the late 1990s may not be extrapolated to other time periods in which nephrology referral pattern may change.

In conclusion, elderly ESRD patients' access to local non-nephrologist physicians and nephrologists significantly affect the use of early nephrology care prior to dialysis initiation. Characteristics of patients receiving early nephrology care may differ significantly from those of patients not receiving early nephrology care before initiating dialysis. Clinical outcome studies, which attempt to evaluate the value of early nephrology care prior to dialysis initiation using claims data, need to take into account significant variations in patients' characteristics. To better understand patients' use of early nephrology care prior to dialysis initiation and related outcomes, more studies are needed.

MATERIALS AND METHODS
Patient population
This was a retrospective cohort study of patients aged 67 years and above who were started on hemodialysis in the years 1996–1999, who had Medicare Part A and Part B coverage in the fee-for-service system during the 2-year time period prior to hemodialysis initiation, who visited a physician for disease evaluation and management between 24 and 4 months prior to dialysis initiation, and who resided in United States except Alaska, Hawaii, and US territories. Patients who were diagnosed with AIDS/HIV in Medicare claims were excluded from the study. In addition, patients whose

residence ZIP codes could not match with the US 2000 Census data were also excluded because their physician access variables could not be created.

Definition of variables
Medicare enrollment files were used to identify patients' coverage in Medicare fee-for-service system in the 2-year time period prior to dialysis initiation. Patients' demographic characteristics were obtained from End Stage Renal Disease Medical Evidence Report (form 2728) data of Centers for Medicare and Medicaid Services (CMS). Patients' initial dialysis modality was identified from United States Renal Data System (USRDS) Modality Sequence files. Early nephrology care and non-nephrologist physician visits were collected from CMS physician/supplier files with the Current Procedural Terminology (CPT) codes specifying face-to-face contact with the patient for disease evaluation and management.[17] Chronic kidney disease and 10 comorbidities of chronic kidney disease were identified from Medicare Part A and Part B claims based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes and/or CPT codes, as well as Healthcare Common Procedure Coding System (HCPCS) codes.

Patients' access to local physicians was measured with three variables. (a) Non-nephrologist physicians per 10,000 population in a local area, defined as an area within 30 miles of the centroid of a patient's residence ZIP code; (b) nephrologists per 1000 prevalent elderly ESRD patients in the local area; and (c) distance from the patient's residence to the nearest nephrologist. The three access-related variables were computed with longitudes and latitudes of patients' residence and physicians' practicing ZIP codes gathered from Medicare claims of elderly ESRD patients and US 2000 Census data, which also contain the information about patients' residence area characteristics. In all the analyses, patients were stratified into eight groups based on the distance to the nearest nephrologist (<4, 4–10, 10–20, 20–30, 30–40, 40–50, 50–60, and $\geqslant60$ miles) and into groups based on quintiles, deciles, or semideciles of other two physician access variables in the study sample.

To control for the impact of income on access to physician services, patients were stratified into groups based on quartiles of two measures developed by US Census Bureau as follows: (a) median household income and (b) percentage population below the poverty level in 1999. A rural area in this study was defined as an area that was neither a primary MSA with more than 1 million people living in adjacent areas nor a freestanding MSA with 50,000–1 million residents in nearby areas developed by US Office of Management and Budget for federal statistics.

Statistical methods
χ^2 tests and multivariate logistic regressions were used to identify the effects of physician access factors on early nephrology care prior to hemodialysis initiation. All statistical analyses were performed using SAS 9.0 at the 0.05 level of significance.

REFERENCES

1. Owen Jr WF. Patterns of care for patients with chronic kidney disease in the United States: dying for improvement. *J Am Soc Nephrol* 2003; **14**: S76–S80.
2. Lameire N, Wauters J-P, Teruel JLG *et al*. An update on the referral pattern of patients with end-stage renal disease. *Kidney Int* 2002; **61**: S27–S34.
3. Pereira BJG. Optimization of pre-ESRD care: the key to improved dialysis outcomes. *Kidney Int* 2000; **57**: 351–365.
4. Avorn J, Bohn RL, Levy E *et al*. Nephrologist care and mortality in patients with chronic renal insufficiency. *Arch Intern Med* 2002; **162**: 2002–2006.
5. Stack AG. Impact of timing of nephrology referral and pre-ESRD care on mortality risk among new ESRD patients in the United States. *Am J Kidney Dis* 2003; **41**: 310–318.
6. Obrador GT, Pereira BJ. Early referral to the nephrologist and timely initiation of renal replacement therapy: a paradigm shift in the management of patients with chronic renal failure. *Am J Kidney Dis* 1998; **31**: 398–417.
7. Roubicek C, Brunet P, Huiart L *et al*. Timing of nephrology referral: influence on mortality and morbidity. *Am J Kidney Dis* 2000; **36**: 35–41.
8. Kinchen KS, Sadler J, Fink N *et al*. The timing of specialist evaluation in chronic kidney disease and mortality. *Ann Intern Med* 2002; **137**: 479–486.
9. Winkelmayer WC, Glynn RJ, Levin R. Determinants of delayed nephrologist referral in patients with chronic kidney disease. *Am J Kidney Dis* 2001; **38**: 1178–1184.
10. Arora P, Obrador GT, Ruthazer R *et al*. Prevalence, predictors, and consequences of late nephrology referral at a tertiary care center. *J Am Soc Nephrol* 1999; **10**: 1281–1286.
11. Kazmi WH, Obrador GT, Khan SS *et al*. Late nephrology referral and mortality among patients with end-stage renal disease: a propensity score analysis. *Nephrol Dial Transplant* 2004; **19**: 1808–1814.
12. Wavamunno MD, Harris DCH. The need for early nephrology referral. *Kidney Int* 2005; **67**: s128–s132.
13. Wauters J-P, Lameire N, Davison A *et al*. Why patients with progressing kidney disease are referred late to the nephrologist: on causes and proposals for improvement. *Nephrol Dial Transplant* 2005; **20**: 490–496.
14. Schmidt RJ, Domico JR, Sorkin MI *et al*. Early referral and its impact on emergent first dialyses, health care costs, and outcome. *Am J Kidney Dis* 1998; **32**: 278–283.
15. Winkelmayer WC, Schneeweiss S, Mogun H *et al*. Identification of individuals with CKD from Medicare claims data: a validation study. *Am J Kidney Dis* 2005; **46**: 225–232.
16. Elixhauser A, Steiner C, Harris DR *et al*. Comorbidity measures for use with administrative data. *Med Care* 1998; **36**: 8–27.
17. Kirschner CG, Davis SJ, Jackson JA *et al*. CPT '97: Physicians' Current Procedural Terminology, 4th edn. American Medical Association: Chicago, IL, 1997.