Low Rates of Testing and Diagnostic Codes Usage in a Commercial Clinical Laboratory: Evidence for Lack of Physician Awareness of Chronic Kidney Disease

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Improving outcomes for chronic kidney disease (CKD) requires early identification and recognition by physicians. There are few data on rates of testing or use of diagnostic codes for CKD. A cross-sectional analysis was performed of patients who were older than 40 yr and had one or more laboratory tests between April 1, 2002, and March 31, 2003, at a Laboratory Corporation of America regional laboratory. Objectives were to determine the frequency of testing for serum creatinine; prevalence of CKD, defined as estimated GFR <60 ml/min per 1.73m^2; and sensitivity of diagnostic codes for CKD for patients with and without risk factors for CKD and with or without cardiovascular disease (CVD). Of the 277,111 patients, 19% had serum creatinine measured, compared with 33 and 71% who had measurements of serum glucose and lipids, respectively. Patients with hypertension, diabetes, and age >60 yr were more likely to be tested for serum creatinine with odds ratio (OR; 95% confidence interval) of 2.09 (2.05 to 2.14), 1.22 (1.19 to 1.25), and 1.24 (1.22 to 1.27) respectively. Among patients tested, 30% had CKD. Sensitivity and specificity of kidney disease diagnostic codes compared with CKD defined by estimated GFR <60 ml/min per 1.73 m^2 were 11 and 96%, respectively. In patients with hypertension, diabetes, age >60 years, and CVD, rates of testing and sensitivity of diagnostic codes were 53 and 14%, respectively. Low rates of testing for serum creatinine and insensitivity of diagnostic codes for CKD, even in high-risk patients, suggests inadequate physician awareness of CKD and limited utility of administrative databases for identification of patients with CKD.

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Adverse outcomes associated with chronic kidney disease (CKD) are due, in part, to late detection of CKD, resulting in delays in diagnosis, treatment, and referral to a nephrologist (1–4). Clinical practice guidelines provide evidence-based recommendations for evaluation and management of CKD (5–8). Physician awareness of CKD is central to the success of these guidelines in achieving improved outcomes. Health care organizations and insurance plans can assist physicians in providing the recommended care by targeting appropriate patients for quality improvement activities. Some organizations maintain laboratory databases that can be used to identify patients with CKD (9). However, in others, including Medicare, laboratory data are not available and diagnostic codes from claims data are used to identify CKD (10). The frequency of patients with CKD who are identified through laboratory testing for serum creatinine and use of diagnostic codes for kidney disease has not been well described. Low rates of testing and use of diagnostic codes may indicate lack of awareness of CKD by physicians and limit utility of administrative databases for identification of patients with CKD.

We examined the frequency of testing for serum creatinine and the accuracy of diagnostic codes for CKD in one region of a national clinical commercial laboratory. We hypothesized that frequency of testing would be higher in high-risk groups but low compared with testing for other chronic conditions that are also risk factors for cardiovascular disease, such as diabetes and hyperlipidemia. We also hypothesized that diagnostic codes would identify only a small subset of the patients with CKD, defined as estimated GFR <60 ml/min per 1.73 m^2, and that diagnostic codes are used preferentially in patients with more severe reduction in GFR.

Materials and Methods

Study Population

The study population included all people who were 40 yr of age or older and had at least one laboratory test performed between April 1, 2002, and March 31, 2003, at the Laboratory Corporation of America (LabCorp) regional laboratory located in Columbus, OH. This laboratory serves a population of 35 million in the Ohio, West Virginia, Illinois, northern Indiana, and western Pennsylvania regions. LabCorp provides approximately 20% of the medical laboratory testing to this region. Individuals who were pregnant during the year or who were on dialysis were excluded on the basis of the presence of a pregnancy- or

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dialysis-related diagnosis code. Individuals with missing identification numbers were also excluded.

Data Source

The database consisted of information that was submitted on the laboratory requisition and provided on the laboratory reports to the clinical providers. Physicians (providers) must supply diagnostic codes to order laboratory tests. Codes defined by the *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD-9-CM) were used for this purpose.

Demographic and Clinical Characteristics

Hypertension, diabetes, and age >60 yr were defined as risk factors for CKD. CKD is highly associated with cardiovascular disease (CVD) (9,11–13). Patients with risk factors for CKD and with CVD were considered to be at highest risk for CKD. Diabetes, hypertension, and CVD were defined from an ICD-9-CM code for the condition submitted at least once during the measurement year on any laboratory test requisition. Given that the data set is limited to a 12-mo interval, we did not require two diagnostic codes for the definition of diabetes, as is generally required with the use of the larger claims-based administrative data sets (14). We compared laboratory and ICD-9-CM–based definition for diabetes using standard cutoffs recommended by the American Diabetes Association (15). Sensitivity and specificity of ICD-9-CM–based definitions were 81 and 85%, respectively, compared with the laboratory definition. To test the impact of the ICD-9-CM–based and lab-based definitions on identification of diabetes, we performed all analyses using both definitions. No substantive differences were seen, and all results reported here use the ICD-9-CM–based diagnosis. CVD codes were categorized into those related to cardiac disease (*e.g.*, coronary artery disease, myocardial disease), cerebral vascular disease, and peripheral vascular disease. Diagnostic codes for all diseases are listed in the Appendix.

Outcomes of Interest

We considered three outcomes. First, we calculated the proportion of patients who were tested for kidney disease with serum creatinine on at least one occasion in a 12-mo period. We compared the number of patients who were tested for serum creatinine with the number of patients who received all laboratory tests necessary to evaluate other chronic diseases (*e.g.*, diabetes, hyperlipidemia) and commonly ordered tests, such as complete blood count and electrolytes.

Second, we determined the prevalence of CKD, defined as estimated GFR <60 ml/min per 1.73 m^2, among patients in whom serum creatinine was measured. The upper limit of normal for serum creatinine at LabCorp is 1.5 mg/dl for both men and women. Calibration of creatinine is necessary for accurate GFR estimates (16–19). The LabCorp serum creatinine assay was calibrated to the Cleveland Clinic National Institute of Health Core Biochemistry Laboratory (CCL), the central laboratory for the Modification of Diet in Renal Disease (MDRD) Study. Fifty samples in each of the following ranges of serum creatinine concentration were analyzed for serum creatinine by both CCL and LabCorp: <0.8 mg/dl, 0.8 to 1.3 mg/dl, 1.4 to 2.0 mg/dl, and >2.0 mg/dl. The sera were analyzed in duplicate for serum creatinine at LabCorp using the Roche Rate Jaffè/Modular assay. At CCL, the Beckman Rate Jaffè/CX3 Synchron assay was used. The mean difference (calibration difference) between the average values (SD) for measurement of serum creatinine at the two laboratories was −0.18 (0.13) mg/dl. Regression analysis between the LabCorp and the Cleveland Clinic data resulted in a calibration factor of 1.087 × [serum creatinine concentration] + 0.035 mg/dl.

Estimated GFR was calculated from the first serum creatinine during the time interval using the four-variable MDRD equation: GFR = $186.3 \times [(\text{serum creatinine}^{-1.154}] \times (\text{age}^{-0.203}) \times 1.212$ (if black) × 0.742 (if female). Creatinine was measured in mg/dl. The calibrated values for the LabCorp serum creatinine were used. Estimated GFR was divided into categories of >60, 30 to 59, and <30 ml/min per 1.73 m^2. An inadequate number of patients with estimated GFR <15 ml/min per 1.73 m^2 were available to examine this group separately. A single estimated GFR of <60 ml/min per 1.73 m^2 was considered to be CKD as in other epidemiologic studies (9,12,20,21). In patients who had more than one measurement of serum creatinine, we examined the persistence of decreased levels of estimated GFR across time.

Data on race were not available and could not be used in the estimation of GFR. Thus, the primary analysis assumed that all patients were not black. This has the effect of underestimating GFR by 21% for black individuals. Census data from the counties serviced by this laboratory report that 9% of the population is black (22). To test the impact of this assumption, we performed sensitivity analyses assuming a prevalence of black individuals in the study population of 9 and 18%.

Third, we assessed accuracy of ICD-9-CM codes related to kidney disease. ICD-9-CM codes were categorized into acute kidney disease, chronic kidney disease, dialysis, and kidney transplantation (see Appendix). Sensitivity, specificity, and predictive value were computed for the study sample and subgroups defined by risk factors for CKD and CVD.

Table 1. Demographics and clinical characteristics[a]

Variable	*n* (%)
N	277,111 (100)
Female	140,694 (50.8)
Risk factors	
age	
mean (SD)	58.5 (10.8)
≥60 yr	117,181 (42.3)
diabetes	
ICD-9-CM code	48,343 (20.1)
high glucose	45,786 (16.5)
hypertension	74,716 (31.1)
three risk factors	11,316 (4.1)
none of the above	89,324 (32.2)
CVD[b]	
coronary artery disease	13,872 (5.8)
myocardial disease	3434 (1.4)
cerebral vascular disease	1586 (0.7)
peripheral arterial disease	1124 (0.5)
no CVD	220,389 (79.8)
Kidney disease	
acute	164 (0.06)
chronic	6646 (2.4)
dialysis	7 (<0.01)
transplant	175 (0.06)
none	270,127 (97.1)

[a]ICD-9-CM, *International Classification of Disease, Ninth Revision, Clinical Modification*; CVD, cardiovascular disease.
[b]Patients may belong to more than one category.

Table 2. Frequency of testing for serum creatinine and other common laboratory tests[a]

	n	Frequency of Testing (%)[b]				
		Creatinine	Glucose	Lipids	CBC	Electrolytes
All	277,111	19.3	33.7	71.0	9.6	11.9
Female	140,694	19.5	33.4	71.2	9.6	12.3
CKD risk groups						
age > 60 yr	117,181	21.4	35.0	67.0	8.2	12.5
diabetes	48,343	21.9	91.9	71.9	6.5	11.7
hypertension	74,716	27.9	40.5	84.3	7.5	16.9
three risk factors	11,316	27.8	93.8	78.7	6.7	14.9
no risk factor	89,324	14.0	19.8	74.0	10.0	9.4
CVD[c]						
coronary artery disease	13,872	22.1	35.6	87.7	7.1	12.2
myocardial disease	3434	35.2	44.2	55.7	10.0	21.9
cerebral vascular disease	1586	22.9	30.6	65.7	8.8	15.5
peripheral arterial disease	1124	29.9	34.0	71.1	10.0	14.4
no CVD	220,389	19.0	33.5	74.0	8.5	11.7
Kidney disease						
acute	164	58.4	37.8	52.4	7.9	30.5
chronic	6646	36.2	35.5	53.5	12.7	15.2
transplant	175	49.7	49.7	78.2	8.0	36.6
no kidney disease	270,127	18.9	33.4	71.4	9.5	12.2

[a]CBC, complete blood count; CKD, chronic kidney disease.
[b]Row percentages.
[c]Patients may belong to more than one category.

Statistical Analyses

Descriptive statistics are presented as frequencies or means with SD or medians with 5th and 95th percentiles, depending on the underlying distribution. Comparisons were conducted using χ^2 test or OR, as appropriate. The study was approved by the Institutional Review Board at Tufts-New England Medical Center.

Results

A total of 277,111 individuals had 4,015,562 tests in 489,389 visits that were performed from April 1, 2002, to March 31, 2003, and processed at the Columbus, OH, laboratory of LabCorp. Table 1 shows the demographics and clinical char-

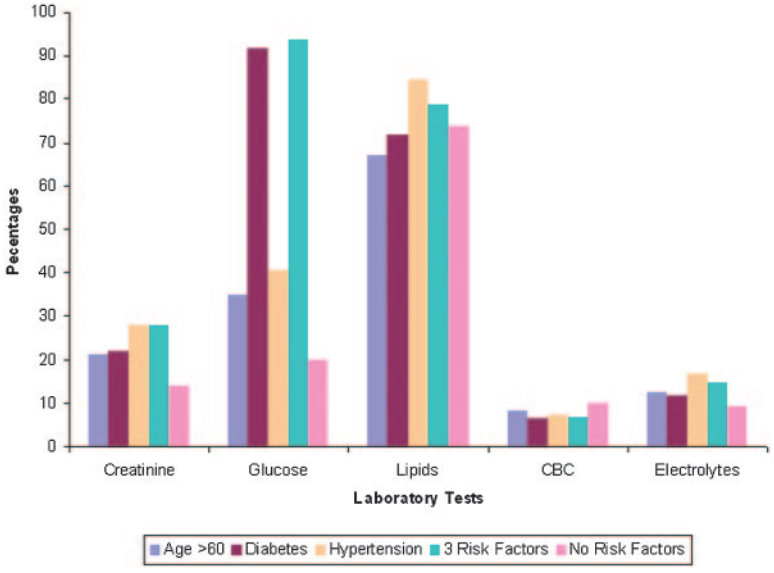

Figure 1. Frequency of testing for creatinine compared with other common laboratory tests by risk factor condition. Percentages are the patients who did or did not have the risk factor and were tested for each test.

acteristics of the population. Of the patients who were older than 60 yr, 50% had either diabetes or hypertension.

Testing for Serum Creatinine

In the study population, 19% of patients had at least one measurement of serum creatinine (Table 2, Figure 1). A significantly greater proportion of patients were tested for serum glucose (34%; OR [95% confidence interval] 2.09 [2.07 to 2.12]) and for serum lipids (71%; OR 10.19 [10.06 to 10.31]). Frequency of testing for serum creatinine was higher in patients with CKD risk factor conditions, CVD, or kidney disease codes (Tables 2 and 3, Figure 1). The median number of visits to the laboratory in individuals who did not have measurement of serum creatinine was one visit (59 maximum). For individuals who had all three risk factors and did not have a measurement of serum creatinine, the median number of visits was three visits (46 maximum). Patients with kidney disease codes were more likely to be tested for serum creatinine than patients without these codes (37%; OR 5.71 [5.48 to 5.95]).

Prevalence of CKD

In the patients who had measurement of serum creatinine, 30% had CKD (estimated GFR <60 ml/min per 1.73 m^2), and of those with CKD, 11% had estimated GFR <30 ml/min per 1.73 m^2. Table 4 shows the mean estimated GFR and proportions who had estimated GFR ≥60, 30 to 59, and <30 ml/min per 1.73 m^2 in subgroups defined by risk factors for CKD, CVD, or presence of kidney disease codes. Significantly more patients with CKD risk factor conditions, CVD, and kidney disease codes had CKD. Sensitivity analysis assuming 9 and 18% prevalence of black individuals increased the mean GFR by only 2 and 3 ml/min per 1.73 m^2, respectively, and decreased the prevalence of CKD by only 2.7 and 4.5%, respectively.

In 89% of women and 70% of men with CKD, serum creatinine results were within normal limits for the laboratory (≤1.5 mg/dl; Figure 2). In patients with CKD but normal serum creatinine, median (range) estimated GFR was 52 (30 to 59) ml/min per 1.73 m^2. Of the patients who had discordance between estimated GFR and serum creatinine, 76 and 69% of women and men, respectively, were older than 60 yr.

Table 3. Odds ratio for serum creatinine testing[a]

	OR (95% CI)
Risk factor groups[b]	
age > 60 yr	1.24 (1.22 to 1.27)
diabetes	1.22 (1.19 to 1.25)
hypertension	2.09 (2.05 to 2.14)
three risk factors	1.64 (1.58 to 1.71)
no risk factors[c]	0.58 (0.56 to 0.59)
CVD[d]	
coronary artery disease	1.19 (1.14 to 1.24)
myocardial disease	2.29 (2.14 to 2.46)
cerebral vascular disease	1.23 (1.10 to 1.39)
peripheral artery disease	1.78 (1.56 to 2.02
no CVD[c]	0.89 (0.87 to 0.91)
Kidney disease codes[b]	
chronic	2.42 (2.30 to 2.56)
acute	5.87 (4.30 to 8.02)
transplant	4.13 (3.07 to 5.55)
no kidney disease[c]	0.40 (0.38 to 0.42)

[a]OR, odds ratio; CI, confidence interval.
[b]Compared with not having the condition.
[c]Compared with having any of the above.
[d]Patients may belong to more than one category.

Accuracy of Diagnostic Codes for CKD

ICD-9-CM codes for kidney disease were used in 3% of all patients. Sensitivity of the codes for detecting patients with estimated GFR of <60 and <30 ml/min per 1.73 m^2 was 11 and 39%, respectively. Specificity of the codes was 98 and 96%, respectively. High specificity for CKD stages 3 to 5 suggests that physicians are not using CKD codes for earlier stages of CKD, detected by markers of kidney damages, such as albuminuria. Positive and negative predictive values of diagnostic codes for kidney disease for GFR <60 ml/min per 1.73 m^2 were 65 and 72%, respectively, and for GFR <30 ml/min per 1.73 m^2 were 24 and 98%, respectively. The positive predictive value of diagnostic codes for GFR <30 ml/min per 1.73 m^2 was lower than for GFR <60 ml/min per 1.73 m^2 because diagnostic codes for kidney disease are not stage specific and may be used appropriately in patients with GFR 30 to 59 ml/min per 1.73 m^2. Sensitivity and specificity did not differ substantially by presence or absence of risk factors or CVD (data not shown).

Outcomes in Subgroups Defined by Combinations of Risk Factors and CVD

Table 5 shows the three outcomes described above according to groups defined by the presence or absence of risk factors for CKD and CVD. Even in high-risk groups, most patients are not tested, and among those tested, most are not identified by diagnostic codes. For patients who were in the highest risk group and did not have a serum creatinine, the median (maximum) number of visits to the laboratory was three (57). As expected, because sensitivity and specificity do not vary substantially across subgroups, the positive predictive value increases as the prevalence of disease increases. For patients who were older than 60 yr, the sensitivity of diagnostic codes for GFR estimates <60 and <30 ml/min per 1.73 m^2 was 10 and 37%, respectively, compared with 12 and 47%, respectively, in patients who were younger than 60 yr (P = 0.004 and 0.001).

Outcomes in the Subgroup of Patients with Repeated Measurements of Serum Creatinine

Among 53,601 patients with measurements of serum creatinine, 11,494 (21%) had more than one measurement. Of those, 13% had discordant results with regard to GFR estimates ≥ or <60 ml/min per 1.73 m^2. In the 2766 patients who

Table 4. Prevalence of estimated GFR categories by condition

	No. Tested	Prevalence (%)[a,b]				GFR Mean (SD)[b]
		GFR >60	GFR 30 to 59	GFR <30	*P* Value[c]	
All	53601	70.4	27.6	2.9		68.4 (19.7)
Female	27371	70.4	26.6	3.0	0.69	68.2 (19.7)
Risk factors[c]						
age > 60 yr	25030	52.6	42.4	5.0	<0.0001	66.8 (18.9)
diabetes	10596	64.1	31.0	4.9	<0.0001	67.1 (22.9)
hypertension	20822	64.5	32.3	3.2	<0.0001	66.2 (19.8)
three risk factors	3147	50.0	43.1	6.9	<0.0001	59.6 (20.3)
no risk factors[d]	12473	87.7	11.5	0.8	<0.0001	75.3 (17.3)
CVD[c,e]						
coronary artery disease	3060	53.7	40.6	5.7	<0.0001	61.0 (19.8)
myocardial disease	1210	33.4	51.7	15.0	<0.0001	58.0 (22.7)
cerebral vascular disease	363	50.7	42.7	6.6	<0.0001	60.4 (21.6)
peripheral arterial disease	336	45.5	46.4	8.0	<0.0001	58.7 (20.6)
no CVD[d]	41755	71.4	26.0	2.5	<0.0001	69.0 (19.7)
Kidney disease codes						
acute	96	13.5	57.3	29.2	<0.0001	39.2 (17.2)
chronic	2401	36.7	39.8	23.5	<0.0001	50.7 (25.4)
transplant	87	14.0	65.2	21.0	<0.0001	42.1 (17.0)
no kidney disease[d]	51062	72.2	25.9	1.9	<0.0001	69.3 (19.0)

[a]Row percentages.
[b]Units of GFR are ml/min per 1.73 m^2.
[c]χ^2 statistic: Compared with not having the condition.
[d]Compared with any of the above.
[e]Patients may belong to more than one category.

had persistent reduction in GFR for 3 mo or longer, the sensitivity of diagnostic codes was 22%.

Discussion

Our results suggest that many patients with risk factors for CKD are not being tested for CKD, and most patients with CKD are not identified by diagnostic codes, even in patients who are at highest risk for CKD and even those with persistent reduction in GFR. These findings are particularly notable in comparison with the higher frequency of testing for serum glucose or lipids and the higher sensitivity of ICD-9-CM codes for diabetes. Altogether, these results suggest that physicians are not aware of CKD or its relationship to CVD, especially in comparison with awareness of other CVD risk factors, such as diabetes and hyperlipidemia. This highlights three important implications for improving outcomes for CKD.

First, current recommendations are regular testing for CKD in people who are at increased risk for CKD or have CVD (7,23,24); thus, these low rates of testing suggest lack of adherence to current recommendations. Although treatments of proven effectiveness are available, substantial improvement in patient outcomes requires early identification, appropriate evaluation, and management (25). Therefore, the lack of adherence to the guidelines represents missed opportunities to initiate appropriate treatment strategies. In addition, the low levels of testing for anemia even in patients with known CKD (*i.e.*, those with diagnostic codes for kidney diseases) suggests that care for patients with known CKD are not at recommended levels.

Second, the low frequency of testing and sensitivity of diagnostic codes for CKD should influence the interpretation of studies of CKD performed in clinical populations. It is likely that such studies included only a small fraction of patients with CKD, and studies that used diagnostic codes alone were more likely to include patients with a severe reduction in GFR (10,21,26,27). This raises important questions about the accuracy and generalizability of these studies. Studies of CKD in clinical populations should identify patients with CKD from laboratory tests, report the fraction of patients who were tested for CKD, and express results of outcomes and costs of care according to level of GFR, corresponding to CKD stage.

Third, improvement in quality of care is often the result of quality improvement programs implemented by large health care organizations. The low frequency of testing and use of diagnostic codes observed in this study suggests that use of administrative data to identify patients for inclusion in quality improvement programs for CKD may limit the effectiveness of these programs to only a small fraction of the patients

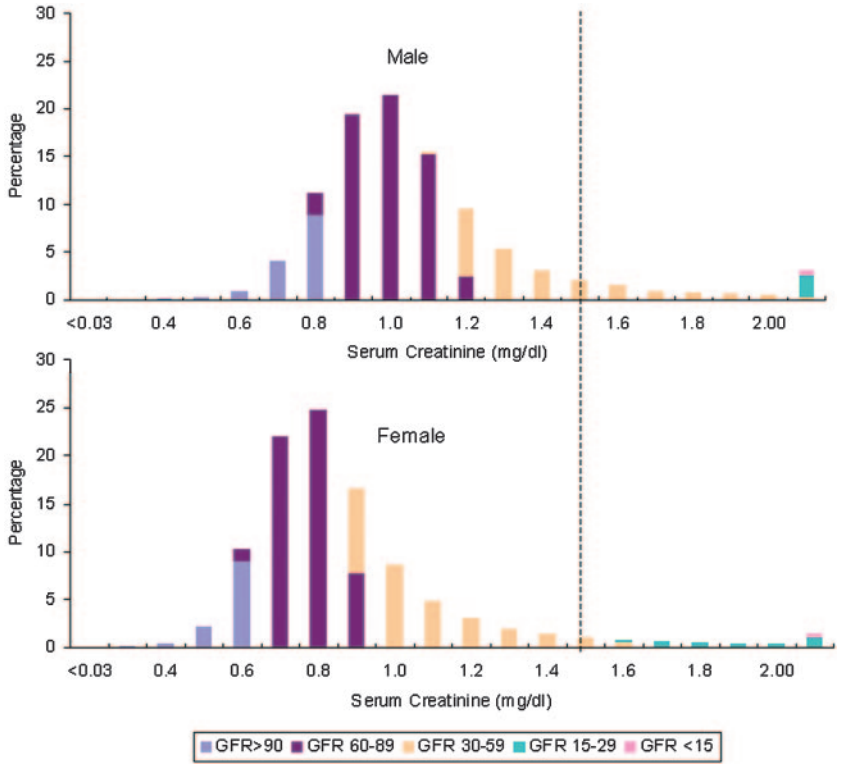

Figure 2. Distribution of serum creatinine tests according to level of estimated GFR. Serum creatinine is reported as mg/dl. GFR is reported as ml/min per 1.73 m^2. Upper limit of normal for serum creatinine in this laboratory is 1.5 mg/dl, as indicated by the dashed line. Of the female and male patients with GFR <60 ml/min per 1.73 m^2, 89 and 70%, respectively, had serum creatinine ≤1.5 mg/dl.

Table 5. Outcomes according to combinations of CKD risk factor and CVD status[a]

Groups			Creatinine Tests[b]	GFR Prevalence[b,c]			Diagnostic Accuracy[b]							
							GFR <60				GFR <30			
Renal Failure	CVD	*n* (%)[d]		>60	30 to 59	<30	Sens	Spec	PPV	NPV	Sens	Spec	PPV	NPV
No	No	105,531 (38)	16,355 (15)	88.4	10.8	0.9	10	98	40	89	39	97	11	99
Any	No	151,709 (55)	32,378 (21)	64.3	32.4	3.3	10	97	68	66	38	96	24	98
Any	Yes	16,292 (6)	4233 (26)	46.4	45.4	8.2	14	97	86	50	41	94	37	95
All	No	97,11 (4)	2605 (26)	52.2	41.8	6.0	12	96	73	54	37	94	28	96
All	Yes	1605 (1)	542 (34)	39.1	49.3	11.6	14	97	87	42	51	95	59	94

[a]Sens, sensitivity; Spec, specificity; PPV, positive predictive value; NPV, negative predictive value.
[b]Row percentages.
[c]Units of GFR are ml/min per 1.73 m^2.
[d]Percentage of total population (N = 277,111). Categories are not exclusive.

with CKD, and when diagnostic codes alone are used, these patients are more likely to be in the later stages of CKD.

One potential reason for the low rates of awareness of CKD may be the relatively recent publication of guidelines that define CKD irrespective of cause (2002) and establishment of the National Kidney Disease Education Program (2001) (5,23). By contrast, guidelines and education programs for diabetes and hyperlipidemia have been in existence since 1997 and 1985, respectively. The current low rates of testing and use of diagnostic codes for CKD reported here serve as a baseline measure and emphasize the magnitude of the change in clinical practice that needs to be accomplished.

Another reason for lack of awareness of CKD may be the discordance between serum creatinine and estimated GFR as has been shown in multiple previous populations and settings (28–31). The discordance suggests that increased fre-

quency of testing for serum creatinine without reporting estimated GFR is not likely to improve detection of CKD and is the basis for recommendations by national and international organizations for automatic GFR reporting whenever serum creatinine is ordered (5,7,23,32) and for implementation of these recommendations by large health organizations and clinical laboratories (18,33). Indeed, the one study to assess the impact of automatic reporting of GFR estimates showed that physicians' awareness of CKD improved from 22 to 88% with introduction of GFR reports by the clinical laboratory. In this study, we suspect that improvement in physicians' awareness was due to the concurrent educational sessions by a dedicated nephrologist over the study duration and to implementation in an academic medical center, where physicians may be more motivated to change their practice. It will be important to reassess frequency of serum creatinine measurements and accuracy of diagnostic codes after implementation of automatic GFR reporting in a general outpatient setting.

Lack of awareness is only one potential explanation for why physicians may not use diagnostic codes for kidney disease. A diagnosis of kidney disease is not required for justification of laboratory tests; therefore, physicians may preferentially code other diseases, such as hypertension or diabetes. In addition, physicians may not know how to use ICD-9-CM codes for CKD, given that the current ICD-9-CM classification system for CKD is based on cause and therefore is not consistent with the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative definition for CKD, which can be applied irrespective of cause. These issues are not particular to use of diagnostic codes used in association with laboratory tests and would also be expected to influence the accuracy of diagnostic codes in the claims-based administrative databases. Irrespective of the reason, the lack of use of diagnostic codes limits use of administrative data for epidemiologic studies or quality improvement without explicit validation.

This is the first study to document the low frequency of laboratory testing for serum creatinine and the low sensitivity of ICD-9-CM codes for kidney disease for CKD in a large national outpatient clinical laboratory. The strengths of this study are its wide age range, large fraction of patients with risk factors for CKD and CVD, and comparison of testing for serum creatinine with that of other common laboratory analytes. Importantly, the calibration of serum creatinine to the MDRD Study laboratory substantially improves the accuracy of the GFR estimates (16–19).

There are several limitations of this study. First, use of kidney disease codes was ascertained only from codes that were submitted to the laboratory. To minimize the impact of this issue, we used ICD-9-CM codes in association with any laboratory test (not just with serum creatinine tests) to increase the capture of relevant diagnostic codes. Possibly, the accuracy of diagnostic codes from other sources would have been higher, but this has not been reported to our knowledge. Note that similar to CKD, a diagnosis of hypertension is not required for justification of any laboratory test, yet 31% of the study population had a diagnosis of hypertension on the basis of diagnostic codes. Second, information on the demographics and clinical characteristics of the cohort was obtained from information that was submitted on laboratory requisitions, potentially leading to misclassification of patients with regard to risk factors for CKD or CVD. However, the use of a laboratory-based definition for diabetes did not substantially change the proportion with diabetes or the effect size in these subgroups. Third, race is not available in the data set. Census data show that approximately 9% of residents in this area are black (22), and it is known that black individuals are at higher risk for CKD (5,34). The sensitivity analysis showed the minimal impact on the mean GFR and prevalence of CKD if up to 18% of patients were black, but these analyses do not incorporate differential prevalence of CKD. Fourth, some patients may have had serum creatinine measurements at other laboratories during the study period rather than at LabCorp. The high rate of testing for lipids suggests that this is not a likely explanation. Furthermore, the number of visits to the laboratory in high-risk patients who did not have a serum creatinine measurement emphasizes the magnitude of missed opportunities for testing. Overall, we believe that these weaknesses do not seriously detract from the conclusions of our study.

Our findings suggest that physicians are not aware of CKD or its risk factors or associations with CVD. This would seriously limit physicians' ability to deliver quality care to patients with CKD. It also would limit the utility of laboratory and administrative databases for identification of patients with CKD for implementation of quality improvement programs. Integrated programs for other important chronic conditions, such as the Health Plan Employer Data and Information Set measures of the National Committee Quality Assurance (NCQA) and Quality Improvement Collaborations, are incentives for health care organizations to improve detection, evaluation, and management for these conditions. In contrast, no similar programs exist for CKD. This is due in part to its newly recognized status as a significant contributor to adverse outcomes and health care costs. This work provides emphasis for the importance of implementation programs recommended by the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative, National Kidney Disease Education Program, and other organizations.

Appendix

Diagnostic codes used in this analysis

Condition	Description	Codes[b]
Kidney disease[c]		
glomerular	Goodpasture's syndrome, acute glomerulonephritis, nephrotic syndrome, chronic glomerulonephritis, acute glomerulonephritis, nephritis and nephropathy (not specified as acute or chronic)	446.21, 580, 581, 582, 583
diabetes	Diabetes with nephropathy	250.4X
hypertension	Hypertensive renal disease, hypertensive heart and renal disease, secondary hypertension renovascular	403, 404, 405
renovascular disease	Renal artery stenosis, vascular complications of renal artery	440.1, 997.72
malignancy	Malignant neoplasm of kidney, malignant neoplasm of unspecified of genitourinary, benign neoplasm of the kidney, benign urinary tract tumor, cancer of the kidney and ureter, unspecified renal tumor, lymphoma of the kidneys	189.0, 189.9, 223.0, 223.9, 236.91, 139.5, 202.80
gout	Gouty nephropathy	274.1
lead	Lead nephropathy	984.9
hepatorenal	Hepatorenal syndrome	572.4
infection	Tuberculosis of the kidney, AIDS nephropathy, syphilis of the kidney, chronic pyelonephritis, acute pyelonephritis	16.0, 42.9, 95.4, 590
structural	Small kidney, other disorders of the kidney and ureter	589, 593
congenital	Renal agenesis, cystic kidney disease, obstructive defects of renal pelvis and ureter	753
nonspecific	Acute renal failure; chronic renal failure; renal failure (unspecified);, renal sclerosis (unspecified); disorder resulting from impaired renal function, hematuria, renal agenesis, and dysgenesis; proteinuria; abnormal kidney function test; urinary complications	584 to 588, 599.7, 791.0, 794.4, 997.5
dialysis	Dialysis, complications peculiar to dialysis procedures, postprocedural renal dialysis, accidents occurring during dialysis	V56, 996.1, 996.56, 996.62, 996.68, 996.73, V45.1, E870.2, E871.2, E872.2, E874.2, E879.1
transplant	Kidney transplant, complication of transplanted kidney, abnormal reaction of patient during transplantation of kidney	V42.0, 996.81, E 978.0
Hypertension	Essential hypertension, hypertensive heart disease, hypertensive renal disease, hypertensive heart and renal disease, secondary hypertension	401 to 405
Diabetes	Diabetes, polyneuropathy in diabetes, diabetic retinopathy, diabetic cataract	250, 357.2, 362.0, 366.41, 648.0
CVD[a]		
coronary	Acute myocardial infarction, other acute and subacute forms of ischemic heart disease, old myocardial infarction, angina, other forms of chronic ischemic heart disease	410 to 414
myocardial	Cardiomyopathy, heart failure, ill-defined descriptions and complications of heart disease, hypertensive heart disease with heart failure, hypertensive heart and renal disease with heart failure	425, 428, 429, 402, 404
cerebrovascular	Occlusion and stenosis of precerebral arteries, occlusion of cerebral arteries, transient cerebral ischemia, ill-defined cerebrovascular disease, late effect of cerebrovascular disease	433 to 437, 438, 438.8, 438.89, 438.9
peripheral vascular	Atherosclerosis, other peripheral vascular disease, arterial embolism and thrombosis, atheroembolism	440, 443 to 445
nonspecific	Complications peculiar to cardiac or vascular devices, postprocedural status (coronary), accidents occurring during cardiac catheterization, abnormal reaction of patient during cardiac catheterization	996.0, 996.03, 996.1, 996.61, 996.72, V45.81, V45.82, E870.6, E871.6, E872.6, E874.5, E879
Pregnancy	All related diagnoses and complications	640 to 648

[a]CVD, cardiovascular disease.
[b]If fourth or fifth digits are not specified, then assume that entire family of codes is included.
[c]The classification of kidney disease categories as shown here was not used in the analysis.

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