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Hypertension Awareness, Treatment, and Control in Adults With CKD: Results From the Chronic Renal Insufficiency Cohort (CRIC) Study

Paul Muntner, Amanda Anderson, Jeanne Charleston, Zhen Chen, Virginia Ford, Gail Makos, Andrew O'Connor, Kalyani Perumal, Mahboob Rahman, Susan Steigerwalt, Valerie Teal, Raymond Townsend, Matthew Weir, Jackson T Wright, and for the Chronic Renal Insufficiency Cohort (CRIC) Study Investigators

Mount Sinai School of Medicine, University of Pennsylvania, Johns Hopkins University, Case Western Reserve University, University of Illinois at Chicago, University of Michigan, University of Maryland at Baltimore

Abstract

Background—A low rate of blood pressure control has been reported among patients with chronic kidney disease (CKD). These data were derived from population-based samples with a low rate of CKD awareness.

Study Design—Cross-sectional

Setting & Participants—Data from the baseline visit of the Chronic Renal Insufficiency Cohort (CRIC) study (n=3612) were analyzed. Participants with an estimated glomerular filtration rate of 20 to 70 ml/min/1.73m² were identified from physician offices and review of laboratory databases.

Outcomes—Prevalence and awareness of hypertension, treatment patterns, control rates and factors associated with hypertension control.

Measurements—Following a standardized protocol, blood pressure was measured three times by trained staff and hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg and/or self-reported antihypertensive medication use. Patients' awareness and treatment of hypertension were defined using self-report and two levels of hypertension control were evaluated: systolic/diastolic blood pressure <140/90 mmHg and <130/80 mmHg.

Results—The prevalence of hypertension was 85.7%, and 98.9% of CRIC participants were aware of this diagnosis, 98.3% were treated with medications while 67.1% and 46.1% had their hypertension controlled to <140/90 mmHg and <130/80 mmHg, respectively. Of CRIC participants with hypertension, 15%, 25%, 26% and 32% were taking one, two, three and four or

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Address correspondence and reprint requests to: Paul Muntner, Department of Epidemiology, University of Alabama at Birmingham, 1665 University Boulevard, Suite 230J, Birmingham, AL 35294, (205) 975-8077, pmuntner@uab.edu.

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Supplementary Material Item S1: List of Chronic Renal Insufficiency Cohort Study Investigators.

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more antihypertensive medications, respectively. After multivariable adjustment, older patients, blacks, those with higher urinary albumin excretion were less likely while participants taking ACE-inhibitors and angiotensin receptor blockers were more likely to have controlled their hypertension to <140/90 mmHg and <130/80 mmHg.

Limitations—Data were derived from a single study visit.

Conclusions—Despite almost universal hypertension awareness and treatment in this cohort of patients with CKD, rates of hypertension control were sub-optimal.

Studies suggest that CKD affects more than 20 million US adults^{1;2}. Untreated or inadequately controlled hypertension is considered one of the most important risk factors for the progression of CKD³. The prevalence of hypertension among adults with CKD in previous studies consistently exceeds 60%⁴⁻⁶.

Despite the high prevalence of hypertension in patients with CKD, low rates of hypertension control have been reported^{3;5;7;8}. However, most of the data on hypertension control among patients with CKD have been generated using general population samples. Also, in these samples, CKD awareness has been relatively low^{7;8}. Rates of hypertension awareness, treatment and control may be substantially different for adults with CKD who present for healthcare and comprise an identifiable subset of CKD patients.

Our goal was to evaluate rates of hypertension prevalence, awareness, treatment and control in a cohort of patients with CKD identified in physician offices and clinical laboratory databases. Additionally, because identifying mediators of hypertension control may be useful for developing interventions, we investigated factors associated with hypertension control. To accomplish these goals, we analyzed data from the baseline visit of the Chronic Renal Insufficiency Cohort (CRIC) study.

METHODS

Study Population

The CRIC Study includes a racially and ethnically diverse group of adults, 21 to 74 years of age, with a broad spectrum of renal disease severity⁹. CRIC participants were recruited between June 2003 and March 2007 from 13 sites among seven centers in the United States (Baltimore, MD, Philadelphia, PA, Cleveland, OH, Detroit, MI, Chicago, IL, New Orleans, LA, and Oakland, CA). Patients were identified through laboratory database searches of recently measured serum creatinine values, referrals from physicians' offices, and self-referral. Inclusion into the CRIC cohort was based on age-specific eGFR levels, calculated using serum creatinine measured at a screening visit; eGFR of 20-70 ml/min/1.73m² for patients 21 to 44 years of age, 20-60 ml/min/1.73m² for patients 45 to 64 years of age, and 20-50 ml/min/1.73m² for patients 65 to 74 years of age. The current analysis is based on the experience of 3612 CRIC participants who completed the baseline study visit.

Data Collection

During the baseline study visit, all CRIC study data were collected by trained study staff. Of relevance to the current analysis, data were obtained by questionnaires, review of patients' pill bottles, anthropometric measures, resting blood pressure measurements, and collection of blood specimens and a 24 hour urine sample. Participants reporting a prior diagnosis of hypertension were asked whether they were using lifestyle modifications (i.e., salt reduction, weight loss, exercise, or alcohol reduction, separately) to lower their blood pressure. Participants were asked the last time they had their blood pressure checked. This variable was not analyzed as over 98% of CRIC participants reported this within the year prior to their study visit. Body weight and height were measured and body mass index (BMI) was

calculated as weight in kilograms divided by height in meters squared. Patients were categorized as underweight ($\text{BMI} < 18.5 \text{ kg/m}^2$), normal weight ($18.5 - 24.9 \text{ kg/m}^2$), overweight ($25.0 - 29.9 \text{ kg/m}^2$), or obese ($\geq 30 \text{ kg/m}^2$). Diabetes mellitus was defined as a plasma glucose $\geq 126 \text{ mg/dL}$ after fasting for a minimum of 8 hours, a non-fasting plasma glucose $\geq 200 \text{ mg/dL}$ and/or self-reported current use of insulin or anti-diabetes medication. Using blood collected at baseline, serum calcium and phosphorus levels were measured at the central CRIC laboratory. Serum calcium was corrected for serum albumin using the formula: adjusted calcium = measured calcium - $[(4.0 - \text{serum albumin in g/dl}) \times 0.8]$. Participants were given instructions and asked to collect their urine for the 24 hours prior to the baseline study visit. Urinary albumin excretion was categorized into four levels: <30 , 30 to 299, 300 to 999, and $\geq 1000 \text{ mg/day}$.

Blood pressure measurements

Three blood pressure measurements were obtained in the sitting position after at least 5 minutes of quiet rest by trained staff according to a standard protocol. An aneroid sphygmomanometer was used with one of 4 cuff sizes (pediatric, regular adult, large adult, or thigh) based on the participant's arm circumference. Participants were advised to refrain from coffee, tea, or alcohol intake, cigarette smoking, and vigorous exercise for at least 30 minutes prior to their examination. All blood pressure observers successfully completed training sessions on the use of the blood pressure measurement protocol. Requirements for certification as a CRIC blood pressure observer consisted of satisfactory performance on a written test assessing knowledge of preparation of study participants for blood pressure measurement, selection of an appropriate cuff size, and standard blood pressure measurement techniques, a standardized videotape examination, and concordant live blood pressure measurements with an instructor using a Y-tube stethoscope.

Hypertension-related definitions

Based on the average of all three blood pressure measurements, hypertension was defined as systolic blood pressure $\geq 140 \text{ mmHg}$ and/or diastolic blood pressure $\geq 90 \text{ mmHg}$ and/or current antihypertensive medication use as reported on the baseline study questionnaire. Results were markedly similar when hypertension was defined on the basis of blood pressure measurements from the CRIC screening and baseline visits and are, therefore, not presented. To assess awareness of their diagnosis of hypertension, all CRIC participants were asked "Has a doctor or other health professional ever told you that you have hypertension or high blood pressure?" Additionally, patients were defined as receiving antihypertensive treatment if they responded affirmatively to the question "Do you currently take prescribed medication for your hypertension or high blood pressure?" Blood pressure control was defined using two definitions; systolic/diastolic blood pressure $< 140/90 \text{ mmHg}$ and $< 130/80 \text{ mmHg}$, separately.

This study was approved by the institutional review boards for each of the CRIC participating centers and the Scientific Data Coordinating Center and informed consent was obtained from all participants. This study also conformed to the Health Insurance Portability and Accountability Act (HIPAA) guidelines.

Statistical Methods

The distributions of systolic and diastolic blood pressure were plotted. Mean systolic and diastolic blood pressure levels were calculated overall and by age grouping (21-44, 45-64 and ≥ 65 years), race, gender, diabetes mellitus status, and strata of eGFR (< 30 , 30-39, 40-49, 50-59, and $\geq 60 \text{ ml/min/1.73m}^2$). Differences in blood pressure levels across sub-groupings were determined using Student's t-tests or linear regression. The prevalence of hypertension and, for CRIC participants with hypertension, rates of awareness, treatment

and control were determined. Rates of hypertension and hypertension control were determined by patient characteristics including age, race, gender, education, marital status, cigarette smoking, income, BMI, diabetes mellitus, history of cardiovascular disease, serum calcium, phosphorus, the calcium*phosphorus product, eGFR, albuminuria, having seen a nephrologist, use of lifestyle modification and class and number of anti-hypertensive medications being taken. Additionally, the age, race, gender, and CRIC clinical site adjusted prevalence ratios of hypertension control associated with each of these factors were calculated using log binomial regression models. Prevalence ratios are recommended, in lieu of odds ratios, for cross-sectional studies with common outcomes¹⁰. Final multivariable adjusted regression models were used to calculate prevalence ratios for patient characteristics associated with hypertension control. These models included age, race, gender, CRIC clinical site, and variables significantly associated with hypertension control after adjustment for age, race, gender, and CRIC clinical site. A secondary analysis was conducted by evaluating the medications being taken and hypertension control rates for individuals on a single antihypertensive medication class. All analyses were conducted using SAS 9.1 (SAS Incorporated, www.sas.com).

RESULTS

The distribution of systolic and diastolic blood pressure at baseline in the CRIC study population is presented in Figure 1. The mean systolic and diastolic blood pressure was 127.7 mmHg and 71.4 mmHg, respectively (Table 1). Systolic blood pressure levels were higher at older age and among blacks and participants of other races compared to whites, participants with compared to without diabetes mellitus and participants with lower levels of eGFR. Diastolic blood pressure was lower at older age, among women, participants with diabetes mellitus and at lower eGFR levels and higher among blacks and participants of races other than white or black.

Overall, 85.7% of CRIC participants had hypertension at baseline (Figure 2). Among CRIC participants with hypertension, 98.9% were aware of this diagnosis and 98.3% were receiving pharmacological antihypertensive treatment. Systolic and diastolic blood pressure control rates to <140/90 mmHg and <130/80 mmHg were 67.1% and 46.1%, respectively. Overall, 74% and 59% of all CRIC participants had SBP < 140 mmHg and < 130 mmHg, respectively, and 88% and 78% had DBP < 90 mmHg and < 80 mmHg, respectively and only 73 participants had isolated diastolic hypertension (i.e., SBP < 140 mmHg and DBP ≥ 90 mmHg). Using the lower blood pressure targets, 212 participants had isolated diastolic hypertension (i.e., SBP < 130 mmHg and DBP ≥ 80 mmHg). Additionally, 36.4% of the population had systolic and diastolic blood pressure <120/80 mmHg. In contrast, 8.8% of individuals had SBP or diastolic blood pressure ≥ 160 mmHg or 100 mmHg.

Socio-demographic factors and hypertension control

The prevalence of hypertension was higher at older age and among black participants and lower among participants with at least a high school education and at higher income levels (Table 2). Blood pressure control to <140/90 mmHg was lower at older age, and among blacks and CRIC participants who reported their race to be other than white or black. Additionally, higher rates of blood pressure control to <140/90 mmHg were present among CRIC participants with at least a high school education and a higher income. These factors, with the exception of older age, were associated with hypertension control to <130/80 mmHg.

Behavioral factors and medical history and hypertension control

Hypertension was more common at higher BMI categories, among current and former cigarette smokers, participants with diabetes mellitus, a history of cardiovascular disease, at higher levels of serum phosphorus, calcium*phosphorus product, urinary albumin excretion, lower eGFR levels and among CRIC participants who had seen a nephrologist (Table 3). CRIC participants with diabetes mellitus and higher levels of albumin excretion, separately, were less likely to have their hypertension controlled to either <140/90 mmHg or <130/80 mmHg. In contrast, those with higher serum calcium levels were more likely to have controlled their hypertension.

Lifestyle modification and pharmacological therapy and hypertension control

The use of lifestyle modifications were reported by almost all CRIC participants with hypertension (Table 4). CRIC participants with hypertension who reported attempting to lose weight to control their blood pressure, diabetes mellitus, or high cholesterol were more likely to have controlled their hypertension to systolic and diastolic blood pressure levels <140/90 mmHg. However, none of the lifestyle modifications investigated were associated with hypertension control to systolic and diastolic blood pressure <130/80 mmHg. Beta-blockers and ACE-inhibitors were the most commonly used antihypertensive medications among CRIC participants. CRIC participants taking beta-blockers, calcium channel blockers, and vasodilators were less likely to have their systolic and diastolic blood pressure controlled to <140/90 or to <130/80. In contrast, CRIC participants taking ACE-inhibitors, and potassium-sparing and thiazide-type diuretics were more likely to have controlled their systolic and diastolic blood pressure to <140/90 and <130/80 mmHg. Also, a renin angiotensin system blocker was being taken by 74% of CRIC participants and these individuals were more likely to have controlled blood pressure. Among CRIC participants with hypertension, 15%, 25%, 26%, and 32% were taking one, two, three and four or more antihypertensive medications, respectively (Figure 2, left panel). An inverse association was present such that CRIC participants on progressively more antihypertensive medication were less likely to have controlled their hypertension (Figure 2, right panel). Compared to patients on a single antihypertensive medication, the age, race, gender adjusted prevalence ratio of hypertension control to <140/90 mmHg associated with taking two, three and four or more antihypertensive medications was 0.97 (95% CI: 0.91 – 1.03), 0.95 (95% CI: 0.89 – 1.02), and 0.86 (95% CI: 0.80 – 0.92), respectively. The prevalence ratios were nearly identical for hypertension control to systolic and diastolic blood pressure < 130/80 mmHg, respectively (data not shown).

Multivariable adjusted associations with hypertension control

After multivariable adjustment, CRIC participants who were older, reported their race as black, and with higher urinary albumin excretion were less likely to have controlled hypertension to <140/90 mmHg and <130/80 mmHg compared to referent groups (Table 5). Also after multivariable adjustment, CRIC participants on ACE-inhibitors were more likely to have controlled their hypertension to <140/90 mmHg and <130/80 mmHg. Diabetes was not associated with a lower prevalence ratio of hypertension control after multivariable adjustment. However, in a multivariable-adjusted model without albuminuria (i.e., with all of the same variables except albuminuria), diabetes was associated with a significantly lower prevalence ratio of hypertension control (0.96 [95% CI: 0.93 - 0.99] for SBP/DBP < 140/90 mmHg and 0.93 [95% CI: 0.88 - 1.00] for SBP/DBP < 130/80 mmHg).

Secondary Analysis

Among CRIC participants taking only one antihypertensive medication, ACE-inhibitors was the most common class (42%) followed by angiotensin receptor blockers (15%), thiazide-

type diuretics (14%), calcium channel blockers (14%) and beta-blockers (13%). Blood pressure control rates to <140/90 mmHg were highest among CRIC participants taking angiotensin receptor blockers (91%) and ACE-inhibitors (82%) versus 68%, 60%, and 58% for those taking thiazide-type diuretics, beta-blockers, and calcium channel blockers respectively.

DISCUSSION

Previous population-based studies have reported high rates of hypertension in patients with moderate CKD. In the current study of patients with CKD primarily identified by healthcare providers and through clinical databases, 85.7% of participants had hypertension. In contrast to previous reports of low rates of hypertension awareness and treatment among adults with CKD, these rates exceeded 98% in the CRIC study. Furthermore, in the context of almost universal hypertension awareness and treatment, hypertension control rates were higher than in several previous reports of adults with CKD. However, hypertension control rates were still far from optimal; 67.1% and 46.1% of CRIC participants had their hypertension controlled to systolic and diastolic blood pressure levels <140/90 mmHg and <130/80 mmHg, respectively.

Recruiting CKD patients from clinic settings resulted in a population that is different from those previously used to study hypertension control among individuals with CKD in previous observational studies. For example, the prevalence of hypertension was 71% among Framingham Offspring Study participants with CKD⁵. While 86% of these participants were treated, only 37% controlled their hypertension to systolic and diastolic blood pressure <140/90 mmHg, respectively. Furthermore, hypertension control to <130/80 mmHg was only 27%. Factors associated with hypertension control were not evaluated in the Framingham cohort with CKD. In NHANES III, Coresh reported only 27% of individuals with elevated serum creatinine had a systolic/diastolic blood pressure < 140/90 mmHg⁴. Further, only 75% of those with hypertension were taking antihypertensive medication. Peralta and colleagues evaluated hypertension control to <130/80 mmHg among individual with CKD, eGFR < 60 ml/min/1.73m² or albuminuria, in the 1999-2002 National Health and Nutrition Examination Survey and only 56% and 37% had controlled their blood pressure to <140/90 and <130/80 mmHg, respectively⁸.

A recent analysis of the National Kidney Foundation's Kidney Early Evaluation Program (KEEP), a screening program aimed at identifying patients with CKD, was conducted to assess rates of hypertension awareness, treatment and control⁷. Among patients with stage 3 CKD, defined as an eGFR between 30 and 59 ml/min/1.73m², 81.9% of patients with hypertension were aware of this diagnosis and 72.7% were receiving pharmacological treatment. Despite these relatively high awareness and treatment rates, hypertension control rates were substantially lower than in the current study; only 20.3% of KEEP participants with stage 3 CKD had their systolic and diastolic blood pressure controlled to <140/90 mmHg. A major difference between KEEP and the CRIC study is that only 6.5% of KEEP participants were aware of their CKD. The substantially higher rate of hypertension control in the CRIC study is noteworthy. It suggests that clinical feedback may play a key role in achieving hypertension control.

Consistent with the current study, non-Hispanic blacks in KEEP were less likely to have controlled their hypertension. In contrast, male gender and lower BMI were associated with hypertension control in the KEEP study but not in the CRIC study. However, the factors associated with hypertension control in the KEEP study may be confounded by low antihypertensive treatment rates. Reasons for the sub-optimal rates of hypertension control

among patients with CKD prescribed antihypertensive medications warrant further investigation.

The lack of an association between several factors studied and hypertension control warrants discussion. For example, in contrast to previous studies, overweight and obesity and cigarette smoking were not associated with hypertension control. It is possible that previous studies may have been confounded by differential access to healthcare. Supporting this assertion, over 98% of CRIC participants had their blood pressure checked within the year prior to their study visit. In a previous study of the general US population, adults with hypertension who had their blood pressure checked in the prior year were five times more likely to have controlled hypertension¹¹. Hypertension control rates were similar also for CRIC participants who had and had not seen in a nephrologist previously.

Diabetes was associated with lower hypertension control rates in a multivariable adjusted regression model that did not include albuminuria. However, this association was no longer present after adjustment for albuminuria levels. Albuminuria levels are higher among individuals with diabetes and may indicate the need for more aggressive treatment. An additional unexpected result was the lack of an association between eGFR and hypertension control. This may have resulted from more aggressive treatment among CRIC participants with lower eGFR. Specifically, 42.1% of CRIC participants with an eGFR < 30 ml/min/1.73m² were taking 4 or more classes of antihypertensive medications, compared to 39.2%, 27.4%, 26.0%, and 18.6% for those with an eGFR of 30-39, 40-49, 50-59 and ≥ 60 ml/min/1.73m², respectively. However, no association was present between higher serum creatinine and lower hypertension control rates in a prior analysis of NHANES 1999-2002⁸.

Clinical trials have demonstrated that weight loss, sodium reduction, exercise, and alcohol restriction reduce blood pressure among adults with hypertension¹²⁻¹⁵. In a previous study of the general population, adults using these lifestyle changes were six times more likely to have controlled hypertension¹¹. The lack of an association between lifestyle modifications and hypertension control in the current study should not be inferred to mean that these interventions are not beneficial. The higher rates of hypertension control in the current study compared to previous studies may be due to the high utilization of lifestyle modifications. Nonetheless, the lack of association with hypertension control for lifestyle modifications warrants further investigation into the quantity and quality of lifestyle modifications being performed among patients with CKD.

Findings from the current analysis must be considered within the context of its limitations. Most notably, data were derived from a single study visit. However, the rates of hypertension prevalence, awareness, treatment and control were markedly similar when blood pressure measurements from the CRIC screening and baseline visits were used to define hypertension. The CRIC study is observational. Therefore, as mentioned previously, caution should be taken when considering the association between the number and classes of antihypertensive medication taken and lifestyle changes and hypertension control. Also, the assessment of lifestyle changes were based on single questions and measurement error for this domain is possible. Finally, the CRIC study population was identified mostly through physicians and clinical databases. Therefore, the results are not representative of all patients with moderate CKD. However, the current study provides data on hypertension awareness, treatment and control in the context of patients with CKD in the clinical environment, an area with few published data available.

The current analysis maintains several strengths including the large population of patients with CKD enrolled in the CRIC study and collection of an extensive array of demographic, socio-economic, behavioral, and medical-related factors. Such extensive data collection

permitted conduct of a comprehensive analysis of factors associated with hypertension control in patients with CKD. Additional strengths include the use of a standardized protocol with stringent quality control procedures for measurement of blood pressure. Finally, the current study included a diverse population with respect to degree of renal insufficiency.

Hypertension is a common co-morbidity affecting the vast majority of patients with CKD. Given the high risk of CVD and CKD progression associated with hypertension, its control may have important benefits for patients with CKD. Despite almost ubiquitous awareness and antihypertensive treatment rates in the current study, fewer than 50% of CRIC participants achieved the target blood pressure of systolic/diastolic blood pressure < 130/80 mmHg. Increased efforts are needed to identify the reasons for inadequate hypertension control and approaches to increase blood pressure control among patients with CKD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Figure 1.

Systolic and diastolic blood pressure distribution among participants in the Chronic Renal Insufficiency Cohort (CRIC) study (n=3612). Abbreviations: SBP – systolic blood pressure; DBP – diastolic blood pressure.

Figure 2.

Overall rates of hypertension prevalence, awareness, treatment and control among participants of the Chronic Renal Insufficiency Cohort (CRIC) study. HTN-hypertension (prevalence among all CRIC participants; Aware and Treated are the percent among all participants with hypertension. Hypertension control rates are calculated for all CRIC participants with hypertension.

Figure 3. Number of blood pressure medications being taken by participants and blood pressure control in the Chronic Renal Insufficiency Cohort study.

Table 1

Mean systolic and diastolic blood pressure for Chronic Renal Insufficiency Cohort study participants

		Sample size	SBP	DBP
Overall		3612 (100%)	127.7 [21.9]	71.4 [12.8]
Age, years				
	21-44	487 [13%]	119.4 [20.0]	76.5 [13.1]
	45-64	2072 [57%]	128.0 [21.6]	72.7 [12.6]
	65-74	1053 [29%]	130.9 [22.3]	66.5 [11.6]
Race				
	White	1767 [49%]	122.7 [19.3]	69.1 [11.5]
	Black	1658 [46%]	132.9 [23.1]	73.7 [13.8]
	Other	187 [5%]	128.9 [23.4]	72.4 [11.6]
Gender				
	Men	1959 [54%]	127.6 [21.3]	72.8 [13.2]
	Women	1653 [46%]	127.7 [22.6]	69.7 [12.2]
Diabetes mellitus				
	No	1927 [54%]	123.6 [20.5]	73.1 [12.6]
	Yes	1685 [46%]	132.4 [22.5]	69.4 [12.8]
Estimated GFR, ml/min/1.73m ²				
	<30	671 [19%]	130.5 [23.5]	69.9 [13.3]
	30 – 39	849 [24%]	129.4 [23.2]	70.1 [12.6]
	40 – 49	969 [27%]	127.6 [21.3]	71.5 [12.7]
	50 – 59	723 [20%]	125.5 [20.1]	72.3 [12.4]
	≥60	400 [11%]	123.5 [20.0]	74.8 [12.8]

Value shown are no. (%) or mean [SD].

Abbreviations: BP – blood pressure; SD – standard deviation; GFR – glomerular filtration rate.

Due to rounding, percentages may not sum to 100%.

Table 2

Prevalence of hypertension and rates and prevalence ratios of control by demographic and socio-economic status characteristics

	Overall, n (%)	Prevalence of HTN	HTN control to < 140 / 90 mmHg		HTN control to < 130 / 80 mmHg	
			Rate	Prevalence Ratio (95% CI)	Rate	Prevalence Ratio (95% CI)
Age group						
21 – 44	487 (13%)	336 (69%)	239 (71%)	1.00 (ref)	158 (47%)	1.00 (ref)
45 – 64	2072 (57%)	1782 (86%)	1194 (67%)	0.95 (0.88 – 1.01)	802 (45%)	0.93 (0.83 – 1.04)
65 – 74	1053 (29%)	969 (92%)	639 (66%)	0.91 (0.84 – 0.98)	475 (49%)	0.95 (0.84 – 1.07)
Race						
White	1767 (49%)	1414 (80%)	1074 (76%)	1.00 (ref)	792 (56%)	1.00 (ref)
Black	1658 (46%)	1542 (93%)	925 (60%)	0.82 (0.78 – 0.86)	586 (38%)	0.72 (0.67 – 0.78)
Other	187 (5%)	150 (80%)	97 (65%)	0.86 (0.76 – 0.96)	60 (40%)	0.72 (0.59 – 0.88)
Gender						
Men	1959 (54%)	1704 (87%)	1159 (68%)	1.00 (ref)	545 (47%)	1.00 (ref)
Women	1653 (46%)	1389 (84%)	916 (66%)	0.98 (0.94 – 1.03)	422 (46%)	1.01 (0.94 – 1.09)
Education						
Less than high school	606 (17%)	576 (95%)	334 (58%)	1.00 (ref)	120 (36%)	1.00 (ref)
High school graduate or more education	3006 (83%)	2525 (84%)	1768 (70%)	1.07 (1.00 – 1.14)	866 (49%)	1.19 (1.06 – 1.34)
Marital status						
Not married	1665 (46%)	1449 (87%)	927 (64%)	1.00 (ref)	399 (43%)	1.00 (ref)
Married	1947 (54%)	1635 (84%)	1145 (70%)	1.01 (0.97 – 1.06)	561 (49%)	1.05 (0.96 – 1.12)
Household income						
< \$20k	1009 (33%)	919 (91%)	551 (60%)	1.00 (ref)	220 (40%)	1.00 (ref)
\$20 - \$50k	906 (30%)	806 (89%)	564 (70%)	1.06 (1.00 – 1.13)	277 (49%)	1.10 (0.99 – 1.22)
\$50 - \$100k	725 (24%)	580 (80%)	418 (72%)	1.06 (0.99 – 1.13)	205 (49%)	1.05 (0.93 – 1.18)
> \$100k	389 (11%)	288 (74%)	236 (82%)	1.12 (1.05 – 1.21)	139 (59%)	1.24 (1.09 – 1.41)

Due to missing values, the number of CRIC participants with hypertension is not equal when compared across different characteristics. Prevalence ratios are adjusted for age, race, gender, and CRIC clinical site. Hypertension control rates and prevalence ratios were limited to participants with hypertension.

ref. reference.

Table 3

Prevalence of hypertension and rates and prevalence ratios of control by behavioral and kidney-related characteristics.

	Overall, %	Prevalence of HTN	HTN control to < 140 / 90 mmHg		HTN control to < 130 / 80 mmHg	
			Rate	Prevalence Ratio (95% CI)	Rate	Prevalence Ratio (95% CI)
Body Weight						
Underweight	19 (1%)	13 (68%)	7 (54%)	0.91 (0.55 - 1.51)	4 (31%)	0.79 (0.35 - 1.78)
Normal Weight	578 (16%)	439 (76%)	277 (63%)	1.00 (ref)	198 (45%)	1.00 (ref)
Overweight	1018 (28%)	845 (83%)	583 (69%)	1.07 (0.99 - 1.16)	397 (47%)	1.04 (0.92 - 1.17)
Obesity	1987 (55%)	1788 (90%)	1216 (68%)	1.07 (1.00 - 1.16)	823 (46%)	1.04 (0.93 - 1.16)
Cigarette Smoking						
Never	1593 (44%)	1322 (83%)	899 (68%)	1.00 (ref)	608 (46%)	1.00 (ref)
Current	494 (14%)	430 (87%)	271 (63%)	1.00 (0.96 - 1.04)	185 (43%)	0.97 (0.90 - 1.05)
Former	1525 (42%)	1342 (88%)	913 (68%)	0.98 (0.92 - 1.05)	644 (48%)	1.01 (0.89 - 1.13)
Diabetes Mellitus						
No	1927 (53%)	1580 (80%)	1154 (73%)	1.00 (ref)	790 (50%)	1.00 (ref)
Yes	1685 (47%)	1517 (92%)	940 (62%)	0.94 (0.90 - 0.97)	637 (42%)	0.90 (0.84 - 0.97)
History of CVD						
No	2377 (66%)	1973 (83%)	1361 (69%)	1.00 (ref)	927 (47%)	1.00 (ref)
Yes	1235 (34%)	1136 (92%)	727 (64%)	0.97 (0.93 - 1.02)	511 (45%)	1.02 (0.95 - 1.11)
Serum Calcium, mg/dL						
Lowest quartile, <8.95	1042 (29%)	896 (86%)	529 (59%)	1.00 (ref)	349 (39%)	1.00 (ref)
Second quartile, 8.95 - 9.22	914 (26%)	768 (84%)	553 (72%)	1.10 (1.05 - 1.15)	376 (49%)	1.19 (1.07 - 1.32)
Third quartile, 9.23 - 9.52	850 (24%)	714 (84%)	500 (70%)	1.09 (1.03 - 1.14)	364 (51%)	1.22 (1.1 - 1.36)
Highest quartile, > 9.52	775 (22%)	690 (89%)	490 (71%)	1.09 (1.03 - 1.15)	338 (49%)	1.17 (1.05 - 1.31)
Serum Phosphorus, mg/dL						
Lowest quartile, <3.3	1071 (30%)	878 (82%)	615 (70%)	1.00 (ref)	413 (47%)	1.00 (ref)
Second quartile, 3.3 - 3.7	889 (25%)	747 (84%)	530 (71%)	1.03 (0.98 - 1.08)	366 (49%)	1.08 (0.98 - 1.19)
Third quartile, 3.8 - 4.1	789 (22%)	686 (87%)	453 (66%)	0.99 (0.94 - 1.04)	323 (47%)	1.07 (0.96 - 1.18)
Highest quartile, > 4.1	800 (23%)	728 (91%)	451 (62%)	0.96 (0.9 - 1.01)	313 (43%)	0.99 (0.89 - 1.1)
Ca × P, mg ² /dl ²						

	Overall, %	Prevalence of HTN	HTN control to < 140 / 90 mmHg		HTN control to < 130 / 80 mmHg	
			Rate	Prevalence Ratio (95% CI)	Rate	Prevalence Ratio (95% CI)
Lowest quartile, < 29.8	897 (25%)	727 (81%)	509 (70%)	1.00 (ref)	341 (47%)	1.00 (ref)
Second quartile, 29.8 – 33.6	879 (25%)	738 (84%)	502 (68%)	0.99 (0.94 - 1.05)	340 (46%)	1.01 (0.91 - 1.13)
Third quartile, 33.7 – 37.8	885 (25%)	770 (87%)	524 (68%)	1 (0.95 - 1.05)	370 (48%)	1.06 (0.96 - 1.17)
Highest quartile, > 37.8	881 (25%)	802 (91%)	513 (64%)	0.97 (0.91 - 1.02)	361 (45%)	1.02 (0.91 - 1.13)
Albuminuria, mg per day						
< 30	1418 (41%)	1522 (79%)	1248 (82%)	1.00 (ref)	929 (61%)	1.00 (ref)
30 to 299	950 (28%)	1483 (88%)	1008 (68%)	0.95 (0.92 - 0.98)	697 (47%)	0.84 (0.79 - 0.91)
300 to 999	524 (15%)	1373 (90%)	824 (60%)	0.92 (0.89 - 0.96)	508 (37%)	0.74 (0.67 - 0.82)
> 1000	528 (15%)	1888 (95%)	849 (45%)	0.86 (0.82 - 0.89)	453 (24%)	0.57 (0.51 - 0.64)
eGFR, mL/min/1.73m ²						
< 30	671 (19%)	617 (92%)	395 (64%)	0.97 (0.89 - 1.04)	278 (45%)	1.04 (0.89 - 1.21)
30 – 39	848 (23%)	772 (91%)	502 (65%)	0.97 (0.90 - 1.05)	370 (48%)	1.06 (0.91 - 1.23)
40 – 49	969 (27%)	853 (88%)	597 (70%)	1.00 (0.93 - 1.08)	392 (46%)	0.98 (0.86 - 1.14)
50 – 59	723 (20%)	593 (82%)	421 (71%)	1.01 (0.94 - 1.10)	279 (47%)	1.02 (0.88 - 1.19)
≥ 60	401 (11%)	269 (67%)	185 (69%)	1.00 (ref)	118 (44%)	1.00 (ref)
Seen a nephrologist						
No	1162 (32%)	941 (81%)	649 (69%)	1.00 (ref)	442 (47%)	1.00 (ref)
Yes	2450 (68%)	2156 (88%)	1445 (67%)	0.96 (0.91 - 1.00)	992 (46%)	0.99 (0.91 - 1.08)

Due to missing values, the number of CRIC participants with hypertension is not equal when compared across different characteristics.

Prevalence ratios are adjusted for age, race, gender, and CRIC clinical site.

Hypertension control rates and prevalence ratios were limited to participants with hypertension

Note: Conversion factors for units: calcium in mg/dL to mmol/L, 0.2495; phosphorus in mg/dL to mmol/L, $\times 0.3229$; eGFR in mL/min/1.73m² to mL/s/1.73m², $\times 0.01667$.

ref, reference

Table 4

Use of lifestyle modification and pharmacologic anti-hypertensive medication and rates and prevalence ratios of hypertension control associated with their usage.

	Among CRIC participants with HTN	HTN control to < 140 / 90 mmHg		HTN control to < 130 / 80 mmHg	
		Rate	Prevalence Ratio (95% CI)	Rate	Prevalence Ratio (95% CI)
Lifestyle Modification					
ANY	3035 (98%)	2033 (67%)	1.01 (0.89 - 1.14)	1396 (46%)	1.27 (0.96 - 1.68)
Weight Loss	2323 (75%)	1603 (69%)	1.05 (1.00 - 1.10)	1092 (47%)	1.04 (0.95 - 1.13)
Exercise	1951 (63%)	1327 (68%)	1.01 (0.98 - 1.06)	917 (47%)	1.02 (0.94 - 1.10)
Alcohol reduction	1982 (64%)	1328 (67%)	0.98 (0.94 - 1.03)	912 (46%)	0.97 (0.90 - 1.05)
Salt Reduction	2663 (86%)	1758 (66%)	0.97 (0.92 - 1.02)	1225 (46%)	0.99 (0.90 - 1.10)
Anti-HTN Medication Usage					
Beta-blockers	1703 (55%)	1090 (64%)	0.93 (0.89 - 0.97)	749 (44%)	0.93 (0.86 - 0.99)
CCBs	1456 (47%)	917 (63%)	0.95 (0.92 - 0.99)	597 (41%)	0.85 (0.79 - 0.91)
ACEi	1641 (53%)	1165 (71%)	1.05 (1.01 - 1.08)	821 (50%)	1.14 (1.06 - 1.22)
ARBs	867 (28%)	598 (69%)	1.01 (0.96 - 1.05)	399 (46%)	1.00 (0.92 - 1.08)
RAS blockers [†]	2292 (74%)	1604 (70%)	1.07 (1.02 - 1.12)	1100 (48%)	1.16 (1.06 - 1.28)
Vasodilators	465 (15%)	265 (57%)	0.92 (0.86 - 0.98)	190 (41%)	0.96 (0.86 - 1.07)
α_1 adrenergic receptor blockers	496 (16%)	337 (68%)	1.00 (0.95 - 1.06)	243 (49%)	1.02 (0.92 - 1.12)
α_2 adrenergic receptor blockers	310 (10%)	167 (54%)	0.88 (0.81 - 0.95)	99 (32%)	0.75 (0.63 - 0.88)
Potassium sparing diuretics	341 (11%)	273 (80%)	1.09 (1.05 - 1.14)	208 (61%)	1.26 (1.16 - 1.37)
Thiazide diuretics	991 (32%)	723 (73%)	1.07 (1.02 - 1.11)	525 (53%)	1.15 (1.07 - 1.24)
Loop diuretics	1270 (41%)	813 (64%)	0.97 (0.93 - 1.01)	559 (44%)	0.98 (0.91 - 1.06)

Due to missing values, the number of CRIC participants with hypertension is not equal when compared across different characteristics.

Prevalence ratios are adjusted for age, race, gender, and CRIC clinical site and the reference categories are comprised of those not using each lifestyle modification (e.g., weight loss versus no weight loss) or anti-hypertensive drug class (e.g., using ACE-inhibitors versus not using ACE-inhibitors).

[†] Renin angiotensin system blockers include ACE-inhibitors and angiotensin receptor blockers; 7% of CRIC participants were taking both an ACE-inhibitor and an angiotensin receptor blocker

Diuretics (potassium sparing, thiazide, or loop) were being taken by 63% of CRIC study participants.

Hypertension control rates and prevalence ratios were limited to participants with hypertension

Table 5

Multivariable adjusted prevalence ratios of hypertension control

	HTN Control to <140/90	HTN Control to <130/80
	Prevalence Ratio (95% CI)	Prevalence Ratio (95% CI)
Age group, years		
21 - 44	1.00 (ref)	1.00 (ref)
45 - 64	0.96 (0.92, 1.01)	0.92 (0.87, 0.98)
65 - 74	0.94 (0.90, 0.99)	0.92 (0.86, 0.99)
Black vs. white race	0.96 (0.93, 0.99)	0.93 (0.89, 0.97)
Other vs. white race	0.98 (0.91, 1.05)	0.93 (0.84, 1.03)
Female	0.99 (0.96, 1.02)	0.99 (0.95, 1.04)
Diabetes mellitus	0.99 (0.96, 1.02)	1.00 (0.96, 1.04)
High school education or higher	1.01 (0.97, 1.05)	1.04 (0.98, 1.10)
Serum Calcium, mg/dL		
Lowest quartile, <8.95	1.00 (ref)	1.00 (ref)
Second quartile, 8.95 – 9.22	1.01 (0.97, 1.05)	1.02 (0.97, 1.08)
Third quartile, 9.23 – 9.52	1.01 (0.97, 1.05)	0.99 (0.94, 1.05)
Highest quartile, > 9.52	1.01 (0.97, 1.05)	1.01 (0.95, 1.07)
Albuminuria, mg/day		
< 30	1.00 (ref)	1.00 (ref)
30 to 299	0.97 (0.93, 1.02)	0.94 (0.88, 1.00)
300 to 1000	1.05 (1.01, 1.08)	1.08 (1.03, 1.14)
>1000	0.90 (0.86, 0.95)	0.82 (0.76, 0.88)
AntiHTN medication classes		
Beta-blockers	0.99 (0.96, 1.02)	0.99 (0.95, 1.03)
CCBs	0.99 (0.96, 1.02)	0.96 (0.92, 1.00)
ACEi	1.04 (1.01, 1.07)	1.08 (1.03, 1.13)
ARBs	1.03 (1.00, 1.07)	1.06 (1.01, 1.11)
Vasodilators	0.99 (0.95, 1.03)	1.02 (0.96, 1.08)
α_1 adrenergic receptor blockers	1.02 (0.98, 1.06)	1.03 (0.97, 1.09)
α_2 adrenergic receptor blockers	0.97 (0.92, 1.02)	0.94 (0.87, 1.02)
Potassium sparing diuretics	1.03 (0.98, 1.07)	1.06 (1.00, 1.12)
Thiazide-type diuretics	1.01 (0.98, 1.04)	1.02 (0.98, 1.07)
Loop diuretics	1.00 (0.97, 1.03)	1.02 (0.97, 1.06)

All variables were included in the models simultaneously

Models included adjustment for CRIC clinical site.

Note: Conversion factors for units: calcium in mg/dL to mmol/L, 0.2495.