Research Square

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Clinical Correlates of Lumbar Quantitative Computed Tomography- Derived Bone Mineral Density in Maintenance Hemodialysis Patients

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Research Article

Keywords: maintenance hemodialysis, quantitative computed tomography, bone mineral density, chronic kidney disease-mineral and bone disorder, cross-sectional study

Posted Date: November 24th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11587710/v1

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Additional Declarations: No competing interests reported.

Abstract

Purpose

To evaluate associations between lumbar quantitative computed tomography-derived bone mineral density (QCT-BMD) and routinely collected clinical variables in patients receiving maintenance hemodialysis (MHD).

Methods

This retrospective single-center cross-sectional study included 156 patients receiving regular hemodialysis who underwent abdominal or lumbar computed tomography between January 2020 and June 2023. The mean QCT-BMD of L1-L5 was the study outcome. Associations were summarized using Spearman rank correlation coefficients with available-case analysis. To address multiple testing across 20 correlations, P values were adjusted using the Benjamini-Hochberg false discovery rate procedure.

Results

Ninety participants (57.7%) were classified as having normal bone mass, 34 (21.8%) as having osteopenia, and 32 (20.5%) as having osteoporosis. After false discovery rate adjustment, QCT-BMD was inversely associated with age (rho = -0.570, P < 0.0001, q < = 0.002) and eGFR (rho = -0.298, P = 0.0002, q = 0.002), and positively associated with NT-proBNP (rho = 0.252, P = 0.001, q = 0.007) and uric acid (rho = 0.208, P = 0.009, q = 0.045). Serum phosphorus and intact parathyroid hormone were not significant after adjustment.

Conclusion

In this exploratory cohort, age, eGFR, NT-proBNP, and uric acid were associated with lumbar QCT-BMD. These cross-sectional findings do not establish causality and warrant prospective validation.

1 Introduction

Chronic kidney disease (CKD) is a major cause of morbidity worldwide. In China, the Global Burden of Disease 2023 analysis estimated that approximately 156 million people were living with CKD in 2023 [1]. Disturbances in mineral metabolism, bone turnover, and skeletal strength are common as CKD advances and form part of chronic kidney disease mineral and bone disorder (CKD-MBD) [2, 3].

Patients receiving dialysis have a higher risk of hip and nonvertebral fracture than people without advanced CKD [4, 5]. Fractures are clinically important because they are associated with disability, hospitalization, and mortality [6]. The 2017 Kidney Disease Improving Global Outcomes guideline

recommends bone mineral density testing in patients with CKD G3a-G5D when results will affect treatment decisions, while emphasizing that bone mineral density does not identify the type of renal osteodystrophy [2].

Dual-energy X-ray absorptiometry predicts fracture risk in CKD, but lumbar measurements may be influenced by degenerative change and calcification. Quantitative computed tomography (QCT) provides volumetric assessment of trabecular bone and may provide information that differs from areal measurements obtained by dual-energy X-ray absorptiometry [7–10]. Evidence for the clinical interpretation of lumbar QCT-BMD in MHD remains limited.

This study evaluated associations between lumbar QCT-BMD and routinely collected clinical and biochemical variables in patients receiving MHD. Because the design was cross-sectional, the objective was to identify associations rather than causal risk factors or treatment effects.

2 Materials and methods

2.1 Study design and participants

This retrospective single-center cross-sectional study reviewed adults receiving regular hemodialysis who underwent abdominal or lumbar computed tomography at Southwest Hospital, Army Medical University, between January 2020 and June 2023. Patients were eligible when computed tomography images were suitable for lumbar QCT assessment and the clinical record contained the variables required for the planned analysis. Records with unusable images or missing primary-outcome data were excluded. For individual covariates, analyses used all available observations; therefore, the denominator varied by variable.

2.2 Quantitative computed tomography

Computed tomography examinations were performed as part of routine clinical care. Images of L1-L5 that were suitable for QCT analysis were evaluated using the radiology department's QCT workflow. Trabecular regions were assessed while avoiding cortical bone and focal structural abnormalities when possible, and the mean volumetric QCT-BMD across evaluable L1-L5 vertebrae was expressed in mg/cm³. In accordance with Chinese QCT criteria, values greater than 120 mg/cm³ were classified as normal bone mass, values from 80 to 120 mg/cm³ as osteopenia, and values below 80 mg/cm³ as osteoporosis [15].

2.3 Clinical and laboratory variables

Demographic and clinical variables were obtained from the electronic medical record. Laboratory measurements documented in temporal proximity to the computed tomography examination were abstracted according to routine clinical practice. Variables included age, sex, dialysis vintage, body size, hypertension, diabetes mellitus, serum calcium, phosphorus, magnesium, uric acid, bicarbonate, albumin, alkaline phosphatase, hemoglobin, platelet count, intact parathyroid hormone (iPTH), N-terminal

pro-B-type natriuretic peptide (NT-proBNP), fasting blood glucose, triglycerides, and estimated glomerular filtration rate (eGFR).

2.4 Statistical analysis

Continuous variables are presented as median (interquartile range), and categorical variables as number (percentage). The primary association analysis used Spearman rank correlation because most continuous variables were summarized using medians and interquartile ranges and several biomarkers were strongly right-skewed. Each analysis used available cases, and the sample size is reported for every coefficient. Twenty correlations with QCT-BMD were evaluated. To limit false-positive findings, the Benjamini-Hochberg procedure controlled the false discovery rate at 5%. Pearson analyses and correlations performed after stratifying by the QCT-BMD outcome were not included in the primary analysis because of duplication, range restriction, and multiple testing. No multivariable model was specified because a parsimonious covariate set had not been prespecified. All tests were two-sided. Statistical analyses were performed using SAS 9.4.

3 Results

3.1 Participant characteristics

The study included 156 participants, comprising 94 men and 62 women. Ninety participants (57.7%) had normal bone mass, 34 (21.8%) had osteopenia, and 32 (20.5%) had osteoporosis. Baseline values are shown descriptively in Table 1.

Table 1
Baseline characteristics by QCT-BMD category

Characteristic	Overall	Osteopenia	Normal	Osteoporosis
	N = 156	N = 34	N = 90	N = 32
Age, years	53.00 (40.00, 68.00)	64.50 (55.00, 71.00)	44.00 (34.00, 54.00)	70.50 (63.25, 75.75)
Serum calcium, mmol/L	2.18 (2.00, 2.32)	2.22 (2.01, 2.33)	2.16 (2.02, 2.31)	2.19 (1.97, 2.33)
Serum phosphorus, mmol/L	1.84 (1.47, 2.27)	2.04 (1.57, 2.45)	1.91 (1.50, 2.34)	1.55 (1.16, 1.96)
iPTH, pg/mL	191.45 (101.58, 361.35)	220.25 (106.40, 378.40)	216.70 (125.50, 435.10)	100.77 (47.90, 186.90)
NT-proBNP, pg/mL	8,560 (2,169, 34,027)	15,200 (2,226, 27,863)	9,288 (2,600, 35,000)	5,941 (1,550, 11,700)
Serum albumin, g/L	35.05 (30.08, 40.13)	35.60 (32.35, 40.28)	36.10 (30.00, 40.30)	32.45 (28.45, 36.95)
Serum magnesium, mmol/L	0.93 (0.82, 1.01)	0.96 (0.83, 1.06)	0.93 (0.82, 1.00)	0.89 (0.80, 1.01)
eGFR, mL/min/1.73 m²	6.34 (4.47, 8.89)	6.29 (4.81, 9.15)	5.69 (4.20, 7.23)	7.92 (6.07, 12.17)
Uric acid, micromol/L	430.33 (348.68, 567.41)	401.77 (346.14, 457.66)	464.56 (362.78, 620.75)	395.88 (332.49, 465.75)
Bicarbonate, mmol/L	19.30 (15.98, 22.64)	18.12 (15.93, 24.09)	19.30 (15.70, 22.45)	20.10 (17.15, 22.55)
Alkaline phosphatase, IU/L	82.60 (65.53, 116.00)	80.38 (69.08, 111.33)	86.50 (66.03, 118.45)	80.10 (60.95, 99.93)
Height, cm	160.00 (157.00, 168.00)	165.00 (160.00, 170.00)	160.00 (158.00, 168.75)	160.00 (153.75, 163.00)
Body weight, kg	58.00 (50.00, 65.00)	59.00 (53.25, 68.75)	58.00 (50.00, 65.00)	58.00 (50.75, 63.00)
Platelet count, x10^9/L	159.50 (112.75, 216.00)	154.00 (121.75, 196.75)	165.00 (122.00, 213.75)	151.00 (91.25, 235.25)
Hemoglobin, g/L	87.00 (73.75, 109.00)	102.50 (80.50, 119.75)	87.00 (73.25, 104.75)	82.50 (67.75, 97.25)
QCT-BMD, mg/cm³	129.30 (95.80, 164.70)	102.30 (94.80, 110.58)	159.60 (136.00, 182.20)	68.45 (53.50, 77.85)

Characteristic	Overall N = 156	Osteopenia N = 34	Normal N = 90	Osteoporosis N = 32
Fasting blood glucose, mmol/L	5.59 (5.00, 7.19)	5.43 (4.99, 7.45)	5.62 (5.13, 7.00)	6.10 (4.90, 7.18)
Triglycerides, mmol/L	1.60 (1.08, 2.25)	1.29 (0.80, 2.31)	1.72 (1.16, 2.36)	1.43 (1.15, 1.82)
Dialysis vintage, months	3.00 (1.00, 24.00)	1.00 (0.00, 10.50)	4.00 (1.00, 26.00)	6.50 (1.00, 36.25)
Sex, n (%)	Men 94 (60.3); women 62 (39.7)	-	-	-

Data are median (interquartile range) unless otherwise indicated. Group-specific sex counts and inferential group-comparison P values were not included in the available analytical summary. iPTH, intact parathyroid hormone; NT-proBNP, N-terminal pro-B-type natriuretic peptide; eGFR, estimated glomerular filtration rate; QCT-BMD, quantitative computed tomography derived bone mineral density.

3.2 Correlations with lumbar QCT-BMD

After false discovery rate adjustment, age and eGFR were inversely associated with QCT-BMD, while NT-proBNP and uric acid were positively associated with QCT-BMD (Table 2). Nominal associations for alkaline phosphatase did not remain significant after adjustment. Serum phosphorus, iPTH, diabetes mellitus, and dialysis vintage were not associated with QCT-BMD after false discovery rate adjustment.

Table 2
Spearman correlations with lumbar QCT-BMD

Variable	rho	P value	FDR q value	N
Age	-0.570	< 0.0001	<=0.002	156
Serum calcium	0.046	0.560	0.700	156
Serum phosphorus	0.153	0.056	0.160	156
iPTH	0.143	0.075	0.173	154
NT-proBNP	0.252	0.001	0.007	148
Serum albumin	0.011	0.891	0.938	156
Serum magnesium	0.023	0.774	0.860	156
Diabetes mellitus	-0.155	0.052	0.160	156
eGFR	-0.298	0.0002	0.002	155
Uric acid	0.208	0.009	0.045	156
Alkaline phosphatase	0.176	0.0277	0.111	156
Height	0.053	0.507	0.676	156
Body weight	-0.081	0.310	0.564	156
Platelet count	0.071	0.374	0.623	156
Hemoglobin	-0.029	0.719	0.846	156
Hypertension	0.062	0.440	0.629	156
Fasting blood glucose	0.001	0.993	0.993	143
Triglycerides	0.144	0.087	0.174	141
Dialysis vintage	-0.140	0.078	0.173	156
Bicarbonate	0.066	0.406	0.625	156

FDR q values were calculated using the Benjamini-Hochberg procedure across 20 tests. The age P value was reported as P < 0.0001; q < = 0.002 is therefore shown conservatively. FDR, false discovery rate.

4 Discussion

In this exploratory cross-sectional cohort, older age and a higher eGFR were associated with lower lumbar QCT-BMD, whereas NT-proBNP and uric acid were associated with higher QCT-BMD after false discovery rate adjustment. The analysis does not establish directionality, biological mechanism, or clinical utility.

The inverse association with age is consistent with established age-related loss of bone mass and deterioration of trabecular structure [11]. The magnitude of the age correlation was greater than that of the other reported variables, but the cross-sectional design prevents estimation of within-person bone loss over time.

The positive association between uric acid and QCT-BMD is consistent with observations in some non-CKD populations [12, 13]. In advanced CKD, however, uric acid reflects reduced renal clearance, medications, nutrition, and comorbidity. The present result should therefore be considered hypothesis-generating rather than evidence of a protective effect.

The positive association with NT-proBNP was unexpected. NT-proBNP concentrations in hemodialysis are influenced by cardiac function, volume status, dialysis timing, and residual kidney function. This finding should not be interpreted as evidence that higher NT-proBNP concentrations protect bone and requires confirmation in studies with standardized sampling.

The inverse association between eGFR and QCT-BMD also requires cautious interpretation. In patients already receiving MHD, a creatinine-based eGFR is not interchangeable with measured residual kidney function. Residual kidney function is clinically important but is usually assessed using timed urine clearances rather than a routine creatinine-based equation [14].

Serum phosphorus and iPTH were not significant after false discovery rate adjustment. This does not diminish their established role in CKD-MBD management, which is based on serial evaluation of calcium, phosphate, PTH, alkaline phosphatase, clinical context, and treatment exposure rather than a single cross-sectional correlation with BMD [2, 3].

This study has several limitations. It was retrospective and conducted at one center, creating risks of selection bias and residual confounding. The sample was modest, and some variables were missing. Exact laboratory timing relative to computed tomography and dialysis was not consistently available. Detailed scanner-level acquisition, calibration, software, and reproducibility metadata were not retained in the analytical summary. The study evaluated BMD rather than incident fractures and cannot support claims about fracture prevention, dynamic monitoring, or treatment effects.

5 Conclusion

Age, eGFR, NT-proBNP, and uric acid were associated with lumbar QCT-BMD in this exploratory MHD cohort after false discovery rate adjustment. These findings require prospective validation and should not be interpreted as causal relationships or used alone to guide treatment.

Declarations

Author contributions

Conceptualization: Pan Xie, Kanfu Peng. Methodology: Shaohua Li, Pan Xie, Kanfu Peng. Data curation: Shaohua Li, Yuting Wang, Huan Chang, Qian Yuan, Yan Zhuo. Investigation: Shaohua Li, Yuting Wang, Huan Chang, Qian Yuan, Yan Zhuo, Zuhai Hu. Formal analysis: Shaohua Li, Hongwen Zhao. Visualization: Shaohua Li, Yuting Wang. Funding acquisition: Pan Xie. Project administration: Pan Xie. Supervision: Pan Xie, Kanfu Peng. Writing original draft: Shaohua Li. Writing review and editing: Pan Xie, Kanfu Peng. All authors approved the final manuscript.

Ethics approval

This retrospective study was approved by the Ethics Committee of Southwest Hospital, Army Medical University (Approval No. KY2025140) and was conducted in accordance with the Declaration of Helsinki and its later amendments.

Consent to participate

The requirement for informed consent was waived by the Ethics Committee because of the retrospective design.

Funding

This study was supported by the Investigator-Initiated Trial Project (Grant No. 2024IITZDB08), the Natural Science Foundation of Chongqing, China (Grant No. CSTB2023NSCQ-MSX0570), and the Chongqing Appropriate Health Technology Promotion Project (Grant No. 2025JSTG031).

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Data availability

The datasets generated or analyzed during this study are not publicly available because they contain potentially identifiable patient information but may be available from the corresponding author on reasonable request and subject to institutional approval.

Acknowledgements

The authors thank the staff of the Departments of Nephrology and Radiology, Southwest Hospital, Army Medical University, for support with data collection and imaging assessment.

Generative AI statement

During preparation of this manuscript, the authors used ChatGPT (OpenAI) solely for language and copy editing, including improvements to the readability, grammar, style, and formatting of author-written text. The tool was not used to generate or analyze study data, produce results, or formulate scientific conclusions. All authors reviewed and approved the final text and take full responsibility for the content.

Clinical trial number

Not applicable.

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