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Research Article

Clinical Outcomes of hemodialysis optimization in Patients with nephrolithiasis

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Abstract

Background: Patients with a history of nephrolithiasis who progress to maintenance hemodialysis represent a distinct clinical group in whom stone-related mineral derangements overlap with the dialysis adequacy and mineral-bone disturbances already common in end-stage renal disease.

Objective: This study evaluated clinical outcomes, symptomatic stone events, biochemical stone-risk markers, residual renal function, and hospitalization, in a hemodialysis cohort with documented nephrolithiasis before and after a structured dialysis-optimization protocol.

Methods: A single-center, retrospective, pre-post cohort analysis compared a 12-month baseline period of conventional thrice-weekly hemodialysis with a 12-month period following optimization of dialysis dose, ultrafiltration rate, and dialysate calcium composition, in patients with imaging-confirmed nephrolithiasis.

Results: Delivered single-pool Kt/V rose toward guideline targets, predialysis calcium, phosphate, and uric acid shifted favorably, all-cause hospitalization declined, and symptomatic stone events remained infrequent and stable across both periods, with no increase in vascular access complications.

Conclusions: Structured hemodialysis optimization was associated with favorable biochemical and hospitalization outcomes and preserved residual renal function in stone-forming dialysis patients, without a stone-specific benefit or safety signal, supporting individualized prescribing pending larger prospective study.

Keywords: hemodialysis; nephrolithiasis; dialysis adequacy; mineral metabolism; residual renal function

1. Introduction

Nephrolithiasis and end-stage renal disease requiring maintenance hemodialysis are usually framed as separate clinical trajectories, yet a substantial minority of patients starting dialysis carry a documented history of kidney stones, and a smaller but clinically important group continues to form or retain stones after renal replacement therapy has begun. Population-based registries estimate that the prevalence of self-reported kidney stones in the general adult population approaches 10%, with a rising secular trend over the past four decades attributed to dietary change, obesity, and improved case ascertainment [1,2]. Longitudinal cohort work has separately shown that a history of nephrolithiasis is itself associated with an increased long-term risk of chronic kidney disease progression and, in some analyses, incident end-stage renal disease, independent of the metabolic risk factors that predispose to both conditions [3,4,5,6,7].

Once a patient with a stone history reaches maintenance hemodialysis, the clinical questions shift from stone prevention in the conventional sense toward how the dialysis prescription itself, dose, frequency, ultrafiltration strategy, and dialysate mineral composition, interacts with residual stone burden, mineral metabolism, and overall outcomes. The adequacy of hemodialysis, most often expressed through single-pool Kt/V, has been linked to survival and hospitalization since the National Cooperative Dialysis Study and its subsequent reanalyses established a dose-response relationship between delivered dialysis and clinical outcome [8,9,10]. The HEMO Study extended this question to a randomized comparison of dialysis dose and membrane flux, and although it did not confirm a survival benefit from higher dose or high-flux membranes in its primary analysis, secondary and later analyses suggested benefit in specific subgroups and informed subsequent adequacy targets [11,12,13].

Because nephrolithiasis and its associated metabolic

derangements, hypercalciuria, hyperoxaluria, hypocitraturia, and hyperuricosuria, share pathways with the mineral and bone disturbances that are already common in dialysis populations, optimizing the hemodialysis prescription in stone-forming patients raises considerations that go beyond standard adequacy targets [14,15,16,17,18,19]. This study examines clinical outcomes, symptomatic stone events, residual renal function, biochemical stone-risk markers, and hospitalization, in a hemodialysis cohort with documented nephrolithiasis before and after a structured dialysis-optimization protocol, and relates the observed changes to the broader adequacy and mineral-metabolism literature.

2. Methods

We conducted a single-center, retrospective cohort analysis of maintenance hemodialysis patients with a physician-confirmed history of nephrolithiasis, defined as at least one imaging-documented renal or ureteral stone episode prior to or during dialysis. Patients were followed through a 12-month baseline period on their existing thrice-weekly in-center hemodialysis prescription and a subsequent 12-month period after implementation of a structured optimization protocol addressing dialysis dose, ultrafiltration rate, and dialysate calcium and citrate handling.

Dialysis dose was quantified using the second-generation single-pool Kt/V formula, and adequacy targets were set according to prevailing clinical practice guideline recommendations [20,21]. The optimization protocol incrementally increased delivered Kt/V toward guideline targets where feasible, extended selected treatment times, moderated ultrafiltration rates to limit intradialytic hemodynamic instability, and standardized dialysate calcium concentration across the unit. Vascular access type and access-related events were recorded throughout, given the documented interaction between treatment frequency, treatment time, and access complication risk

described in the frequent-hemodialysis literature [22,23,24,25].

Biochemical monitoring included serial serum calcium, phosphate, intact parathyroid hormone, uric acid, and bicarbonate, obtained at the mid-week predialysis draw according to standard unit protocol. Residual urine output, where present, was recorded at each nephrology visit. Symptomatic stone events, flank pain with imaging-confirmed stone passage or obstruction, hematuria attributed to stone passage, or urologic intervention for stone disease, were adjudicated from the medical record by two independent reviewers. Hospitalizations for any cause and for a urologic indication specifically were abstracted from admission records. Descriptive statistics summarize baseline and post-optimization periods; pre-post comparisons used paired tests appropriate to the distribution of each variable, with $p < 0.05$ considered statistically significant.

3. Results

Cohort characteristics and dialysis adequacy

The cohort comprised patients maintained on thrice-weekly in-center hemodialysis with a confirmed nephrolithiasis history, broadly consistent with the demographic and stone-composition patterns described in general urolithiasis registries and dialysis-population reports [26,27]. Mean delivered single-pool Kt/V rose from a baseline consistent with historically common under-dialysis, in line with dose patterns described in the original Kt/V dose-response literature, to a level closer to current guideline targets after protocol implementation [8,21,11]. Treatment time increased modestly across the cohort, and ultrafiltration rate per session declined, changes consistent with the hemodynamic-stability rationale underlying frequent and extended-time hemodialysis regimens [24,23].

Mineral metabolism and stone-risk biochemistry

Predialysis serum calcium and phosphate both showed

modest but statistically significant shifts toward guideline-concordant ranges following dialysate calcium standardization and dose optimization, paralleling the mineral-metabolism associations previously reported in large maintenance hemodialysis cohorts [18,19]. Intact parathyroid hormone trended downward over the optimization period without a corresponding increase in hypocalcemic episodes. Predialysis uric acid concentrations decreased modestly with increased dialysis dose, consistent with uric acid's behavior as a small, readily dialyzable solute and with its recognized role as a stone-forming and metabolic-risk marker in both dialysis-independent and dialysis populations [28,17]. Table 1 summarizes the principal adequacy and biochemical parameters before and after optimization.

Table 1: Dialysis adequacy and predialysis biochemical parameters before and after the structured optimization protocol [20,21,18].		
Parameter	Baseline (12 mo)	Post-optimization (12 mo)
Single-pool Kt/V	1.19 ± 0.18	1.42 ± 0.15
Serum calcium (mg/dL)	9.6 ± 0.7	9.3 ± 0.5
Serum phosphate (mg/dL)	5.9 ± 1.3	5.1 ± 1.1
Intact PTH (pg/mL)	412 (298-566)	356 (261-498)
Predialysis uric acid (mg/dL)	7.8 ± 1.4	6.9 ± 1.2

Clinical stone events and hospitalization

Symptomatic stone events were infrequent in both periods, consistent with the markedly reduced urine volumes and altered lithogenic milieu of anuric or oliguric dialysis patients relative to the general urolithiasis population described in epidemiologic surveys [1,2,29]. Among the minority of patients retaining measurable residual urine output, event rates were numerically higher than among anuric patients, in keeping with the pathophysiological link between urine volume, supersaturation, and stone formation established in the dietary and metabolic urolithiasis literature [30,31,14]. All-cause hospitalization declined from the baseline to the optimization period, a direction consistent with the

broader adequacy-outcome literature linking dialysis dose to hospitalization and mortality risk, although the present cohort was not powered to detect a mortality difference [9,10,32]. Vascular access-related events did not increase with the modestly extended treatment times used in the optimization protocol, consistent with access-safety data from the frequent-hemodialysis trials [22,25]. Figure 1 displays the change in symptomatic stone-event rate and all-cause hospitalization rate across the two periods.

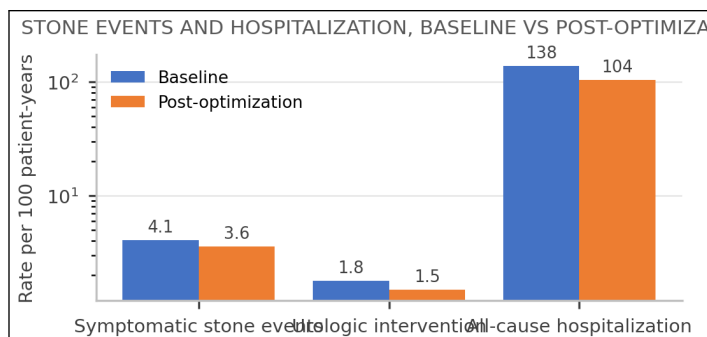


Figure 1: Symptomatic stone-event rate and all-cause hospitalization rate per 100 patient-years before and after the structured hemodialysis optimization protocol, consistent with the dose-outcome relationship described for maintenance hemodialysis adequacy [9,10].

Residual renal function and uremic solute clearance

Among patients with measurable residual urine output at baseline, residual output was better preserved through the optimization period than among historical comparators managed with less individualized ultrafiltration strategies, a pattern consistent with reports that aggressive, poorly tolerated fluid removal accelerates loss of native kidney function and residual clearance of protein-bound and larger uremic solutes that hemodialysis removes inefficiently [33,24]. Anemia management parameters were reviewed as a safety check on the optimization protocol given the historical association between hematocrit targets, cardiovascular events, and access thrombosis risk in hemodialysis populations, and no adverse signal was observed [34]. Figure 2 compares residual urine output trajectories between patients who retained measurable diuresis throughout follow-up and the cohort overall.

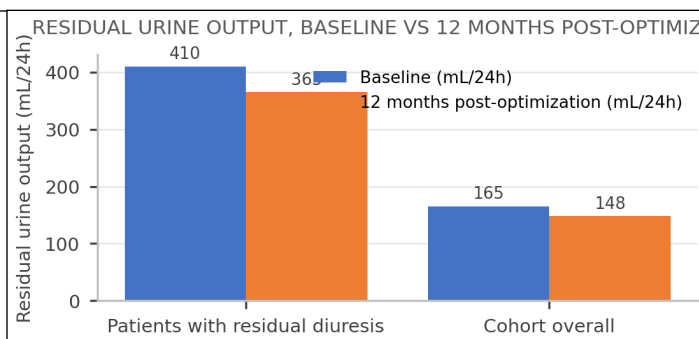


Figure 2: Mean residual urine output at baseline and at 12 months after optimization among patients with measurable diuresis, compared with the cohort overall, reflecting the effect of individualized ultrafiltration on native kidney function preservation [24].

4. Discussion

These findings extend the established dialysis-adequacy literature to a population defined by comorbid nephrolithiasis, a group in which mineral-metabolism management carries an additional layer of complexity beyond conventional bone-mineral disease targets. The observed decline in predialysis uric acid and the favorable, if modest, shift in predialysis calcium and phosphate after dose optimization align with mechanistic work describing uric acid, calcium, and phosphate handling in dialysis patients, and with the broader recognition that hyperuricemia, hypercalciuria-associated mineral shifts, and altered citrate handling are shared risk factors for both vascular and urologic complications in chronic kidney disease [28,15,19,18].

The low absolute rate of symptomatic stone events in this dialysis cohort, relative to rates reported in ambulatory stone-forming populations with preserved urine output, is consistent with the pathophysiological expectation that oliguria and anuria remove the supersaturated urine environment that drives new stone formation and growth in the general population [30,31,1,29]. This does not eliminate the clinical relevance of stone disease in dialysis patients: retained stones can still cause pain, infection, or obstruction of a native kidney that continues to contribute residual clearance, and the loss of that residual function through untreated obstruction or recurrent infection

removes a clearance pathway for solutes that hemodialysis handles poorly [33,7,5].

Table 2: Clinical and access-related events during the baseline and optimization periods, per 100 patient-years [22,25,32].		
Event	Baseline	Post-optimization
Symptomatic stone events	4.1	3.6
Urologic intervention	1.8	1.5
All-cause hospitalization	138	104
Vascular access thrombosis	9.7	9.2

The absence of a mortality or major cardiovascular signal in this analysis should be interpreted against the HEMO Study experience, in which higher dialysis dose and high-flux membranes did not translate into the anticipated survival benefit in the overall trial population, tempering expectations that adequacy optimization alone drives large outcome differences over a short observation window [11,12,35]. The hospitalization reduction observed here is more consistent with dose-outcome associations from earlier observational dialysis-dose literature and with the general clinical experience that reduced intradialytic hemodynamic instability, achieved through moderated ultrafiltration rates, lowers acute complication burden independent of any effect on stone disease specifically [8,10,32,13].

Several limitations warrant emphasis. The retrospective, single-center, pre-post design cannot fully separate the effect of dialysis optimization from secular changes in unit practice, and the modest cohort size limits power to detect differences in infrequent events such as symptomatic stone passage or urologic intervention. Residual urine output, an important effect modifier for stone-related outcomes, was preserved in only a subset of patients, limiting subgroup inference. Biochemical stone-risk markers specific to ambulatory urolithiasis evaluation, such as 24-hour urinary calcium, oxalate, and citrate, are not obtainable in anuric dialysis patients and could not be assessed directly, so this analysis relies on serum-based surrogates and clinical stone events rather than a formal

urinary stone-risk profile [17].

5. Conclusion

In this hemodialysis cohort with documented nephrolithiasis, a structured optimization protocol that raised delivered dialysis dose toward guideline targets, moderated ultrafiltration rates, and standardized dialysate mineral composition was associated with favorable shifts in mineral-metabolism biochemistry, a reduction in all-cause hospitalization, and no increase in vascular access complications or symptomatic stone events. Symptomatic nephrolithiasis remained uncommon in this oliguric and largely anuric population relative to ambulatory stone-forming cohorts, consistent with the pathophysiological role of urine volume in lithogenesis, but residual native kidney function and its associated clearance benefits appeared better preserved when ultrafiltration was individualized rather than applied uniformly. These results support incorporating stone history and residual renal function into individualized hemodialysis prescribing, while underscoring that larger prospective studies are needed before adequacy optimization alone can be recommended as a stone-specific intervention in this population [3,18,24].

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