Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Biopsy-Anchored Clinical Phenotyping and Renal Outcomes in Phosphate Nephropathy: A 47-Patient Cohort Study

Meryem Keleş

meryem.keles@sbu.edu.tr

Ankara Bilkent City Hospital

Aysel Çolak

Ankara Bilkent City Hospital

Burak Aslum

Ankara Bilkent City Hospital

Emre Çankaya

Ankara Bilkent City Hospital

Müge Üzerk Kibar

Ankara Bilkent City Hospital

Şimal Köksal Cevher

Ankara Bilkent City Hospital

Fatih Yılmaz

Antalya Şehir Hastanesi

Ezgi Coşkun Yenigün

Ankara Bilkent City Hospital

Fatih Dede

Ankara Bilkent City Hospital

Research Article

Keywords: Phosphate nephropathy, acute phosphate nephropathy, oral sodium phosphate, acute kidney injury, chronic kidney disease, nephrocalcinosis, kidney biopsy

Posted Date: July 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10164020/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Phosphate nephropathy (PN) is a crystal-induced tubulointerstitial kidney injury classically associated with oral sodium phosphate (OSP) bowel preparation. Although biopsy-confirmed PN has been well described, the clinical relevance and long-term renal outcomes of patients diagnosed without histological confirmation remain less clearly defined. We aimed to compare the clinical characteristics and renal outcomes of biopsy-confirmed and clinically probable PN and to assess whether PN represents a delayed acute kidney injury-to-chronic kidney disease (AKI-to-CKD) syndrome.

Methods

We conducted a single-center retrospective cohort study including 47 patients diagnosed with PN after OSP exposure between 2019 and 2026. Nineteen patients had biopsy-confirmed native kidney PN, whereas 28 were classified as clinically probable PN based on a compatible temporal relationship between OSP exposure and kidney dysfunction after exclusion of alternative etiologies. Demographic characteristics, comorbidities, laboratory parameters, histopathological findings, and long-term renal outcomes were analyzed. Persistent renal dysfunction was defined as a final estimated glomerular filtration rate (eGFR) below 60 mL/min/1.73 m² without recovery. Severe renal outcome was defined as a final eGFR below 30 mL/min/1.73 m² and/or the need for kidney replacement therapy.

Results

The mean age of the cohort was 64.2 ± 9.5 years, and 61.7% of patients were female. Diabetes mellitus and hypertension were present in 53.2% and 85.1% of patients, respectively. Histologically, all biopsy-confirmed cases showed intratubular calcium-phosphate crystal deposition confirmed by positive von Kossa staining. Renal recovery occurred in only 5 patients (10.6%). Persistent renal dysfunction developed in 42 of 47 patients (89.4%), while severe renal outcomes occurred in 14 patients (29.8%). The prevalence of persistent renal dysfunction was nearly identical between the biopsy-confirmed and clinically probable PN groups (89.5% vs. 89.3%). However, severe renal outcomes were significantly more frequent in biopsy-confirmed PN (57.9% vs. 10.7%, p = 0.001). Exploratory analyses showed that severe renal outcomes were significantly associated with biopsy-confirmed PN (p = 0.0009), higher first post-exposure serum creatinine (p = 0.034), higher urine protein-to-creatinine ratio (p = 0.0007), higher parathyroid hormone levels (p = 0.038), and lower vitamin D levels (p = 0.0037).

Conclusions

Phosphate nephropathy is associated with a high burden of persistent kidney dysfunction and frequently follows a delayed AKI-to-CKD trajectory. Clinically probable PN cases showed long-term renal outcomes comparable to biopsy-confirmed disease, suggesting that PN may be substantially underrecognized in routine clinical practice. Given the largely preventable nature of OSP-associated kidney injury, greater awareness and careful post-exposure monitoring are warranted, particularly in high-risk populations.

Introduction

Colonoscopy remains an essential procedure for the screening and diagnosis of colorectal diseases, and its diagnostic yield is closely dependent on the adequacy of bowel preparation (1). Since the 1990s, oral sodium phosphate (OSP) solutions have been widely adopted as an alternative to polyethylene glycol-based regimens because they require a lower ingestion volume, are generally better tolerated by patients, and provide effective bowel cleansing (1,2). However, despite these practical advantages, OSP is not without risk. Rapid intestinal phosphate absorption may lead to marked hyperphosphatemia, particularly in susceptible individuals, and can precipitate a distinctive pattern of iatrogenic kidney injury that was first characterized histologically by Desmeules and colleagues (1,3).

The pathogenesis of acute phosphate nephropathy (APN) is primarily driven by an excessive phosphate load, which leads to hyperphosphatemia and volume depletion caused by osmotic fluid shifts into the intestinal lumen (2). Increased serum phosphate levels stimulate parathyroid hormone (PTH) secretion, thereby decreasing proximal tubular phosphate reabsorption and increasing the calcium-phosphate burden delivered to the distal nephron (2,4). At the same time, hypovolemia reduces renal perfusion, slows tubular flow, and increases urinary concentration, creating conditions that favor calcium-phosphate precipitation within the distal tubules and collecting ducts (2,5). This intratubular crystal deposition leads to nephrocalcinosis, tubular epithelial injury, inflammation, and, over time, interstitial fibrosis. A definitive diagnosis requires kidney biopsy showing intratubular calcium-phosphate crystal deposits, usually confirmed by positive von Kossa staining (6–8).

One distinguishing feature of APN is the discrepancy between pathological certainty and routine clinical practice. Although kidney biopsy remains the diagnostic gold standard, particularly when calcium-phosphate crystal deposits are confirmed by von Kossa staining, many patients with suspected APN do not undergo biopsy. This may be due to advanced age, comorbidities, nonspecific urinary findings, or delayed recognition after the initial phosphate exposure. As a result, biopsy-confirmed cohorts may capture predominantly the more clinically evident or severe cases, whereas milder, subclinical, or unrecognized forms of APN are likely underrepresented.

Long-term renal outcomes are central to the clinical relevance of APN. Previous biopsy-based studies have shown that APN is often associated with incomplete recovery of kidney function and persistent chronic kidney impairment (1,9). Similarly, the Icelandic cohort reported an unfavorable renal prognosis, with some patients progressing to end-stage kidney disease or dying as a consequence of progressive renal failure (10). Taken together, these findings indicate that phosphate nephropathy should not be viewed simply as a transient biochemical abnormality, but rather as a delayed and potentially chronic complication that may evolve from acute kidney injury (AKI) to chronic kidney disease (CKD), representing a distinct AKI-to-CKD syndrome.

Despite increasing recognition of phosphate nephropathy, studies directly comparing biopsy-confirmed cases with clinically diagnosed probable cases remain scarce. In this study, we characterized a cohort of patients with biopsy-confirmed phosphate nephropathy and compared their clinical features, laboratory findings, and long-term renal outcomes with those of patients classified as having clinically probable

phosphate nephropathy. We also aimed to evaluate whether phosphate nephropathy, irrespective of its diagnostic pathway or mode of presentation, represents a delayed AKI-to-CKD syndrome.

Materials and Methods

Study Design and Patient Selection

This single-center, retrospective observational cohort study included 47 patients diagnosed with phosphate nephropathy between 2019 and 2026. During the study period, 1,425 native kidney biopsies were performed; among these, 19 patients were identified as having biopsy-confirmed phosphate nephropathy. An additional 28 patients were classified as having clinically probable phosphate nephropathy.

All included patients had undergone bowel preparation with the oral sodium phosphate (OSP) formulation Fleet® Phospho-soda (Prestige Consumer Healthcare, formerly C.B. Fleet Company, Inc., Lynchburg, VA, USA) before colonoscopy. Each 45-mL dose contains 24.4 g of monobasic sodium phosphate monohydrate and 10.8 g of dibasic sodium phosphate heptahydrate, corresponding to a total phosphate salt content of 35.2 g per dose. The standard split-dose regimen, consisting of two doses administered approximately 10–12 hours apart, therefore delivers a cumulative phosphate salt load of approximately 70.4 g, equivalent to about 20.16 g of elemental phosphorus.

Clinical suspicion of phosphate nephropathy was based on acute or chronic deterioration in kidney function occurring in temporal association with colonoscopy. For all patients, repeated urinalyses were reviewed to assess the presence of proteinuria and hematuria. Proteinuria was quantified using either the spot urine protein-to-creatinine ratio (UPCR) or 24-hour urinary protein excretion. Relevant imaging studies were also reviewed to exclude urinary tract obstruction or other structural abnormalities. Patients with clinical or laboratory findings suggestive of systemic diseases that could independently affect kidney function were excluded.

Laboratory evaluation included serum creatinine, electrolytes including sodium, potassium, calcium, and phosphate, serum albumin, parathyroid hormone (PTH), 25-hydroxyvitamin D, and urinalysis. To exclude immune-mediated kidney diseases, complement levels (C3 and C4), antineutrophil cytoplasmic antibodies (ANCA), proteinase-3 (PR3), myeloperoxidase (MPO), and anti-double-stranded DNA (anti-dsDNA) antibodies were assessed. When clinically indicated, serum protein electrophoresis was performed to evaluate for plasma cell dyscrasia.

All patients had at least one serum creatinine measurement within three months before colonoscopy, which was considered the baseline value. The peak serum creatinine level after OSP exposure and the need for acute dialysis were recorded. Serum creatinine measured approximately six months after the procedure was also documented.

In biopsy-confirmed cases, phosphate nephropathy was diagnosed on the basis of a temporal relationship between phosphate-containing bowel preparation and subsequent renal dysfunction, together with characteristic histopathological findings. In patients who did not undergo kidney biopsy, clinically probable phosphate nephropathy was defined by renal dysfunction temporally associated with OSP exposure, supported by compatible clinical and laboratory features.

Histopathological findings considered diagnostic of phosphate nephropathy included intratubular calcium-phosphate crystal deposits, basophilic or calcified crystalline casts within tubular lumina, and non-birefringent calcified deposits on polarized light microscopy, along with positive von Kossa staining. Direct immunofluorescence findings and any concomitant glomerular pathologies were also recorded.

Demographic, clinical, laboratory, medication, biopsy, and follow-up data were retrospectively retrieved from patient records and the hospital electronic database. Collected variables included age, sex, diabetes mellitus, hypertension, coronary artery disease, pre-existing chronic kidney disease, mode of presentation, interval between phosphate exposure and diagnosis or biopsy, and total duration of follow-up.

For patients without a documented estimated glomerular filtration rate (eGFR), eGFR was calculated using the CKD-EPI equation based on serum creatinine, age, and sex. Serum creatinine values were reported in mg/dL.

Persistent renal dysfunction was defined as an eGFR below 60 mL/min/1.73 m² in the absence of renal recovery. A severe renal outcome was defined as a final eGFR below 30 mL/min/1.73 m² or progression to kidney replacement therapy during follow-up.

The study protocol was approved by the Institutional Ethics Committee of Ankara Bilkent City Hospital (Approval No: TABED 2/1262/2025; Date: May 28, 2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical Analysis

Statistical analyses were performed in the overall cohort of 47 patients. Patients with biopsy-confirmed phosphate nephropathy were compared with those classified as having clinically probable phosphate nephropathy in terms of demographic characteristics, clinical presentation, laboratory parameters, and renal outcomes.

The distribution of continuous variables was evaluated using visual inspection and appropriate normality tests. Normally distributed variables were reported as mean ± standard deviation (SD), whereas non-normally distributed variables were presented as median with interquartile range (IQR). Categorical variables were summarized as numbers and percentages.

Between-group comparisons were performed using Student’s t-test or the Mann–Whitney U test for continuous variables, as appropriate. Categorical variables were compared using the chi-square test or

Fisher’s exact test when expected cell counts were low. Missing data were excluded from the analysis of the relevant variable, and the number of available observations was reported where applicable.

Because persistent renal dysfunction was present in the majority of patients, the construction of a robust multivariable model to predict persistent kidney injury was not feasible. Therefore, factors potentially associated with severe renal outcomes were assessed using exploratory univariable analyses. Given the limited sample size, multivariable analyses were restricted, and the results should be interpreted as hypothesis-generating. A two-sided p value of <0.05 was considered statistically significant.

Results

The primary comparative cohort included 47 patients with phosphate nephropathy (PN). Among them, 19 patients (40.4%) had biopsy-confirmed PN, while 28 patients (59.6%) were classified as having clinically probable PN.

The mean age of the overall cohort was 64.2 ± 9.5 years. Twenty-nine patients (61.7%) were female and 18 (38.3%) were male. Before colonoscopy, diabetes mellitus was present in 25 patients (53.2%), hypertension in 40 patients (85.1%), and pre-existing chronic kidney disease in 8 patients (17.0%) (Table 1).

Use of medications that may modify renal risk was frequent. At the time of phosphate exposure, 25 patients (54.3%) were receiving diuretics, 30 (63.8%) were treated with angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, and 4 patients (8.5%) were receiving sodium-glucose cotransporter-2 inhibitors (Table 1).

Table 1. Baseline Demographic, Clinical, and Renal Outcome Characteristics of the Overall Cohort (n = 47)

Variable	Overall Cohort (n=47)
Biopsy-confirmed PN	19 (40.4)
Clinically probable PN	28 (59.6)
Age, years	64.2 ± 9.5
Female sex	29 (61.7)
Diabetes mellitus	25 (53.2)
Hypertension	40 (85.1)
Pre-existing CKD	8 (17.0)
Diuretic use	25/46 (54.3)
ACEi/ARB use	30 (63.8)
SGLT2 inhibitor use	4 (8.5)
Renal recovery	5 (10.6)
Persistent renal dysfunction (eGFR <60 mL/min/1.73 m²)	42 (89.4)
Severe renal outcome (eGFR <30 mL/min/1.73 m² or KRT)	14 (29.8)

Abbreviations: *PN, phosphate nephropathy; CKD, chronic kidney disease; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; SGLT2, sodium-glucose cotransporter-2; eGFR, estimated glomerular filtration rate; KRT, kidney replacement therapy.*

Data are presented as mean ± standard deviation or n (%). Persistent renal dysfunction was defined as eGFR <60 mL/min/1.73 m² at last follow-up. Severe renal outcome was defined as eGFR <30 mL/min/1.73 m² or the need for kidney replacement therapy.

Comparison Between Biopsy-Confirmed PN and Clinically Probable PN

The biopsy-confirmed phosphate nephropathy (PN) group included 19 patients, whereas the clinically probable PN group comprised 28 patients. The mean age was 60.2 ± 8.1 years in the biopsy-confirmed group and 67.0 ± 9.5 years in the clinically probable group. Patients with biopsy-confirmed PN were significantly younger than those with clinically probable PN ($p = 0.020$).

Female sex was observed in 13 of 19 patients (68.4%) in the biopsy-confirmed group and in 16 of 28 patients (57.1%) in the clinically probable group, without a statistically significant difference. Diabetes mellitus was present in 12 patients (63.2%) in the biopsy-confirmed group and in 13 patients (46.4%) in the clinically probable group. Hypertension was documented in 15 of 19 patients (78.9%) and 25 of 28 patients (89.3%), respectively. Pre-existing chronic kidney disease before colonoscopy was present in 3 of 19 patients (15.8%) in the biopsy-confirmed group and in 5 of 28 patients (17.9%) in the clinically

probable group. No significant between-group differences were observed in diabetes mellitus, hypertension, or pre-existing chronic kidney disease (Table 2).

Exposure to medications associated with an increased risk of phosphate nephropathy was also broadly comparable between groups. Diuretic use was documented in 8 of 18 patients (44.4%) in the biopsy-confirmed group and in 17 of 28 patients (60.7%) in the clinically probable group. Angiotensin-converting enzyme inhibitor (ACEi) use was recorded in 4 of 19 patients (21.1%) and 8 of 28 patients (28.6%), respectively, whereas angiotensin receptor blocker (ARB) use was reported in 7 of 19 patients (36.8%) and 11 of 28 patients (39.3%), respectively. None of these medication-related variables differed significantly between the two groups (Table 2).

Overall, the biopsy-confirmed and clinically probable PN groups showed largely similar baseline demographic characteristics, comorbidity profiles, and exposure to recognized risk-modifying medications. Age was the only baseline variable that differed significantly between the groups.

Table 2. Comparison of Demographic Characteristics, Comorbidities, Clinical Presentation, and Renal Outcomes Between Patients With Biopsy-Confirmed and Clinically Probable Phosphate Nephropathy

Variable	Biopsy-confirmed PN (n=19)	Clinically Probable PN (n=28)	p value
Age, years	60.2 ± 8.1	67.0 ± 9.5	**0.020**
Female sex	13 (68.4)	16 (57.1)	0.546
Diabetes mellitus	12 (63.2)	13 (46.4)	0.373
Hypertension	15 (78.9)	25 (89.3)	0.417
Coronary artery disease	4/19 (21.1)	5/27 (18.5)	1.000
Pre-existing CKD	3 (15.8)	5 (17.9)	1.000
NSAID use	4/17 (23.5)	2/27 (7.4)	0.186
Diuretic use	8/18 (44.4)	17/28 (60.7)	0.367
ACEi or ARB use	11 (57.9)	19 (67.9)	0.546
SGLT2 inhibitor use	1 (5.3)	3 (10.7)	0.638
Hematuria	0 (0.0)	1 (3.6)	1.000
Proteinuria	6 (31.6)	6 (21.4)	0.506
AKI presentation	16 (84.2)	25 (89.3)	0.674
Renal recovery	2 (10.5)	3 (10.7)	1.000
Persistent renal dysfunction	17 (89.5)	25 (89.3)	1.000
Severe renal outcome	11 (57.9)	3 (10.7)	**0.001**

Data are presented as mean ± standard deviation or n (%). Comparisons were performed using Student's t-test, Mann–Whitney U test, χ^2 test, or Fisher's exact test, as appropriate.

Abbreviations: PN, phosphate nephropathy; CKD, chronic kidney disease; NSAID, nonsteroidal anti-inflammatory drug; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; SGLT2, sodium-glucose cotransporter-2; AKI, acute kidney injury.

Definitions: Persistent renal dysfunction was defined as failure to recover kidney function with a final eGFR <60 mL/min/1.73 m². Severe renal outcome was defined as a final eGFR <30 mL/min/1.73 m² and/or the need for kidney replacement therapy.

Comparison of Laboratory Findings

Baseline renal function parameters were generally comparable between the two groups. Mean baseline blood urea nitrogen was 33.2 ± 12.4 mg/dL in the biopsy-confirmed PN group and 41.8 ± 17.0 mg/dL in the clinically probable PN group. Mean baseline serum creatinine was 0.89 ± 0.42 mg/dL and 1.00 ± 0.31

mg/dL, respectively, and was significantly lower in the biopsy-confirmed group (p = 0.045). Mean baseline eGFR was 79.8 ± 26.0 mL/min/1.73 m² in the biopsy-confirmed group and 70.4 ± 18.6 mL/min/1.73 m² in the clinically probable group; however, this difference did not reach statistical significance (Table 3).

At the first post-exposure assessment, renal function parameters were similar between the groups. Mean serum creatinine was 2.79 ± 1.38 mg/dL in the biopsy-confirmed group and 2.76 ± 2.21 mg/dL in the clinically probable group. Mean blood urea nitrogen levels were 99.3 ± 45.5 mg/dL and 80.0 ± 32.3 mg/dL, respectively, with no statistically significant between-group difference (Table 3).

At the three-month assessment, serum creatinine and blood urea nitrogen levels remained numerically higher in the biopsy-confirmed group, although these differences were not statistically significant. Mean serum creatinine at three months was 2.07 ± 1.26 mg/dL in the biopsy-confirmed group compared with 1.45 ± 0.51 mg/dL in the clinically probable group. The corresponding blood urea nitrogen levels were 69.3 ± 43.1 mg/dL and 53.3 ± 17.4 mg/dL, respectively (Table 3).

Assessment of mineral metabolism parameters showed significantly higher parathyroid hormone (PTH) levels among patients with biopsy-confirmed PN. Mean PTH concentration was 117.2 ± 56.7 pg/mL in the biopsy-confirmed group and 91.5 ± 56.0 pg/mL in the clinically probable group (p = 0.045). Serum 25-hydroxyvitamin D levels tended to be lower in the biopsy-confirmed group, although this difference did not reach statistical significance (Table 3).

Urinalysis Findings and Proteinuria

Hematuria was not observed in any patient in the biopsy-confirmed PN group, whereas one patient (3.6%) in the clinically probable PN group had hematuria. Proteinuria was present in 6 of 19 patients (31.6%) in the biopsy-confirmed PN group and in 6 of 28 patients (21.4%) in the clinically probable PN group. Neither hematuria nor proteinuria differed significantly between the groups (p = 1.000 and p = 0.506, respectively). Overall, urinary findings were largely comparable between patients with biopsy-confirmed and clinically probable PN (Table 2).

Table 3. Renal Function Parameters in Biopsy-Confirmed and Clinically Probable Phosphate Nephropathy

Variable	Biopsy-confirmed PN	Clinically Probable PN	p value
Baseline sodium, mmol/L	139.62 ± 2.28	139.68 ± 3.27	0.765
Baseline potassium, mmol/L	4.28 ± 0.52	4.48 ± 0.32	0.197
Baseline calcium, mg/dL	9.61 ± 0.52	9.66 ± 0.59	0.987
Baseline phosphate, mg/dL	3.47 ± 0.51	3.56 ± 0.45	0.901
Post-exposure calcium, mg/dL	9.36 ± 0.57	9.08 ± 0.94	0.498
Post-exposure phosphate, mg/dL	4.44 ± 1.24	4.76 ± 1.70	0.621
UPCR, mg/g	506.63 ± 643.56	249.31 ± 261.82	0.161
PTH, pg/mL	117.21 ± 56.67	91.54 ± 56.02	0.045
25-Hydroxyvitamin D, ng/mL	25.80 ± 14.78	44.52 ± 34.22	0.055
Baseline serum creatinine, mg/dL	0.89 ± 0.42	1.00 ± 0.31	0.045
Baseline eGFR, mL/min/1.73 m²	79.82 ± 26.01	70.43 ± 18.62	0.128
Baseline serum urea, mg/dL	33.19 ± 12.42	41.77 ± 16.97	0.138
First post-exposure serum creatinine, mg/dL	2.79 ± 1.38	2.76 ± 2.21	0.292
First post-exposure serum urea, mg/dL	99.28 ± 45.50	80.00 ± 32.25	0.183
6-month serum creatinine, mg/dL	2.07 ± 1.26	1.45 ± 0.51	0.104
6-month serum urea, mg/dL	69.29 ± 43.08	53.29 ± 17.38	0.405
Time to diagnosis, days	29.74 ± 39.77	26.75 ± 51.35	0.441
Follow-up duration, months	12.11 ± 9.27	12.50 ± 7.92	0.671

Data are presented as mean ± standard deviation.

Abbreviations: PN, phosphate nephropathy; eGFR, estimated glomerular filtration rate. UPCR, urine protein-to-creatinine ratio; PTH, parathyroid hormone.

Renal Outcomes

Renal recovery was observed in only 5 of 47 patients (10.6%) in the overall cohort. At the final follow-up, 28 patients (59.6%) had an eGFR of 30–60 mL/min/1.73 m², 11 patients (23.4%) had an eGFR of 15–30 mL/min/1.73 m², and 3 patients (6.4%) had an eGFR below 15 mL/min/1.73 m². One patient remained dependent on maintenance dialysis. Overall, persistent renal dysfunction, defined as a final eGFR below 60 mL/min/1.73 m² and/or the need for kidney replacement therapy, was present in 42 patients (89.4%).

Persistent renal dysfunction occurred in 17 of 19 patients (89.5%) in the biopsy-confirmed PN group and in 25 of 28 patients (89.3%) in the clinically probable PN group. Accordingly, the overall frequency of persistent loss of kidney function was nearly identical between the two groups.

However, the severity of renal outcomes differed substantially between groups. In the biopsy-confirmed PN group, 2 patients (10.5%) achieved renal recovery, 6 (31.6%) had a final eGFR of 30–60 mL/min/1.73 m², 8 (42.1%) had a final eGFR of 15–30 mL/min/1.73 m², and 3 (15.8%) progressed to a final eGFR below 15 mL/min/1.73 m²; one of these patients became dialysis-dependent. In contrast, among patients with clinically probable PN, 3 patients (10.7%) achieved renal recovery, 22 (78.6%) had a final eGFR of 30–60 mL/min/1.73 m², and 3 (10.7%) had a final eGFR of 15–30 mL/min/1.73 m². No patient in the clinically probable PN group progressed to kidney failure requiring kidney replacement therapy.

Thus, although the prevalence of persistent renal dysfunction was nearly identical between the biopsy-confirmed and clinically probable PN groups (89.5% vs. 89.3%), severe renal outcomes, defined as a final eGFR below 30 mL/min/1.73 m² and/or the need for kidney replacement therapy, were significantly more frequent in the biopsy-confirmed group (57.9% vs. 10.7%, p = 0.001) (Table 4).

Table 4. Comparison of Renal Outcomes Between Patients With Biopsy-Confirmed and Clinically Probable Phosphate Nephropathy

Renal Outcome	Biopsy-confirmed PN (n=19)	Clinically Probable PN (n=28)
Renal recovery	2 (10.5)	3 (10.7)
Final eGFR 30–60 mL/min/1.73 m²	6 (31.6)	22 (78.6)
Severe renal outcome	11 (57.9)	3 (10.7)

Data are presented as n (%).

Abbreviations: PN, phosphate nephropathy; eGFR, estimated glomerular filtration rate.

Note: The distribution of renal outcomes differed significantly between groups (p = 0.004, Fisher's exact test).

(Severe renal outcome = final eGFR <30 mL/min/1.73 m² and/or kidney replacement therapy)

Factors Associated With Severe Renal Outcomes

Because persistent renal dysfunction was observed in the vast majority of patients, a reliable multivariable model to identify predictors of persistent kidney injury could not be constructed. Therefore, we performed an exploratory analysis focused on the severity of renal outcomes. A severe renal

outcome was defined as a final eGFR below 30 mL/min/1.73 m² and/or the need for kidney replacement therapy.

Biopsy-confirmed PN, higher first post-exposure serum creatinine levels, higher urine protein-to-creatinine ratio (UPCR), higher parathyroid hormone (PTH) levels, and lower 25-hydroxyvitamin D concentrations were significantly associated with severe renal outcomes (p = 0.0009, p = 0.034, p = 0.0007, p = 0.038, and p = 0.0037, respectively).

In contrast, age, diabetes mellitus, hypertension, pre-existing chronic kidney disease, baseline serum creatinine, baseline eGFR, diuretic use, and ARB use were not significantly associated with severe renal outcomes (Table 5).

Given the limited sample size and the exploratory nature of this analysis, these findings should be interpreted as hypothesis-generating rather than as evidence of independent prognostic factors.

Table 5. Exploratory Analysis of Factors Associated With Severe Renal Outcomes in Patients With Phosphate Nephropathy

Variable	Severe Renal Outcome (n=14)	Non-Severe Renal Outcome (n=33)	p value
Biopsy-confirmed PN	11 (78.6)	8 (24.2)	**0.0009**
Age, years	62.9 ± 8.1	64.8 ± 10.0	0.522
Diabetes mellitus	9 (64.3)	16 (48.5)	0.358
Hypertension	11 (78.6)	29 (87.9)	0.410
Pre-existing CKD	3 (21.4)	5 (15.2)	0.679
Baseline serum creatinine, mg/dL	0.93 ± 0.28	0.98 ± 0.38	0.797
Baseline eGFR, mL/min/1.73 m²	71.6 ± 23.3	74.9 ± 21.7	0.681
First post-exposure serum creatinine, mg/dL	4.01 ± 2.99	2.32 ± 1.10	**0.034**
UPCR, mg/g	692.6 ± 678.3	206.8 ± 233.7	**0.0007**
PTH, pg/mL	130.0 ± 67.9	89.8 ± 47.0	**0.038**
25-Hydroxyvitamin D, ng/mL	20.3 ± 9.9	43.9 ± 31.7	**0.0037**
Diuretic use	7 (50.0)	18/32 (56.3)	0.755
ARB use	6 (42.9)	12 (36.4)	0.749
ACE inhibitor use	1 (7.1)	11 (33.3)	0.077

Data are presented as mean ± standard deviation or n (%).

Abbreviations: PN, phosphate nephropathy; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; UPCR, urine protein-to-creatinine ratio; PTH, parathyroid hormone; ARB, angiotensin receptor blocker.

Definition: Severe renal outcome was defined as a final eGFR <30 mL/min/1.73 m² and/or the requirement for kidney replacement therapy.

Note: Owing to the limited sample size, these analyses should be considered exploratory and hypothesis-generating. Associations identified in this table should not be interpreted as independent predictors of severe renal outcomes.

Histopathological Findings

Among the 19 patients with biopsy-confirmed native phosphate nephropathy (PN), basophilic and/or calcified intratubular deposits were identified within the tubular lumina and/or the tubulointerstitial compartment. Von Kossa staining was positive in all cases, confirming calcium-phosphate crystal deposition and supporting the diagnosis of phosphate nephropathy (Figures 1 and 2).

Variable degrees of tubulointerstitial injury were observed, including interstitial inflammation, tubular atrophy, and interstitial fibrosis. Interstitial inflammation ranged from mild focal infiltrates to more extensive involvement. Similarly, the extent of tubular atrophy and interstitial fibrosis varied substantially across patients.

Direct immunofluorescence findings were negative or nonspecific in most cases. In a subset of patients, staining for IgM/C3, IgA, or IgG/albumin was observed and was attributed to concomitant glomerular lesions or areas of glomerulosclerosis.

Concomitant kidney diseases were identified in a minority of cases, including diabetic nephropathy in three patients, focal segmental glomerulosclerosis in two patients, and IgA nephropathy in one patient (Table 6).

Table 6. Histopathological Characteristics of Biopsy-Confirmed Native Kidney Phosphate Nephropathy

Parameter	Value
Biopsy-confirmed native kidney PN cases	19/19 (100%)
Glomeruli per biopsy, median (range)	12 (3–52)
Global glomerulosclerosis, median (range)	1 (0–14)
GBM thickening	9/19 (47.4%)
Mesangial hypercellularity	8/19 (42.1%)
Mesangial expansion	11/19 (57.9%)
Interstitial inflammation	18/19 (94.7%)
Tubular atrophy/interstitial fibrosis	15/19 (78.9%)
Intratubular and/or tubulointerstitial calcium-phosphate crystal deposits	19/19 (100%)
Positive von Kossa staining	19/19 (100%)
Negative or nonspecific direct immunofluorescence findings	13/19 (68.4%)

Data are presented as n (%) unless otherwise indicated.

Abbreviations: PN, phosphate nephropathy; GBM, glomerular basement membrane.

Discussion

This study presents a substantial cohort evaluating the clinical characteristics and renal outcomes of acute phosphate nephropathy (APN) following oral sodium phosphate (OSP) use for colonoscopy preparation. In our cohort of 47 patients, 40.4% of cases were biopsy-confirmed, highlighting that APN is not merely a clinical suspicion but a pathologically verifiable form of severe tubulointerstitial injury [6,1,8].

In this single-center, retrospective, biopsy-anchored cohort study, we demonstrated that phosphate nephropathy (PN) is not confined to a transient episode of acute kidney injury (AKI). Rather, it represents a delayed AKI-to-CKD syndrome that leads to persistent renal dysfunction in a substantial proportion of patients. In the overall cohort, patients with biopsy-confirmed APN and those classified as having clinically probable PN/APN were broadly comparable in terms of demographic characteristics, comorbidities, and exposure to risk-modifying medications. The most notable finding was that, irrespective of diagnostic pathway, nearly 90% of patients (42/47) did not recover baseline kidney function and subsequently developed chronic kidney disease (CKD) or progressed to end-stage kidney disease (ESKD).

When renal outcomes were evaluated in the overall cohort, renal recovery was observed in only 5 patients (10.6%). This low recovery rate is consistent with previous reports, in which recovery has been

described in approximately 16–19% of cases [1,11]. Persistent renal dysfunction was present in 42 patients (89.4%), whereas severe renal outcomes, defined as an eGFR below 30 mL/min/1.73 m² or the requirement for renal replacement therapy, occurred in 14 patients (29.8%).

Taken together, these findings reinforce the view that OSP exposure is an underrecognized but clinically important cause of iatrogenic chronic kidney disease (CKD), with potentially serious long-term consequences [2,6,8,10,12,13]. In the seminal studies by Markowitz and colleagues, kidney injury after oral sodium phosphate (OSP) exposure was frequently irreversible, and biopsies commonly demonstrated extensive tubular atrophy and interstitial fibrosis [14,6,15]. Similarly, the Icelandic cohort highlighted the long-term association between OSP-related APN and persistent renal failure [10].

In the literature, advanced age, female sex, hypertension, diabetes mellitus, pre-existing CKD, volume depletion, and the use of ACEIs/ARBs, diuretics, or NSAIDs have been identified as major risk factors for APN [1,9,10]. The mean age of our cohort was 64.2 years, with a median age of 65 years, which is consistent with previous observations that individuals older than 55–60 years are particularly vulnerable to this toxic injury [10,1,13]. In older patients, age-related reductions in glomerular filtration rate (GFR), together with prolonged intestinal transit time, may increase phosphate absorption and impair renal phosphate excretion, thereby amplifying kidney injury [1,2].

Female patients accounted for 61.7% of our cohort, a finding broadly consistent with previous series in which women represented the majority of APN cases, in some reports exceeding 80% [6,10,1]. However, the proportion of male patients in our cohort was also substantial, indicating that APN is not confined to female patients. This suggests that, although lower body weight may increase susceptibility to a fixed phosphate load, additional clinical risk factors likely play an important role in determining individual vulnerability [1].

When comorbidities and medication use were evaluated, hypertension was present in 85.1% of patients, closely mirroring the 80–87% prevalence reported in previous studies [10,1]. Hypertension may increase susceptibility to calcium-phosphate crystal precipitation by limiting the kidney's adaptive response to hypovolemia and hemodynamic stress [1,2]. The high prevalence of diabetes mellitus in our cohort (53.2%) further supports existing evidence that diabetes is an important susceptibility factor for APN [6,8,2].

In addition, 54.3% of patients were receiving diuretics, and a substantial proportion were using ACE inhibitors or ARBs. These findings reinforce the concept that medications affecting renal perfusion, volume status, and intrarenal hemodynamics may interact with OSP exposure to create a "triple whammy" effect, thereby promoting calcium-phosphate crystal accumulation and kidney injury [6,10,13,12,1].

No statistically significant differences were observed between the biopsy-confirmed and clinically probable PN groups with respect to sex distribution, hypertension, diabetes mellitus, or exposure to risk-modifying medications, including diuretics and ACEIs/ARBs ($p = 0.546$, $p = 0.373$, $p = 0.417$, and $p =$

0.546, respectively). Moreover, the nearly identical frequency of persistent renal dysfunction in the two groups (89.5% vs. 89.3%) suggests that clinically probable cases also represent a true PN phenotype and carry a comparable risk of long-term renal impairment.

Because APN is often diagnosed on the basis of clinical suspicion and post-exposure creatinine elevation in population-based studies where kidney biopsy is not feasible, our findings provide supportive evidence for the clinical validity of probable PN criteria [2,1].

In terms of clinical course, the median time to diagnosis was 11 days, with a mean of 28 days, indicating that APN often has an insidious onset and that the rise in serum creatinine may not be recognized until days or even weeks after exposure [16,13]. This delayed recognition is further facilitated by the typically bland urinary sediment and minimal proteinuria observed in many patients, which may obscure the diagnosis in routine clinical practice [6,1,8].

In contrast, severe outcomes, defined as an eGFR below 30 mL/min/1.73 m² or the requirement for renal replacement therapy, were more frequent in the biopsy-confirmed group. This difference may partly reflect selection bias, as patients who underwent biopsy were likely referred for histological evaluation because of more severe, persistent, or unexplained renal impairment at presentation.

Furthermore, the higher PTH levels observed in the biopsy-confirmed group are noteworthy from a pathogenetic perspective. Acute phosphate loading is known to trigger a compensatory PTH response, particularly in the setting of reduced serum calcium [5,17]. Elevated PTH inhibits proximal tubular phosphate reabsorption, thereby increasing phosphate delivery to the distal nephron and, consequently, the risk of intratubular crystallization [5,14]. This mechanism may help explain why biopsied patients exhibited a more severe renal phenotype, including final eGFR below 30 mL/min/1.73 m² or progression to ESKD. Higher PTH levels may have contributed to greater calcium-phosphate crystal accumulation and more extensive tubular injury.

In contrast, the finding that biopsied patients were younger and had lower baseline serum creatinine levels likely reflects patient selection in routine clinical practice. As noted in the literature, unexplained creatinine elevations in older patients are often attributed to vascular disease or age-related physiological decline, and such patients may be followed without biopsy [10,12]. In younger patients with better baseline renal reserve, however, unexpected deterioration in kidney function is more likely to prompt clinicians to pursue kidney biopsy for a definitive diagnosis.

Our biopsy findings clearly demonstrate the pathognomonic features of PN. Calcium-phosphate crystal deposits were identified within the tubular lumina and/or tubulointerstitial compartment in all 19 native kidney biopsies examined (100%), and these deposits were confirmed by positive von Kossa staining. In the seminal studies by Markowitz and colleagues, widespread calcium-phosphate deposition within distal tubules and collecting ducts was established as the principal diagnostic criterion for APN [1]. Von Kossa staining remains a key histochemical method for confirming confirming these deposits and

distinguishing them from calcium oxalate crystals, which typically show birefringence under polarized light and are von Kossa negative [9].

Accompanying interstitial inflammation was observed in 94.7% of cases, while tubular atrophy and/or interstitial fibrosis (TA/IF) were present in 78.9%. These findings suggest that crystal deposition is not merely an acute obstructive event, but also initiates a chronic injury process characterized by persistent scarring and nephron loss [1]. Previous studies have shown that calcium-phosphate crystals can bind to tubular epithelial cells and induce oxidative stress and cytokine release, thereby promoting fibrosis and irreversible nephron loss [18,17,19]. In our biopsy specimens, the high frequency of TA/IF represents a key pathological correlate explaining why APN is associated with a high rate of persistent chronic kidney disease (CKD) [8,20]. Similarly, in the biopsy-based series by Markowitz and colleagues, kidney function failed to return to baseline in a substantial proportion of patients [9].

The frequent presence of glomerular basement membrane (GBM) thickening (47.4%) and mesangial expansion (57.8%) in our cohort suggests that APN often develops on a background of pre-existing renal injury. Although comorbidities such as hypertension and diabetes have been reported in the majority of APN cases in previous studies, the underlying pathological changes have rarely been described in detail in biopsy series [16,10,2,8]. Our findings indicate that OSP exposure, when superimposed on pre-existing lesions such as diabetic nephropathy or IgA nephropathy, may overwhelm an already limited renal reserve [16,7]. This may partly explain why bowel preparation–associated kidney injury follows a more severe course in high-risk populations [1,19].

In our study, the greater severity of persistent kidney injury in the biopsy-confirmed group ($p = 0.0009$) may be explained by both selection bias, as previously noted in the literature, and a higher burden of pathological injury. In routine clinical practice, patients whose renal function recovers promptly or who follow a milder clinical course are often monitored without biopsy, whereas those with persistent creatinine elevation or more severe renal failure are more likely to undergo biopsy for definitive diagnosis [8]. Thus, the biopsy-confirmed group may represent a phenotype characterized by a greater tubulointerstitial calcium-phosphate crystal burden and/or more advanced chronic tubulointerstitial injury.

The association between higher peak post-procedure serum creatinine levels and the severity of persistent kidney injury ($p = 0.034$) provides important evidence that the magnitude of the initial tubular insult may predict long-term renal outcomes. Previous studies have reported that most patients whose serum creatinine exceeded 2.0 mg/dL after oral sodium phosphate (OSP) exposure did not return to baseline kidney function [1]. Markowitz et al. linked functional impairment, reflected by creatinine elevation, to structural injury by showing that early biopsies in acute phosphate nephropathy (APN) are characterized by widespread calcium-phosphate crystal deposition in distal tubules together with features of acute tubular necrosis (ATN) [9,21,1]. In the epidemiological study by Hurst et al., the magnitude of serum creatinine increase, particularly an increase of ≥50%, was associated with the severity of acute kidney injury and was considered relevant to longer-term renal outcomes [22,1].

Taken together, higher peak post-procedure creatinine levels may serve as an indirect marker of the extent of nephron exposure to massive intratubular crystallization and acute tubular injury [14,16]. They may therefore be useful as a clinically accessible prognostic indicator for identifying patients at increased risk of progression to irreversible chronic kidney injury [14,1,22].

Although APN is classically characterized by bland urinary sediment and minimal proteinuria, the association between higher proteinuria levels and more severe renal outcomes in our study is noteworthy ($p = 0.0007$) [10,8]. Previous studies have suggested that proteinuria may disturb tubular phosphate handling and contribute to higher intratubular phosphate burden, thereby intensifying tubular injury [23,24]. In addition, APN may develop on a background of pre-existing glomerular disease, such as diabetic nephropathy or IgA nephropathy [8,7].

In this context, higher proteinuria may serve as a marker of reduced renal reserve and underlying structural kidney damage, identifying patients who are more vulnerable to the toxic phosphate burden imposed by OSP exposure.

The strong association between elevated PTH levels and injury severity, one of the most notable findings of our study, supports the concept of a self-perpetuating pathogenic mechanism in APN ($p = 0.0007$). Following OSP ingestion, the acute phosphate load stimulates PTH secretion. Elevated PTH inhibits phosphate reabsorption in the proximal tubules through downregulation of NaPi-2a/c transporters. Although this represents a physiological compensatory response, it markedly increases phosphate delivery to the distal nephron, thereby promoting calcium-phosphate supersaturation and crystal precipitation.

This mechanism suggests that a stronger PTH response may be associated with more extensive distal tubular crystallization, greater tubular injury, and subsequent permanent nephron loss, ultimately contributing to the AKI-to-CKD transition [5,2,17,15]. Consistent with this concept, disturbances in mineral metabolism have also been linked to renal calcification in allograft studies [25].

The association between low vitamin D levels and more severe renal outcomes in our study ($p = 0.0037$) may reflect the dual role of vitamin D in the context of PN. The renal proximal tubules are the principal site of active vitamin D synthesis, particularly 1,25-dihydroxyvitamin D production [15,8]. Therefore, widespread calcium-phosphate crystal deposition and tubular injury in PN may directly impair this metabolic function, contributing to reduced vitamin D levels [15,5].

In this context, low vitamin D levels may serve as an indirect biomarker of the extent of tubular injury and nephron loss following phosphate nephropathy, rather than merely representing a pre-existing metabolic abnormality.

In conclusion, our findings suggest that biopsy-confirmed diagnosis, higher peak serum creatinine, greater proteinuria, elevated PTH, and lower vitamin D levels may serve as clinically relevant prognostic indicators of the severity of persistent kidney injury following PN. The presence of these variables should

be regarded as a clinical warning sign, indicating the need for closer follow-up to detect and manage the insidious development of CKD.

These findings emphasize that creatinine elevation after phosphate-containing bowel preparation, particularly in older patients with hypertension and diabetes mellitus, should not be regarded as a transient or benign event. Renal function should be monitored closely after the procedure, and patients should be followed for at least three months to detect the possible development of insidious CKD. Even when kidney biopsy cannot be performed, an appropriate clinical-temporal relationship, bland urinary findings, and renal dysfunction not explained by alternative causes may strongly support the diagnosis of PN.

The main contribution of this study is that it reframes PN not merely as a rare pathological diagnosis requiring biopsy confirmation, but as an AKI-to-CKD phenotype that often remains unbiopsied in routine clinical practice and is therefore underrecognized. The similar rate of persistent renal dysfunction observed in the clinically probable PN/APN group and the biopsy-confirmed group suggests that cases defined by an appropriate clinical-temporal relationship and exclusion of alternative etiologies may represent a clinically meaningful PN phenotype, even when kidney biopsy cannot be performed.

The strength of this study lies in its detailed presentation of pathological findings from biopsy-confirmed cases and its systematic comparison of these cases with a clinically probable, non-biopsied group. The main limitations include its retrospective design, limited sample size, and single-center setting.

In conclusion, PN should not be viewed merely as a rare condition identified only through biopsy in clinical practice, but rather as a difficult-to-recognize AKI-to-CKD phenotype associated with a high rate of persistent renal injury. Patients who meet clinically probable criteria appear to carry a similarly high risk of long-term renal dysfunction as biopsy-confirmed patients. Because OSP exposure is a modifiable risk factor, the use of phosphate-free alternative bowel preparation agents in at-risk populations is of critical importance.

Declarations

Funding

The authors received no specific funding for this work.

Author Contribution

Author ContributionsConceptualization: M. Keleş, E. CankayaData Collection: M. Keleş, Burak Aslum, Ş. Köksal Cevher, M. Üzerk KibarPathological Evaluation: A. ÇolakData Analysis and Interpretation: M. Keleş, E. Cankaya, E. Coşkun YenigünManuscript Drafting: M. KeleşCritical Revision of the Manuscript: E.

Coşkun Yenigün, E. Cankaya, F. YılmazConceptualization and Supervision: F. Dede, E. Coşkun Yenigün3All authors reviewed and approved the final manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to the presence of patient-level clinical and histopathological data and institutional/ethical restrictions, but are available from the corresponding author on reasonable request and subject to approval by the relevant institution.

References

1. Markowitz GS, Perazella MA. Acute phosphate nephropathy. Kidney Int. 2009; 76: 1027–1034.
2. Turkmen E, Halacli B, Arici M. Acute Phosphate Nephropathy. BANTAO Journal. 2011; 9(2): 59-62.
3. Desmeules S, Bergeron MJ, Isenring P. Acute phosphate nephropathy and renal failure. N Engl J Med. 2003;349(10):1006-1007. doi:10.1056/NEJM200309043491020.
4. Pelham RW, Cleveland MvB, DiPalma JA. Sodium phosphate tablets and acute phosphate nephropathy: how much hydration is “adequate”? Am J Gastroenterol. 2010;105(2):476-477. doi:10.1038/ajg.2009.571.
5. Parmar MS. The perils of protocols: acute phosphate nephropathy after intravenous phosphate replacement. Diagnosis. 2015; 2(4): 249–253.
6. Chang HH, Chang FC. Acute phosphate nephropathy - An old issue in the new era. J Formos Med Assoc. 2018; 117: 348-349.
7. Şenocak D, Genç AB, Yıldırım M, et al. Akut Fosfat Nefropatisi. Türk Nefroloji Diyaliz ve Transplantasyon Dergisi. 2018.
8. Özdemir E, Özdemir P, Yadigar S, et al. An Overlooked Etiology of Acute Kidney Injury: A Clinicopathological Analysis of Phosphate Nephropathy and Review of the Literature. J Clin Med. 2025; 14: 4081.
9. Markowitz GS, Stokes MB, Radhakrishnan J, D’Agati VD. Acute phosphate nephropathy following oral sodium phosphate bowel purgative: an underrecognized cause of chronic renal failure. J Am Soc Nephrol. 2005;16(11):3389-3396. doi:10.1681/ASN.2005050496.
10. Pálmadóttir VK, Gudmundsson H, Harðarson S, Arnadottir M, Magnusson T, Andrésdóttir MB. Incidence and outcome of acute phosphate nephropathy in Iceland. PLoS One. 2010;5(10):e13484. doi:10.1371/journal.pone.0013484.
11. Fernández-Juárez G, Parejo L, Villacorta J, Tato A, Cazar R, Guerrero C, et al. Kidney injury after sodium phosphate solution beyond the acute renal failure. Nefrologia. 2016;36(3):243-248. doi:10.1016/j.nefro.2016.02.010.

12. Jacobs W, Stas K, Coenegrachts JL. Acute kidney injury after use of oral Fleet Phospho Soda as bowel preparation for colonoscopy. Acta Gastroenterol Belg. 2011; 74: 77-78.
13. Weiss J, Thorp ML. Acute phosphate nephropathy: a cause of chronic kidney disease. BMJ Case Reports. 2011.
14. Rubio-Aliaga I. Phosphate and Kidney Healthy Aging. Kidney Blood Press Res. 2020; 45: 802–811.
15. Mitchell T, Verma V, Fajol A, Faul C. The effects of elevated phosphate on the kidney: damaging the gatekeeper. Pflugers Arch. 2026;478:34. doi:10.1007/s00424-026-03160-5.
16. Yamada Y, Harada M, Yamaguchi A, et al. Acute Phosphate Nephropathy with Diffuse Tubular Injury Despite Limited Calcium Phosphate Deposition. Intern Med. 2016; 55: 2229-2235.
17. Lochy S, Jacobs R, Honoré PM, et al. Phosphate induced crystal acute kidney injury – an under-recognized cause of acute kidney injury potentially leading to chronic kidney disease: case report and review of the literature. Int J Nephrol Renovasc Dis. 2013; 6: 61–64.
18. Medina-Liabres KRP, Kim BM, Kim S. Biopsy-proven acute phosphate nephropathy: A case report. World J Clin Cases. 2020; 8(12): 2585-2589.
19. Jahan S, Lea-Henry T, Brown M, Karpe K. An Unusual Case of Acute Phosphate Nephropathy. Kidney Int Rep. 2019; 4: 1023–1026.
20. Fogo AB, Lusco MA, Najafian B, Alpers CE. Atlas of Renal Pathology II: Nephrocalcinosis and acute phosphate nephropathy. Am J Kidney Dis. 2017; 69(3): e17-e18.
21. Markowitz GS, Nasr SH, Klein P, Anderson H, Stack JI, Alterman L, Price B, Radhakrishnan J, D'Agati VD. Renal failure and acute nephrocalcinosis following oral sodium phosphate bowel cleansing. Hum Pathol. 2004;35(6):675-684. doi:10.1016/j.humpath.2004.03.005.
22. Hurst FP, Bohen EM, Osgard EM, Oliver DK, Das NP, Gao SW, Abbott KC. Association of oral sodium phosphate purgative use with acute kidney injury. J Am Soc Nephrol. 2007;18(12):3192-3198. doi:10.1681/ASN.2007020145.
23. de Seigneux S et al (2015) Proteinuria increases plasma phosphate by altering its tubular handling. J Am Soc Nephrol 26(7):1608– 1618. h t t p s : / / d o i . o r g / 1 0 . 1 6 8 1 / A S N . 2 0 1 4 0 1 0 1 0 4
24. Lundberg S, Qureshi AR, Olivecrona S, Gunnarsson I, Jacobson SH, Larsson TE (2012) FGF23, albuminuria, and disease progres-sion in patients with chronic IgA nephropathy. Clin J Am Soc Nephrol 7(5):727–734. h t t p s : / / d o i . o r g / 1 0 . 2 2 1 5 / C J N . 1 0 3 3 1 0 1 1
25. Çeltik, A., Şen, S., Yılmaz, M. et al. The effect of hypercalcemia on allograft calcification after kidney transplantation. Int Urol Nephrol 48, 1919–1925 (2016). https://doi.org/10.1007/s11255-016-1391-z

Figures

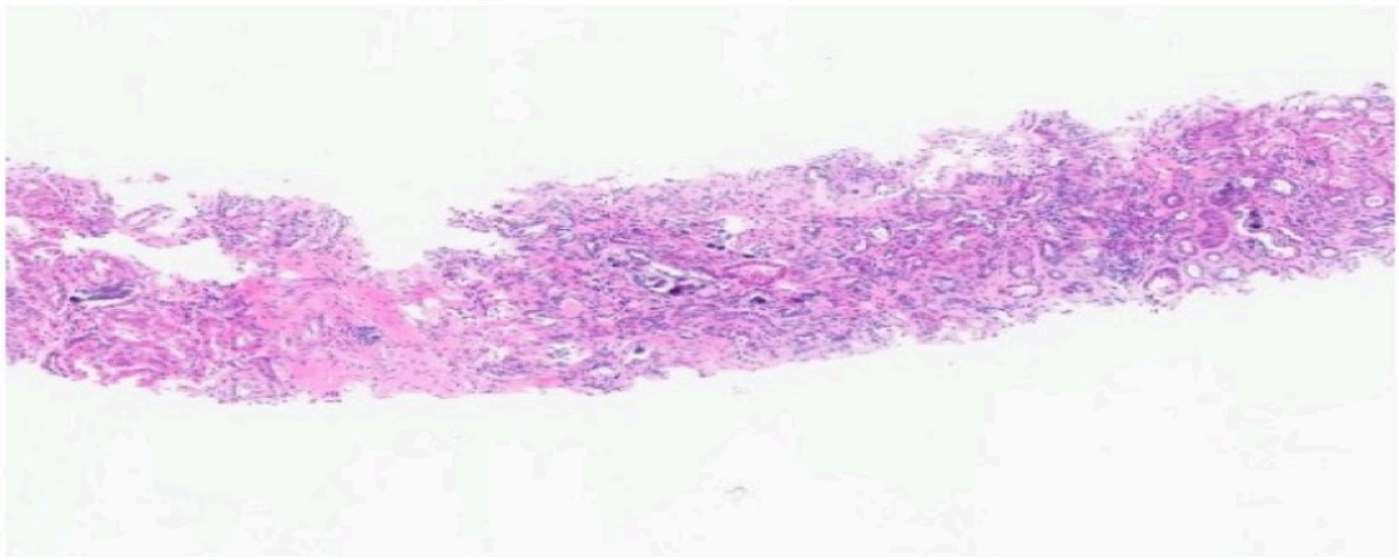


Figure 1

Representative biopsy specimen from a patient with phosphate nephropathy showing extensive basophilic intratubular calcium-phosphate crystal deposits. Hematoxylin and eosin stain, ×100.

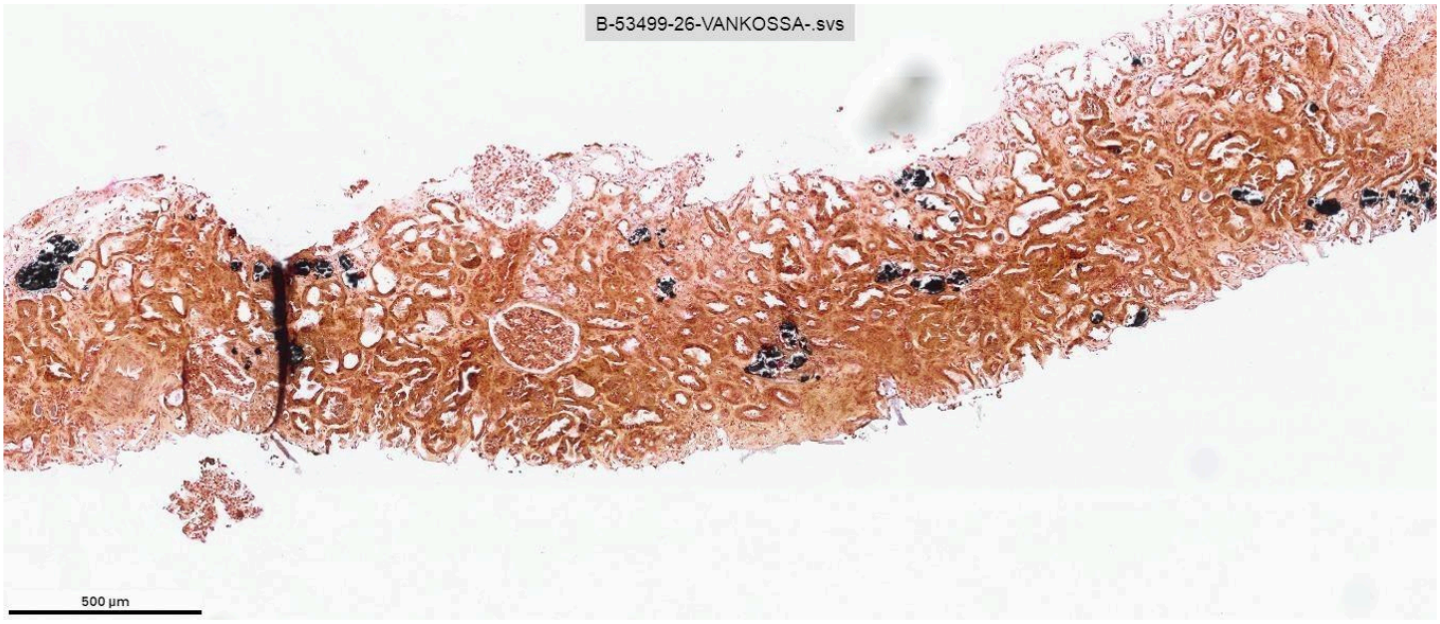


Figure 2

Corresponding Von Kossa stain highlighting intratubular calcium-phosphate crystal deposits as black granular aggregates, confirming phosphate nephropathy. Original magnification ×100.