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Renal Artery Calcium, Cardiovascular Risk Factors and Indices of Renal Function

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Abstract

Vascular calcium is well studied in the coronary and peripheral arteries although there is limited data focusing on calcium deposits specific to renal arteries. The associations between renal artery calcium (RAC), cardiovascular disease (CVD) risk factors, and indices of renal function are unknown. We examined 2699 Framingham Heart Study participants who were part of a multidetector computed tomography substudy from 2008–2011. RAC was measured as a calcified plaque of >130 Hounsfield units and an area of >3 contiguous pixels. Detectable RAC was defined as an Agatston score >0. Chronic kidney disease (CKD) was defined as an eGFR <60 mL/min/1.73m². Microalbuminuria was defined as ACR ≥17 mg/g for men and ≥25 mg/g for women. Multivariable adjusted logistic regression models were used to evaluate the associations between RAC, CVD risk factors, and renal function. The associations were secondarily adjusted for coronary artery calcium (CAC) that was used as a marker of non-renal systemic vascular calcium. The prevalence of RAC was 28.2%; this was similar in women (28.8%) and men (27.5%). Individuals with RAC had a higher odds of microalbuminuria (OR 1.79, 95% CI 1.22–2.61, p=0.003), hypertension (OR 2.11, 95% CI 1.69–2.64, p<0.001) and diabetes (OR 1.60, 95% CI 1.14–2.24, p=0.01) but not CKD (OR 0.87, 95% CI 0.58–1.32). After adjustment for CAC, the association with microalbuminuria and hypertension persisted but the association with diabetes became non-significant. In conclusion, RAC is common and independently associated with microalbuminuria and hypertension after adjustment for non-renal vascular calcium. RAC may be uniquely associated with these markers of renal end-organ damage.

Keywords

cardiovascular risk factors; microalbuminuria; renal artery calcium

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Introduction

Computed tomography (CT) using the multidetector or electron beam method is a noninvasive method that can be effectively applied to quantify arterial wall calcium. Several studies using the electron beam CT method have shown an association between renal artery calcium (RAC) and hypertension.¹⁻⁴ RAC was also shown to be an independent predictor of progression to end-stage renal disease (ESRD) and associated with all-cause mortality.^{5,6} However, these studies were limited by selection bias or small sample size. Thus, the associations between RAC and kidney parameters have not been fully evaluated. The purpose of the present study is to examine the associations between RAC, cardiovascular disease (CVD) risk factors, and renal indices using a large community dwelling population with rigorous risk factor ascertainment. We hypothesized that the presence of RAC would be uniquely associated with chronic kidney disease (CKD) and microalbuminuria independent of traditional CVD risk factors and non-renal vascular calcium.

Methods

The Framingham Heart Study is a community-based cohort study that began in 1948. The objectives of the study, selection criteria, and study design have been previously described.⁷ Offspring of the original cohort were enrolled in 1971 as well as spouses of the offspring. Data on Third Generation family members with at least one parent in the original cohort was collected starting in 2002 with standardized clinic visits that included an interview conducted by physicians, a physical examination, and laboratory tests. The current study sample consists of 1333 Offspring and 1431 Third Generation participants who took part in the second multidetector CT substudy from 2008 to 2011. Participants were drawn from those living in the greater New England area. Men had to be ≥ 35 years old and women had to be ≥ 40 years old. Women who were pregnant or who had been breast-feeding for <6 months were not eligible. There was a weight limit of ≤ 450 lb due to scanner limitations. Multiple precautions were taken to limit the risks of radiation exposure including avoidance of the true pelvis, exclusion of young adults, and assessment of pregnancy status for pre-menopausal women. The study protocol was approved by the Boston University Medical Center and Massachusetts General Hospital institutional review boards. All subjects provided written informed consent. Of the 2764 participants imaged, 4 had uninterpretable CT measures for RAC and 61 had missing covariates resulting in a sample size of 2699 for analysis.

Assessment of RAC was obtained from non-contrast abdominal CT imaging using a Discovery VCT 64-slice PET/CT scanner with fixed 120 kVp and automatic mA adjustment for body mass index (BMI) in a range of 100–300 with 2.5 mm slice thickness (GE Healthcare, Waukesha, Wisconsin). Images were interpreted on an Aquarius Workstation (TeraRecon, Foster City, California). RAC scoring was consistent with the quantification methods described by Agatston et al.⁸ Briefly, regions of interest were identified by a single reader as having a density of >130 Hounsfield units and an area of >3 contiguous pixels (>1.0 mm²). Detectable RAC was defined as an Agatston score >0 . Final scoring was the sum of both renal arteries and did not include calcified plaque beyond the ostia that extended into the abdominal aorta. Intra-reader reproducibility on a sample of 46 scans demonstrated an intra-class correlation coefficient (ICC) of 0.98. Chest CT images were obtained with fixed 120 kVp, 0.625 mm slice thickness and a mA of 300 if the weight was ≤ 220 lb and a mA of 350 for weight >220 lb. Coronary artery calcium (CAC) scores were derived using protocols previously described.⁹ Intra-reader reproducibility demonstrated an ICC of 0.99.

Serum creatinine was measured using the Jaffe assay on a Roche Hitachi 911 (Roche Diagnostics, Indianapolis, Indiana) with an intra-assay coefficient of variation of 3.1%.

CKD was defined as an estimated glomerular filtration rate of $<60 \text{ mL/min/1.73m}^2$ using the Chronic Kidney Disease Epidemiology Collaboration equation.¹⁰ This cutoff value is consistent with CKD Stage 3 or greater set forth in the clinical practice guidelines of the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative.¹¹ Urinary albumin and creatinine was quantified from spot urine samples collected during participant examinations and stored at -80°C . Urinary albumin was measured using immunoturbidimetry (Tina-quant albumin assay, Roche Diagnostics, Indianapolis, Indiana; intra-assay coefficient of variation = 1.9%, inter-assay coefficient of variation = 5.5%) and estimation of urinary creatinine was made using a modified Jaffe method on a Roche Hitachi 911 with an intra-assay coefficient of variation of 1.2% and inter-assay coefficient of variation of 2.2%. Microalbuminuria was defined using urinary albumin to creatinine ratios (UACR) with sex-specific cutoffs of 17 mg/g for men and 25 mg/g for women to reflect the greater urinary creatinine excretion in men compared to women.^{12,13}

Manual blood pressure measurements were taken in the left upper extremity by a physician using a mercury sphygmomanometer on two separate occasions during the same visit following a standardized protocol. Hypertension was defined as a systolic blood pressure $\geq 140 \text{ mmHg}$, diastolic blood pressure $\geq 90 \text{ mmHg}$, or current use of antihypertensive medications. Fasting morning serum samples were obtained for measurement of glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides. Diabetes was defined as a fasting glucose $\geq 126 \text{ mg/dL}$ or use of anti-diabetic medication. BMI was calculated by the participant's weight in kilograms divided by the height in meters squared. Smoking was defined as using a cigarette, pipe, or cigar at least once per day in the year preceding the examination.

Sample means and standard deviations were calculated for normally distributed continuous values, medians and interquartile ranges were calculated for non-normally distributed variables, and proportions were calculated for categorical data. Spearman correlation coefficients were calculated to study the relationship between $\log(\text{RAC}+1)$ and continuous variables after adjusting for age and sex. The Chi-square test was used to measure differences between detectable RAC in each age-group and overall stratified by sex. A stepwise logistic regression model with forward selection was used to identify independent correlates for the presence of RAC including age, sex, BMI, hypertension, diabetes, smoking, CKD, microalbuminuria, total cholesterol, HDL cholesterol, and triglycerides.

We then performed a series of multivariable logistic regressions evaluating detectable RAC as a cross-sectional predictor including microalbuminuria, diabetes, hypertension, and CKD. Here, RAC was log transformed using $\log(\text{RAC}+1)$. For the outcome of microalbuminuria, we adjusted for age, sex, smoking, BMI, hypertension, and diabetes. For the outcomes of diabetes and hypertension we adjusted for age, sex, smoking, and BMI. For the outcome of CKD we adjusted for age, sex, smoking, hypertension, and diabetes.

As a secondary analysis, we recreated the stepwise model and all multivariable models to include CAC scores using $\log(\text{CAC}+1)$ transformation. CAC was used as a proxy for non-renal vascular calcification to determine if an association was related to more generalized systemic vascular calcification or only to RAC. CAC scores were not available for 112 participants with detectable RAC and 33 participants without RAC. To assess the significance of RAC in the absence of systemic vascular calcium, the Chi-square test was used to compare the group of participants with $\text{RAC} = 0$ and $\text{CAC} \leq 10$ versus the group with $\text{RAC} > 0$ and $\text{CAC} < 10$. This comparison was adjusted for age and sex.

All analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, North Carolina). A one-tailed p-value < 0.05 was considered statistically significant.

Results

The clinical characteristics of the study cohort are presented in Table 1 and stratified by the presence or absence of RAC >0. In general, participants with RAC compared to RAC =0 were older (71.0 vs 55.7 years, respectively) and had higher rates of microalbuminuria, hypertension, diabetes, and CKD. Median CAC scores were higher in participants with detectable RAC. Overall, the prevalence of detectable RAC was 28.2% and this was similar in women (28.8%) and men (27.5%, $p=0.46$ for sex difference). The prevalence of RAC increased with each 10-year age group and there were no significant sex differences across any group (Figure 1). There was a significant positive correlation between RAC and clinical covariates including log(UACR) and systolic blood pressure (Table 2). From a stepwise regression analysis, significant variables associated with RAC were age, microalbuminuria, hypertension, smoking, and BMI. When we adjusted for CAC, the odds ratios were modestly attenuated but the risk factor associations with RAC remained statistically significant except for BMI (Table 3).

Next, we examined the cross-sectional associations of RAC with microalbuminuria, hypertension, diabetes, and CKD (Table 4). Participants with RAC had a 2-fold higher odds for hypertension (OR 2.11, $p<0.001$) compared to those with no detectable RAC. Similar findings were observed for microalbuminuria (OR 1.79, $p=0.003$). RAC was also associated with a higher odds ratio for diabetes (OR 1.60, $p=0.01$) relative to participants without RAC. Conversely, we observed no association of RAC with CKD (OR 0.87, $p=0.52$). In order to assess whether associations were independent of non-renal calcium, we secondarily adjusted for CAC. Although the odds ratios were modestly attenuated, the resulting odds ratios for hypertension (OR 1.77, $p<0.001$) and microalbuminuria (OR 1.85, $p=0.004$) remained statistically significant. However, the odds ratio for diabetes was markedly attenuated and no longer statistically significant (OR 1.08, $p=0.68$).

The results of a comparison between discordant groups of RAC and CAC showed notable differences with regard to microalbuminuria and diabetes (Figure 2). Specifically, the group that had detectable RAC in the absence of CAC (RAC >0, CAC <10) showed a higher rate of microalbuminuria with borderline significance ($p=0.06$) compared to the group with RAC =0, CAC =10. The prevalence of hypertension and CKD were also higher in the former group but the differences were not significant. After adjustment for age and sex, there was a higher prevalence of diabetes in the comparison group with RAC =0, CAC =10 ($p=0.03$). The group without RAC or CAC had the lowest prevalence of disease and the group with both RAC and CAC had the highest rates.

Discussion

In this well established cohort of community dwelling women and men, the presence of RAC was common, affecting nearly one-third of participants. The prevalence of RAC increased with age but there was no difference between women and men. RAC was associated with a 2-fold higher odds of microalbuminuria and hypertension compared to individuals without RAC and this persisted after adjustment for CAC, which was used as a surrogate for non-renal systemic vascular calcium. Individuals with RAC and no systemic vascular calcium had less diabetes but were more likely to have microalbuminuria when compared to the group with CAC and no RAC. Taken together, these findings suggest a unique association between RAC and factors related to end organ damage of the kidney.

A central question to the relevance of RAC is whether it merely reflects systemic vascular calcium or whether it exhibits independent properties. Large studies show that individuals with diabetes have a greater burden of vascular calcium.¹⁴ We found no association between

RAC and diabetes after adjustment for CAC which was consistent with earlier studies.² This suggests that RAC may be a marker of systemic vascular calcium when observed in individuals with diabetes.

However, the idea that calcium deposits in the renal arteries may have unique characteristics is supported by several prior findings. First, individuals with RAC were shown to have a 1.6-fold higher odds for the presence of hypertension compared to those without RAC.³ Second, patients with RAC had a higher risk of progression to ESRD independent of CAC and other risk factors.⁵ Finally, RAC was associated with an increased risk of mortality after adjustment for CAC.⁶ Our study extends these novel findings of RAC to include an association with albuminuria which is a feature of kidney damage. Two prior studies of RAC failed to detect an association with proteinuria but these were limited by small sample size and focus on participants with diabetes.^{1,5} We not only addressed these limitations but also found that the group with RAC in the absence of CAC, when compared to the group with CAC and no RAC, was more likely to have microalbuminuria despite a lower prevalence of diabetes. These results underscore the association between RAC and albuminuria.

We found similar rates of RAC in both women and men, in contrast to prior studies that showed higher rates of vascular calcium in men compared to women.^{3,4} In large studies assessing CAC scores, both the MESA cohort and a British population (n=16,222) showed higher levels in men compared to women although RAC scores were not reported.^{15,16} The overall prevalence of RAC in the current study was about one-third. This value is similar to some published data,^{4,5} but appears to vary in other studies as a result of the referral process, sample size, and threshold used to define RAC.^{1,6}

There are several potential mechanistic explanations for the unique association between RAC, microalbuminuria and hypertension. Vascular calcium is thought to be a marker of atherosclerosis and occurs in the setting of chronic inflammation. The renin-angiotensin-aldosterone system (RAAS) is implicated in this process and is associated with the development of atherosclerosis, hypertension, and proteinuria.¹⁷⁻¹⁹ The development of RAC may indicate a generalized state of RAAS activation. Vascular calcification is also associated with increased arterial stiffness.²⁰ Increased stiffness of the renal arteries may result in transmission of an elevated pulse pressure leading to the downstream effects of glomerular and/or tubular damage.^{21,22} Proteinuria, as a marker of renal damage, was previously shown to be associated with an elevated pulse pressure.²³ Another study demonstrated that microalbuminuria is an independent predictor of arterial stiffness.²⁴ Taken together, these data support a possible role for calcification of the renal arteries in the setting of either hypertension or microalbuminuria.

We demonstrated an independent association between RAC with CVD risk factors including microalbuminuria and hypertension. CVD risk factor modification continues to be a challenge but studies of vascular calcification may offer new insights into explaining the high morbidity and mortality of some populations. Specifically, focus on the prevention or amelioration of RAC and how such interventions may alter markers of kidney damage could be considered. The possibility of mitigating these CVD risk factors through a single target such as RAC is an attractive notion.

The strengths of our study include a large community dwelling cohort, rigorous risk factor ascertainment, measurements of renal function, and concurrent CAC scores. However, our study had some limitations that warrant mention. The study population was predominantly composed of white non-Hispanic Americans and these results may not be generalizable to other ethnic groups. We did not account for statin use. Also, CT is not able to differentiate

between intimal and medial layer calcifications. Intimal changes are associated with atherosclerotic plaques and contribute to vessel occlusion while medial artery calcification is more commonly seen with disorders of mineral metabolism and may exacerbate arterial stiffness.²⁵ There are likely overlaps between the two forms affecting renal hemodynamics and distinguishing the location of the calcification may help provide additional clues as to the etiology of our findings. Finally, the cross-sectional design of our study provides no evidence of a temporal relationship between exposure and outcome.

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References

1. Freedman BI, Hsu FC, Langefeld CD, Bowden DW, Moossavi S, Dryman BN, Carr JJ. Renal artery calcified plaque associations with subclinical renal and cardiovascular disease. *Kidney Int.* 2004; 65:2262–2267. [PubMed: 15149339]
2. Allison MA, DiTomasso D, Criqui MH, Langer RD, Wright CM. Renal artery calcium: relationship to systemic calcified atherosclerosis. *Vasc Med.* 2006; 11:232–238. [PubMed: 17390546]
3. Allison MA, Lillie EO, DiTomasso D, Wright CM, Criqui MH. Renal artery calcium is independently associated with hypertension. *J Am Coll Cardiol.* 2007; 50:1578–1583. [PubMed: 17936157]
4. Tolkin L, Bursztyn M, Ben-Dov IZ, Simanovsky N, Hiller N. Incidental renal artery calcifications: a study of 350 consecutive abdominal computed tomography scans. *Nephrol Dial Transplant.* 2009; 24:2170–2175. [PubMed: 19225015]
5. Chiu YW, Adler S, Budoff M, Takasu J, Ashai J, Mehrotra R. Prevalence and prognostic significance of renal artery calcification in patients with diabetes and proteinuria. *Clin J Am Soc Nephrol.* 2010; 5:2093–2100. [PubMed: 20705966]
6. Rifkin DE, Ix JH, Wassel CL, Criqui MH, Allison MA. Renal artery calcification and mortality among clinically asymptomatic adults. *J Am Coll Cardiol.* 2012; 60:1079–1085. [PubMed: 22939556]
7. Dawber TR, Kannel WB, Lyell LP. An approach to longitudinal studies in a community: the Framingham Study. *Ann N Y Acad Sci.* 1963; 107:539–556. [PubMed: 14025561]
8. Agatston AS, Janowitz WR, Hildner FJ, Zusmer NR, Viamonte M Jr, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. *J Am Coll Cardiol.* 1990; 15:827–832. [PubMed: 2407762]
9. Hoffmann U, Massaro JM, Fox CS, Manders E, O'Donnell CJ. Defining normal distributions of coronary artery calcium in women and men (from the Framingham Heart Study). *Am J Cardiol.* 2008; 102:1136–1141. [PubMed: 18940279]
10. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, Feldman HI, Kusek JW, Eggers P, Van Lente F, Greene T, Coresh J, CKDEPI. A new equation to estimate glomerular filtration rate. *Ann Intern Med.* 2009; 150:604–612. [PubMed: 19414839]
11. Levey AS, Coresh J, Balk E, Kausz AT, Levin A, Steffes MW, Hogg RJ, Perrone RD, Lau J, Eknoyan G. National Kidney F. National Kidney Foundation practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Ann Intern Med.* 2003; 139:137–147. [PubMed: 12859163]
12. Mattix HJ, Hsu CY, Shaykevich S, Curhan G. Use of the albumin/creatinine ratio to detect microalbuminuria: implications of sex and race. *J Am Soc Nephrol.* 2002; 13:1034–1039. [PubMed: 11912263]
13. O'Seaghdha CM, Hwang SJ, Upadhyay A, Meigs JB, Fox CS. Predictors of incident albuminuria in the Framingham Offspring cohort. *Am J Kidney Dis.* 2010; 56:852–860. [PubMed: 20599306]

14. Wong ND, Nelson JC, Granston T, Bertoni AG, Blumenthal RS, Carr JJ, Guerci A, Jacobs DR Jr, Kronmal R, Liu K, Saad M, Selvin E, Tracy R, Detrano R. Metabolic syndrome, diabetes, and incidence and progression of coronary calcium: the Multiethnic Study of Atherosclerosis study. *JACC Cardiovasc Imaging*. 2012; 5:358–366. [PubMed: 22498324]
15. McClelland RL, Chung H, Detrano R, Post W, Kronmal RA. Distribution of coronary artery calcium by race, gender, and age: results from the Multi-Ethnic Study of Atherosclerosis (MESA). *Circulation*. 2006; 113:30–37. [PubMed: 16365194]
16. Kouloukidis G, Jenkins PJ, McArthur T. Prevalence and distribution of coronary artery calcification in asymptomatic british population. *Can J Cardiol*. 2013; 29:131. [PubMed: 23149000]
17. Abedin M, Tintut Y, Demer LL. Vascular calcification: mechanisms and clinical ramifications. *Arterioscler Thromb Vasc Biol*. 2004; 24:1161–1170. [PubMed: 15155384]
18. Brewster UC, Perazella MA. The renin-angiotensin-aldosterone system and the kidney: effects on kidney disease. *Am J Med*. 2004; 116:263–272. [PubMed: 14969655]
19. Ferrario CM, Strawn WB. Role of the renin-angiotensin-aldosterone system and proinflammatory mediators in cardiovascular disease. *Am J Cardiol*. 2006; 98:121–128. [PubMed: 16784934]
20. Guerin AP, London GM, Marchais SJ, Metivier F. Arterial stiffening and vascular calcifications in end-stage renal disease. *Nephrol Dial Transplant*. 2000; 15:1014–1021. [PubMed: 10862640]
21. Mitchell GF. Increased aortic stiffness: an unfavorable cardiorenal connection. *Hypertension*. 2004; 43:151–153. [PubMed: 14718350]
22. Safar ME, London GM, Plante GE. Arterial stiffness and kidney function. *Hypertension*. 2004; 43:163–168. [PubMed: 14732732]
23. Pedrinelli R, Dell'Omo G, Penno G, Bandinelli S, Bertini A, Di Bello V, Mariani M. Microalbuminuria and pulse pressure in hypertensive and atherosclerotic men. *Hypertension*. 2000; 35:48–54. [PubMed: 10642274]
24. Kohara K, Tabara Y, Tachibana R, Nakura J, Miki T. Microalbuminuria and arterial stiffness in a general population: the Shimanami Health Promoting Program (J-SHIP) study. *Hypertens Res*. 2004; 27:471–477. [PubMed: 15302983]
25. Cannata-Andia JB, Rodriguez-Garcia M, Carrillo-Lopez N, Naves-Diaz M, Diaz-Lopez B. Vascular calcifications: pathogenesis, management, and impact on clinical outcomes. *J Am Soc Nephrol*. 2006; 17:S267–273. [PubMed: 17130273]

Figure 1.
Prevalence of renal artery calcium by 10-year age groups in women and men.

Figure 2.

Prevalence of microalbuminuria, diabetes, hypertension, and chronic kidney disease among the four different combinations of RAC and CAC. P values presented are between the two discordant groups of a RAC = 0, CAC ≥ 10 and RAC > 0, CAC < 10. MA = microalbuminuria; DM = diabetes mellitus; HTN = hypertension; CKD = chronic kidney disease.

Table 1

Clinical characteristics of sample stratified by presence or absence of renal artery calcium

Variable	RAC >0 (n = 760)	RAC =0 (n = 1939)
Age (years)	71.0 ± 9.3	55.7 ± 9.8
Women	391 (51.4%)	967 (49.9%)
Body mass index (kg/m ²)	30.0 (5.3%)	28.3 (5.4%)
Hypertension	504 (66.3%)	508 (29.9%)
Hypertension treatment	427 (56.4%)	458 (23.6%)
Systolic blood pressure (mm Hg)	130.7 ± 17.1	119.5 ± 13.8
Diastolic blood pressure (mm Hg)	72.9 ± 9.9	75.0 ± 8.9
Diabetes	132 (17.4%)	126 (6.5%)
Current smoker	53 (7.0%)	140 (7.2%)
Chronic kidney disease	109 (14.3%)	56 (2.9%)
Estimated GFR (mL/min/1.73m ²)	77.1 ± 16.1	89.6 ± 14.3
Microalbuminuria	110 (14.5%)	86 (4.4%)
UACR (mg/g)	6.1 (3.6–12.7)	4.1 (2.6–8.0)
Total cholesterol (mg/dL)	184.2 ± 37.2	191.2 ± 34.7
HDL cholesterol (mg/dL)	56.5 ± 17.2	58.9 ± 18.2
Triglycerides (mg/dL)	104.0 (79.0–144.5)	91.2 (79.9–100.7)
Lipid treatment	401 (52.8%)	481 (24.8%)
Coronary artery calcium score	204.8 (29.4–645.7)	0 (0–34.3)
Renal artery calcium score	71.7 (22.4–179.1)	0 (0–0)

Data are presented as mean ± SD, number (%), or median and interquartile range (25–75%).

GFR = glomerular filtration rate; UACR = urine to albumin creatinine ratio.

Table 2

Spearman correlation between log renal artery calcium and clinical covariates adjusted for age and sex

Variable	r	p Value
Age	0.58	<0.001
Body mass index	0.07	<0.001
Systolic blood pressure	0.11	<0.001
Diastolic blood pressure	-0.04	0.02
Log(urinary albumin to creatinine ratio)	0.11	<0.001
Estimated glomerular filtration rate	-0.01	0.71
Glucose	0.12	<0.001
Total cholesterol	-0.07	<0.001
High-density lipoprotein cholesterol	-0.03	0.09
Low-density lipoprotein cholesterol	-0.06	<0.001
Log(triglycerides)	0.03	0.09
Log(coronary artery calcium score +1)	0.29	<0.001

Table 3

Odds ratios and 95% confidence intervals of the multivariable stepwise logistic regression for the presence of a renal artery calcium score >0 before and after adjustment for coronary artery calcium

Variable	OR (95% CI)	p Value	CAC Adjusted OR (95% CI)	p Value
Age (10 years)	4.12 (3.65–4.67)	<0.001	2.96 (2.58–3.40)	<0.001
Sex (women)	0.86 (0.69–1.06)	0.16	1.52 (1.17–1.96)	0.001
Body mass index (per SD of BMI increase)	1.14 (1.02–1.27)	0.03	1.07 (0.95–1.21)	0.25
Current smoker	2.55 (1.70–3.83)	<0.001	2.05 (1.31–3.21)	0.002
Hypertension	2.13 (1.70–2.68)	<0.001	1.80 (1.41–2.30)	<0.001
Microalbuminuria	1.81 (1.22–2.70)	0.003	1.80 (1.15–2.82)	0.01
Coronary artery calcium	-	-	1.32 (1.25–1.39)	<0.001

SD = standard deviation.

Table 4

Odds ratios and 95% confidence intervals of the multivariable adjusted logistic regression for the association between log renal artery calcium and individual outcomes of microalbuminuria, diabetes, hypertension, and chronic kidney disease before and after adjusting for coronary artery calcium

Outcome	OR (95% CI)	p Value	CAC Adjusted OR (95% CI)	p Value
Microalbuminuria [*]	1.79 (1.23–2.61)	0.003	1.85 (1.21–2.81)	0.004
Diabetes [†]	1.60 (1.14–2.24)	0.01	1.08 (0.74–1.57)	0.68
Hypertension [‡]	2.11 (1.69–2.64)	<0.001	1.77 (1.39–2.26)	<0.001
Chronic kidney disease [‡]	0.87 (0.58–1.32)	0.52	0.80 (0.50–1.26)	0.33

^{*} Adjusted for age, sex, smoking, body mass index, hypertension, and diabetes.

[†] Adjusted for age, sex, smoking, and body mass index.

[‡] Adjusted for age, sex, smoking, hypertension, and diabetes.