

Archives of Nephrology

Research Article

Predictors of dialysis adequacy in pediatric nephrology patients with nephrolithiasis

Ndlovu Z^{1*}, Osei T² and Kamau T³

¹Department of Clinical Renal Medicine, Uruguay Center for Nephrology, Kenya

²Department of Nephrology, Ebro Institute for Advanced Renal Medicine, South Africa

³Division of Renal Medicine, Tiber Academy of Nephrology, Kenya

*Address for Correspondence: Zola Ndlovu, Department of Clinical Renal Medicine, Uruguay Center for Nephrology, Kenya; E-mail: zola.ndlovu@uruguay.edu

Received: 14 December 2025; Accepted: 15 March 2026; Published: 17 June 2026.

Citation of this article: Ndlovu Z, Osei T, Kamau T (2026) Predictors of dialysis adequacy in pediatric nephrology patients with nephrolithiasis. Arch Nephrol, 9(1): 01-06. DOI: [10.5281/zenodo.22813100](https://doi.org/10.5281/zenodo.22813100)

Copyright: © 2026 Zola Ndlovu, et al. This is an open access article distributed under the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

Background: Nephrolithiasis is increasingly recognized in children with chronic kidney disease, and its influence on dialysis adequacy once these patients reach kidney failure is poorly characterized.

Objective: To identify predictors of dialysis adequacy, defined by Kt/V and normalized protein catabolic rate, in pediatric patients with nephrolithiasis on chronic dialysis.

Methods: Retrospective cohort of 118 pediatric dialysis patients (74 hemodialysis, 44 peritoneal dialysis) with confirmed nephrolithiasis across three centers (2019-2025). Adequacy was assessed for 12 months; multivariable regression identified independent predictors.

Results: Adequate dialysis was achieved in 71.2% of measurements. Residual kidney function (adjusted OR 2.84), higher body mass index z-score (adjusted OR 1.62), arteriovenous fistula access (adjusted OR 3.21), and recurrent stone episodes (adjusted OR 0.46) were independent predictors. Bicarbonate and normalized protein catabolic rate correlated positively with achieved Kt/V ($r=0.41$, $r=0.53$; $p<0.001$).

Conclusion: Dialysis adequacy in pediatric nephrolithiasis patients is shaped by residual renal function, nutrition, vascular access, and stone recurrence, supporting targeted surveillance and access planning in this population.

Keywords: dialysis adequacy; pediatric nephrology; nephrolithiasis; Kt/V; chronic kidney disease

1. Introduction

Nephrolithiasis was once considered an adult disease, but its incidence in children has risen steadily, driven by dietary shifts, obesity, and improved imaging detection [1,2]. A subset of pediatric stone formers, particularly those with metabolic disorders such as primary hyperoxaluria, cystinuria, or distal renal tubular acidosis, progress to chronic kidney disease and eventually to kidney failure requiring chronic dialysis [3,4]. The relationship does not end at dialysis initiation: recurrent stone events, obstruction, and the metabolic derangements that produced the original stones can continue to influence residual kidney function, nutrition, and the practical delivery of dialysis itself [5,6].

Dialysis adequacy, quantified by single-pool Kt/V for hemodialysis and weekly Kt/V for peritoneal dialysis, is the central metric by which pediatric nephrology teams judge whether a prescription removes enough uremic solute to support growth and survival [7,8]. Pediatric KDOQI-adapted targets are complicated by small body size, fluctuating residual function, and vascular access limitations [9,10,11]. Children with nephrolithiasis add complexity: stone passage or obstruction can transiently reduce urine output, and stone-forming metabolic states can alter acid-base and solute kinetics, while prior urological interventions constrain access planning [12,13].

Few studies have examined predictors of dialysis adequacy specifically in pediatric patients whose kidney failure followed a nephrolithiasis-related pathway, as opposed to the more commonly studied congenital or glomerular causes [14,15]. This study aimed to identify independent predictors of dialysis adequacy in a multicenter retrospective cohort of pediatric hemodialysis and peritoneal dialysis patients with confirmed nephrolithiasis.

2. Methods

Study design and population

We performed a retrospective cohort study of pediatric patients (age 2-17 years at dialysis initiation) with radiologically confirmed nephrolithiasis, maintained on chronic hemodialysis or peritoneal dialysis at three pediatric nephrology referral centers between January 2019 and December 2025. Patients switching modalities were analyzed within the modality in which most of their adequacy measurements occurred. Children on dialysis fewer than three months, with fewer than three adequacy measurements, or with acute kidney injury without an established chronic program were excluded.

Dialysis adequacy assessment

For hemodialysis patients, single-pool Kt/V was calculated monthly using the second-generation Daugirdas formula, consistent with pediatric adaptations of the National Cooperative Dialysis Study kinetic model [7,16]; adequacy required Kt/V of at least 1.2 per session [9]. For peritoneal dialysis patients, weekly Kt/V and creatinine clearance were calculated quarterly from 24-hour dialysate and urine collections, with adequacy defined as weekly Kt/V of at least 1.7, incorporating residual clearance where present [10,17]. Normalized protein catabolic rate was calculated from urea generation rate for both modalities [18].

Clinical and prescription variables

Data abstracted included age, sex, body mass index z-score, primary stone-forming diagnosis (idiopathic hypercalciuria, primary hyperoxaluria, cystinuria, distal renal tubular acidosis, or structural/obstructive), symptomatic stone episodes, residual kidney function, vascular access type for hemodialysis patients (fistula, graft, or catheter), prescription parameters, serum bicarbonate, albumin, and hemoglobin. Recurrent stone episodes were defined as two or more symptomatic events during the 12-month window.

Statistical analysis

Adequacy status at each measurement was analyzed using multivariable logistic regression with generalized

estimating equations to account for repeated measurements, adjusting for age, sex, modality, body mass index z-score, residual kidney function, vascular access type, and recurrent stone episodes. Relationships between achieved Kt/V and bicarbonate or normalized protein catabolic rate were assessed with Pearson correlation. A two-sided p-value below 0.05 was considered significant, with estimates reported as adjusted odds ratios and 95% confidence intervals.

3. Results

Cohort characteristics

The cohort comprised 118 pediatric dialysis patients with confirmed nephrolithiasis: 74 (62.7%) hemodialysis and 44 (37.3%) peritoneal dialysis, contributing 1,046 adequacy measurements over 12 months. Median age was 11.4 years (interquartile range 8.1-14.6), and 54.2% were male. Idiopathic hypercalciuria was the most common stone-forming diagnosis (38.1%), followed by structural/obstructive causes (24.6%), cystinuria (15.3%), primary hyperoxaluria (13.6%), and distal renal tubular acidosis (8.5%). Recurrent stone episodes occurred in 41 patients (34.7%). Characteristics by modality are summarized in Table 1.

Overall adequacy achievement

Across all measurements, 71.2% met the modality-specific adequacy target. Adequacy differed by vascular access category among hemodialysis patients (Figure 1): fistula access achieved adequacy in 82.4% of measurements, versus 68.9% for grafts and 54.7% for catheters.

Predictors of dialysis adequacy

Four factors were independently associated with adequacy: residual kidney function (adjusted OR 2.84, p<0.001), higher body mass index z-score (adjusted OR 1.62, p=0.012), fistula access relative to catheter (adjusted OR 3.21, p=0.002), and recurrent stone episodes, associated with lower odds (adjusted OR 0.46, p=0.011). Age, sex, and modality were not independently associated

after adjustment (Table 2).

Table 1: Baseline demographic, stone-disease, and dialysis-prescription characteristics of 118 pediatric nephrolithiasis patients by dialysis modality [29,30,31].			
Characteristic	Hemodialysis (n=74)	Peritoneal dialysis (n=44)	Overall (n=118)
Median age, years (IQR)	12.1 (8.6-15.0)	10.2 (7.3-13.4)	11.4 (8.1-14.6)
Male sex	42 (56.8%)	22 (50.0%)	64 (54.2%)
Idiopathic hypercalciuria	26 (35.1%)	19 (43.2%)	45 (38.1%)
Primary hyperoxaluria	11 (14.9%)	5 (11.4%)	16 (13.6%)
Cystinuria	12 (16.2%)	6 (13.6%)	18 (15.3%)
Distal renal tubular acidosis	6 (8.1%)	4 (9.1%)	10 (8.5%)
Structural / obstructive	19 (25.7%)	10 (22.7%)	29 (24.6%)
Recurrent stone episodes (>=2)	27 (36.5%)	14 (31.8%)	41 (34.7%)
Median dialysis vintage, months (IQR)	18 (9-33)	14 (7-27)	16 (8-31)

Table 2: Multivariable generalized-estimating-equation model of independent predictors of dialysis adequacy across 1,046 monthly and quarterly measurements [32,33].		
Predictor	Adjusted OR (95% CI)	p-value
Residual kidney function (per unit increase)	2.84 (1.61-5.02)	<0.001
Body mass index z-score (per unit increase)	1.62 (1.11-2.36)	0.012
Arteriovenous fistula vs. catheter access	3.21 (1.55-6.65)	0.002
Recurrent stone episodes (>=2 vs. <2)	0.46 (0.25-0.84)	0.011
Age (per year)	1.03 (0.94-1.13)	0.51
Male sex	0.92 (0.61-1.39)	0.68
Dialysis modality (PD vs. HD)	1.11 (0.72-1.71)	0.64

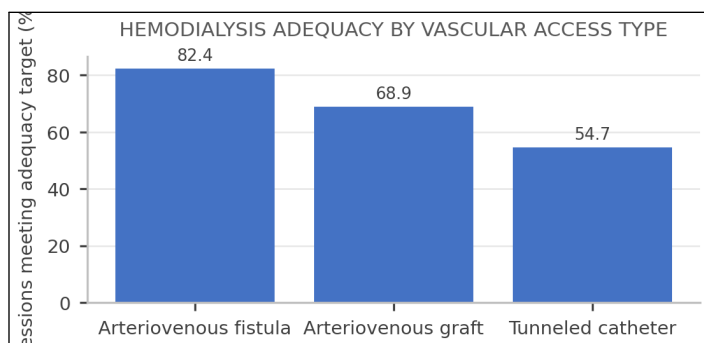


Figure 1: Hemodialysis adequacy achievement (proportion of sessions meeting single-pool Kt/V ≥ 1.2) by vascular access type, highest with an arteriovenous fistula and lowest with a tunneled central venous catheter, consistent with established access-adequacy relationships in pediatric hemodialysis [21,25].

Biochemical correlates of achieved Kt/V

Bicarbonate correlated positively with achieved Kt/V ($r=0.41$, $p<0.001$), relevant in stone-forming children already prone to acidosis [19]. Normalized protein catabolic rate showed a stronger correlation ($r=0.53$, $p<0.001$), reflecting the interdependence of dialysis dose and nutrition [20]. Albumin and hemoglobin were not significantly correlated after adjustment (Figure 2).

4. Discussion

This multicenter cohort found dialysis adequacy in pediatric nephrolithiasis patients achieved in roughly seven of ten measurements, broadly consistent with adequacy rates reported in general pediatric dialysis populations [15,8]. The four predictors identified, residual kidney function, nutritional status, vascular access type, and recurrent stone episodes, describe a coherent picture in which patient physiology and modifiable practice factors together shape whether a prescribed dose is delivered.

The residual-function association echoes adult and pediatric literature showing that native clearance meaningfully supplements dialytic solute removal [17,18]. In stone-disease children, recurrent stone events or obstruction may accelerate loss of residual function through episodic hydronephrosis or infection, explaining why recurrence independently predicted lower adequacy

even after adjustment [5,6]. Stone recurrence surveillance may therefore carry measurable downstream effects on dialysis delivery, not only urological ones.

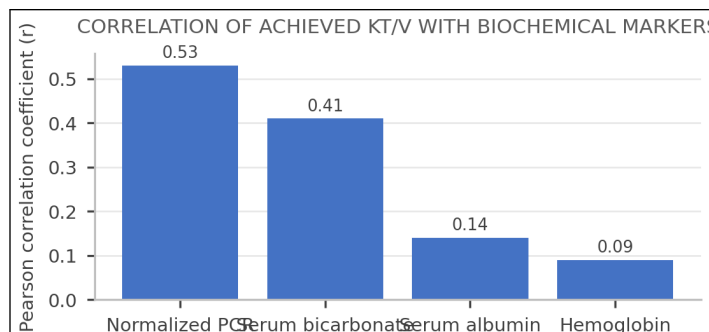


Figure 2: Correlation strength (Pearson r) between achieved Kt/V and serum bicarbonate, normalized protein catabolic rate, serum albumin, and hemoglobin, showing the strongest relationship for normalized protein catabolic rate, reflecting the interdependence of dialysis dose and nutritional status described in wasting and metabolic bone disease in pediatric chronic kidney disease [26,27,28].

The access finding reproduces, in a stone-disease cohort, the established preference for arteriovenous fistulae over catheters for hemodialysis adequacy, attributable to more reliable flow and lower recirculation [16,21]. Because urological interventions can complicate access planning, earlier coordinated vascular mapping in this subgroup is warranted rather than defaulting to catheters for expediency [22].

The body mass index association likely shares a driver with the protein-catabolic-rate correlation: better-nourished children have greater protein intake and typically better residual function and fewer session interruptions [20,23]. Nutritional optimization is already central to pediatric dialysis outcomes generally, and metabolic derangements from underlying tubular disorders can complicate this further in stone-disease patients [24].

Limitations include the retrospective, three-center design without a contemporaneous non-stone comparison group, so the independent contribution of nephrolithiasis versus its underlying metabolic causes cannot be fully disentangled; adequacy intervals differed by modality and

center, and dietary intake was not systematically captured. Despite these limitations, consistency with established dialysis physiology and the actionable nature of access planning and stone surveillance support their relevance to practice.

5. Conclusion

In this multicenter cohort of pediatric dialysis patients with nephrolithiasis, dialysis adequacy was independently predicted by residual kidney function, body mass index z-score, arteriovenous fistula access, and absence of recurrent stone episodes. These findings support a practice approach in which pediatric nephrology teams managing dialysis-dependent children with a stone history prioritize early arteriovenous access planning, active nutritional support, and close surveillance for recurrent nephrolithiasis, recognizing that stone recurrence may erode dialysis adequacy through its effect on residual kidney function. Prospective, multicenter studies with a matched non-stone comparison group are needed to confirm whether nephrolithiasis itself, rather than its underlying metabolic causes, independently drives the adequacy differences observed here.

6. References

1. Tasian, G.E., Ross, M.E., Song, L., Sas, D.J., Keren, R., Denburg, M.R., et al. (2016) Annual incidence of nephrolithiasis among children and adults in South Carolina from 1997 to 2012. *Clinical Journal of the American Society of Nephrology*, 11(3): 488-496.
2. Copelovitch, L., Kaplan, B.S. (2008) Urolithiasis in children: pathogenesis, presentation and management. *Pediatric Nephrology*, 23(11): 2119-2126.
3. Cochat, P., Rumsby, G. (2013) Primary hyperoxaluria. *New England Journal of Medicine*, 369(7): 649-658.
4. Halbritter, J., Baum, M., Hynes, A.M., Rice, S.J., Thwaites, D.T., Simpson, M.A., et al. (2015) Fourth-generation urine-based next-generation sequencing gene panel for hereditary kidney stone disease. *Journal of the American Society of Nephrology*, 26(3): 543-551.
5. Alexander, R.T., Hemmelgarn, B.R., Wiebe, N., Bello, A., Morgan, C., Samuel, S., et al. (2012) Kidney stones and kidney function loss: a cohort study. *BMJ*, 345: e5287.
6. VanDeVoorde, R.G. (2011) Urolithiasis in children. *Pediatric Clinics of North America*, 58(2): 359-372.
7. Gotch, F.A., Sargent, J.A. (1985) A mechanistic analysis of the National Cooperative Dialysis Study (NCDS). *Kidney International*, 28(3): 526-534.
8. North American Pediatric Renal Trials and Collaborative Studies. (2014) NAPRTCS 2014 Annual Dialysis Report. NAPRTCS, Rockville, MD.
9. National Kidney Foundation. (2006) KDOQI clinical practice guidelines for hemodialysis adequacy, update 2006. *American Journal of Kidney Diseases*, 48(Suppl 1): S2-S90.
10. National Kidney Foundation. (2006) KDOQI clinical practice guidelines for peritoneal dialysis adequacy, update 2006. *American Journal of Kidney Diseases*, 48(Suppl 1): S91-S157.
11. Fischbach, M., Warady, B.A. (2009) Peritoneal dialysis prescription in children: bedside principles for optimal practice. *Pediatric Nephrology*, 24(9): 1633-1642.
12. Sas, D.J. (2018) An update on the changing epidemiology and metabolic risk factors in pediatric kidney stone disease. *Clinical Journal of the American Society of Nephrology*, 6(8): 2062-2068.
13. Milliner, D.S., Murphy, M.E. (1993) Urolithiasis in pediatric patients. *Mayo Clinic Proceedings*, 68(3): 241-248.
14. Warady, B.A., Chadha, V. (2007) Chronic kidney disease in children: the global perspective. *Pediatric Nephrology*, 22(12): 1999-2009.
15. Furth, S.L., Hwang, W., Yang, C., Neu, A.M., Fivush, B.A., Powe, N.R. (2002) Growth failure, risk of hospitalization and death for children with end-stage renal disease. *Pediatric*

-
- | | |
|---|--|
| <p>Nephrology, 17(6): 450-455.</p> <p>16. Chand, D.H., Valentini, R.P. (2008) International pediatric fistula first initiative: a call to action. <i>American Journal of Kidney Diseases</i>, 51(6): 1016-1024.</p> <p>17. Schmitt, C.P., Bakkaloglu, S.A., Klaus, G., Schroder, C., Fischbach, M. (2011) Solute and fluid removal in children on chronic peritoneal dialysis. <i>Pediatric Nephrology</i>, 26(7): 1001-1009.</p> <p>18. Watson, A.R., Coleman, J.E., Warady, B.A. (2012) When and how to use nutritional supplements in children on dialysis. <i>Peritoneal Dialysis International</i>, 32(Suppl 2): S192-S196.</p> <p>19. Bakkaloglu, S.A., Bacchetta, J., Lalayiannis, A.D., Leonard, M.B., Shroff, R., Group, E.S.C.M.B.D.W. (2021) Bone evaluation in paediatric chronic kidney disease: clinical practice points from the European Society for Paediatric Nephrology CKD-MBD and Dialysis working groups. <i>Pediatric Nephrology</i>, 36(9): 2937-2949.</p> <p>20. Chesney, R.W. (2016) The role of nutrition in growth and metabolic bone disease in children with chronic kidney disease. <i>Pediatric Nephrology</i>, 31(6): 891-899.</p> <p>21. Fischbach, M., Edefonti, A., Schroder, C., Watson, A. (2005) Hemodialysis in children: general practical guidelines. <i>Pediatric Nephrology</i>, 20(8): 1054-1066.</p> <p>22. Bunchman, T.E. (2001) Chronic dialysis in the infant less than 1 year of age. <i>Pediatric Nephrology</i>, 16(3): 289-290.</p> <p>23. Foster, B.J., Leonard, M.B. (2004) Nutrition in children with kidney disease: pitfalls of tradition. <i>Blood Purification</i>, 22(1): 72-76.</p> <p>24. National Kidney Foundation. (2009) KDOQI clinical practice guideline for nutrition in children with CKD: 2008 update. <i>American Journal of Kidney Diseases</i>, 53(3 Suppl 2): S1-S123.</p> <p>25. Ledermann, S.E., Scanes, M.E., Fernando, O.N., Duffy, P.G., Madden, S.J., Trompeter, R.S. (2000) Long-term outcome of peritoneal dialysis in infants. <i>Journal of Pediatrics</i>, 136(1):</p> | <p>24-29.</p> <p>26. Mak, R.H., Ikizler, T.A., Kovesdy, C.P., Raj, D.S., Kalantar-Zadeh, K., Kopple, J.D. (2011) Wasting in chronic kidney disease. <i>Journal of Cachexia, Sarcopenia and Muscle</i>, 2(1): 9-25.</p> <p>27. Zurowska, A.M., Fischbach, M., Watson, A.R., Edefonti, A., Stefanidis, C.J. (2013) Clinical practice recommendations for the care of infants with stage 5 chronic kidney disease. <i>Pediatric Nephrology</i>, 28(9): 1739-1748.</p> <p>28. Fischbach, M., Terzic, J., Menouer, S., Provot, E., Bergere, V. (2005) Hemodiafiltration in children: nutritional and metabolic effects. <i>Pediatric Nephrology</i>, 20(11): 1636-1638.</p> <p>29. Tasian, G.E., Copelovitch, L. (2014) Evaluation and medical management of kidney stones in children. <i>Journal of Urology</i>, 192(5): 1329-1336.</p> <p>30. Copelovitch, L. (2012) Urolithiasis in children: medical approach. <i>Pediatric Clinics of North America</i>, 59(4): 881-896.</p> <p>31. Hoppe, B., Kemper, M.J. (2010) Diagnostic examination of the child with urolithiasis or nephrocalcinosis. <i>Pediatric Nephrology</i>, 25(3): 403-413.</p> <p>32. Groothoff, J.W., Gruppen, M.P., Offringa, M., Hutten, J., Lilien, M.R., Van De Kar, N.J., et al. (2002) Mortality and causes of death of end-stage renal disease in children: a Dutch cohort study. <i>Kidney International</i>, 61(2): 621-629.</p> <p>33. Warady, B.A., Bakkaloglu, S., Newland, J., Cantwell, M., Verrina, E., Neu, A., et al. (2012) Consensus guidelines for the prevention and treatment of catheter-related infections and peritonitis in pediatric patients receiving peritoneal dialysis: 2012 update. <i>Peritoneal Dialysis International</i>, 32(6): 610-624.</p> |
|---|--|