



ORIGINAL ARTICLE

Impact of poverty and race on pre-end-stage renal disease care among dialysis patients in the United States

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Abstract

Background: Access to nephrology care prior to end-stage renal disease (ESRD) is significantly associated with lower rates of morbidity and mortality. We assessed the association of area-level and individual-level indicators of poverty and race/ethnicity on pre-ESRD care provided by nephrologists.

Methods: In this retrospective cohort study using the US Renal Data System database, we identified 739 537 patients initiated on maintenance dialysis from 1 January 2007 through 31 December 2012. We assessed the Medicare–Medicaid dual eligibility status as an indicator of individual-level poverty and ZIP code–level median household income (MHI) data obtained from the 2010 US census. We conducted multivariable logistic regression of pre-ESRD nephrology care as the outcome variable.

Results: Among patients in the lowest area-level MHI quintile, 61.28% received pre-ESRD nephrology care versus 67.68% among those in higher quintiles ($P < 0.001$). Similarly, the proportions of dual-eligible and nondual-eligible patients who had pre-ESRD nephrology care were 61.49 and 69.84%, respectively ($P < 0.001$). Patients in the lowest area-level MHI quintile were associated with significantly lower likelihood of pre-ESRD nephrology care (adjusted odds ratio [aOR] 0.86 [95% confidence interval (CI) 0.85–0.87]) compared with those in higher quintiles. Both African American (AA) and Hispanic patients were significantly less likely to have received pre-ESRD nephrology care [aOR 0.85 (95% CI 0.84–0.86) and aOR 0.72 (95% CI 0.71–0.74), respectively].

Conclusions: Individual- and area-level measures of poverty, AA race and Hispanic ethnicity were independently associated with a lower likelihood of pre-ESRD nephrology care. Efforts to improve pre-ESRD nephrology care may require focusing on the poor and minority groups.

Key words: end-stage renal disease, poverty, pre-ESRD care, racial disparities

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Introduction

For patients approaching end-stage renal disease (ESRD), practice guidelines recommend timely referral for renal replacement therapy (RRT) planning to ensure good clinical decision making [1]. Access to care provided by a nephrologist prior to RRT initiation is associated with improved clinical outcomes [2]. For instance, pre-ESRD nephrology care is associated with higher rates for arteriovenous fistula (AVF) placement [3, 4], access to kidney transplantation [5, 6] and improved patient survival [7, 8]. A recent US Renal Data System (USRDS) study demonstrated that pre-ESRD nephrology care for >12 months was associated with lower first-year mortality, higher albumin and hemoglobin, choice of peritoneal dialysis, native fistula and discussion of transplantation options [9]. Conversely, late nephrology referral is associated with higher mortality after the initiation of dialysis [10]. Despite these benefits, about one-third of incident dialysis patients in the USA had received no pre-ESRD nephrology care [11].

There are conflicting data regarding the role of geographic variation and socioeconomic factors on the rates of pre-ESRD nephrology care. Hao et al. [12] reported significant regional variability in the rates of pre-ESRD nephrology care across the USA. Furthermore, dialysis facilities with the lowest rates of pre-ESRD nephrology care were more likely to be located in urban counties with high African American (AA) populations and low educational attainment [12]. However, Maripuri et al. [13] did not observe significant geographic differences in the attainment of pre-ESRD nephrology care. Plantinga et al. [14] did not find a significant association between dialysis facility neighborhood poverty and receipt of pre-ESRD nephrology care. Given these limited and conflicting data, an assessment of area-level income would be helpful in interpreting the impact of socioeconomic status (SES) on the likelihood of receiving pre-ESRD nephrology care.

We therefore conducted a retrospective cohort study using data from the USRDS to assess the association of ZIP code-level median household income (MHI) with pre-ESRD care provided by nephrologists, as reported on the Centers for Medicare and Medicaid Services (CMS) Form 2728. Because such data are area-based and thus ecological, we also assessed Medicare-Medicaid dual eligibility status as an indicator of individual-level poverty [15–18] and its association with pre-ESRD nephrology care. Furthermore, we assessed the impact of race/ethnicity and its interaction with measures of poverty on pre-ESRD nephrology care. We hypothesized that measures of poverty would be independently associated with lower rates of pre-ESRD nephrology care.

Materials and methods

This study used the USRDS, which incorporates baseline and follow-up demographic and clinical data on all patients accessing the Medicare ESRD program in the USA. We conducted a retrospective cohort study consisting of patients initiated on either hemodialysis or peritoneal dialysis from 1 January 2007 through 31 December 2012. Our cohort excluded patients with missing data on comorbidities ($n = 8137$) as well as those not included in the USRDS Annual Data Reports for the years studied ($n = 76$). We merged the USRDS database with the 2010 US census for ZIP code-level MHI data. There were 14 879 patients who had missing MHI data and were therefore excluded from data analysis. The study cohort consisted of 739 537 dialysis patients. The primary outcome was pre-ESRD nephrology care as reported on CMS Form 2728, under question 18b 'Prior to ESRD therapy: Was patient under care of a nephrologist?' Pre-ESRD nephrology care was analyzed as a binary outcome

($n = 647\,810$, yes or no). Missing data ($n = 70$) on the status of pre-ESRD nephrology care and patients in the 'Unknown' category ($n = 91\,657$) were excluded. The Supplementary data, Table shows the baseline demographic and clinical characteristics of patients of 'Unknown' status versus patients with known status for pre-ESRD nephrology care as reported on CMS Form 2728. This study was approved as exempt from review by the Walter Reed National Military Medical Center Institutional Review Board.

Patients and sources

The demographics of the dialysis population in this study have been described in the USRDS Annual Data Reports for the years studied [19]. Variables included in the USRDS standard analysis files (SAFs), as well as data collection methods and validation studies, are listed on the USRDS website (www.usrds.org). The file SAF.PATIENTS was used as the primary dataset and SAF.MEDEVID was used for additional information coded in the CMS Form 2728 as modified in 2005. Files from the 2010 US census (<http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>) were used to merge by ZIP code with USRDS files. The variable 'dualelig' was used to determine individual patients' dual eligibility for Medicare and Medicaid. Although eligibility varies by state, means testing is stricter than for either Medicare or Medicaid alone and usually includes the poorest patients receiving care, at most <135% poverty and generally lower than 100% poverty [16, 20].

Predictor variables

Covariates in our analysis included age at initiation of dialysis, year at first ESRD service, gender, AA versus non-AA, Hispanic ethnicity (a nonmutually exclusive category that could overlap with race), diabetes mellitus, hypertension, other comorbid conditions from the CMS Form 2728 (Table 1), tobacco use, body mass index, serum albumin, hemoglobin, amputation, ambulatory status, institutionalization status (assisted living, nursing home or other institution) and socioeconomic factors [quintiles of area-level MHI, individual employment status, Veterans Affairs (VA) health care coverage, Medicare, Medicaid and dual eligibility for Medicare and Medicaid as a surrogate for individual-level poverty].

Statistical analysis

Analyses were performed using Stata 13 SE (StataCorp, College Station, TX, USA). Univariate analyses were performed with χ^2 testing for categorical variables (Fisher's exact test used for violations of Cochran's assumptions) and Student's *t*-test for continuous variables (Mann-Whitney test used for nonnormally distributed variables). *P*-values <0.05 were considered statistically significant for univariate comparisons.

We conducted logistic regression analyses in forward stepwise fashion to evaluate factors independently associated with pre-ESRD nephrology care. We stratified the model by MHI quintile levels and by dual-eligible status to assess effect modification of area-level and individual-level poverty on the association between race/ethnicity and pre-ESRD nephrology care. We also stratified the model by VA coverage to evaluate its effect modification with race/ethnicity in a unique single-payer health system. Variables with *P*-values <0.10 in unadjusted analysis were introduced into multivariate analysis as covariates because of the possibility of negative confounding. Also, our model development used 'forced' entry to account for factors known to be

Table 1. Baseline demographic and comorbidity characteristics of incident dialysis patients in the USA, 2007–12, lowest area-level MHI quintile versus higher quintiles

Variables	Lowest MHI quintile (n = 145 581)	Higher MHI quintiles (n = 593 956)	P-value
Race			
White	69 305 (47.61)	415 259 (69.91)	<0.001
AA	71 110 (48.85)	142 033 (23.91)	<0.001
Hispanic ethnicity	32 774 (22.51)	79 121 (13.32)	<0.001
Gender			
Male	77 922 (53.53)	338 353 (56.97)	<0.001
Female	67 648 (46.47)	255 588 (43.03)	<0.001
Mean age (year) at start of dialysis (±SD)	59.48 (±15.48)	62.32 (±16.14)	<0.001
Vascular access			
AVF use at start of dialysis	17 438 (11.98)	81 520 (13.72)	<0.001
Graft use at start of dialysis	4815 (3.31)	16 332 (2.75)	<0.001
Catheter use at start of dialysis	112 915 (77.56)	435 053 (73.25)	<0.001
Predialysis nephrology care			
Yes	77 293 (61.28)	353 053 (67.68)	<0.001
No	48 843 (38.72)	168 621 (32.32)	<0.001
If yes, duration of predialysis care			
<6 months	16 545 (11.36)	80 007 (13.47)	<0.001
6–12 months	28 174 (19.35)	115 645 (19.47)	0.31
>12 months	32 570 (22.37)	157 380 (26.50)	<0.001
Amputation	5418 (3.72)	17 494 (2.95)	<0.001
Nonambulatory	10 546 (7.24)	40 166 (6.76)	<0.001
Institutionalized	10 252 (7.05)	49 706 (8.38)	<0.001
Unemployed	42 082 (28.91)	120 812 (20.34)	<0.001
Tobacco use	11 507 (7.90)	35 704 (6.01)	<0.001
Cause of ESRD			
Diabetes mellitus	71 251 (48.94)	262 168 (44.14)	<0.001
Hypertension	43 027 (29.56)	158 428 (26.67)	<0.001
Glomerulonephritis	10 392 (7.14)	53 382 (8.99)	<0.001
Polycystic kidney disease	2035 (1.40)	14 055 (2.37)	<0.001
Other renal disorders	1320 (0.91)	8753 (1.47)	<0.001
Unknown	4213 (2.89)	21 392 (3.60)	<0.001
Comorbid conditions			
COPD	12 104 (8.31)	54 169 (9.12)	<0.001
Diabetes mellitus	83 958 (57.67)	312 767 (52.66)	<0.001
Hypertension	128 069 (87.97)	504 396 (84.92)	<0.001
Atherosclerotic heart disease	25 644 (17.61)	117 308 (19.75)	<0.001
Congestive heart failure	45 094 (30.98)	182 043 (30.65)	0.02
Peripheral vascular disease	19 342 (13.29)	75 707 (12.75)	<0.001
Cerebrovascular disease (CVA, TIA)	13 877 (9.53)	52 926 (8.91)	<0.001
Cancer	8057 (5.53)	43 868 (7.39)	<0.001
Mean body mass index (kg/m ²) (±SD)	29.71 (±8.33)	29.23 (±8.01)	<0.001
Serum albumin (g/dL)	3.16 (±4.02)	3.27 (±5.15)	<0.001
Hemoglobin (g/dL)	10.20 (±19.94)	10.39 (±24.34)	0.006
Insurance			
Medicare primary	69 054 (47.43)	311 169 (52.39)	<0.001
Medicaid	52 855 (36.31)	147 816 (24.89)	<0.001
VA	2979 (2.05)	11 112 (1.87)	<0.001
Dual eligible for Medicare and Medicaid ^a	76 845 (52.79)	229 267 (38.60)	<0.001
Mean ZIP code-level MHI (\$/year) ^b	38 795 (± 5902)	71 791 (± 24 863)	<0.001

Data are n (%) or mean ± SD.

Univariate analyses were performed with χ^2 testing for categorical variables (Fisher's exact test used for violations of Cochran's assumptions) and Student's t-test for continuous variables (Mann–Whitney test used for nonnormally distributed variables).

SD, standard deviation; AVF, arteriovenous fistula; ESRD, end-stage renal disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular disease; TIA, transient ischemic attack; MHI, median household income; AA, African-American; VA, Veterans Affairs.

^aDual-eligible status as defined in the Materials and Methods section.

^bBased on ZIP code from the 2010 US census.

clinically associated with the outcome variable, based on the existing literature [8, 21, 22].

The overall percentage of correct classification of fitted values was 67.96 (an observation is classified as a positive

outcome if its predicted probability threshold is $\geq 50\%$). For very large data sets ($n > 25\,000$), Hosmer–Lemeshow goodness-of-fit testing is not recommended since the power of the statistical test increases with sample size, thus even small

Table 2. Multivariable logistic regression model of factors associated with pre-ESRD nephrology care

Variables	aOR	95% CI	P-value
AA	0.85	0.84–0.86	<0.001
Hispanic ethnicity	0.72	0.71–0.74	<0.001
Male gender	0.88	0.87–0.89	<0.001
Age at start of dialysis	1.00	1.00–1.00	<0.001
Year at first ESRD service	1.04	1.03–1.04	<0.001
Amputation	0.98	0.95–1.02	0.03
Nonambulatory	0.67	0.66–0.69	<0.001
Institutionalized	0.56	0.55–0.57	<0.001
Unemployed	0.66	0.65–0.67	<0.001
Tobacco use	0.84	0.82–0.86	<0.001
Chronic obstructive pulmonary disease	0.88	0.87–0.90	<0.001
Diabetes mellitus	1.35	1.34–1.37	<0.001
Hypertension	1.50	1.47–1.52	<0.001
Atherosclerotic heart disease	1.15	1.14–1.17	<0.001
Congestive heart failure	0.84	0.83–0.85	<0.001
Peripheral vascular disease	1.11	1.09–1.13	<0.001
Cerebrovascular disease (CVA, TIA)	1.03	1.02–1.06	0.001
Cancer	0.88	0.86–0.89	<0.001
Mean body mass index >30 kg/m ² (versus <30 kg/m ²)	1.13	1.11–1.14	<0.001
Serum albumin <3.0 g/dL (versus >3 g/dL)	0.59	0.58–0.59	<0.001
Hemoglobin <9 g/dL (versus >9 g/dL)	0.70	0.70–0.71	<0.001
Medicare primary (versus other insurance types)	1.23	1.21–1.24	<0.001
Medicaid (versus other insurance types)	1.07	1.06–1.09	<0.001
VA (versus other insurance types)	1.38	1.32–1.44	<0.001
Dual-eligible status (versus nondual eligible)	0.78	0.77–0.79	<0.001
MHI quintile levels			
Bottom fifth quintile (range \$6993–46 211/year)	0.75	0.74–0.76	<0.001
Lower middle quintile (range \$46 212–54 991/year)	0.81	0.80–0.82	<0.001
Middle quintile (range \$54 992–64 539/year)	0.85	0.83–0.86	<0.001
Upper middle quintile (range \$64 541–80 793/year)	0.89	0.87–0.91	<0.001
Top fifth quintile (range \$80 800–499 965/year)	1.0 (Reference)		

ESRD, end-stage renal disease; CVA, cerebrovascular disease; TIA, transient ischemic attack; MHI, median household income; aOR, adjusted odds ratio; CI, confidence interval; AA, African-American; VA, Veterans Affairs.

departures from the regression model will be considered significant [23].

Results

We identified 739 537 dialysis patients from 1 January 2007 through 31 December 2012. Table 1 shows demographic and unadjusted characteristics of those in the lowest area-level MHI quintile versus higher quintiles (a composite of second, third, fourth and highest quintiles). Among patients in the lowest area-level MHI quintile, 61.28% received pre-ESRD nephrology care versus 67.68% among those in higher quintiles. Similarly, the proportions of dual-eligible and nondual-eligible patients who had pre-ESRD nephrology care were 61.49 and 69.84%, respectively ($P < 0.001$). Compared with patients in higher area-level MHI quintiles, those in the lowest area-level MHI quintile were more likely to be AA or Hispanic, female, younger at dialysis initiation, unemployed, diabetic and hypertensive. Furthermore, these patients were more likely to have Medicaid or dual eligibility status for both Medicare and Medicaid coverage. Patients in the higher quintiles, on the other hand, were more likely to be older, white, male and more likely to initiate hemodialysis with an AVF.

In the fully adjusted logistic regression model, patients in the lowest area-level MHI quintile were associated with a significantly lower likelihood of pre-ESRD nephrology care (adjusted odds

ratio [aOR] 0.86 [95% confidence interval (CI) 0.85–0.87]) compared with those in higher quintiles. As presented in Table 2, there was an independent, graded association between area-level MHI quintiles and the likelihood of pre-ESRD nephrology care, demonstrating that patients in a lower area-level MHI quintile were less likely to have received pre-ESRD nephrology care relative to their counterparts in a higher quintile group. Furthermore, dual eligibility was associated with significantly lower likelihood of pre-ESRD nephrology care (aOR 0.78).

Both AA and Hispanic patients were significantly less likely to have received pre-ESRD nephrology care (aOR 0.85 and aOR 0.72, respectively). Interaction terms between area-level MHI quintiles and AA race ($P < 0.001$) and Hispanic ethnicity were significant ($P < 0.001$). Because of these significant interactions, we conducted separate analyses stratified by the lowest MHI quintiles versus higher MHI quintiles (a composite of second, third, fourth and highest quintiles) as illustrated in Table 3. We also conducted similar analyses, stratifying the model by dual-eligible status. In these stratified analyses, both AA and Hispanic patients had similar likelihoods for pre-ESRD nephrology care, regardless of area-level MHI quintiles or dual-eligible status. Thus racial/ethnic disparities in the receipt of pre-ESRD nephrology care persisted when stratified by either area-level or individual-level measure of income categories.

Among incident ESRD patients with VA health insurance, 73.19% had pre-ESRD nephrology care (versus 66.3% of patients

Table 3. Multivariable logistic regression models of factors associated with pre-ESRD nephrology care, stratified by MHI quintile and dual eligibility status for Medicare and Medicaid

Covariables	Lowest MHI quintile (n = 125 961) ^a			Higher MHI quintiles (n = 520 972) ^a		
	aOR	95% CI	P-value	aOR	95% CI	P-value
AA	0.87	0.85–0.89	<0.001	0.83	0.82–0.84	<0.001
Hispanic	0.71	0.69–0.74	<0.001	0.73	0.72–0.74	<0.001
	Dual-eligible status (n = 257 432) ^b			Nondual-eligible status (n = 375 453) ^b		
AA	0.86	0.84–0.87	<0.001	0.87	0.85–0.88	<0.001
Hispanic	0.74	0.72–0.76	<0.001	0.74	0.72–0.75	<0.001

ESRD, end-stage renal disease; MHI, median household income; aOR, adjusted odds ratio; CI, confidence interval; AA, African-American.

^aOther variables in the model include age at initiation of dialysis, year at first ESRD service, gender, diabetes mellitus, hypertension, chronic obstructive pulmonary disease, tobacco use, atherosclerotic heart disease, cerebrovascular disease, congestive heart failure, peripheral vascular disease, cancer, body mass index, serum albumin, hemoglobin, amputation, ambulatory status, institutionalization status (assisted living, nursing home or other institution), individual employment status (unemployed versus employed), Medicare, Medicaid, VA coverage and dual-eligible status for both Medicare and Medicaid.

^bOther variables in the model include age at initiation of dialysis, year at first ESRD service, gender, diabetes mellitus, hypertension, chronic obstructive pulmonary disease, tobacco use, atherosclerotic heart disease, cerebrovascular disease, congestive heart failure, peripheral vascular disease, cancer, body mass index, serum albumin, hemoglobin, amputation, ambulatory status, institutionalization status (assisted living, nursing home or other institution), individual employment status (unemployed versus employed), Medicare, Medicaid, VA coverage and MHI quintile levels.

in the general ESRD population; $P < 0.001$). In the adjusted model, VA patients were significantly more likely to have pre-ESRD nephrology care compared with patients with other insurance types (aOR 1.38). Interaction terms between VA insurance and AA race ($P < 0.001$) and Hispanic ethnicity were significant ($P < 0.001$). Because of these significant interactions, we conducted separate analyses stratified by VA versus other insurance coverage. As presented in Table 4, racial/ethnic disparities in pre-ESRD nephrology care among AA and Hispanic patients were eliminated by having VA coverage. Of note, among those with VA coverage, AA patients were significantly more likely to have pre-ESRD nephrology care than non-AA patients (aOR 1.12).

Discussion

Optimal pre-ESRD care includes timely referral to a nephrologist, implementation of educational programs and timely creation of an arteriovenous access [24]. We found in a national, multiyear study of the US incident dialysis population that both individual-level and area-level measures of poverty were associated with a significantly lower likelihood of pre-ESRD nephrology care. In particular, an independent, graded association was observed between area-level MHI quintiles and the likelihood of pre-ESRD nephrology care. Thus patients in a lower area-level MHI quintile were less likely to have received pre-ESRD nephrology care relative to their counterparts in a higher quintile group. These findings persisted despite accounting for insurance type, dual eligibility status, employment status, race/ethnicity, age, comorbidities and other demographic factors. Furthermore, we used dual eligibility status for Medicare and Medicaid as a measure of individual-level poverty. These dual-eligible beneficiaries represent a disadvantaged subgroup of older Americans who are generally impoverished and have a higher prevalence of

Table 4. Multivariable logistic regression models of factors associated with pre-ESRD nephrology care, stratified by VA coverage

Covariables	VA insurance (n = 12 208)			Non-VA insurance (n = 620 677)		
	aOR	95% CI	P-value	aOR	95% CI	P-value
AA	1.12	1.02–1.23	0.02	0.85	0.84–0.86	<0.001
Hispanic	1.05	0.91–1.22	0.48	0.72	0.71–0.73	<0.001

ESRD, end-stage renal disease; aOR, adjusted odds ratio; CI, confidence interval; VA, veterans affairs; AA, African-American.

Other variables in the model include age at initiation of dialysis, year at first ESRD service, gender, diabetes mellitus, hypertension, chronic obstructive pulmonary disease, tobacco use, atherosclerotic heart disease, cerebrovascular disease, congestive heart failure, peripheral vascular disease, cancer, body mass index, serum albumin, hemoglobin, amputation, ambulatory status, institutionalization status (assisted living, nursing home or other institution), individual employment status (unemployed versus employed), Medicare, Medicaid, dual-eligible status for both Medicare and Medicaid and MHI quintile levels.

physical and cognitive impairments, less education and lower levels of social support than their Medicare-only counterparts [25, 26]. Dual-eligible individuals in our cohort were significantly less likely to have received pre-ESRD nephrology care, a finding that is congruent with the area-level measure of poverty. Our results on both patient-level and area-level indicators of poverty validate and expand the previous findings of Yan *et al.* [27], who reported that state-level poverty was inversely associated with nephrologist care at least 12 months before ESRD. A notable exception found that dialysis facility-level pre-ESRD nephrology care was not associated with poverty (defined as $\geq 20\%$ of households in a US census tract living below federal poverty threshold) in dialysis facility neighborhoods [21]. As a potential explanation for their unexpected findings, the authors noted that it was possible that the neighborhood where the patient received pre-ESRD nephrology care might have a different poverty status than that of their eventual dialysis facility. Also, the individual-level measure of poverty was not assessed, as in the current study.

Minority populations in the USA are disproportionately affected by chronic kidney disease (CKD), and given the interdependency of race, ethnicity and socioeconomic factors on adverse clinical outcomes in patients with ESRD [22, 28, 29], we assessed the impact of poverty on the racial/ethnic disparities in pre-ESRD nephrology care. Our analysis demonstrated that AA and Hispanic patients were less likely to receive pre-ESRD nephrology care, independent of employment status, area-level income, dual eligibility status and other insurance types. Thus racial/ethnic disparities in pre-ESRD nephrology care persisted despite income differences. The differences in aORs for pre-ESRD nephrology care in these minority groups between the lowest and higher area-level MHI quintiles appear to be nominal and not clinically significant. Thus higher area-level MHI quintiles do not substantially impact minority access to pre-ESRD nephrology care. Furthermore, AA and Hispanic patients had a similar likelihood of pre-ESRD nephrology care, regardless of dual-eligible status. These findings may suggest that income level is important but not sufficient for eliminating minority gaps in pre-ESRD nephrology care and are consistent with the multidimensional aspects of health care access to include availability, accessibility, accommodation, affordability and acceptability [30]. Of note, dual eligibility for Medicare and Medicaid, which is designed to supplement patients who have financial and other disadvantages, did not ameliorate the racial/ethnic disparities in access to pre-

ESRD nephrology care. The program could attenuate such differences, but this impact would be impossible to measure.

We found that VA patients were more likely to receive pre-ESRD nephrology care compared with the general ESRD population (73.19 versus 66.3%, respectively) with an OR of 1.38 in an adjusted model. Potential reasons for the higher likelihood of pre-ESRD nephrology care among VA patients include greater access to subspecialty care, use of electronic health records, case management services and defined referral algorithms [31, 32]. Since 2001, the Department of Veterans Affairs and Department of Defense have had integrated clinical practice guidelines for the early recognition and management of CKD and pre-ESRD, which are made available to primary care physicians in their respective systems [33]. We further found that racial/ethnic disparities in the likelihood of pre-ESRD nephrology care among AA and Hispanic patients were eliminated by having VA coverage. As a model of a single-payer system in the USA, the VA is unlike other medical insurance plans in many aspects, one of which is that it takes effect well before the onset of ESRD and thus may facilitate health care access and pre-ESRD nephrology care more effectively than other plans.

Our study has certain limitations. We cannot make conclusions about causality given the retrospective nature of our study. Another limitation is ascertainment bias related to providers' responses on CMS Form 2728, as demonstrated by Kim et al. [34], who reported substantial disagreement between information from the form and Medicare claims on the timing of earliest pre-ESRD nephrology care. The authors did acknowledge, however, that only Medicare primary patients ≥ 67 years of age were evaluated, and concordance may differ among younger patients with alternative insurance coverage. In our study cohort, $\sim 12\%$ ($n = 91\ 657$) had an 'Unknown' status for pre-ESRD nephrology care as reported on CMS Form 2728 and were therefore excluded from analysis. With some exceptions, however, the 'Unknown' cohort was comparable to the 'Known' cohort of patients (Supplementary data, Table).

In the absence of individual-level income data, we used ZIP code-based MHI as a surrogate for patient income. We acknowledge potential biases associated with ZIP code as a proxy measure of individual-level socioeconomic status. Census tracts as defined by the US Census Bureau may provide a closer approximation of individual SES given that they represent smaller and more homogeneous aggregate units than ZIP codes, which are assigned by the US Postal Service [35, 36]. Nevertheless, the concordance of our findings for both area-based and individual-level poverty complement each other, providing more robust findings since an association observed with income on an aggregate level may not represent the association that exists at an individual income level [37]. The association of Medicare-Medicaid dual eligibility and pre-ESRD nephrology care may be confounded by a high degree of frailty in this population; however, we adjusted for clinical indicators of poor functional capacity to include amputation, inability to ambulate and institutionalization. Dual eligibility is, by definition, binary and provides no additional information for income above poverty level. Residual confounders may exist between residents of higher versus lower MHI ZIP codes, such as disparities in education levels, health care access or quality.

In conclusion, both individual-level and area-level measures of poverty were independently associated with lower rates of pre-ESRD nephrology care. AA and Hispanic patients with ESRD were also less likely to have received pre-ESRD nephrology care, independent of poverty status. Efforts to improve pre-ESRD nephrology care may require focusing on the poor and minority groups who are most likely to benefit given their greater risk of progression from CKD to ESRD.

Supplementary data

Supplementary data are available online at <http://ckj.oxfordjournals.org>.

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Conflict of interest statement

The views expressed in this article are those of the authors and do not reflect the official policy of the Department of the Army, Department of the Navy, Department of Defense, National Institutes of Health or the United States government. The results presented in this article have not been published previously in whole or part, except in abstract format.

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