

# A Retrospective Analysis of the Relationship Between Comorbid Hypertension and Diabetes and Recent Chronic Kidney Disease Diagnosis

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## ABSTRACT

The purpose of this study was to examine the relationships among preexisting diabetes, preexisting hypertension, and newly diagnosed chronic kidney disease (CKD). A randomized, retrospective study involving 500 CKD patient cases and 500 non-CKD patient controls was performed. Patients were registered at a large academic medical center and received a new CKD diagnosis between January 1, 2022, and January 31, 2024. Patients with CKD were more than 2.7 times as likely to have hypertension ( $P < .001$  [95% CI 1.872–3.986]), more than twice as likely to have diabetes ( $P < .021$  [95% CI 1.127–4.216]), and more than 3.5 times as likely to have comorbid hypertension and diabetes compared with patients without CKD ( $P = .001$  [95% CI 2.287–5.414]). The study was confined to the medical center's patients. Another limitation is the retrospective design of the study. Those with CKD are significantly more likely to have hypertension and diabetes, singly or together.

**ABBREVIATIONS:** CKD - chronic kidney disease.

**INDEX TERMS:** CKD, comorbid HTN, comorbid diabetes, kidney disease, diabetes, hypertension.

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## INTRODUCTION

The prevalence of chronic kidney disease (CKD) among American adults is estimated to be approximately 15%, and of this proportion, a further 808,000 are estimated to be living with end-stage renal disease (ESRD).<sup>1,2</sup> Numerous risk factors for CKD exist, with diabetes and hypertension featuring prominently among them.<sup>1</sup>

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Inadequate control of those and other conditions not only predisposes to CKD, but once CKD manifests, the risk for ESRD appreciably increases.<sup>1,3</sup> To provide clarity, CKD further complicates cardiac health, with a 2-fold increase in risk for cardiovascular diseases such as atherosclerosis.<sup>1,3</sup> Additionally, there is a well-documented higher incidence of CKD among women compared with men, African Americans, and Hispanics compared with Whites, and adults older than 65 years.<sup>1</sup> As the population ages, the increasing prevalence of chronic conditions complicates health care as elderly individuals acquire multiple chronic comorbidities. Rates of unawareness, both in the United States and the world, among individuals with CKD are markedly increased, with an estimated 82% to 90% of those with stage 1 CKD being unaware and up to 40% of individuals with ESRD being unaware.<sup>2,4</sup> Treatments for ESRD are few—to date, dialysis and transplant procedures are the “last resort.”<sup>1</sup> Poor detection of CKD represents a looming public health crisis that points to a need for earlier diagnosis among those with predisposing conditions.

The complexities of CKD are exacerbated by its significant relationship with diabetes, which is the leading cause of transplant-requiring renal failure globally.<sup>3</sup> Although an estimated 40% of people living with diabetes will eventually develop CKD, approximately 20% of diabetics in the United States are unaware that they have diabetes.<sup>3</sup> When paired with undiagnosed CKD, the need to identify significant associations between analytes not traditionally associated with kidney dysfunction and CKD becomes urgent to improve diagnosis and prognosis. There is also a significant relationship between CKD and hypertension, with hypertension being both a cause and a result of CKD.<sup>5</sup> Most patients with CKD are hypertensive.<sup>5</sup> The combination of CKD and hypertension renders treatment more difficult, as hypertensive medications must often be used in various combinations, and their potential impacts on kidney function must be taken into consideration.<sup>5</sup>

The purpose of the study was to examine the relationship among newly diagnosed CKD, preexisting diabetes, and preexisting hypertension. In particular, the identification of an additive or synergistic effect between hypertension and diabetes was of interest. This is particularly important, as the formula for estimated glomerular filtration rate (eGFR) was updated in 2021 to exclude African American race as a covariant, which potentially impacts the detection and staging of CKD. The associations CKD

has with both diabetes and hypertension bears investigation considering the eGFR equation's recent update.

## METHODS

A retrospective study involving 500 patients with CKD and 500 patients without CKD was conducted using data from an academic medical center hospital system's EPIC electronic medical record (EMR). CKD was classified based on the *International Statistical Classification of Diseases, Tenth Revision (ICD-10)* codes (Table 1).

Power analysis was conducted, which suggested that the study has greater than 80% power. Based on this analysis, a sample size of 1,000 was selected. This was derived using a creatinine-based eGFR's reported sensitivity of 47.8% at detecting early CKD among patients with hypertension combined with an estimated CKD prevalence of 20% among African Americans in the United States.<sup>6,7</sup>

Patient data were extracted from the EMR's Clarity database using structured query language by an EPIC-certified analyst affiliated with the university health system

**Table 1.** *International Classification of Diseases, Tenth Revision codes for CKD*

Code	Stage of Disease	Severity Level
N18	CKD	
N18.1	CKD, stage 1	
N18.2	CKD, stage 2	Mild
N18.3	CKD, stage 3	Moderate
N18.30	CKD, stage 3	Unspecified
N18.31	CKD, stage 3a	
N18.32	CKD, stage 3b	
N18.4	CKD, stage 4	Severe
N18.5	CKD, stage 5	
N18.6	ESRD	
N18.9	CKD	Unspecified
E08.22	Diabetic CKD	
E09.22	Diabetic CKD	
E10.22	Diabetic CKD	
E11.22	Diabetic CKD	
E13.22	Diabetic CKD	
I12	Hypertensive CKD	
I12.0	Hypertensive CKD with stage 5 CKD or ESRD	
I12.9	Hypertensive CKD, stage 1–4 or unspecified	

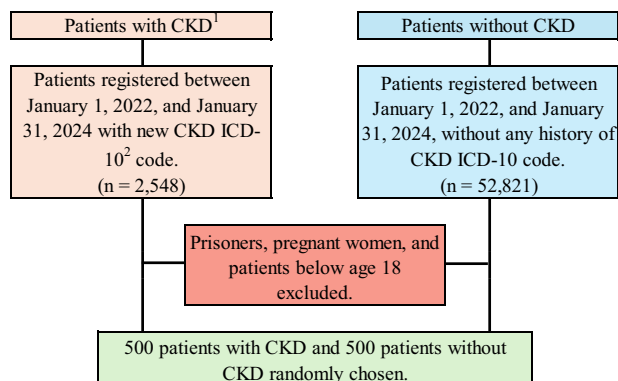
Reprinted from "ICD-10-CM Codes > N00-N99 > N17-N19 > Chronic kidney disease (CKD) N18," retrieved from <https://www.icd10data.com/ICD10CM/Codes/N00-N99/N17-N19/N18->.

Abbreviations: CKD, chronic kidney disease; ESRD, end-stage renal disease.

using simple, nonsequential random sampling. As shown in Figure 1, only patients registered between January 1, 2022, and January 31, 2024, were eligible for inclusion. For the 500 patients who were CKD positive, CKD diagnoses were new and were identified by searching records for at least 1 of the *ICD-10* codes in Table 1. While case-control studies are ideally matched using as many variables as possible, such as age, sex, race, and ethnicity, patients in this study were selected depending on the presence of at least 1 (cases) or the absence of all (controls) of the *ICD-10* codes corresponding to a CKD diagnosis. Patients diagnosed with CKD in the EMR prior to implementation of revised eGFR in 2021, prisoners, pregnant women, and patients aged younger than 18 years were excluded.

Variables of interest included age, sex, race, ethnicity, eGFR, smoking history, hypertension history, diabetes history, body mass index, Charlson Comorbidity Index, serum albumin, urine albumin, microalbumin, phosphorus, calcium, creatinine, blood urea nitrogen (BUN), white blood cell count (WBC), absolute neutrophil count, absolute lymphocyte count, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and glycosylated hemoglobin A1C.

Statistical analyses were conducted on IBM SPSS Statistics version 27 software. Patients with CKD and patients without CKD were assessed using point biserial correlation, and  $\phi$  correlation coefficient when appropriate to identify associations of significance between variables and CKD status. Significant variables at the bivariate level of analysis were included in a bivariate logistic regression model to analyze for potential risk factors associated with CKD according to age, sex, race, ethnicity, comorbid diabetes, and comorbid hypertension, with likelihood (odds ratios [ORs]), 95% CIs, and *P* values recorded. Bivariate logistic regression was performed to observe for a synergistic effect between comorbid diabetes and hypertension and CKD diagnosis, again with ORs, 95% CIs, and *P* values documented.



**Figure 1.** Sample selection flowchart. Abbreviations: CKD, chronic kidney disease; ICD-10, *International Classification of Diseases, Tenth Revision*.

All patients in the study had values for the Charlson Comorbidity Index, serum albumin, creatinine, serum calcium, BUN, WBC, absolute neutrophil count, and absolute lymphocyte count. While a vast majority of subjects, both with and without a CKD diagnosis, had values for A1C and phosphorus, there were many lacking values for ESR, CRP, and urine albumin. In instances where values were missing, data imputation was not performed, and pairwise deletion was used when appropriate in all stages of analysis.

Clinical laboratories affiliated with the medical center in this study are accredited by the College of American Pathology and adhere to stringent requirements equal to or beyond those minimally required by the Clinical Laboratory Improvement Amendment of 1988. Laboratory records obtained from the medical center's EMR are, therefore, deemed to be reliable. This does not preclude the possibility for diagnostic or reporting errors by either the laboratory or individual providers.

Prior to the commencement of study activities, the approval of the institutional review board was obtained. All patient data were deidentified and stored in a password-protected computer. The anticipated level of risk to study participants was none to minimal.

## RESULTS

The demographic breakdown can be viewed in Table 2. The bivariate analyses found significant associations between CKD status and the demographic variables of age ( $P < .001$ ), race ( $P = .004$ ), Hispanic ethnicity ( $P < .001$ ), history of diabetes ( $P < .001$ ), history of hypertension ( $P < .001$ ), and Charlson Comorbidity Index ( $P < .001$ ). Significant associations were also found between CKD status and serum albumin ( $P < .001$ ), serum creatinine ( $P < .001$ ), A1C ( $P < .001$ ), and absolute lymphocyte count ( $P = .006$ ). Variables considered statistically significant at the bivariate level of analysis (Table 3) were included in the logistic regression models using a dichotomous CKD diagnosis (present or absent) as the dependent variable.

The first logistic regression model included hypertension diagnosis, age, race, and Hispanic ethnicity as independent variables (Table 4). In this model, statistically significant associations with CKD diagnosis remained for age ( $P < .001$ ; OR 1.056 [95% CI 1.043–1.070]), hypertension ( $P < .001$ ; OR 2.732 [95% CI 1.872–3.986]), and African American race ( $P = .029$ ; OR 1.717 [95% CI 1.057–2.791]). The results of this analysis indicate that patients with CKD were 2.7 times more likely to be hypertensive than those who did not have CKD.

The second logistic regression model included diabetes diagnosis, age, race, and Hispanic ethnicity as independent variables (Table 5). The following variables maintained significant associations with CKD diagnosis: age ( $P < .001$ ; OR 1.055 [95% CI 1.035–1.074]) and diabetes diagnosis ( $P = .021$ ; OR 2.180 [95% CI 1.127–4.216]).

The results of this analysis indicate that patients with CKD were twice as likely to have diabetes as those who did not have CKD.

The third logistic regression model included comorbid hypertension and diabetes, age, race, and Hispanic ethnicity as independent variables (Table 6). The following variables remained significant: age ( $P < .001$ ; OR 1.052 [95% CI 1.037–1.068]) and comorbid diagnoses of hypertension and diabetes ( $P < .001$ ; OR 3.519 [95% CI 2.287–5.414]). The results of this analysis indicate that patients with CKD were 3.5 times more likely to have comorbid hypertension and diabetes than those who did not have CKD.

The fourth logistic regression model included age, race, Hispanic ethnicity, hemoglobin A1C, serum albumin, absolute lymphocyte count, and eGFR (as a continuous variable) as independent variables (Table 7). Variables that remained significant were age ( $P = .004$ ; OR 1.051 [95% CI 1.016–1.087]), hemoglobin A1C ( $P = .027$ ; OR 1.320 [95% CI 1.032–1.688]), and eGFR ( $P < .001$ ; OR 0.889 [95% CI 0.864–0.914]).

The fifth, final logistic regression model included the same independent variables as the fourth model with one exception: eGFR was a dichotomous variable that separated patients by whether their eGFR values were greater or less than 90 mL/min/1.73 m<sup>2</sup> (Table 7). This was due to the lack of eGFR values above 90 mL/min/1.73 m<sup>2</sup> among CKD cases, while there were numerous instances of eGFR values below 90 mL/min/1.73 m<sup>2</sup> among control patients without CKD. In this model, the following variables remained significant: age ( $P < .001$ ; OR 1.058 [95% CI 1.034–1.082]), hemoglobin A1C ( $P = .003$ ; OR 1.328 [95% CI 1.100–1.604]), serum albumin ( $P = .038$ ; OR 0.467 [95% CI 0.227–0.960]), and eGFR ( $P < .001$ ; OR 57.596 [95% CI 7.609–435.978]).

Numerous variables were found to be significantly associated with CKD diagnosis at the bivariate level of analysis. Age is to be expected, as a higher prevalence of CKD is observed among the elderly.<sup>8</sup> Serum creatinine is also to be expected, given its role as a marker for kidney function and its inclusion in the eGFR formula. The Charlson Comorbidity Index is a more complicated variable because of the variations among versions. For example, the index originally consisted of 19 comorbid conditions, such as diabetes, peripheral vascular disease, myocardial infarction, dementia, and numerous others.<sup>9</sup> However, other versions use ICD-10 codes or age, and conditions included might be pulled from patient records or self-reported, thus resulting in questions concerning inter-rater reliability.<sup>9</sup> Though found to be significant, the association between CKD and the index among the academic medical center patient population might not be readily clear at this time because of potential confounders or location-specific demographic aspects rendering findings in this study ungeneralizable to other populations. For comorbid conditions, there might be more relevance to the significant associations that hypertension and diabetes have with CKD. The comorbid presence of either

**Table 2.** Demographics and bivariate analyses

Variables	Total n (%) N = 1,000	CKD <sup>1</sup> Cases n (%) N = 500	Controls: No CKD n (%) N = 500	P Value
Gender				.75 <sup>a</sup>
Male	411 (41.1)	208 (41.6)	203 (40.6)	
Female	589 (58.9)	292 (58.4)	297 (59.4)	
Race				.004 <sup>*a</sup>
White	787 (78.7)	371 (74.2)	416 (83.2)	
Black	189 (18.9)	118 (23.6)	71 (14.2)	
Other	24 (2.4)	11 (2.2)	13 (2.6)	
Ethnicity				<.001 <sup>*a</sup>
Hispanic or Latino	212 (21.2)	77 (15.4)	135 (27.0)	
Not Hispanic or Latino	778 (77.8)	420 (84.0)	358 (71.6)	
Unknown	10 (1.0)	3 (0.6)	7 (1.4)	
Smoking status				.06 <sup>a</sup>
Yes	198 (19.8)	97 (19.4)	101 (20.2)	
No	636 (63.6)	306 (61.2)	323 (64.6)	
Unknown	166 (16.6)	97 (19.4)	76 (15.2)	
History of diabetes				<.001 <sup>*a</sup>
Yes	287 (28.7)	188 (37.6)	99 (19.8)	
No	713 (71.3)	312 (62.4)	401 (80.2)	
History of hypertension				<.001 <sup>*a</sup>
Yes	663 (66.3)	412 (82.4)	251 (50.2)	
No	337 (33.7)	88 (17.6)	249 (49.8)	
History of comorbid diabetes and hypertension				<.001 <sup>*a</sup>
Yes	260 (26.0)	174 (34.8)	86 (17.2)	
No	740 (74.0)	326 (65.2)	414 (82.8)	
<b>Additional Variables</b>	<b>Total Mean (SD)</b>	<b>CKD Cases Mean (SD)</b>	<b>Controls: No CKD Mean (SD)</b>	<b>P Value</b>
Age	64.0 (16.5)	68.4 (12.0)	54.8 (17.1)	<.001 <sup>*b</sup>
Median income by zip (\$)	78,588 (24,855)	78,227 (24,030)	78,950 (25,672)	.65 <sup>b</sup>
BMI	31.42 (8.01)	31.50 (7.92)	31.35 (8.11)	.77 <sup>b</sup>
Charlson Comorbidity Index	1.8 (2.2)	2.6 (2.5)	1.0 (1.5)	<.001 <sup>*b</sup>

Abbreviations: BMI, body mass index; CKD, chronic kidney disease.

<sup>a</sup>Performed using Phi coefficient correlation.

<sup>b</sup>Performed using point biserial correlation.

(or both) condition(s) alongside CKD is well documented in the literature and could partially be contributing to the significant association found between CKD and the Charlson Comorbidity Index in this study.<sup>3,10</sup> Lastly, race and ethnicity align with the findings reported in the available literature. Higher CKD prevalence and more rapid disease progression have been observed for years among African Americans.<sup>11</sup> The Hispanic population has a similar CKD prevalence to that of the general population; however, more rapid disease progression is also observed among Hispanics compared to non-Hispanic Whites.<sup>12</sup> For laboratory markers, serum albumin, serum creatinine,

eGFR, absolute lymphocyte count, and hemoglobin A1C were significant at the bivariate level of analysis.

In the logistic regression models, not all variables found to be significant at the bivariate level of analysis remained significant. In the "hypertension only" model, variables that remained significant were age, African American race, and hypertension diagnosis. Based on the results in this model, individuals with CKD were more than 2.7 times likely to have a hypertension diagnosis compared with their non-CKD counterparts, patients who were African American with CKD were more than 1.7 times likelier than Whites with CKD to have a hypertension

**Table 3.** Bivariate analyses between CKD and additional variables

Variables	Total Mean (SD)	CKD Cases Mean (SD)	Controls CKD Mean (SD)	P Value <sup>a</sup>
Serum albumin (g/dL)	4.2 (0.4)	4.1 (0.4)	4.3 (0.4)	<.001*
Urine albumin (mg/g)	230.1 (948.8)	248.7 (757.7)	203.3 (1181.8)	.75
Serum calcium (mg/dL)	9.3 (0.6)	9.3 (0.6)	9.3 (0.5)	.24
Urine creatinine (mg/dL)	112.9 (79.2)	112.4 (80.8)	113.9 (76.5)	.88
Serum creatinine (mg/dL)	1.13 (0.72)	1.44 (0.87)	0.83 (0.34)	<.001*
Hemoglobin A1C (%)	6.3 (1.6)	6.8 (1.8)	6.0 (1.3)	<.001*
Absolute lymphocyte count (10 <sup>9</sup> cells/L)	1.89 (0.83)	1.78 (0.88)	1.95 (0.80)	.006*
Absolute neutrophil count (10 <sup>9</sup> cells/L)	4.98 (2.75)	5.14 (3.01)	4.88 (2.52)	.20
Phosphorus (mg/dL)	3.9 (1.0)	3.9 (0.9)	3.6 (1.1)	.25
Sedimentation rate (mm/hour)	36 (33)	45 (37)	32 (30)	.17
White blood cell count (10 <sup>9</sup> cells/L)	7.71 (2.94)	7.98 (3.13)	7.65 (2.78)	.46
Neutrophil:lymphocyte ratio	3.51 (5.33)	3.83 (4.63)	3.29 (5.75)	.18

Abbreviation: CKD, chronic kidney disease.

<sup>a</sup>Performed using point biserial correlation.

**Table 4.** Logistic regression models for HTN<sup>1</sup> only (N = 687)

Variable	OR	P Value	95% CI
Age	1.056	<.001*	1.043–1.070
Race <sup>a,b</sup>	1.557	.059	0.984–2.464
African American race	1.717	.029*	1.057–2.791
Hispanic ethnicity	0.623	.065	0.376–1.030
HTN	2.732	<.001*	1.872–3.986

Abbreviation: HTN, hypertension.

<sup>a</sup>Referent race is White.

<sup>b</sup>Other racial categories combined due to having <10 members each.

diagnosis, and increasing age among patients with CKD was correlated with a higher likelihood of a hypertension diagnosis.

In the logistic regression model examining patients with diabetes only (and not hypertension or comorbid hypertension and diabetes), age and diabetes diagnosis remained significant. Patients with CKD were more than twice as likely than patients without CKD to have a diabetes diagnosis in their history.

In the third logistic regression model that included patients with comorbid diagnoses of both hypertension and diabetes, both age and the comorbid presence of hypertension and diabetes remained significant. Compared with patients without CKD, CKD cases were more than 3.5 times as likely to have comorbid hypertension and diabetes, which is twice that of a single diagnosis of hypertension or diabetes.

In the fourth model, variables that remained significant were age, hemoglobin A1C, and eGFR. This suggested that, again, patients with CKD tend to be significantly older and tend to have significantly higher hemoglobin A1C values and that eGFR values are significantly different

**Table 5.** Logistic regression for diabetes only (N = 337)

Variable	Odds Ratio	P Value	95% CI
Age	1.055	<.001*	1.035–1.074
Race <sup>a,b</sup>	1.169	.708	0.517–2.643
African American race	1.082	.867	0.428–2.739
Hispanic ethnicity	0.632	.665	0.063–5.814
Diabetes	2.180	.021*	1.127–4.216

<sup>a</sup>Referent race is White.

<sup>b</sup>Other racial categories collapsed because of each having <10 members each.

between those with CKD and those without CKD. However, in this model, the GFR's OR was less than 1.0. The reason for this is likely due to the lack of spread in GFR values among patients with CKD. None of the patients with CKD had GFR values above 90 mL/min/1.73 m<sup>2</sup>, while the GFR range among control patients without CKD ranged from below 90 and above 90 mL/min/1.73 m<sup>2</sup>. This necessitated a fifth logistic regression model that included eGFR as an independent variable but as a dichotomous variable rather than a continuous one. The findings for this model indicate patients with CKD are more than 57 times more likely to have a GFR below 90 mL/min/1.73 m<sup>2</sup> than patients without CKD.

The logistic regression models examined the relationships among CKD, hypertension, and diabetes because of the potential for a synergistic effect between hypertension and diabetes on CKD outcomes. Other studies to date have mostly been indeterminate or unable to demonstrate a significant effect among simple hypertension and diabetes with respect to CKD diagnosis.<sup>13,14</sup> However, a study published in 2025 was at least able to identify a synergistic effect between hypertension and high glucose among

**Table 6.** Logistic regression for comorbid HTN<sup>1</sup> and diabetes (N = 544)

Variable	Odds Ratio	P Value	95% CI
Age	1.052	<.001*	1.037–1.068
Race <sup>a,b</sup>	1.574	.087	0.936–2.648
African American race	1.702	.062	0.973–2.977
Hispanic ethnicity	0.828	.458	0.502–1.364
Comorbid HTN and diabetes	3.519	<.001*	2.287–5.414

Abbreviation: HTN, hypertension.

<sup>a</sup>Referent race is White.

<sup>b</sup>Other racial categories collapsed because of each having <10 members.

patients not on antihypertensive therapy.<sup>15</sup> Yet another study identified a synergistic effect between diabetes and hypertension on CKD, but it analyzed cross-sectional data between the years 1999 and 2006 from the National Health and Nutrition Examination Survey prior to implementation of the race-free eGFR.<sup>16</sup> Although the association between hypertension and diabetes was not directly able to be analyzed, the results of this study appear to agree with the likely existence of a synergistic relationship.

In terms of laboratory markers, elevated A1C levels have been reported among patients with CKD in other studies.<sup>17</sup> Serum albumin was not found to be significant in the logistic regression models, most likely because of the similarity of the means in both patients with CKD and non-CKD controls. Despite that, serum albumin has been observed to demonstrate a significant correlation with CKD when levels fall below 4.1 g/dL.<sup>18</sup> Absolute lymphocyte counts also failed to remain significant in the logistic regression models, but the literature has suggested that higher lymphocyte counts could be preventative for CKD progression.<sup>19</sup>

**Table 7.** Logistic regression models for all other significant variables (N = 386)

Variable	GFR as Continuous Variable			GFR as Dichotomous Variable (<90)		
	OR	P Value	95% CI	OR	P Value	95% CI
Age (years)	1.051	.004*	1.016–1.087	1.058	<.001*	1.034–1.082
Race <sup>a</sup>	0.597	.237	0.254–1.403	1.306	.429	0.674–2.532
African American race	1.901	.154	0.786–4.600	1.299	.455	0.654–2.582
Hispanic ethnicity	2.274	.139	0.765–6.757	1.179	.663	0.562–2.472
Hemoglobin A1C (%)	1.320	.027*	1.032–1.688	1.328	.003*	1.100–1.604
Serum albumin (g/dL)	1.660	.345	0.580–4.749	0.467	.038*	0.227–0.960
Absolute lymphs (10 <sup>9</sup> cells/L)	1.110	.687	0.669–1.842	1.095	.583	0.792–1.516
eGFR (mL/min/1.73 m <sup>2</sup> )	0.889	<.001*	0.864–0.914			
eGFR <90 (mL/min/1.73 m <sup>2</sup> )				57.596	<.001*	7.609–435.978

<sup>a</sup>Referent race is White; all non-White racial categories combined.

## DISCUSSION

The hypothesis that patients with CKD are significantly more likely to have hypertension, diabetes, or comorbid hypertension and diabetes than patients without CKD was strongly supported by the study's findings. Among patients with either or both hypertension and diabetes in this study, those conditions predated the new diagnoses of CKD on file in EPIC at our academic medical center. This strongly suggests the arguments that individuals with hypertension are 2.7 times as likely to develop CKD compared with those without hypertension, that individuals with diabetes are more than twice as likely to develop CKD than those without diabetes, and that individuals with comorbid diabetes and hypertension are more than 3.5 times as likely to develop CKD compared with those without comorbid diabetes and hypertension.

No additional markers of interest were found to be significant independent predictors for CKD. Future studies interested in the identification of laboratory markers as independent predictors for CKD might increase their chances by stratifying patients with CKD by stage and eGFR value(s) and by ensuring a healthy spread of eGFR values on both sides of 90 mL/min/1.73 m<sup>2</sup>.

Hispanic ethnicity was significant at the bivariate level of analysis but did not remain so in the logistic regression models. Because Hispanics are approximately 33% more likely to have kidney failure compared with non-Hispanics, future studies should continue to focus on Hispanic populations in the search for additional laboratory markers for CKD diagnosis and CKD-related risk factors.

There are some notable limitations in this study. First, its confinement to the academic medical center is a limitation because of the higher acuity typically observed among patients in a teaching hospital. Confinement to an academic medical center's population may also impact generalizability to other geographic areas and potentially underrepresented demographic groups. Next, the retrospective, cross-sectional nature of the study could

affect the availability of items and variables of interest. Additionally, patients positive for CKD were not matched with patients negative for CKD using demographic variables, only by the presence or absence of CKD ICD-10 codes. Lastly, internal validity was potentially impacted by human variation for data entered in EPIC by clinical staff. This includes, but is not limited to, diagnoses of diabetes, hypertension, CKD, and all associated ICD-10 codes as well as transcription or interface errors that occurred during laboratory testing.

This study was able to demonstrate, albeit in reverse, that the synergistic relationship previously identified in the National Health and Nutrition Examination Survey study examining the race-inclusive eGFR still likely exists following implementation of the race-free eGFR formula. Future prospective studies should investigate the nature of the relationship between diabetes and hypertension on CKD.

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## SUMMARY

Patients newly diagnosed with chronic kidney disease (CKD) are significantly more likely to have diabetes or hypertension, either singly or together. Cases with CKD are more than 3.5 times as likely to have comorbid hypertension and diabetes than controls without CKD.

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