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Primary Care Referrals to Nephrology in Patients With Advanced Kidney Disease

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Abstract

OBJECTIVES: Optimizing care for patients with advanced kidney disease requires close collaboration between primary care physicians (PCPs) and nephrologists. Factors associated with PCP referral to nephrology were assessed in patients with estimated glomerular filtration rates (eGFRs) less than 30 mL/min/1.73 m^2.

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STUDY DESIGN: Electronic health record review at an integrated health care network.

METHODS: Factors associated with referral status were identified using Fisher's exact tests, *t* tests, and multivariable logistic regression.

RESULTS: Of 133,913 patients regularly seeing PCPs between October 2017 and September 2019, 1119 had a final eGFR less than 30 mL/min/1.73 m^2 and were not on renal replacement therapy. Care was provided by 185 PCPs (61 practices). Analyses were restricted to the 97.1% (n = 1087) of patients who were African American or European American. Of these, 54.6% had not been referred to nephrology. Nonreferred patients had higher numbers of PCP visits (P = .004). In contrast, referred patients were younger, were more often African American, and had PCPs at the academic medical center (all P <.0001). Referred patients had more complex medical histories with higher Charlson Comorbidity Index scores, more hospitalizations, and greater numbers of inpatient days (all P < .0001). Analyses restricted to patients with serum creatinine concentration of at least 2 mg/dL yielded similar results. Age, number of hospitalizations, ancestry, academic physician, diabetic end-organ damage, peripheral vascular disease, and tumor status were independent predictors of nephrology referral.

CONCLUSIONS: Impediments to appropriately timed nephrology referrals persist in patients with high likelihoods of progression to end-stage kidney disease. Improved access to nephrology care should be rapidly addressed to meet targets in the 2019 Executive Order on Advancing American Kidney Health.

Optimizing outcomes for patients with advanced chronic kidney disease (CKD) can best be achieved with appropriately timed nephrology consultation.[1] Nephrologists attempt to slow the progression of CKD, educate patients regarding the optimal choice of renal replacement therapy (including preemptive kidney transplantation), assess medication dosage and safety, and assist primary care providers (PCPs) with management of hypertension, cardiovascular disease risk factors, anemia, and bone and mineral health. Patients receiving regular nephrology care prior to renal replacement therapy for treatment of end-stage kidney disease (ESKD) have slower rates of CKD progression,[2] higher rates of functioning arteriovenous fistulae as initial hemodialysis vascular access, and fewer tunneled central vein catheters.[3] Effects of earlier referral on mortality are less clear.[3,4]

Barriers to recognition of advanced CKD likely include absence of symptoms and minimally elevated serum creatinine (SCr) concentrations, particularly in elderly and frail patients. More precise equations for computing the estimated glomerular filtration rate (eGFR) are widely available and simplify the detection of kidney disease.[5] However, many physicians focus on the SCr concentration in lieu of eGFR assessment and presence or severity of proteinuria.

National efforts have been undertaken to ensure that PCPs recognize the presence of CKD at early stages in an attempt to slow disease progression.[6] The 2019 Executive Order on Advancing American Kidney Health targets slowing of nephropathy progression and higher rates of kidney transplant and home-based dialysis therapy.[7] As such, appropriately timed referral to nephrology remains critical for improving outcomes, increasing access to home dialysis, and performing preemptive and early kidney transplant.[8] The frequencies with which PCPs affiliated with a Southeastern US academic health care network referred

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patients with advanced kidney disease to a nephrologist were assessed. Factors associated with the likelihood of referral were also analyzed in this older population.

METHODS

Study Population

The Wake Forest Baptist Health (WFBH) Network (WFBHN) is an integrated network. Review of the electronic health record (EHR) identified patients with a most recent eGFR less than 30 mL/min/1.73 m^2 who had been seen by a PCP in the 2-year study period between October 1, 2017, and September 30, 2019. PCPs specializing in internal medicine, family medicine, geriatric medicine, and pediatrics were included and grouped as either academic or community-based according to the location of their primary department. Only actively treated patients, defined as those who had at least 2 visits with their PCP during the 2-year study period, were captured. Nephrology referrals were captured based on having seen a nephrologist or an electronic order for referral; waiting periods until visits did not affect outcomes. Main analyses were limited to African American and European American patients, who composed the vast majority of the sample, and included all patients with at least 1 eGFR during the study period and the data fields necessary to compute a Charlson Comorbidity Index (CCI) score.[9] The Wake Forest School of Medicine (WFSM) Institutional Review Board approved this study.

Data Collection

Clinical and demographic information was extracted from the WFBH EHR (Epic), a single enterprise-wide platform supporting integrated clinical, billing, and ancillary applications. CCI scores were computed by the WFSM Clinical and Translational Science Institute using EHR data.[10] All variables examined aside from the CCI score were extracted using the Epic EHR across the health system using medication, laboratory, and diagnosis definitions using standard ontologies (SNOMED; LOINC; *International Classification of Diseases, Tenth Revision*; National Drug Code; RxNorm) for structured data available in the EHR at the time of the outcome visit. We did not use natural processing to mine/examine free-text entered data from the EHR. The SCr was measured using the modified Jaffe method, kinetic, calibrated to the isotope dilution mass spectrometry reference measurement (Beckman Coulter AU5822). The eGFR was computed using the CKD-Epidemiology Collaboration equation.[11] Patient identifiers were removed from the data set prior to analysis.

Statistical Analysis

Descriptive statistics, including means, SDs, medians, and interquartile ranges (IQRs) for continuous measures and frequencies and proportions for categorical data, were calculated for all study variables. Referred and nonreferred patient groups were compared using independent *t* tests for continuous data and Fisher's exact tests for categorical data. To assess which factors might be associated with which subjects had (or had not) been referred, a logistic regression model to assess independent measures with referral status was created. This employed a mixed models analysis of variance approach with a random intercept component for each physician. This model included the covariates that were significantly different between referred and nonreferred groups in the overall analysis. A secondary

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analysis included only those patients whose most recent SCr was at least 2 mg/dL. SAS version 9.4 (SAS Institute) was used for all analyses, and *P* values less than .05 were considered statistically significant.

RESULTS

A total of 133,913 patients in the WFBHN had at least 2 visits with their PCP during the study period. Of these, 1434 had a most recent eGFR less than 30 mL/min/1.73 m^2, at least 1 eGFR during the study period, and the data necessary to compute a CCI score. Among these, 315 patients were receiving renal replacement therapy and were excluded from analyses. The remaining 1119 patients with nephropathy had primary care provided by 185 unique PCPs in 61 practices. Because 97.1% (n = 1087) of the sample was African American or European American, analyses were restricted to these patients. Of these 1087 patients, 494 (45.4%) had been referred to nephrology and 593 (54.6%) had not been referred.

Table 1 displays demographic, clinical, and laboratory data in the referred and nonreferred patient groups. Patients in both groups saw their PCPs frequently during the 2-year study period, with a median of 6 PCP visits per patient. The number of PCP visits was statistically higher in the nonreferred group ($P = .0036$), likely of minor clinical relevance, and the median age of the nonreferred patients was 5 years older than that of patients in the referred group ($P < .0001$). The median (IQR) eGFR at baseline was similar in the nonreferred (30 [24-36] mL/min/1.73 m^2) and referred (29 [24-35] mL/min/1.73 m^2) patients ($P = .81$). Baseline SCr was also similar in nonreferred (2.0 [1.7-2.5] mg/dL) and referred (1.9 [1.5-2.3] mg/dL) patients ($P = .59$). In contrast, significant differences were seen in the final eGFR and SCr based on referral group. Referred patients ended the study period with 2 mL/min/1.73 m^2 lower median eGFR and 0.2 mg/dL higher median SCr than those not referred (both $P < .005$). The median (IQR) time between the first PCP visit after October 1, 2017, and the outcome visit was 1.6 (1.3-1.8) years overall. There was little change in covariates during this interval; the median percentage change in all conditions assessed was 2.2% (data not shown).

Hospitalizations, numbers of inpatient days, and median CCI score were significantly higher in the referred patient group (all $P < .0001$). Hospital discharge to a skilled nursing facility was also higher in referred patients ($P = .03$). Relative to European Americans, African Americans were more likely to have been referred ($P < .0001$). PCPs grouped as academic were significantly more likely to refer their patients to nephrology than were community-based physicians ($P < .0001$). Gender and Medicare/Medicaid insurance status were not significantly different irrespective of referral to nephrology. The prevalence of congestive heart failure, chronic obstructive pulmonary disease, cerebrovascular disease, diabetes with end-organ damage, myocardial infarction, tumors, and peripheral vascular disease was significantly higher among referred patients. In contrast, no significant differences in nephrology referral were seen based on prescription of renin-angiotensin-aldosterone system antagonists or among patients with dementia, AIDS, hemiplegia, rheumatic disease, or peptic ulcer disease. The median fall in eGFR among referred patients was 6 mL/min/1.73 m^2 during the 2-year study period, compared with 5 mL/min/1.73 m^2 in nonreferred patients.

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A laboratory-based dipstick urinalysis was performed in 30.7% (182 of 593) of nonreferred and 69.2% (342 of 494) of referred patients ($P < .001$). At least 1 quantitative spot urine protein measurement (either urine albumin-creatinine ratio [uACR] or urine protein-creatinine ratio [uPCR]) was performed in 25.6% (152 of 593) of nonreferred patients and 32.6% (160 of 494) of referred patients ($P = .015$). The most recent median (IQR) uACR was 104 (32-536) mg/g in nonreferred patients (22.9% [n = 136] had this measure) vs 209 (40-848) mg/g in referred patients (29.8% [n = 147] had this measure) ($P = .084$ between groups). Only 45 patients had a uPCR (25 nonreferred and 20 referred), without significant between-group differences ($P = .97$).

Table 2 presents results of a multivariable mixed effects logistic regression model analyzing referral status as the outcome. Relationships between covariates that differed significantly between groups in Table 1 were assessed, based on whether or not patients had been referred. A random intercept model, with a clustering factor for PCP, adjusted for the effect of each PCP. SCr was the only variable excluded from the model, as it is a component of the eGFR and had a significant correlation with that measure ($r = -0.69$; $P < .0001$). Only initial eGFR was included as a measure of baseline kidney function. In the fully adjusted model, age ($P = .0003$; those with increasing age less likely to be referred), number of hospitalizations ($P = .0066$; those with increasing numbers more likely to be referred), ancestry ($P < .0001$; African Americans more likely to be referred), academic center PCP ($P < .0001$; academic group physicians more likely to refer), and presence of diabetic end-organ damage ($P = .0041$), peripheral vascular disease ($P = .0057$), and tumors ($P = .016$) increased the odds of referral.

The baseline SCr was assessed in all 1087 patients with an eGFR less than 30 mL/min/1.73 m^2. In all, 1 (0.1%) had a baseline SCr less than 1.5 mg/dL; 31 (2.8%), between 1.5 and less than 1.6 mg/dL; 98 (9.0%), between 1.6 and less than 1.7 mg/dL; 173 (15.9%), between 1.7 and less than 1.8 mg/dL; 255 (23.5%), between 1.8 and less than 1.9 mg/dL; 320 (29.4%), between 1.9 and less than 2.0 mg/dL; and 209 (19.2%), greater than or equal to 2.0 mg/dL. Table 3 displays the likelihood of nephrology referral in the 767 (70.6%) patients with a final SCr of at least 2 mg/dL. In this group, 51.2% of patients (393 of 767) were referred and 48.8% (374 of 767) were not referred. As in the full sample, younger patients, African Americans, those cared for by PCPs grouped as academic, those with greater numbers of hospitalizations and inpatient days, and those with higher median CCI scores were significantly more likely to have been referred (all $P < .001$). Although final kidney function was significantly lower in patients in the referred group, between-group differences were only 2 mL/min/1.73 m^2 in eGFR and 0.2 mg/dL in SCr.

DISCUSSION

Although the Kidney Disease: Improving Global Outcomes (KDIGO) CKD working group recommends that patients with an eGFR less than 30 mL/min/1.73 m^2 be referred to nephrology,[1] this study's results from an academic health care system reveal that only 45.4% of such patients who are actively seeing their PCPs are referred to nephrology. These data are contemporary and reflect the current era of hospitalist services. Men and women were equally likely to have been referred, as were patients with and without primary

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Medicaid/Medicare insurance. Relative to referred patients with advanced nephropathy, nonreferred patients were significantly older and had fewer hospitalizations, fewer inpatient days, and lower CCI scores. Thus, nonreferred patients appear to have less severe nonkidney organ system disease. Relative to European Americans, African Americans were more likely to have been referred, as were patients treated by PCPs grouped as academic vs in the community. It is possible that some older patients may be more resistant to seeing specialists; hence, a subset of nonreferrals could relate to patient choice.

Results were somewhat surprising. We considered that PCPs might have been less likely to refer patients with advanced CKD who had more severe comorbidities or diseases making them less suitable for renal replacement therapy or precluding candidacy for kidney transplantation. Access to health care appears to have been excellent in both the referred and nonreferred patient groups, with a median 6 PCP visits during the 2-year study period. Both groups had similar frequencies of receipt of renin-angiotensin-aldosterone system antagonists ($P = .45$), and significant differences in the prevalence of dementia or AIDS were not observed. Although lack of nephrologists in a region could reduce referrals, it does not appear to have contributed to our findings. The WFBHN consists of 20 nephrologists, 6 advanced practitioners, and 6 nephrology fellows; 16 other nephrologists also practice in the region.

Higher rates of hospitalization ($P < .0001$), discharge from hospital to skilled nursing facility ($P=.03$), cerebrovascular disease ($P=.0059$), congestive heart failure ($P < .0001$), chronic obstructive pulmonary disease ($P < .0001$), diabetes with end-organ damage ($P < .0001$), myocardial infarction ($P = .017$), peripheral vascular disease ($P < .0001$), and malignancy ($P < .0001$) were present in referred patients with advanced nephropathy. We could not determine whether nephrologists were initially consulted during inpatient hospitalizations or as outpatients. Specialty care was significantly more likely to have been requested for individuals with greater numbers of comorbidities and who spent more time as inpatients.

To address the possibility that PCPs might place more weight on the SCr than the eGFR, a subsequent analysis was restricted to the 767 patients with a final SCr of at least 2 mg/dL. Results revealed that only 51.2% of these patients had been referred to nephrology. Regardless of a very low eGFR or markedly elevated SCr, patients with advanced CKD are often not being referred to nephrology. Physicians struggle to determine which patients with a low eGFR are most likely to progress rapidly to ESKD. Risk estimators have been developed that include the degree of proteinuria and plasma biomarkers of kidney injury.[12] However, we note that a routine urinalysis was performed in only 30.7% of nonreferred patients who had an eGFR less than 30 mL/min/1.73 m^2, and fewer PCP-managed patients had a uACR or uPCR to quantify proteinuria.

Prior studies have assessed the likelihood and timing of nephrology referral in patients with CKD. In 2018, the US Renal Data System reported that 35.4% of incident patients with ESKD received little or no predialysis nephrology care.[13] Koraishy et al assessed 2170 African American and European American patients in St Louis, Missouri, between 2008 and 2015.[14] The majority of patients with CKD were not referred to nephrology; however, those with faster rates of decline in eGFR and African Americans were more likely to be referred.

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Winkelmayer et al evaluated 3014 patients and defined “early referral” to nephrology as more than 90 days before the initiation of renal replacement therapy.[15] Patients with comorbidities such as coronary artery disease, malignancy, hypertension, and diabetes were more likely to be referred early, similar to the higher numbers of comorbidities in referred patients from the present report. Earlier referral appears to slow the rate of decline in eGFR[2] and increase rates of arteriovenous fistula placement for hemodialysis vascular access[16] and may reduce postdialysis mortality, although results are controversial.[4,17]

Other studies have reached opposing conclusions. A retrospective report assessed reasons for delayed nephrology referral.[18] As in the present study, nonreferred patients were typically older. However, women, non-White patients, and those with a CCI score greater than 4 were less likely to be referred. A follow-up questionnaire revealed that 62% of PCPs were unfamiliar with Kidney Disease Outcomes Quality Initiative recommendations for referral; 87% used the SCr and 31.8% used stage of CKD for referral. PCPs reported that limited life expectancy, age older than 75 years, patient nonadherence, and dialysis refusal were major factors influencing their decisions on specialty referral.[18] A national cohort study in patients with eGFR less than 30 mL/min/1.73 m^2 from the Department of Veterans Affairs found that older age, heart failure, dementia, and depression were associated with a lower likelihood of nephrology referral.[19] Surveys cite difficulty with PCPs establishing working partnerships with nephrologists, lack of timely and adequate information exchange, unclear roles in management, and lack of access as barriers to specialty referral.[20] Finally, a qualitative study assessing when PCPs were likely to refer patients to nephrology found fewer referrals in older patients and those with moderate dementia and perceived shorter life expectancy. Factors that led to increased nephrology referral included younger age, female sex, non-White race, expectations that nephrologists would have conversations regarding goals of care, and when a PCP experienced anxiety about uncertain diagnosis.[21] Based on these studies’ findings, we hypothesized that patients with more complex medical histories and shorter life expectancies might have been less likely to be referred for nephrology care. However, we found that healthier and older patients were significantly less likely to have been referred. This suggests that PCPs either underestimate severe CKD in patients with fewer symptoms or prefer to manage less symptomatic patients on their own.

Strengths and Limitations

Our study has many strengths, as well as limitations. Results are contemporary, from the era of hospital medicine, and the number of patients and providers was large. This study encompassed all PCPs treating adult patients in an integrated health care system with a diversity of patients and providers in academic and community practices. Data were uniformly collected using a single EHR. However, data were retrospective, observational (subject to selection bias and residual confounding), limited to 2 ancestral populations, EHR based, and from a single center. As such, they require replication and may not be generalizable to American Indians, Asians, Hispanics, and Pacific Islanders. We captured referrals to nephrology, regardless of whether or not patients were seen. We were unable to determine whether differences in physician age or years in practice were associated with likelihood of referral. It is possible that our methods missed a small number of patients referred to nephrology outside the EHR and that some PCPs may have been in the process

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of rechecking the eGFR prior to requesting referral. It is also possible that some patients could have had acute kidney injury (AKI). However, 280 and 290 patients in the nonreferred and referred groups, respectively, had at least 2 eGFRs at least 90 days apart that were 30 mL/min/1.73 m^2 or less, and baseline eGFR in the full sample was 29 mL/min/1.73 m^2. This suggests that AKI was infrequent. Finally, KDIGO guidelines include 9 potential indications for referral to nephrology[22] and Tangri et al developed a kidney failure risk equation for likelihood of progression to ESKD[23]; KDIGO and the Tangri equation both include proteinuria and other factors, whereas our report focused solely on eGFR and did not assess proteinuria because of the low frequency of testing.

Although we found that medically complex patients were more often referred, we were unable to determine when specialty referrals were made. We speculate that referrals may have been made when patients were hospitalized, perhaps by hospitalists or non-PCP providers. We do not know how many patients were referred by their PCP as an outpatient. PCPs at the academic medical center were significantly more likely to refer their patients than community-based PCPs. In fact, community-based PCPs referred only 10% of their patients with advanced nephropathy to nephrologists. Finally, African Americans were more likely to be referred to nephrology than European Americans; this supports relatively good access to health care for this population.

Patients with lower CCI scores were significantly less likely to be referred to a nephrologist. Earlier referrals could maximize their likelihood of preemptive kidney transplant, performance of home dialysis, and placement of an arteriovenous fistula for hemodialysis vascular access. Although they were older, many nonreferred patients are likely equivalent or better candidates for these interventions than referred patients. Conservative management, care coordination, and understanding the underlying disease process are also important in our older population. Despite ongoing educational efforts, PCPs may not consider the eGFR on chemistry profiles. However, similar results were seen in an analysis restricted to patients with SCr at least 2 mg/dL (70.6% of the sample). Lower rates of timely referral among healthier patients with CKD may cause patients who were initially candidates for kidney transplant or home dialysis to develop complications that reduce their independence and could make them more likely to require in-center hemodialysis.

CONCLUSIONS

To improve outcomes in patients with CKD, slow nephropathy progression, maximize the likelihood of kidney transplant, and increase use of home dialysis modalities, we propose considering clinical decision support interventions in the EHR that allow PCPs to plan earlier referral to nephrology based on structured data elements similar to those in this report. Risk prediction algorithms based on plasma biomarker concentrations and EHR data are also likely to be useful in stratifying patients with CKD who are at greatest risk for nephropathy progression.[24] These will help inform PCPs when to refer patients to nephrology.[23] To meet targets in the 2019 Advancing American Kidney Health Executive Order, PCPs should consider early nephrology consultation. Despite advocacy efforts by the American Society of Nephrology and National Kidney Foundation, the present results

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suggest that existing efforts to educate primary care providers about CKD referral have had limited success. Novel efforts are required.

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TAKEAWAY POINTS

Timely nephrology referral improves outcomes in chronic kidney disease and assists with meeting targets set in the 2019 Executive Order on Advancing American Kidney Health. Factors associated with specialty referral were assessed in patients with advanced nephropathy at a large integrated health system.

- The majority of patients were not referred to nephrology.
- Referred patients had higher Charlson Comorbidity Index scores and more hospitalizations and inpatient days.
- Healthier patients, potentially more suitable for kidney transplant or home dialysis, were less likely to be referred.
- Impediments to appropriately timed nephrology referrals persist in patients likely to progress to end-stage kidney disease.

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TABLE 1.

Demographic, Clinical, and Laboratory Data, Stratified by Nephrology Referral Status

Measure	Full sample (n = 1087)	Referred sample (n = 494)	Nonreferred sample (n = 593)	Referred vs nonreferred
		Median (IQR)		*P*
Age in years	79 (70-86)	76 (68-83)	81 (73-87)	<.0001
PCP visits, n	6 (4-9)	6 (4-8)	6 (4-9)	.0036
Initial eGFR, mL/min/1.73 m^2	29 (24-36)	29 (24-35)	30 (24-36)	.81
Initial serum creatinine, mg/dL	1.9 (1.6-2.4)	2.0 (1.7-2.5)	1.9 (1.5-2.3)	.59
Final eGFR, mL/min/1.73 m^2	24 (19-27)	23 (17-27)	25 (20-28)	.0004
Final serum creatinine, mg/dL	2.3 (1.9-2.9)	2.4 (2.1-3.1)	2.2 (1.8-2.7)	.0048
Time between visits in years	1.59 (1.28-1.78|	1.46 (1.03-1.68)	1.72 (1.52-1.84)	<.0001
Hospitalizations, n	0 (0-1)	0 (0-1)	0 (0-0)	<.0001
Inpatient days, n	0 (0-2)	0 (0-5)	0 (0-0)	<.0001
Charlson Comorbidity Index score	5 (3-8)	6 (5-9)	4 (3-7)	<.0001
	Proportion of full sample	Proportion of referred sample	Proportion of nonreferred sample	*P*
Female	59.9%	57.3%	62.1%	.12
African American	19.5%	29.4%	11.3%	<.0001
Academic: yes	19.4%	31.2%	9.6%	<.0001
Medicaid/Medicare insurance	91.0%	91.69%	90.6%	.59
Current smoker	9.2%	10.9%	7.8%	.0016
Former smoker	46.2%	50.2%	42.8%	
Never smoker	44.6%	38.9%	49.4%	
Taking ACE inhibitor/ARB	63.6%	62.4%	64.6%	.45
Taking statins	71.1%	74.5%	68.3%	.027
Hospitalized ≥ 1 time	28.1%	39.9%	18.2%	<.0001
Discharged to SNF: yes	7.7%	9.7%	6.1%	.030
Cerebrovascular disease	31.4%	35.6%	27.8%	.0059
Congestive heart failure	34.2%	42.9%	27.0%	<.0001
COPD	40.1%	47.2%	34.2%	<.0001
Dementia	6.4%	5.9%	6.9%	.54
Diabetes mellitus	7.6%	5.1%	9.8%	.0039
Diabetic end-organ damage	47.3%	60.5%	36.3%	<.0001
Hemiplegia	2.9%	3.6%	2.4%	.28
AIDS	0.3%	0.4%	0.2%	.59
Chronic liver disease	2.0%	3.0%	1.2%	.049
Moderate to severe liver disease	14.8%	15.8%	14.0%	.44
Myocardial infarction	16.3%	19.2%	13.8%	.017
Ulcer	4.4%	5.3%	3.7%	.24

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Measure	Full sample (n = 1087)	Referred sample (n = 494)	Nonreferred sample (n = 593)	Referred vs nonreferred
		Median (IQR)		*P*
Peripheral vascular disease	32.2%	40.9%	25.0%	<.0001
Rheumatic disease	6.6%	8.1%	5.4%	.086
Tumor	12.4%	16.8%	8.8%	<.0001

ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; IQR, interquartile range; PCP, primary care physician; SNF, skilled nursing facility.

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TABLE 2.

Multivariate Logistic Regression Analysis for Measures Associated With Nephrology Referral (full sample; n = 1087)

Measure	*P*	Odds ratio (95% CI)	Reference
Age in years	.0003	0.90 (0.84-0.95)	Per 5-year increase
PCP visits, n	.72	1.01 (0.97-1.04)	Per 1-unit increase
Initial eGFR, mL/min/1.73 m^2	.42	0.99 (0.98-1.01)	Per 1-unit increase
Hospitalizations, n	.0066	1.32 (1.08-1.62)	Per 1-unit increase
Inpatient days, n	.48	0.99 (0.96-1.02)	Per 1-unit increase
Female	.16	1.23 (0.92-1.63)	Male vs female
African American	<.0001	2.01 (1.47-2.75)	African American vs European American
Academic: yes	<.0001	3.06 (1.96-4.79)	Yes vs no
Smoking status	.88	1.03 (0.68-1.58)	Former vs never
Smoking status	.36	1.21 (0.80-1.85)	Current vs never
Taking statins	.32	1.14 (0.87-1.50)	Yes vs no
Discharged to SNF: yes	.37	0.77 (0.44-1.35)	Yes vs no
Cerebrovascular disease	.67	0.95 (0.73-1.23)	Yes vs no
Congestive heart failure	.96	1.01 (0.76-1.33)	Yes vs no
COPD	.11	1.21 (0.95-1.56)	Yes vs no
Diabetes mellitus	.51	0.85 (0.53-1.37)	Yes vs no
Diabetic end-organ damage	.0041	1.48 (1.13-1.94)	Yes vs no
Chronic liver disease	.11	2.10 (0.85-5.23)	Yes vs no
Myocardial infarction	.48	0.88 (0.60-1.27)	Yes vs no
Peripheral vascular disease	.0057	1.51 (1.13-2.03)	Yes vs no
Tumor	.016	1.69 (1.10-2.58)	Yes vs no

COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; PCP, primary care physician; SNF, skilled nursing facility.

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TABLE 3.

Nephrology Referral in the Subset of Patients With Most Recent Serum Creatinine Concentration 2 mg/dL or Higher

Measure	Referred sample (n = 393)	Nonreferred sample (n = 374)	Referred vs nonreferred
	Median (IQR)		*P*
Age in years	73 (66-81)	79 (70-85)	<.0001
PCP visits, n	6 (4-8)	6 (4-9)	.026
Initial eGFR, mL/min/1.73 m^2	28 (22-35)	27 (21-34)	.11
Initial serum creatinine, mg/dL	2.1 (1.8-2.7)	2.2 (1.8-2.7)	.13
Final eGFR, mL/min/1.73 m^2	21 (16-25)	22 (16-25)	.54
Time between visits, years	1.73 (1.54-1.85)	1.42 (1.00-1.67)	<.0001
Hospitalizations, n	0 (0-1)	0 (0-0)	<.0001
Inpatient days, n	0 (0-6)	0 (0-0)	<.0001
Charlson Comorbidity Index score	6 (5-9)	5 (3-7)	<.0001
	Proportion of referred sample	Proportion of nonreferred sample	*P*
Female	47.6%	40.4%	.049
African American	33.8%	15.0%	<.0001
Academic: yes	34.1%	6.7%	<.0001
Medicaid/Medicare	90.2%	88.7%	.55
Current smoker	12.5%	10.2%	.052
Former smoker	52.9%	46.8%	
Never smoker	34.6%	43.0%	
Taking ACE inhibitor/ARB	59.5%	63.4%	.30
Taking statins	76.1%	71.1%	.12
Hospitalized ≥ 1 time	41.7%	19.0%	<.0001
Discharged to SNF: yes	10.2%	5.1%	.0096
Cerebrovascular disease	36.9%	29.4%	.032
Congestive heart failure	45.8%	26.5%	<.0001
COPD	47.8%	31.3%	<.0001
Dementia	5.1%	5.6%	.75
Diabetes mellitus	4.3%	9.1%	.0089
Diabetes end-organ damage	64.6%	40.4%	<.0001
Hemiplegia	4.3%	2.4%	.16
AIDS	0.5%	0.3%	>.99
Chronic liver disease	2.8%	1.3%	.21
Moderate to severe liver disease	14.5%	12.8%	.53
Myocardial infarction	21.1%	15.8%	.063
Ulcer	5.6%	3.7%	.24
Peripheral vascular disease	42.5%	25.1%	<.0001
Rheumatic disease	7.9%	4.8%	.10

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Measure	Referred sample (n = 393)	Nonreferred sample (n = 374)	Referred vs nonreferred
	Median (IQR)		*P*
Tumor	17.1%	9.1%	.0013

ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; IQR, interquartile range; PCP, primary care physician; SNF, skilled nursing facility.