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Clinical testing patterns and cost implications of variation in the evaluation of chronic kidney disease among U.S. physicians

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Abstract

Background—Clinical practice guidelines were established to improve the diagnosis and management of chronic kidney disease (CKD), but the extent, determinants, and cost implications of guideline adherence and variation in adherence have not been evaluated.

Study Design—Cross-sectional survey

Settings & Participants—Nationally representative sample of 301 U.S. primary care physicians and nephrologists

Predictor—Provider and patient characteristics

Outcomes & Measurements—Guideline adherence was assessed as present if physicians recommended at least 5 of 6 clinical tests prescribed by the National Kidney Foundation-Kidney Disease Outcomes and Quality Initiative (KDOQI) guidelines for a hypothetical patient with newly identified CKD. We also assessed patterns and cost of additional non-recommended tests for the initial clinical evaluation of CKD.

Results—Most of the 86 family medicine, 89 internal medicine, and 126 nephrology physicians practiced greater than 10 years (54%), were in non-academic practices (76%), spent greater than 80% of their time performing clinical duties (78%), and correctly estimated kidney function (73%). Overall, 35% of participants were guideline adherent. Compared to nephrologists, internal medicine and family physicians had lower odds of adherence for all recommended testing (Odds Ratio (OR) [95% CI]: 0.6[0.3–1.1] and 0.3[0.1–0.6], respectively). Participants practicing greater than 10 years had lower odds of ordering all recommended testing compared to participants practicing less than 10 years (OR[95% CI]: 0.5[0.3–0.9]). Eighty-five percent of participants recommended additional tests, which resulted in a 23% increased total per patient cost of the clinical evaluation.

Limitations—Recommendations for a hypothetical case scenario may differ from that of actual patients.

Conclusions—Adherence to the recommended clinical testing for the diagnosis and management of CKD was poor and additional testing was associated with substantially increased cost of the clinical

evaluation. Improved clarity, dissemination, and uptake of existing guidelines are needed to improve quality and decrease costs of care for patients with CKD.

Index Words

chronic kidney disease; primary care providers; guidelines; KDOQI; cost

INTRODUCTION

Chronic kidney disease (CKD) represents a growing epidemic with nearly 26 million persons currently affected in the U.S. and a prevalence of end-stage renal disease (ESRD) that is predicted to reach 785,000 by 2020.^{1–2} Care of patients with ESRD has well-documented significant implications on health care costs with total annual expenditures of 32 billion dollars in 2005, representing a 154% rise in expenditures over the past 10 years.^{2–3}

Clinical testing to assess CKD severity and to identify early evidence of treatable associated co-morbid illnesses represents an important cornerstone of care to improve clinical outcomes for CKD. Clinical practice guidelines published in 2002 by the National Kidney Foundation Kidney Disease Outcome and Quality Initiative (KDOQI) prescribe a core set of clinical tests for the diagnosis and ongoing management of CKD.⁴ These guidelines serve as a resource to guide physicians' delivery of appropriate care for patients with CKD.⁴ However, the extent to which physicians adhere to guidelines regarding clinical testing for CKD is unclear and, to our knowledge, determinants of physicians' adherence to guidelines have not been evaluated. In addition, the resource implications of variation in physicians' recommendations for clinical testing of patients with CKD are unknown. Assessment of physician adherence to existing clinical practice guidelines and quantification of variation in clinical practice patterns could aid efforts to improve the quality and efficiency of care for patients with CKD.

In a national study, we examined the extent and determinants of physicians' adherence to clinical practice guidelines and we assessed the cost implications of variation in physician practice patterns in the clinical evaluation of patients with CKD.

METHODS

Study Design and Population

As part of a study to assess physicians' practice patterns for care of patients with CKD, we identified primary care physicians and nephrologists practicing in the U.S. between August 2004 and August 2005 to evaluate their approach to the clinical evaluation of a patient with progressive CKD. Participants completed a self-administered questionnaire (on paper or via the internet), which featured questions regarding a hypothetical clinical scenario of a patient with CKD (Item S1, provided as online supplementary material available with this article at www.ajkd.org).

Using the American Medical Association Physician Master file, we identified and mailed a questionnaire to a national random stratified sample of 400 nephrologists, 400 family physicians, and 400 internists. We excluded physicians who were no longer in active clinical practice as a nephrologist, family physician, or internist or were not contactable through the 7 follow-up mailings or the 4 reminder telephone calls. Participating physicians were reimbursed \$20. The study protocol was approved by the Johns Hopkins Medicine Institutional Review Board.

Questionnaire Content

We presented physicians with one of four randomly assigned hypothetical case scenarios featuring a 50 year-old woman with hypertension, obesity, and progressive chronic kidney disease who was being seen by her primary care physician for the first time. The hypothetical scenario varied on patient race (African American or White) and the patients' presence or absence of diabetes. (Details of scenario are listed in Figure 1)

We asked physicians to identify laboratory and radiology studies they felt a primary care physician should obtain in the evaluation of the hypothetical patient. Clinical tests included 1) serologic studies (basic metabolic panel, comprehensive metabolic panel, magnesium, creatinine, calcium, phosphorous, intact parathyroid hormone, fasting glucose, hemoglobin A1c, uric acid), 2) hematologic studies (complete blood count, manual differential, iron, ferritin, transferrin, activated partial thromboplastin time, prothrombin time), 3) immunologic or virologic studies (antinuclear antibodies, anti-double-stranded DNA, complements C3 and C4, hepatitis B surface antibody, hepatitis B surface antigen, hepatitis C antibody, HIV antibody, rapid plasma reagent, rheumatoid factor test, cryoglobulins, serum protein electrophoresis, urine protein electrophoresis), 4) urine studies (routine urine dipstick, urine microscopic examination, assessment of urine microalbumin) and 5) radiologic studies (chest x-ray, magnetic resonance angiogram (MRA) of renal arteries, renal ultrasound). We also asked physicians to select: 1) the range of the patient's estimated glomerular filtration rate (eGFR) in accordance with KDOQI stages [90 to 120, 60 to 89, 30 to 59, 15 to 29, or <15 mL/min/1.73m² (eGFR in mL/min may be converted to mL/s by multiplying by 0.01167)]; and 2) the appropriate NKF-KDOQI description of the stage of CKD ("normal or no kidney disease", "mild kidney disease", "moderate kidney disease", "severe kidney disease", or "end-stage kidney disease").

Assessment of Physician Characteristics

We assessed physicians' demographic characteristics including their specialty (nephrologist, internist, or family physician), practice type (academic or other), percent of time performing clinical duties, years in practice, ZIP code of practice, sex, and the degree to which they felt they had sufficient resources to care for their patients with CKD. We also assessed physicians' awareness of KDOQI guidelines, their primary sources of clinical practice guidelines (nephrology organizations, U.S. Preventative Services Task Force (USPSTF), other medical organizations), and their educational resources (conferences, scientific journals, or other continuing medical education activities).

Assessment of Adherence to Guidelines and Patterns of Clinical Testing

We classified recommended clinical tests as those which were related primarily to the diagnosis of renal damage and underlying cause of CKD (urinalysis, urine protein quantification and renal ultrasound) or those which were related primarily to the management of co-morbid conditions associated with the presence of CKD (serum phosphorous, intact parathyroid hormone, and lipid profile). We considered physicians' recommendations adherent to guidelines if they recommended a primary care physician order at least 5 of the 6 clinical tests indicated (by guidelines) for the diagnosis or management of CKD (urinalysis, urine protein quantification, renal ultrasound, serum phosphorous, intact parathyroid hormone, and lipid profile). We also assessed whether physicians recommended the patient be referred to a nephrologist in accordance with KDOQI guidelines.

We assessed physicians' recommendations for additional testing of the hypothetical patient (defined as clinical tests not included in KDOQI guidelines for the initial evaluation of patients with progressive CKD or tests which were repeated by physicians when results were already provided in the clinical scenario). Because a majority of adherent physicians ordered additional

tests, we classified physicians as having high (more than the median number of additional tests ordered) versus low (less than or equal to the median number of additional tests ordered) levels of additional testing.

Costs of Clinical Testing

We assessed the costs associated with physicians' testing patterns using the Centers for Medicare and Medicaid Services 2005 Clinical Diagnostic Laboratory National Fee Schedule to assign a cost to each clinical test offered to the participants.⁶ We determined the percent increase in total cost of the evaluation attributed to ordering additional tests for a single hypothetical patient, and we assessed the contribution of individual tests to the aggregate additional cost.

Statistical Analysis

We assessed differences in responding and non-responding physicians in bivariate (chi-square) analyses. For responding physicians, we sought to assess patterns of clinical testing among physicians recognizing CKD. We therefore restricted our analysis to responding physicians correctly identifying the hypothetical patient as having at least mild kidney disease and/or a $\text{GFR} \leq 60 \text{ mL/min/1.73m}^2$. We assessed differences in physician adherence to KDOQI guidelines and additional testing according to provider and hypothetical patient characteristics. We also described patterns of additional testing and assessed differences in additional testing according to physicians' adherence to guidelines. In a subgroup of primary care physicians, we assessed whether adherence or additional testing were associated with physicians' organizational source of clinical practice guidelines.

We used multivariable logistic regression to identify physician and hypothetical patient characteristics independently associated with adherence to KDOQI guidelines for participants with complete data. In analyses stratified according to physicians' adherence to guidelines, we assessed the independent association of physician and hypothetical patient characteristics with high additional testing. In separate multivariable models, we employed interaction terms to assess the joint association of adherence and physician or patient characteristics with high additional testing.

We assessed the proportion of total cost associated with each additional test according to adherence status. We assessed differences in the median cost associated with additional testing among adherent and non-adherent physicians using the Kruskal-Wallis equality of populations rank test.

RESULTS

Characteristics of Study Population

Among 1200 potential participants, 241 physicians were ineligible for the following reasons: 131 were unable to be contacted, 52 were not primary care providers or nephrologists, and 58 were dead or no longer practicing. Of 959 eligible participants, 304 physicians (126 nephrologists, 89 internists, and 89 family physicians) responded. Non-responding and responding physicians did not differ in years in clinical practice (mean $\pm$ standard deviation, 14 ± 11 versus 14 ± 12 years, respectively; $p=0.7$), geographic location (urban or urban/rural, 96% vs. 97%; and rural 3% vs. 4%, respectively; $p=0.3$), or census region of residence (Northeast, 23% versus 25%; Midwest, 24% versus 23%; South, 32% versus 34%; and West, 21% versus 19%, respectively; $p=0.9$). Responding physicians were more likely to be nephrologists (39% nephrologists versus 28% internists versus 28% family physicians, $p=0.003$).

All but 3 physicians who responded to the questionnaire identified the hypothetical patient as having CKD (n=301). Among these participants, most practiced more than 10 years, practiced in urban areas, practiced in non-academic practices, had greater than 80% clinical time, correctly estimated renal function, recommended specialty referral, reported having sufficient clinical and administrative resources to manage CKD patients, and reported attending conferences, reading scientific journals, or using other continuing medical education resources. Physicians reported using nephrology, USPSTF, and other organizations for clinical practice guidelines and were evenly distributed among U.S. census regions. (Table 1) Most nephrologists (80%) but few primary care physicians (34%) were aware of National Kidney Foundation sponsored clinical practice guidelines.

Adherence to Guidelines and Patterns of Clinical Testing

Among all physicians, 35% were adherent with KDOQI guidelines pertaining to the laboratory and radiological evaluation of patients with CKD (47% nephrologists, 33% internists, and 19% family physicians, $p<0.001$). Guideline adherence was more common among physicians correctly estimating the hypothetical patient's GFR or who practiced less than 10 years. (Table 1) Among primary care physicians, guideline adherence was somewhat more common among those reporting they used (versus did not use) renal organizations as a source of clinical practice guidelines (35% versus 22%, respectively, $p=0.07$).

The number of recommended tests ordered by physicians varied: 12% ordered 6 tests, 23% ordered 5 tests, 24% ordered 4 tests, 26% ordered 3 tests, 10% ordered 2 tests, 4% ordered 1 test, and 1% ordered 0 tests, with a median (25th and 75th percentiles) number of 4 (3 and 5) recommended tests. Overall, the most frequently ordered test was urine microalbumin, followed by renal ultrasound, lipid profile, urinalysis, phosphorous, and intact parathyroid hormone. (Figure 2)

In adjusted analyses, compared to nephrologists, internists and family physicians had lower odds of adherence to recommended testing for both the diagnosis and management of CKD. Physicians practicing greater than 10 years and practicing in the West Census region had lower odds of adherence to recommended testing overall compared to their counterparts practicing less than 10 years and practicing in the Northeast. Physicians who received patient scenarios featuring White patients or featuring patients with diabetes had lower odds of adherence to recommended diagnostic testing for patients compared to physicians who received patient scenarios featuring African American patients or patients without diabetes. (Table 2)

Most physicians (85%) recommended at least one additional test (not recommended by KDOQI guidelines) for the hypothetical patient (96% adherent and 80% non-adherent). The median (25th and 75th percentiles) number of additional tests recommended for providers was 4 (1 and 9). Physicians who were adherent to guidelines recommended a greater number of additional tests compared to non-adherent physicians (median (25th and 75th percentiles): 8.5 (3.5 and 12) versus 2 (1 and 6), respectively, $p<0.01$). The most frequently recommended additional tests differed according to physicians' guideline adherence. Among adherent physicians, serum and urine protein electrophoresis, uric acid, and antinuclear antibody were the most frequently recommended additional tests. Among non-adherent physicians, repeat serum glucose, repeat complete blood count and/or differential, and antinuclear antibody were the most frequently recommended additional tests. (Figure 3)

In unadjusted analyses, high additional testing (greater than 4 additional tests) was most frequent among adherent (71%) compared to non-adherent physicians (32%) ($p<0.001$). Among adherent physicians, high additional testing was most common among internists (93%), followed by family physicians (69%), and nephrologists (63%) ($p=0.01$). Adherent physicians with less than 10 years in practice (80%) or evaluating an African American patient (80%) also

were more likely to have high additional testing compared to physicians with greater than 10 years in practice (62%) or evaluating a White patient (62%) ($p=0.05$, respectively). Among non-adherent physicians, high additional testing was more common among those evaluating a patient without (versus with) diabetes (41% and 24%, respectively ($p=0.01$)). There were no statistically significant differences in additional testing according to physicians' perceptions of having sufficient clinical and administrative resources or their use of continuing medical education activities. More primary care physicians reporting (versus not reporting) using renal organizations as a guideline source performed high additional testing (55% versus 37%, $p=0.03$).

After adjustment, among adherent physicians, internists had greater odds of high additional testing compared to nephrologists, while physicians practicing greater than 10 years or evaluating a White hypothetical patient had less odds of high additional testing compared to those practicing less than 10 years or those evaluating an African American patient. Among non-adherent physicians, those practicing in the South (versus Northeast) had greater odds of high additional testing and those evaluating a patient with (versus without) diabetes had less odds of high additional testing. (Table 3) Multivariable models employing interaction terms yielded similar results; however, they did not demonstrate a difference between adherent and non-adherent physicians in the association of years in practice and high additional testing.

Cost of Recommended and Additional Clinical Testing

The cost of all recommended testing for a single hypothetical patient based on KDOQI guidelines was \$222.83. Among all physicians, the median (25th and 75th percentiles) cost of evaluating a single patient was \$205.22 (\$140.07 and \$306.58). The median (25th and 75th percentiles) cost of testing was statistically significantly greater among physicians adhering to guidelines compared to physicians not adhering to guidelines [\$316.95 (\$245.92 and \$397.88) versus \$156.18 (\$92.45 and \$219.55), $p<0.001$]. Among all physicians, additional testing resulted in a 23% increase in the total per patient cost of evaluation (additional median (25th and 75th percentiles) cost of \$50.31 (\$12.64 and \$127.65) per patient). Among adherent physicians, additional testing for a single patient resulted in 55% increased costs [median (25th and 75th percentiles) additional cost was \$122.12 (\$58.14 and \$171.04)]; and among non-adherent physicians, additional testing for a single patient resulted in 13% increased costs [median (25th and 75th percentiles) additional cost \$29.53 (\$5.48 and \$74.17)] ($p<0.001$). Most (58%) of the aggregate additional cost of the clinical evaluation was attributed to: magnetic resonance imaging (28%), serum and urine protein electrophoresis (14%), chest radiographs (8%), and hepatitis B serologies (8%). (Table 4)

DISCUSSION

In this national study of primary care physicians and nephrologists, recommendations for the laboratory and radiological evaluation of patients with progressive CKD were variable, and few (35%) physicians' recommendations were adherent to established clinical practice guidelines. Most physicians recommended additional testing, which was associated with increased cost of patient evaluations. High levels of additional testing were most common among physicians adhering to guidelines, especially primary care physicians and physicians with fewer years in practice.

While previous studies have demonstrated variation in physicians' recognition, recommendations for referral, and management of CKD, to the best of our knowledge, this is the first national study to examine variation in recommendations for the clinical evaluation of CKD and the costs associated with variation.⁷⁻¹¹ Both under-testing (non-adherence to guideline recommendations) and additional testing (ordering tests beyond guideline recommendations) contributed to variation with profound cost implications. If patterns of the

recommended care we observed in this study were extrapolated to reflect patterns of care for patients with incident Stage 3 CKD nationally, the aggregate additional cost of the evaluation for approximately 1 million patients with progressive CKD could amount to \$45 million annually.^{1,2,12}

Physicians' non-adherent recommendations may reflect not only lack of knowledge regarding the appropriate clinical testing necessary for the diagnosis and management of CKD but also lack of clarity in clinical practice guidelines regarding the appropriate extent and timing of clinical testing.¹³ For example, lack of testing for metabolic bone disease likely reflects physicians' inaccurate knowledge regarding necessary tests for the management of CKD-associated co-morbidities. Guidelines designed to improve physicians' understanding of the pathophysiology of early CKD and its associated co-morbidities as well as the justification for appropriate tests could enhance rates at which necessary tests are recommended. In contrast, recommendations to order expensive testing to evaluate proteinuria (i.e. hepatitis B serologies and serum and urine protein electrophoresis) may reflect some physicians' appropriate desire to more fully investigate the etiology of kidney damage and their concerns regarding time available to complete all of the necessary testing. Although more in-depth evaluation when warranted is supported by guidelines, obtaining additional tests as part of the initial evaluation is not explicitly recommended and could increase potential harms from testing (i.e. patient discomfort or false positives). The majority of additional cost of the evaluation in our study was attributed to physicians recommending four tests (magnetic resonance imaging of renal arteries, serum and urine protein electrophoresis, chest radiograph, and hepatitis B serologies). Future efforts to improve clinical practice guidelines should specifically address the judicious use of expensive tests in the clinical evaluation of CKD as well as the use of tests that may be harmful or lead to interventions with unclear clinical benefit.^{14–16}

Primary care physicians and physicians further away from their training years had the lowest guideline adherence. Physicians' prior practice patterns, lack of awareness, and disagreement with guidelines perceived to have questionable validity have been shown to contribute to variation in guideline adherence.¹³ Although KDOQI guidelines are the most widely disseminated guidelines regarding the clinical evaluation for CKD, the degree to which physicians, particularly primary care physicians, are aware of guidelines related to the diagnostic evaluation of CKD is unclear.^{17–20} Differences in guideline adherence according to patient race in our study may reflect a variety of factors, including physicians' possible perceptions of increased risk of co-morbid conditions among African American patients or physicians' more frequent use of serum creatinine as an indicator of kidney function rather than use of estimated GFR or creatinine clearance, which could mislead them as to the severity of patients' kidney dysfunction. This suggests limited exposure to guidelines on measurement of kidney function by eGFR. Indeed, few primary care physicians in our study were aware of clinical practice guidelines for CKD. Other studies have also demonstrated that few primary care providers are influenced by KDOQI guidelines when managing patients with CKD.²¹ In addition, the evidence for some recommendations is limited, possibly resulting in greater disagreement among physicians regarding guidelines' usefulness.⁴ Efforts to improve dissemination and uptake of guidelines by primary care physicians and physicians further away from their training years are needed.

The limitations of our study deserve mention. First, recommendations for a hypothetical patient seen on a single visit may differ from actual practice patterns. However, the use of a standardized patient scenario facilitated observation of physician practice under uniform circumstances. Second, although we identified a national sample of physicians, the response was limited and the sample size was relatively small. Practice patterns observed in our study may not be generalizable to all physicians, and our study may not have had the statistical power to observe all relevant associations between provider characteristics and practice patterns.

However, with the exception of physician specialty, there were no differences between responding and non-responding physicians, and study participants were evenly distributed by geographic locations around the U.S. The higher response rate among nephrologists may reflect their greater knowledge, interest, and familiarity with evaluating a patient with CKD. Third, our definition of adherence (ordering 5 out of the 6 tests recommended by guidelines) favored physicians who performed more testing in general, but it did not penalize physicians performing indiscriminant testing. We did not assess whether primary care physicians recommending fewer tests did so because they preferred consulting nephrologists complete the evaluation. However, guideline adherence was greater among physicians who recommended referral, and additional testing did not differ according to recommendations for referral, suggesting referral did not play a role in physicians' testing decisions. Finally, our scenario asked physicians to make recommendations about care a primary care provider should deliver. Thus nephrologists' recommendations may not fully reflect their own preferences for the complete evaluation of patients with CKD.

In summary, this study represents the first attempt to describe clinical testing patterns and associated costs in the diagnosis and management of CKD among a national sample of practicing physicians. Physicians' adherence to recommendations for clinical testing in the diagnosis and management of patients with progressive CKD varied significantly, and variation was associated with increased cost of the clinical evaluation. Improved dissemination of guidelines to physicians (particularly primary care physicians and physicians further away from their training years) and increased efforts to enhance the clarity of existing guidelines may improve physicians' guideline adherence as well as clinical outcomes and costs of care for patients with CKD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Research Support/Financial Conflicts of Interest

Research Support

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An initial visit between a primary care physician and a 50 year old woman (African American or White).^a **Past Medical History:** Hypertension of 10-year duration and obesity (with or without diabetes mellitus type 2 of 5 year duration).^a **Social History:** She is married with 3 children and works as an administrative assistant. She is a non-smoker. She is insured by an indemnity (fee for service) health insurance plan. **Review of Systems:** Negative. No neurological or vascular symptoms. **Medications:** Daily diuretic and acetaminophen [Angiotensin 2 receptor agent and oral hypoglycemic agent].^b **Physical Exam:** Blood pressure 125/80, weight 154 pounds, and height 5'2". The remainder of examination was normal.

Laboratory Results:

Laboratory Tests	4 months before visit	1 week before visit
Serum Creatinine (mg/dL):		
White	1.8 ^c	2.0 ^d
African American	2.1 ^c	2.3 ^d
Comprehensive metabolic panel ^e	Normal	Normal
Complete Blood Count ^e	Normal	Normal
HbA1C ^e (for patient with diabetes)	6.3	6.8
Proteinuria (gross dipstick)	1+	1+

Figure 1. Hypothetical patient scenario

^a Participants were randomly assigned one of 4 possible scenarios that varied on patient race (African American or White) and the presence or absence of diabetes.

^b Medications for patient with diabetes

^c Estimated glomerular filtration rate (GFR) for the White and African American patient was 32 mL/min/1.73m² [using the 4-variable MDRD Study equation]⁵

^d Estimated GFR was 28 mL/min/1.73m² and 29 mL/min/1.73m² for the White and African American patient, respectively [using the MDRD Study equation]⁵

^e Comprehensive metabolic panel includes sodium, potassium, chloride, bicarbonate, glucose, calcium, creatinine, blood urea nitrogen, albumin, total protein, alkaline phosphatase, alanine amino transferase, aspartate amino transferase, and bilirubin. Complete blood count includes hemoglobin, hematocrit, white blood cell count, and platelets. Hb1AC: hemoglobin A1C.

Note: Serum creatinine in mg/dL may be converted to μmol/L by multiplying by 88.4; GFR in mL/min may be converted to mL/s by multiplying by 0.01667.

Figure 2. Percent of physicians ordering guideline recommended tests

The percent of physicians ordering guideline recommended tests according to adherence status (Adherent: obtaining at least 5 of the 6 clinical tests recommended by guidelines). All p values were <0.001.

Abbreviation: PTH-parathyroid hormone

Figure 3. Percent of physicians ordering additional tests

The percent of physicians ordering each additional test according to adherence status.

(Adherent: obtaining at least 5 of the 6 clinical tests recommended by guidelines).

Abbreviation: spep, serum protein electrophoresis; upep, urine protein electrophoresis; cbc, complete blood count; hiv, human immunodeficiency virus; iron studies, include serum iron, ferritin, and transferrin; anti-ds dna, anti-double stranded deoxyribonucleic acid; pt, prothrombin time; aptt, activated partial thromboplastin; MRA, magnetic resonance imaging. All p values $p < 0.05$, except for creatinine and CBC/differential.

^aClinical test results already provided in the clinical scenario

Table 1

Characteristics of physicians and hypothetical patients according to physician adherence to guidelines in the clinical evaluation of chronic kidney disease

Physician Characteristics	All (N=301)	Adherent ^a (N=104)	Non-Adherent (N=197)	P value
	n	n (%)	n (%)	
Specialty Type:				<0.001
Family Physician	86	16 (19)	70 (81)	
Internal Medicine	89	29 (33)	60 (67)	
Nephrology	126	59 (47)	67 (53)	
Recommend Nephrology Referral:				<0.001
Yes	249	98 (39)	151 (61)	
No	46	3 (7)	43 (93)	
Correct Glomerular Filtration Rate estimate:				0.02
Yes	215	82 (38)	133 (62)	
No	79	19 (24)	60 (76)	
Educational Resources:				
Conferences	270	96 (36)	174 (64)	0.4
Scientific Journals	280	97 (35)	183 (65)	0.4
Other CME	144	51 (35)	93 (65)	0.5
Guideline Organizations:				
Nephrology	169	73 (43)	96 (57)	<0.001
USPSTF	125	40 (32)	85 (68)	0.4
Other	222	78 (35)	144 (65)	0.7
Practice Characteristics				
Years in Practice:				0.01
≤10 years	139	59 (42)	80 (58)	
>10 years	162	45 (28)	117 (72)	
Practice Type:				0.9
Academic	71	24 (34)	47 (66)	
Other	220	77 (35)	143 (65)	
Percent Clinical Time:				0.2
<80%	68	28 (41)	40 (59)	
≥80%	233	76 (33)	157 (67)	
Sufficient Clinical/Administrative Resources:				0.5
Yes	168	61 (36)	107 (64)	
No	131	43 (33)	88 (67)	
Census Region:				0.08
Northeast	72	28 (39)	44 (61)	
Midwest	65	20 (31)	45 (69)	
South	99	41 (41)	58 (59)	
West	65	15 (23)	50 (77)	
Census Urban/Rural Status:				0.09

Physician Characteristics	All (N=301)	Adherent ^a (N=104)	Non-Adherent (N=197)	P value
	n	n (%)	n (%)	
Urban	162	60 (37)	102 (63)	
Urban/Rural	96	29 (30)	67 (70)	
Rural	12	1 (8)	11 (92)	
Clinical Scenario:				
Patient Race:				0.2
White	146	45 (31)	101 (69)	
African American	155	59 (38)	96 (62)	
Diabetes				0.06
Yes	164	49 (30)	115 (70)	
No	137	55 (40)	82 (60)	

^a Adherent: obtaining at least 5 of the 6 clinical tests recommended by guidelines

Note. Due to missing values, categorical frequencies may not equal column total. For educational resources and guideline organizations, selections were not mutually exclusive.

ZIP code used for census region and urban/rural status.

Abbreviations: USPTSF-U.S. Preventative Services Task Force, CME-Continuing Medical Education

Table 2
Physician and hypothetical patient characteristics associated with physician adherence to guidelines in the clinical evaluation of chronic kidney disease (CKD)

	Guideline Adherence ^a					
	Guideline Adherence ^a			Diagnostic Tests ^d		
Characteristics	Adjusted Odds Ratio ^b (95% CI)	P		Adjusted Odds Ratio ^b (95% CI)	P	Management Tests ^d
Specialty Type:						
Internal Medicine	0.56 (0.29–1.08)	0.08		0.89 (0.48–1.68)	0.7	Adjusted Odds Ratio ^b (95% CI)
Family Physician	0.29 (0.14–0.60)	0.001		0.47 (0.25–0.90)	0.02	0.44 (0.20–0.97)
Nephrology	1.0 (Reference)			1.0 (Reference)		0.25 (0.10–0.63)
						1.0 (Reference)
Correct Glomerular Filtration Estimate:						
No	0.59 (0.31–1.14)	0.1		0.73 (0.41–1.30)	0.3	0.58 (0.25–1.36)
Yes	1.0 (Reference)			1.0 (Reference)		1.0 (Reference)
Years in Practice:						
>10 years	0.52 (0.30–0.89)	0.02		0.63 (0.38–1.04)	0.07	0.77 (0.41–1.48)
≤10 years	1.0 (Reference)			1.0 (Reference)		1.0 (Reference)
Academic Practice:						
Academic	0.51 (0.25–1.04)	0.06		0.97 (0.50–1.87)	0.9	0.86 (0.38–1.97)
Other	1.0 (Reference)			1.0 (Reference)		1.0 (Reference)
Percent Clinical Time:						
<80%	1.48 (0.74–2.98)	0.3		1.33 (0.68–2.62)	0.4	0.91 (0.39–2.11)
≥80%	1.0 (Reference)			1.0 (Reference)		1.0 (Reference)
Geographic Location:						
Midwest	0.69 (0.32–1.49)	0.3		0.98 (0.48–2.02)	0.9	0.61 (0.25–1.51)
South	0.87 (0.44–1.71)	0.7		1.18 (0.61–2.30)	0.6	0.55 (0.24–1.23)
West	0.37 (0.16–0.86)	0.02		0.67 (0.32–1.41)	0.3	0.50 (0.19–1.32)
Northeast	1.0 (Reference)			1.0 (Reference)		1.0 (Reference)
Patient Race:						
White	0.60 (0.35–1.03)	0.06		0.60 (0.36–0.98)	0.04	0.69 (0.36–1.30)
African American	1.0 (Reference)			1.0 (Reference)		1.0 (Reference)
Diabetes:						
Yes	0.65 (0.38–1.11)	0.1		0.52 (0.32–0.86)	0.01	1.32 (0.69–2.52)
						0.4

Characteristics	Guideline Adherence ^a					
	Guideline Adherence ^a		Diagnostic Tests ^a		Management Tests ^a	
	Adjusted Odds Ratio ^b (95% CI)	P	Adjusted Odds Ratio ^b (95% CI)	P	Adjusted Odds Ratio ^b (95% CI)	P
No	1.0 (Reference)		1.0 (Reference)		1.0 (Reference)	

^a Adherence: obtaining at least 5 of the 6 clinical tests recommended by guidelines. Adherence was categorized into diagnostic tests, obtaining all tests related to diagnosis of CKD (urinalysis, urine protein quantification, renal ultrasound) and management tests, obtaining all tests related to management of co-morbid conditions associated with CKD (lipid profile, serum phosphorous, intact parathyroid hormone)

^b Adjusted for all characteristics listed in the table

Note. 285 participants are included in each model (Guideline Adherence, Diagnostic Tests and Management Tests).

Table 3

Physician characteristics associated with additional non-recommended testing in the clinical evaluation of chronic kidney disease

	Additional Testing ^a (N=285)			
	Adherent ^b (n=98)		Non-Adherent (n=187)	
Characteristics	Adjusted Odds Ratio ^c (95% CI)	P	Adjusted Odds Ratio ^c (95% CI)	P
Specialty Type:				
Internal Medicine	6.90 (1.21–39.49)	0.03	0.63 (0.26–1.49)	0.3
Family Physician	1.43 (0.36–5.72)	0.6	0.74 (0.33–1.69)	0.5
Nephrology	1.0 (Reference)		1.0 (Reference)	
Correct Glomerular Filtration Estimate:				
No	0.66 (0.16–2.63)	0.6	0.80 (0.37–1.73)	0.6
Yes	1.0 (Reference)		1.0 (Reference)	
Years in Practice:				
>10 years	0.33 (0.12–0.91)	0.03	0.75 (0.38–1.51)	0.4
≤10 years	1.0 (Reference)		1.0 (Reference)	
Academic Practice:				
Academic	0.82 (0.18–3.61)	0.8	0.98 (0.42–2.29)	0.9
Other	1.0 (Reference)		1.0 (Reference)	
Percent Clinical Time:				
<80%	1.14 (0.28–4.56)	0.8	1.33 (0.54–3.26)	0.5
≥80 %	1.0 (Reference)		1.0 (Reference)	
Geographic Location:				
Midwest	0.83 (0.21–3.34)	0.8	0.98 (0.33–2.89)	0.9
South	0.76 (0.23–2.47)	0.6	2.63 (1.01–6.88)	0.05
West	0.84 (0.11–6.40)	0.8	1.83 (0.67–4.98)	0.2
Northeast	1.0 (Reference)		1.0 (Reference)	
Patient Race:				
White	0.37 (0.14–1.0)	0.05	1.56 (0.79–3.06)	0.2
African American	1.0 (Reference)		1.0 (Reference)	
Diabetes:				
Yes	1.40 (0.52–3.77)	0.5	0.51 (0.26–1.00)	0.05
No	1.0 (Reference)		1.0 (Reference)	

^a Additional testing: obtaining more than the median number (4) of tests above those recommended by guidelines

^b Adherent: obtaining at least 5 of the 6 clinical tests recommended by guidelines

^c Adjusted for all characteristics listed in the table

Table 4
Proportion of the aggregate additional cost accounted for by each additional test

Additional tests	Proportion of Aggregate Additional Cost contributed by Tests ^a (%)			P value
	All	Adherent ^b	Non-Adherent	
MRA of renal arteries	28	30	25	0.5
SPEP/UEPEP	14	13	14	0.9
Chest X-ray	8	7	9	0.8
Hepatitis B serologies	8	8	7	0.9
Iron studies	6	7	5	0.8
Antinuclear antibody	6	5	6	0.9
Hepatitis C antibody	5	5	5	0.9
CBC/differential ^c	4	3	5	0.7
Hemoglobin A1C ^c	4	3	5	0.7
Complement	3	4	2	0.7
Magnesium	3	3	2	0.9
Uric acid	2	2	2	0.9
Glucose ^c	2	2	3	0.9
HIV Antibody	2	2	2	0.9
Anti-DS DNA	2	2	1	0.9
Rheumatoid factor	1	1	1	0.9
Creatinine ^c	1	1	1	0.9
Cryoglobulins	1	1	1	0.9
PT/APTT	1	1	1	0.9
Rapid Plasma Reagent	1	1	1	0.9

Abbreviation: spep, serum protein electrophoresis; uepep, urine protein electrophoresis; cbc, complete blood count; hiv, human immunodeficiency virus; iron studies, include serum iron, ferritin, and transferrin; anti-ds dna, anti-double stranded deoxyribonucleic acid; mra, magnetic resonance imaging; pt, prothrombin time; aptt, activated partial thromboplastin

^a Aggregate additional cost of testing = \$29763.31 (Adherent: \$17309.62, Non-Adherent: \$12453.69)

^b Adherent: obtaining at least 5 of the 6 laboratory evaluations recommended by guidelines

^c Clinical test results already provided in clinical scenario