Original Article

Mineral and Bone Disorder and Its Association with Cardiovascular Parameters in Chinese Patients with Chronic Kidney Disease

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Abstract

Background: Mineral and bone disorder (MBD), especially hyperphosphatemia, is an independently risk factor for adverse prognosis in patients with chronic kidney disease (CKD). However, CKD-MBD among Chinese population was poorly studied. This study aimed to investigate the status of MBD and its association with cardiovascular parameters in Chinese patients with predialysis CKD.

Methods: Chinese Cohort Study of Chronic Kidney Disease (C-STRIDE) is a prospective multicenter cohort study involving predialysis CKD patients in China. Markers of MBD, including serum phosphorus, calcium, and intact parathyroid hormone, were measured in baseline samples at the patients' entry. The association between serum phosphorus and abdominal aortic calcification (AAC), left ventricular hypertrophy (LVH) were examined by logistic regression models.

Results: Altogether 3194 predialysis patients with mean estimated glomerular filtration of 51.8 ± 33.1 ml·min^{-1}·1.73 m^{-2} were included. The proportion of patients with hyperphosphatemia were 2.6%, 2.9%, 6.8%, and 27.1% in CKD Stages 3a, 3b, 4, and 5, respectively. Moreover, 71.6% of the patients with hyperphosphatemia did not receive any phosphate-binder (PB). Lateral abdominal X-rays were obtained in 2280 patients, 9.8% of the patients were diagnosed as having AAC. Altogether 2219 patients had data of echocardiography, and 13.2% of them were diagnosed with LVH. Multivariate logistic regression analysis showed that serum phosphorus was independently associated with the presence of AAC and LVH.

Conclusions: In Chinese patients with CKD, the percentage of hyperphosphatemia is comparable to that of other countries while the usage of PBs is suboptimal. The prevalence of vascular calcification in Chinese patients is relatively lower compared with the Caucasian population.

Key words: Chronic Kidney Disease; Hyperphosphatemia; Left Ventricular Hypertrophy; Mineral and Bone Disorder; Vascular Calcification

Introduction

Chronic kidney disease (CKD) is a public health problem in China.[1] A recent survey in China indicated that the prevalence of CKD is 10.8%,[1] which was comparable to reports from other countries. The estimated number of patients with CKD in China is 119.5 million, which would definitely contribute to a substantial burden on the health-care system.

The burden of CKD is not restricted to its effect on demands for renal replacement therapy. It is widely acknowledged that CKD is a risk factor for cardiovascular disease, in both general population,[2] as well as high-risk population.[3] Besides traditional risk factors, nontraditional

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risk factors, especially those involved in mineral and bone disorder (MBD) of CKD, contribute to the increased risk of cardiovascular disease.[4,5] Animal experimental studies showed that high extracellular phosphate levels could stimulate vascular smooth muscle cells (VSMCs) to transdifferentiate into osteoblast-like cells, increase the accumulation of calcium in VSMCs, and therefore induce calcification.[6] Furthermore, other pathways involving hyperphosphatemia could also contribute to vascular calcification (VC), including induction of VSMC apoptosis, inhibition of monocyte/macrophage differentiation into osteoclast-like cells, elevation of fibroblast growth factor 23 (FGF23) levels, and alteration in Klotho expression.[7] Elevated FGF23, along with hypertension and anemia, could lead to left ventricular hypertrophy (LVH), which is also an important manifestation of cardiovascular abnormalities.[8] Therefore, understanding the status of MBD, as well as its association with cardiovascular disease, is important for improving the prognosis of patients with CKD.

Previously, most studies in CKD-MBD are from Western countries, while researches from Asian, especially Asian developing countries are limited, where the diet and medical practice habits are different. Chinese Cohort Study of Chronic Kidney Disease (C-STRIDE) is a large, prospective, multicenter, observational cohort study in China, aiming to investigate the risk factors for renal function deterioration, as well as the incidence and the risk factors for cardiovascular disease among patients with CKD.[9] In the present analyses, the baseline data of participants from C-STRIDE were used to investigate the status of MBD, as well as its association with LVH and VC.

Methods

Study design and participants

The design of C-STRIDE has been described elsewhere in details.[9] In brief, altogether 39 nephrology centers in different geographic regions in China were involved in the study. A total of 3194 CKD participants without on dialysis were enrolled until November 2011 and were therefore included in the study. The inclusion criteria were as follows: (1) aged between 18 years and 74 years; and (2) estimated glomerular filtration rate (eGFR) $\geq$15 ml·min^{-1}·1.73 m^{-2} for patients with glomerulonephritis (GN), or 15 ml·min^{-1}·1.73 m^{-2} $\leq$eGFR <60 ml·min^{-1}·1.73 m^{-2} for patients with etiologies other than GN, or eGFR $\geq$60 ml·min^{-1}·1.73 m^{-2} and "nephrotic range proteinuria" for patients with diabetic nephropathy.[10] A small percentage of patients were classified as CKD Stage 5 by a central laboratory test. Since they also had complete baseline data and were therefore included in the analyses. Participants meeting one of the following criteria were excluded: (1) with serious coexisting illnesses, including chronic heart failure (New York Heart Association Class III or IV), hepatic cirrhosis, human immunodeficiency virus (HIV) infection/acquired immune deficiency syndrome (AIDS), isolated hematuria, and organ transplantation, or (2) CKD caused by systemic inflammatory illness or autoimmune disease, such as systemic lupus erythematosus; or (3) requiring immunosuppression agents within 6 months to treat renal diseases or immune disease; or (4) malignancy treated with chemotherapy within last 2 years; or (5) pregnant or breastfeeding women; or (6) hereditary kidney disease; or (7) in interventional clinical trial. The C-STRIDE study was approved by the Ethics Committee of Peking University First Hospital and was in adherence with the *Declaration of Helsinki*. All the participants gave written informed consent before data collection.

Biochemical tests for mineral and bone disorder

Fasting morning blood specimens were collected at the study visit. All participates' blood samples were transported by cold chain to the Central Laboratory of Peking University First Hospital to avoid the variation of testing values between laboratories. Serum calcium was determined by a colorimetric reaction, with a normal range of 2.12–2.75 mmol/L. Total serum calcium was adjusted if serum albumin was <40 g/L, using the formula: corrected total calcium (mmol/L) = total calcium (mmol/L) + 0.2 × (40 − serum albumin [g/L]). Serum phosphorus concentrations were measured by reflectance spectrophotometry, with a normal range of 0.96–1.62 mmol/L. Serum parathyroid hormone was measured with intact parathyroid hormone (iPTH) assays, with a normal range of 15–65 pg/ml. The eGFR was calculated with the equation developed by adaption of the Modification of Diet in Renal Disease equation on the basis of data from the Chinese CKD patients: eGFR = 175 × (serum creatinine [in μmol/L]/88.4)$^{-1.234}$ × age$^{-0.179}$ × (if female, × 0.79).[11]

Abdominal aortic calcification

Lateral abdominal X-ray to detect abdominal aortic calcification (AAC) was evaluated by a single radiologist blinded to clinical information. Detailed description of the protocol for measurement had been previously described by Kauppila *et al*.[12]

Left ventricular hypertrophy

A two-dimensional guided M-mode echocardiographic study was performed at each nephrology center. Measurements included the diastolic thickness of the interventricular septum (IVST), left ventricular posterior wall (PWT), and the internal diameter of the left ventricle at the end of diastole (LVDd). Left ventricular mass (LVM) was calculated by using the formula: LVM = 0.8 (1.04 [LVDd + IVST + PWT]^3 – [LVDd]^3) + 0.6;[13] left ventricle mass index (LVMI) was measured by dividing left ventricle muscle mass to body surface area (BSA). BSA = 0.0061 × height (cm) + 0.0128 × weight (kg) − 0.1529. LVMI >125 g/m^2 in males and >120 g/m^2 in females were considered as LVH.

Other variables

A questionnaire documenting information of detailed demographics, lifestyle behaviors, and medical and medication history were inquired. Anthropometric measurements (resting blood pressure, height, and weight) were measured using standardized procedures. Body mass index was calculated by using the formula: weight (kg)/height^2 (cm^2).

Statistical analysis

Continuous variables were shown as mean ± standard deviation (SD) except for highly skewed variables, which was presented as median and interquartile ranges (IQRs). Categorical data were presented as percentages. Relevant characteristics are described and stratified according to the eGFR. Analysis of variance or Kruskal-Wallis test was used to compare the differences for continuous variables, and Chi-square test was used for categorical variables.

Multivariate logistic regression models were used to assess the association between the levels of serum phosphorus and the presence of AAC and LVH. Covariates included in the models were age (continuous), gender (male vs. female), smoking status (never smoking vs. former smoking vs. current smoking), eGFR (continuous), fasting blood glucose (FBG, continuous), high-density lipoprotein-cholesterol (HDL-C, continuous), systolic blood pressure (SBP, continuous), albumin (continuous), calcium (continuous), iPTH (continuous), phosphorus (continuous), phosphate-binder (PB, used vs. unused), and vitamin D_3 (used vs. unused). The results were presented as odds ratios (*OR*s) with 95% confidence intervals (*CI*s). Statistical analyses were performed using the SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). A $P < 0.05$ was considered statistically significant.

Results

Altogether 3194 predialysis CKD patients, with mean eGFR of 51.8 ± 33.1 ml·min^{-1}·1.73 m^{-2} were included in our study. The main demographic and clinical characteristics of patients were demonstrated in Table 1. Mean age was 48.7 ± 13.7 years and 58.9% of them were male. GN was the leading cause of CKD. The majority of patients had Stage 3 CKD, with a percentage of 40.5%. The 767 patients (24.0%) had an eGFR between 15 and 30 ml·min^{-1}·1.73 m^{-2} and only 159 patients (5.0%) in Stage 5 CKD were included. The median serum phosphorus level was 1.18 mmol/L (IQR: 1.05–1.33 mmol/L).

Table 2 shows the achievement of mineral metabolism parameters target according to Kidney Disease: Improving Global Outcomes (KDIGO) clinical practice guideline.[5] The proportions of patients with hyperphosphatemia were 2.6%, 2.9%, 6.8%, and 27.1% in CKD Stages 3a, 3b, 4, and 5, respectively. The proportions of patients who lower than the serum phosphorus target were 17.1%, 14.5%, 7.2%, and 1.9% in CKD Stages 3a, 3b, 4, and 5, respectively. Among the patients diagnosed with hyperphosphatemia, 71.6% of them were without the use of PBs. Moreover, 17.5% of the patients with hypophosphatemia were still under the treatment of PBs [Figure 1].

In this study, 2280 (71.3%) individuals had results of lateral abdominal X-ray examination and 9.8% of them were diagnosed with AAC. The associations between increased serum phosphorus and AAC are shown in Table 3. After adjusting for age, gender, eGFR, smoking status, FBG, HDL, and SBP, the level of phosphorus was independently

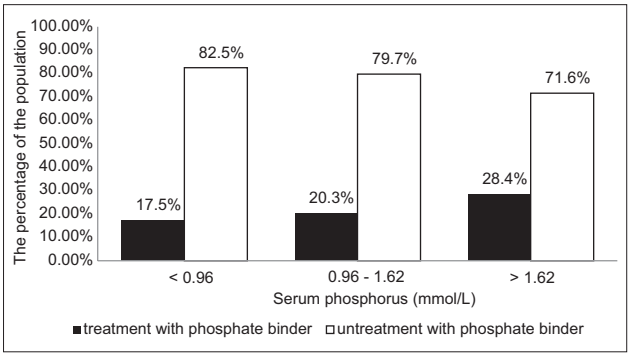

Figure 1: The percentage of stages 3–5 chronic kidney disease patients with or without treatment of phosphate binders.

associated with the presence of AAC, with an *OR* of 1.59 (95% *CI*: 1.01–2.51, $P = 0.050$). Results did not change substantially when further adjusted calcium, iPTH, and mineral metabolism drugs, with *OR* of 1.99 (1.11–3.56, $P = 0.020$). A total of 2219 (69.5%) patients had an echocardiographic measurement, and 13.2% of them were diagnosed with LVH. In the fully adjusted model, serum phosphorus was a strong risk factor with *OR* of 2.11 (1.26–3.22, $P = 0.003$) [Table 3].

Discussion

In this multicenter, prospective cohort study, we found that the percentage of hyperphosphatemia among Chinese CKD population is comparable to reports from other countries, while the usage of PBs is suboptimal. Levels of serum phosphorus are independently associated with the presence of AAC and LVH, while the prevalence of VC among Chinese patients is relatively lower compared with studies in the Caucasian population.

Hyperphosphatemia is a well-known risk factor for patients with CKD, while most studies regarding the serum phosphorus control rate among CKD population are from Western countries. Researches from Asian, especially Asian developing countries, are limited. Our study revealed that Chinese CKD patients had a serum phosphorus level comparable to that from the US,[14,15] Italy,[16] and Japan.[17,18] The control rate of serum phosphorus in China is also comparable to those countries.[14,16,18] In contrast to a previous study of 727 predialysis CKD Stages 3b–5 patients from Italy,[16] a similar prescription rate of PBs was identified (17.3% vs. 20.1%). However, we also noticed that a higher prevalence of the patients (71.6%) with higher phosphorus level was a lack of PBs treatment in our study than that observed in Italy (50.9%).[16] Moreover, a relatively high proportion (17.5%) with hypophosphatemia was still under the treatment of PBs in our cohort. These results reflected a fact that the usage of PBs is unsatisfactory in China.

VC is one of the most common complications in CKD patients. In this study, we used the lateral abdominal X-ray to assess VC. The presence of significant AAC on X-ray was strongly associated with significant coronary artery

Table 1: Baseline characteristics of patients with different stages of CKD

Variables	All (n = 3194)	Stage 1 (n = 443)	Stage 2 (n = 531)	Stage 3a (n = 525)	Stage 3b (n = 769)	Stage 4 (n = 767)	Stage 5 (n = 159)	Statistical values	P
Percentage (%)	100	13.9	16.6	16.4	24.1	24.0	5.0		
Age (years)	48.7 ± 13.7	39.4 ± 12.2	45.2 ± 13.0	50.8 ± 13.2	52.2 ± 12.9	51.6 ± 12.7	48.7 ± 13.9	77.45*	<0.001
Gender (male/female, %)	58.9/41.1	49.9/50.1	61.8/38.2	69.1/30.9	58.9/41.1	56.8/43.2	50.9/49.1	44.93†	<0.001
Causes of CKD (%)								497.59†	<0.001
DN	13.7	2.5	7.2	14.1	19.5	17.7	17.6		
GN	59.2	93.7	82.3	51.8	44.0	45.6	49.7		
HN	14.2	0.9	4.7	17.7	18.5	21.0	17.2		
Other	13.0	2.9	5.8	16.4	18.1	15.6	15.7		
Smoking status (%)								34.15†	<0.001
Former	19.8	15.8	14.6	19.7	21.2	24.8	17.2		
Current	18.3	17.6	17.3	20.7	19.7	16.7	16.3		
Never	61.9	66.7	68.0	59.6	59.0	58.5	66.0		
SBP (mmHg)	129.3 ± 17.6	119.2 ± 13.0	124.2 ± 15.4	129.7 ± 16.6	131.9 ± 17.2	134.7 ± 18.3	138.7 ± 20.0	64.89*	<0.001
DBP (mmHg)	80.8 ± 10.8	76.9 ± 9.2	79.0 ± 9.6	81.3 ± 10.8	81.7 ± 10.8	82.8 ± 11.0	84.5 ± 12.8	23.76*	<0.001
Creatinine (μmol/L)	170.8 ± 126.6	68.5 ± 12.1	97.2 ± 13.9	128.5 ± 14.9	164.6 ± 23.0	251.3 ± 50.5	483.9 ± 350.9	837.93*	<0.001
eGFR (ml·min^{-1}·1.73 m^{-2})	51.8 ± 33.1	115.9 ± 23.9	74.0 ± 8.8	51.7 ± 4.3	37.3 ± 4.3	22.6 ± 4.2	11.5 ± 3.1	6051.01*	<0.001
Albumin (g/L)	38.9 ± 7.2	36.0 ± 8.7	39.3 ± 7.9	40.0 ± 6.7	39.6 ± 6.7	38.8 ± 6.4	38.9 ± 6.8	18.15*	<0.001
FBG (mmol/L)	4.91 (4.40–5.58)	4.75 (4.28–5.26)	4.88 (4.33–5.41)	5.05 (4.47–5.75)	5.00 (4.45–5.81)	4.91 (4.41–5.58)	4.97 (4.56–5.56)	47.45‡	<0.001
TC (mmol/L)	4.75 (3.92–5.81)	4.97 (4.07–6.30)	4.95 (4.12–6.20)	4.81 (3.96–5.80)	4.73 (3.90–5.80)	4.52 (3.74–5.51)	4.44 (3.61–5.53)	51.83‡	<0.001
HDL-C (mmol/L)	1.07 (0.89–1.31)	1.20 (0.98–1.46)	1.09 (0.90–1.33)	1.04 (0.86–1.23)	1.05 (0.88–1.29)	1.04 (0.86–1.29)	1.06 (0.88–1.27)	61.99‡	<0.001
LDL-C (mmol/L)	2.57 (2.05–3.23)	2.81 (2.19–3.67)	2.70 (2.16–3.34)	2.55 (1.97–3.16)	2.51 (2.03–3.18)	2.48 (1.99–3.10)	2.44 (1.92–2.99)	52.81‡	<0.001
TG (mmol/L)	1.79 (1.27–2.61)	1.62 (1.13–2.46)	1.76 (1.19–2.63	1.86 (1.33–2.63)	1.87 (1.35–2.73)	1.77 (1.31–2.55)	1.90 (1.34–2.73)	22.33‡	<0.001
iPTH (pg/ml)								780.45‡	<0.001
Mean ± SD	63.6 ± 61.9	31.4 ± 15.4	38.6 ± 20.8	48.2 ± 28.1	60.3 ± 40.8	89.8 ± 62.6	168.0 ± 152.3		
Meidan (IQR)	46.8 (30.0–74.6)	27.7 (20.8–39.1)	35.2 (24.4–47.5)	42.9 (29.5–59.0)	49.8 (33.7–75.2)	73.4 (48.9–111.9)	116.9 (74.9–204.8)		
Ca (mmol/L)								43.08‡	<0.001
Mean ± SD	2.29 ± 0.17	2.28 ± 0.13	2.29 ± 0.15	2.29 ± 0.18	2.30 ± 0.19	2.28 ± 0.16	2.24 ± 0.21		
Meidan (IQR)	2.29 (2.21–2.37)	2.28 (2.21–2.35)	2.29 (2.22–2.37)	2.30 (2.23–2.38)	2.31 (2.22–2.39)	2.28 (2.21–2.37)	2.22 (2.15–2.32)		
Phosphorus (mmol/L)								273.50‡	<0.001
Mean ± SD	1.22 ± 0.34	1.20 ± 0.24	1.18 ± 0.39	1.15 ± 0.36	1.18 ± 0.28	1.29 ± 0.33	1.48 ± 0.40		
Meidan (IQR)	1.18 (1.05–1.33)	1.19 (1.06–1.31)	1.13 (1.02–1.25)	1.11 (1.00–1.26)	1.16 (1.02–1.30)	1.26 (1.10–1.41)	1.46 (1.24–1.63)		
MBD drugs, n/N (%)									
PB	353/1752 (20.1)	–	–	69/416 (16.6)	118/610 (19.3)	128/592 (21.6)	38/134 (28.4)	9.94†	0.019
VD	303/1752 (17.3)	–	–	46/416 (11.1)	91/610 (14.9)	120/592 (20.3)	46/134 (34.3)	44.57†	<0.001
LVH, n/N (%)	293/2219 (13.2)	27/351 (7.7)	42/395 (10.6)	36/332 (10.8)	87/511 (17.0)	84/518 (16.2)	17/112 (15.2)	24.19†	<0.001
AAC, n/N (%)	223/2280 (9.8)	14/374 (3.7)	20/402 (5.0)	42/358 (11.7)	69/515 (13.4)	63/519 (12.1)	15/112 (13.4)	40.08†	<0.001

*Analysis of variance, F value; †Chi-square test, χ^2 value; ‡Kruskal-Wallis test, H value. –: Not applicable; DN: Diabetic nephropathy; GN: Glomerulonephritis; HN: Hypertensive nephropathy; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; eGFR: Estimated glomerular filtration rate; ALB: Serum albumin; FBG: Fasting blood glucose; TC: Total cholesterol; HDL-C: High-density lipoprotein-cholesterol; LDL-C: Low-density lipoprotein-cholesterol; TG: Triglycerides; iPTH: Intact parathyroid hormone; Ca: Serum albumin-corrected calcium; IQR: Interquartile range; SD: Standard deviation; MBD: Mineral and bone disorder; PB: Phosphate-binder; VD: Vitamin D_3; LVH: Left ventricular hypertrophy; AAC: Abdominal aortic calcification; CKD: Chronic kidney disease.

Table 2: Achievement of phosphorus, calcium, and iPTH target according to KDIGO clinical practice guideline

Parameters	Stages 3–5 (n = 3194)	Stage 3a (n = 525)	Stage 3b (n = 769)	Stage 4 (n = 767)	Stage 5 (n = 159)	χ^2	P
Phosphorus <0.96 mmol/L (%)	11.7	17.1	14.5	7.2	1.9	185.13	<0.001
0.96 mmol/L ≤ Phosphorus ≤1.62 mmol/L (%)	82.4	80.3	82.6	85.9	71.0		
Phosphorus >1.62 mmol/L (%)	5.9	2.6	2.9	6.8	27.1		
Ca <2.12 mmol/L (%)	9.6	8.7	7.6	10.7	17.0	24.45	<0.001
2.12 mmol/L ≤ Ca ≤2.75 mmol/L (%)	89.4	90.9	91.4	88.3	79.7		
Ca >2.75 mmol/L (%)	1.0	0.4	1.0	1.0	3.3		
iPTH <15 pg/ml (%)	3.0	4.0	3.5	1.7	3.6	288.64	<0.001
15 pg/ml ≤ iPTH ≤65 pg/ml (%)	54.1	78.1	62.1	39.4	13.0		
iPTH >65 pg/ml (%)	42.9	17.9	34.3	58.8	83.3		
Meeting all three parameters (%)	35.0	50.9	41.6	23.2	7.5	139.50	<0.001

Ca: Serum albumin-corrected calcium; iPTH: Intact parathyroid hormone; KDIGO: Kidney Disease: Improving Global Outcomes.

Table 3: Odds ratio for the association between serum phosphorus and cardiovascular markers

Model	AAC (n = 2280)		LVH (n = 2219)	
	OR (95% *CI*)	*P*	*OR* (95% *CI*)	*P*
Model 1	1.37 (0.92–2.02)	0.120	1.59 (1.19–2.02)	0.002
Model 2	1.59 (1.01–2.51)	0.050	1.51 (1.08–2.11)	0.020
Model 3	1.99 (1.11–3.56)	0.020	2.11 (1.26–3.22)	0.003

Model 1: Age, gender, and phosphorus; Model 2: Model 1 + estimated glomerular filtration rate, smoking status, fasting blood glucose, high-density lipoprotein-cholesterol, systolic blood pressure; Model 3: Model 2 + serum albumin, serum albumin-corrected calcium, intact parathyroid hormone, phosphate-binder, Vitamin D3. AAC: Abdominal aortic calcification; LVH: Left ventricular hypertrophy; *OR*: Odds ratio; *CI*: Confidence interval.

calcification.[19] Thus, despite it is lower sensitive than electron-beam computed tomography (EBCT) or multislice computed tomography (MSCT), the lateral abdominal X-ray could be used as a more easily available technique to detect the presence of VC.[5] Our study showed a relatively low prevalence of VC compared with studies involving Caucasian CKD patients, which have reported 32% prevalence in Spain predialysis Stages 3–4 CKD patients.[20] While in another study involving 96 Chinese nondiabetic and nondialysis CKD Stages 3–5 patients,[21] which serum phosphorus value was similar to our study, showed a lower presence of VC at a percentage of 27%. Considering the latter study assessed multisite VC in abdomen, pelvis, and hands, and we only detected the VC in abdominal aorta, the participates in China might have a lower incidence of VC compared with that of Caucasian CKD patients. Whether multisite VC measurements are better than the lateral abdominal X-ray in Chinese CKD population, further studies with higher sensitivity measurement were needed to validate this opinion.

The associations of serum phosphorus concentrations with LVM were conducted in many previous studies, while most studies are based on general population. The Framingham Offspring Study[22] reported an association between echocardiography LVH and serum phosphorus in a prospective study of 3300 participants free of heart failure and CKD showed that each 10 mg/L increment in serum phosphorus was associated with a 1.74-fold risk of heart failure (95% *CI*: 1.17–2.59). Furthermore, in Multi-Ethnic Study of Atherosclerosis study,[23] involving 4494 participates without any previous diagnosis of cardiovascular disease, indicated that each quintile increase in the estimated dietary phosphate intake was associated with an estimated 1.06 g (95% *CI*: 0.50–1.62 g) greater LVM. Studies on the association between phosphorus and LVH in CKD population are limited. Chue *et al*.[24] used cardiovascular magnetic resonance imaging (MRI) to demonstrate a correlation between serum phosphorus and LVMI in 208 nondiabetic patients with CKD Stages 2–4 (mean serum phosphorus 1.1 mmol/L). Our study lends further support to this findings, indicating that phosphorus had an influence on cardiovascular structure among all stages of predialysis CKD even when the majority of patients were within the recommendation of KDIGO guidelines.[5] The association between serum phosphorus and LVH in CKD patients may be due to the following two categories: first, VC and arterial stiffness caused by hyperphosphatemia reduced large-vessel compliance[25] which increased after a load of heart. Second, the toxic effects of phosphorus on myocardial cells may be the cause of cardiomyocyte hypertrophy and interstitial cell proliferation, rather than cardiomyocyte proliferation.[26] Of note, the FGF23,[8] an early marker of phosphate load, could also significantly elevate the incidence of LVH. The relationship between LVH and serum phosphorus level is complicated and also represents an area worthy of future study.

Our study has several limitations that deserve to mention. First, this study was based on a cross-section data and therefore we could not make causal inference. Second, several biomarkers and information related to the MBD were not available in our study, such as 25-dihydroxyvitamin D, fractional excretion of phosphate, FGF23, as well as diet habits; therefore, we cannot evaluate their effect on cardiovascular disease as confounding factors. Third, cardiovascular parameters measurements are not available to the entire cohort. Lastly, EBCT/MSCT that assesses VC was not available at our center due to resource limitations. The lack of a sensitive imaging modality may partly explain the low prevalence of AAC in the study population.

In conclusion, our study revealed that in Chinese patients with CKD, the percentage of hyperphosphatemia is comparable to reports from other countries, and levels of phosphorus are independently associated with cardiovascular markers including AAC and LVH. Considering the suboptimal usage of PBs in Chinese patients with CKD, nephrologists should pay more attention on the management of MBD. The prevalence of VC evaluated by the lateral abdominal X-ray in Chinese patients is relatively lower compared with the Caucasian populations, which needs to be validated in other cohorts based on Chinese patients. Further longitudinal studies with comprehensive information of MBD and hard end points were needed to evaluate the association between mineral metabolism disorder and cardiovascular disease.

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Conflicts of interest

There are no conflicts of interest.

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