ADDIS ABABA UNIVERSITY
COLLEGE OF HEALTH SCIENCES
DEPARTMENT OF SURGERY

SHORT AND LONG-TERM RENAL FUNCTION TRAJECTORIES AND ASSOCIATED FACTORS FOLLOWING ULTRASOUND GUIDED PERCUTANEOUS NEPHROLITHOTOMY (PCNL) ASSESSED BY ESTIMATED GLOMERULAR FILTRATION RATE

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A Research Thesis Submitted to Addis Ababa University, College of Health Sciences, Department of Surgery – Urology Unit in Partial Fulfillment of the Requirements for Specialty in Urology Residency Program

December, 2025

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Acronyms and Abbreviations

PCNL – Percutaneous Nephrolithotomy

CKD – Chronic Kidney Disease

eGFR – Estimated Glomerular Filtration Rate

UTI – Urinary Tract Infection

SPSS – Statistical Package for Social Sciences

AAU – Addis Ababa University

IRB - Institutional Review Board

ETB - Ethiopian Birr

CKD-EPI - Chronic Kidney Disease Epidemiology Collaboration

SFU - Society for Fetal Urology

BMI – Body Mass Index

CT – Computed Tomography

SCr – Serum Creatinine

HDN – Hydronephrosis

RAAS - renin–angiotensin–aldosterone system

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Summary

Background: Percutaneous nephrolithotomy (PCNL) is the treatment of choice for large and complex renal stones. Information regarding stone clearance outcomes are well established. But, data on short and long term renal function changes after PCNL procedure, particularly in low resource settings is limited.

Objective: Assess short and long term renal function Pattern after a PCNL procedure and identify factors associated with change in estimated glomerular filtration rate (eGFR) among patients managed at Tikur Anbessa Specialized Hospital between September 1, 2023 and October 30, 2024

Methods: A retrospective cohort study was conducted. A prospectively collected data from a previous research was supplemented by electronic medical record review and analysis was done. Patient's aged ≥15 years were included. Renal function was assessed using eGFR (CKD-EPI 2021) at baseline, 72 hours, 3 months, 6 months, and 12 months. Longitudinal eGFR changes were analyzed using linear mixed-effects models with multiple imputation for missing predictor data.

Results: 100 patients were included in the study with mean age 41.2 ± 12.8 years and 67% male were male. Mean eGFR showed a transient, non-significant decline at 72 hours followed by progressive recovery, exceeding baseline values at 12 months by +5.68 mL/min/1.73 m² (p = 0.034) which was not significant when it was adjusted for other factors. Old age and presence of comorbidities were independently associated with lower eGFR at baseline but has no significant impact on the patter of eGFR during follow-up. Significant effect of hydronephrosis and CKD was seen on the pattern of eGFR. Presence of moderate to severe hydronephrosis showed poor recovery whereas patients with CKD stages 3 and 4 showed significant relative improvement over time. Operative factors were not independently associated with long-term renal function.

Conclusion: PCNL results in a transient early postoperative decline followed by recovery and long-term preservation or improvement in most patients, having no net effect on renal function. Baseline renal function and hydronephrosis severity primarily determine postoperative renal function pattern.

Keywords: Percutaneous nephrolithotomy; Ultrasound PCNL; renal function; GFR; chronic kidney disease; hydronephrosis; Ethiopia.

1. Introduction

1.1 Background

Nephrolithiasis is a major urological health problem worldwide. The prevalence is rising in both developed and developing countries because of factors like changes in lifestyle, hydration, and diet [1]. In Ethiopia, renal stone is one of the leading causes of hospital admission among urological conditions. Many patients present late due to lack of access to diagnostic imaging and specialized care [2].

Percutaneous nephrolithotomy (PCNL) is the gold standard management option for large (>2 cm) and staghorn renal stones, providing the advantage of high stone-free rates and lower morbidity compared to open surgery [4]. PCNL has improved patient outcome by reducing hospital stays and minimizing surgical trauma, which is of great benefit in Ethiopian context [2]. However, questions regarding its potential impact on renal function are raised, particularly among patients who often present with chronic kidney disease (CKD), hydronephrosis and infected stones [3, 5].

Studies across he globe have shown that PCNL may cause a transient early decline in glomerular filtration rate (GFR) within the first 48–72 hours postoperatively, which usually recovers within months once obstruction and infection are relieved [6, 7]. Nonetheless, long-term outcomes vary, especially in those with pre-existing renal impairment, multiple access tracts and severe periprocedural bleeding [8, 9]. Patients in Ethiopia has a high stone burden and frequent late presentation. So, understanding of the short and long term renal function outcome after PCNL is critical for guiding local surgical practice and patient management.

1.2 Problem Statement

Although PCNL is established as a safe and effective procedure, data regarding renal function outcome in Ethiopian patients is scarce. Most local studies have focused on surgical success rates and complications rather than quantitative renal function pattern. Current available evidence shows that renal function after PCNL may improve, remain stable, or decline depending on patient and procedural factors [7-9]. However, African and Ethiopian patients differ substantially from the others in baseline renal reserve, stone complexity and medical access, potentially showing a different trend [2, 3].

Due to lack of data, it is unclear whether renal function fully recovers, stabilizes, or continue to decline after PCNL in our population. This lack of local data regarding the short and long term renal function effect and the associated predictors limit the ability of clinicians to make evidence-based recommendations, surgical planning, and follow-up.

1.3 Significance of the Study

This study aims to fill the existing knowledge gap regarding the short and long term renal function changes following PCNL in Ethiopian patients, who often present late and have limited renal reserve [2, 3]. Determining how renal function changes in the short and long term postoperatively will help differentiate transient postoperative effects from permanent parenchymal loss. Identifying predictors will allow for individualized perioperative risk stratification and better surgical planning [8 - 10].

From a public health point of view, the stakes are even higher in Ethiopia as Dialysis and kidney transplants services are limited, which means protecting renal function after stone surgery is the key to preventing progression to CKD and improve patients' futures. This study also brings much-needed local data to the global conversation.

2. Literature Review

Percutaneous nephrolithotomy (PCNL) is the gold standard treatment option for large and complex kidney stones. The degree of renal function change following PCNL and determinants have been studied and reported.

Early and Short term outcome

Short term studies consistently showed a transient and statistically significant decline in renal function parameters immediately after PCNL. Mukherjee et al. (2019) found a significant rise in serum creatinine from 0.89 to 0.96 mg/dL ($p = 0.0002$), and eGFR dropped from 95.2 to 89.3 mL/min/1.73 m^2 within 72 hours [4]. Hosseini et al. (2015) saw a similar pattern: GFR fell from 74.9 to 64.0 mL/min at 48 hours, but partially bounced back by 72 hours [5]. This suggests a mild injury to the kidney tissue, but one that usually reverses itself.

Sichani et al. (2014) reported that even when only one kidney undergoes PCNL, both kidneys can show a drop in GFR, peaking at 24–36 hours. But there's no lasting damage. They linked this to neural and hormonal responses, including the reno-renal reflex and RAAS-driven vasoconstriction [6]. Interestingly, people with higher preoperative eGFR tended to have a slightly bigger early decline, making baseline kidney function a key predictor right after surgery [4]. Factors like the number of tracts, how much fluid was used, or how long the scope stayed in didn't make much difference to this early GFR drop [4, 5].

Most patients have returned to their baseline eGFR by 3 month postoperatively and some even experience improvement due to relief of obstruction. On their report, Yarimoglu et al. (2022) documented that both normal kidneys and kidneys with mild impairment have an early eGFR decline on postoperative day 1, followed by recovery at 3 months (*p* > 0.05). The peculiar finding was that patients with preoperative CKD (< 60 mL/min) showed significant late improvement ($p = 0.033$) [11].

Jung et al. (2020) also stated that at 12 month functional stability or even improvement is seen in 82.5% of patients following mini-PCNL or retrograde intrarenal surgery (RIRS)

[1]. Similarly, İzol et al. (2021) observed that all CKD stages experienced significant eGFR improvement at 1 and 12 months (mean +10 mL/min/1.73 m², $p < 0.005$), with the largest gain being among patients in stage IV and V [7].

Long-Term Outcomes

Evidence from different studies indicate stabilization or improvement in renal function is the usual norm. Basiri et al. (2012) found that patients maintained or improved DMSA renal uptake 6 months post PCNL, with no significant change in creatinine level [12]. According to Fayad et al. (2014), while patients with normal baseline renal function exhibited minimal eGFR decline (−4 mL/min), those with pre-existing impairment showed sustained deterioration (−16%) over 12 months [8].

Shen and Chen (2025) reported a mean eGFR increase of 8 mL/min at 1 year in patients who has undergone bilateral single-tract PCNL, with 29% showing improvement in CKD stage [10]. İzol et al. (2021) found similar findings where only 17.5% of CKD patients experienced functional worsening at 1 year, mainly linked to multiple access tracts (OR = 9.46, $p < 0.001$) and larger stone burden [7]. These consistent findings show that renal function recovery extends through the first postoperative year. Predictors identified for long-term functional outcome are baseline renal impairment, diabetes, hypertension, and multiple access tracts [7, 8].

Studies running past two years are rare, but the available data supports the preservation of renal funcion. El-Tabey et al. (2014) followed 200 patients with a single kidney for three years and saw that renal function improve or stay stable in 84.5%. Multiple punctures (OR 3.7) and severe bleeding (OR 4.5) stood out as risk factors for those with deteriorated renal function [9]. Lee et al. (2025) found that more than 60% of patients who had mini-PCNL or RIRS maintained stable function over the long run [13]. High preoperative creatinine, hydronephrosis, and complex stones predicted later decline, while mini-PCNL actually protected against it (OR 0.11, $p = 0.045$). So while most patients keep their kidney function for years after PCNL, a subset remains at risk for gradual worsening.

Associated Factors

Renal function outcome correlates with baseline renal function status and procedure related trauma rather than demographic or intraoperative parameters.

Baseline eGFR/Creatinine is consistently a major determinant of postoperative outcome. Lower baseline predicts later improvement and higher baseline predicts transient early decline [4, 11, 1]. Multiple access tracts and severe hemorrhage are linked to long-term deterioration [8, 9]. Comorbidities, mainly diabetes and hypertension accelerate functional loss, especially in CKD [8]. Complicated Stones and hydronephrosis increase risk of late decline [13]. Miniaturized approaches like mini-PCNL and, tubeless PCNL contribute to functional preservation by reducing parenchymal insult without compromising stone clearance [5, 1, 10].

Data from centers in Africa echo patterns similar to rest of the world but late presentation is emphasized as a major determinant. In Ethiopia, 73% of patients presented with hydronephrosis and 4.9% with renal failure. However, 92% of patients retained a good postoperative renal function [2]. Case series from Nigeria and Tunisia reported the feasibility and safety of supine and repeat PCNL even in resource-limited setting and previously operated kidneys [3, 14]. These findings reinforce that prompt intervention and surgical accessibility rather than type of procedure, determine renal function preservation.

In Summary, Cumulative evidence (2012 – 2025) shows PCNL induces a transient early decline in renal function followed by recovery in 3 months, and long-term preservation or improvement in majority of the patients.

3. Objectives

3.1 General Objective

- Assess short and long term renal function changes and identify associated factors among patients who have undergone Ultrasound guided PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

3.2 Specific Objectives

- Determine pattern of renal function change at 72 hours, 3 month, 6 month and 12 month after PCNL among patients who have undergone Ultrasound guided PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.
- Determine factors associated with renal function change following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

4. Methodology

4.1 Study Design and Period

This study takes a retrospective cohort approach, relying on secondary analysis of a prospectively collected PCNL dataset. To fill in any missing information, we went back and reviewed electronic medical records. We pulled data from a prospective PCNL study at Tikur Anbessa Hospital, covering patients who had the PCNL procedure between September 1, 2023, and October 30, 2024. We abstracted medical records between October 20 and November 20, 2025, then moved on to analysis and thesis writing through the end of November 2025.

4.2 Population

4.2.1 Source Population

The source population includes everyone who underwent PCNL at Tikur Anbessa Specialized Hospital from September 1, 2023 to October 30, 2024, and who was already part of the prospective PCNL research dataset.

4.2.2 Study Population

From the source population, we included only patients whose medical records had enough baseline and follow-up data on renal function.

4.3 Inclusion and Exclusion Criteria

4.3.1 Inclusion Criteria

- Patients aged 15 years and older.
- Patients with a baseline creatinine measurement within 14 days before PCNL and at least one postoperative eGFR result at 72 hours, 3 months, 6 months, or 12 months.
- Medical records available so we could fill in any missing variables..

4.3.2 Exclusion Criteria

- Patients who had any additional surgical procedures apart from PCNL.
- Patients who had a repeat PCNL within one year of the first procedure.

4.4 Sample Size Determination and Sampling Technique

4.4.1 Sample Size Determination

We calculated a minimum sample size of 84 patients using a paired comparison method. For this, we assumed a standard deviation of 15 mL/min/1.73 m², a detectable difference of 5 mL/min/1.73 m², 80% power, and a two-sided alpha of 0.05. In the end, the study included 100 patients—more than we needed. While we based the sample size calculation on paired comparisons, our final analysis used linear mixed-effects models, which make more efficient use of all available repeated measures.

4.4.3 Sampling Technique and Procedure

We reviewed all eligible records from the study period and included those that met the inclusion criteria..

4.5 Operational Definitions

- Estimated Glomerular Filtration Rate (eGFR): Calculated using the CKD-EPI 2021 creatinine equation to assess kidney function (mL/min/1.73 m²) [15].
- Hydronephrosis Grade**:** Degree of pelvicalyceal dilation graded 0–4 per SFU system. [16]
- Time to get ultrasound guided access – the time from incision of the skin to efflux of clear urine though the puncture needle.
- Total duration of surgery – the time measured from starting of cystoscope guided ureteric catheter insertion to fixation of the nephrostomy tube.
- Clavien Dindo classification it is a classification used to rank severity of postoperative complications.
    - Minor complications defined as Clavien – Dindo class 1 and 2 complications.

- Major complications defined as Clavien – Dindo class 3 or 4 complications

- Baseline renal function: The most recent serum creatinine measured within 14 days pre-PCNL (use the value closest to surgery if multiple exist).
- Postoperative timepoints:
  - 72 hours: creatinine/eGFR measured 48–96 hours after PCNL (state the window you actually allow).
  - 3 months: 12 ± 2 weeks
  - 6 months: 6 ± 1 months
  - 12 months: 12 ± 1 months
- Bleeding**:** bleeding that required transfusion or transfusion requirement.
- CKD stage**:** Categorized using baseline eGFR per KDIGO staging (Stage 1 ≥90, Stage 2 60–89, Stage 3 30–59, Stage 4 15–29, Stage 5 <15 mL/min/1.73 m^2).
- STONE score: A validated nephrolithometry system used to quantify renal stone complexity based on five preoperative imaging parameters, using Preoperative CT: Stone size (S), Tract length (T), Obstruction (O), Number of calyces involved (N), and stone Essence/density (E). The total score runs from 5 to 13. Higher score mean more complex stones and difficult procedures.

4.6 Study Variables

4.6.1 Dependent Variable

- Primary outcome was pattern of eGFR across time measured a baseline and across time points of 72 hours, 3 months, 6 months, and 12 months following PCNL.

4.6.2 Independent Variables

- Age (years)
- Sex (male/female)
- Body mass index (Catagorical)
- Baseline eGFR (continuous)
- Baseline CKD stage (Stages 1–5)

- Comorbidities (hypertension, diabetes mellitus, retroviral infection…)
- Degree of hydronephrosis (none, mild, moderate, severe)
- Stone characteristics:
    - Stone size (largest diameter, mm)
    - Stone burden / STONE nephrolithometry score
    - Stone laterality (right/left/bilateral)

- Number of access tracts (single vs multiple)
- Tract size (largest sheath size, Fr)
- Operative duration (minutes)
- Ultrasound-guided access time (minutes)
- Hemoglobin change
- Early stone clearance status (yes/no)
- Length of hospital stay (days)
- Duration of nephrostomy drainage (hours)
- Postoperative complications (Clavien–Dindo grade)
- Follow-up time (categorical: baseline, 72 h, 3 months, 6 months, 12 months)

4.7 Data Collection Method and Materials

4.7.1 Data Sources

1. **Prospectively collected Dataset:** One dataset from a research approved done at Tikur Anbessa Hospital after Institutional Review Board (IRB) approval.
2. **Hospital Medical Records:** Electronic medical record was used to collect all the follow-up renal function measures at 3, 6 and 12 months.

4.7.2 Data Collection Instrument

A structured electronic data-extraction form was developed using Microsoft Excel.

4.7.3 Data Collectors

Data extraction was performed by two trained urology residents under the supervision of the principal investigator (PI). Data collectors were trained prior to abstraction.

4.7.4 Data Collection Procedure

1. Permission obtained from the original study investigator and the IRB.
2. The prospective PCNL dataset was exported and harmonized using a unified codebook.
3. Retrospective medical record review was conducted to collect missing variables using medical record numbers (MRNs). Eligible records were identified based on inclusion and exclusion criteria.
4. New study identification numbers were assigned, and all personal identifiers were removed prior to analysis.
5. Double data entry was performed for 5% of records to assess inter-rater reliability.

4.7.5 Data Integration and Coding

Following data extraction, the prospective dataset and chart-review file were merged into a single harmonized dataset. Variable names, coding schemes, and missing-value indicators were standardized prior to statistical analysis.

4.8 Data Processing and Analysis

Descriptive analysis was conducted and Categorical variables were summarized using frequencies and percentages. Whereas for continuous variables normality was assessed and summary produced as mean ± standard deviation (SD) for approximately normally distributed data or median with interquartile range (IQR) for skewed distributions.

Missing data in predictor variables was handled by using multiple imputation, assuming data were missing at random and twenty imputed datasets were generated. Outcome variables (eGFR) were left unimputed. The missingness pattern was tested with Little's MCAR test. To check the stability of imputation, residual distributions was compared across imputations looking at means, variances, skewness and kurtosis—which all stayed consistent, showing the models converged well.

Change in renal function was analyzed used linear mixed-effects models. This approach handles repeated eGFR measurements for each patient even if they have missed follow ups. Follow-up time was treated as a categorical, time-varying variable (baseline, 72 hours, 3 months, 6 months, and 12 months) and specified random intercepts for each patient.

Initially unadjusted model was fitted to evaluate overall time effect on eGFR. Multivariable mixed-effects model was subsequently developed to identify independent predictors of renal function adjusting for covariates. Effect modification was assessed by including interaction terms between follow-up times. Significant interactions were explored using model based estimated marginal means and interaction plots.

We checked model assumptions by looking at residuals with histograms, calculating skewness and kurtosis, and running formal normality tests. Across all imputed datasets, residuals were symmetrically distributed, with skewness from −0.15 to 0.23 and kurtosis from −0.08 to 0.54. Skewness-to-standard-error ratios stayed below 2. Both Kolmogorov–Smirnov tests (with Lilliefors correction) and Shapiro–Wilk tests showed no evidence of non-normality ($p > 0.20$). So, model assumptions for normality held up.

For post hoc analysis, we ran pairwise comparisons between time points and adjusted for multiple testing using Bonferroni correction. Regression coefficients (β), standard errors (SE), 95% confidence intervals (CI), and p-values are reported. All tests are two-sided, with $p < 0.05$ considered statistically significant.

4.9 Data Quality Assurance

Data quality was ensured initially, through training of data collectors and use of a predefined electronic data-extraction form. The data collection instrument was pilot tested prior to full data collection. Double data entry was performed for a subset of records, and discrepancies were resolved through review of source documents. Verification of outliers and consistency check was done during data cleaning before analysis.

4.10 Ethical Considerations

Ethical approval obtained from the Institutional Review Board (IRB) of Addis Ababa University, College of Health Sciences with the reference number of DOS/REC/88/18/25. The study involved secondary analysis of de-identified prospectively collected data with supplementary retrospective chart review. A waiver of informed consent was granted due to minimal risk to participants. Data confidentiality was maintained through de-identification and restricted access in accordance with institutional guidelines.

5. Result

5.1. Sociodemographic and Clinical Characteristics

We included 100 patients who underwent PCNL. The average age was 41.2 years, with a standard deviation of 12.8. Most patients were male, 67%. The median STONE score was 7, and the median estimated glomerular filtration rate (eGFR) was 87.5 mL/min/1.73 m². For most procedures, surgeons used a single-tract approach in 85% of cases. Early stone clearance was successful in 73% of patients (Table 1 and 2).

Table 1: Sociodemographic and clinical characteristics of patients undergoing percutaneous nephrolithotomy (PCNL) at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

Variable	**N**	**Mean ± SD**	**Median [IQR]**	**Shapiro–Wilk *p***
Age (years)	100	41.2 ± 12.8	41.0 [29.8–49.0]	0.109
Baseline eGFR (mL/min/1.73 m²)	100	85.2 ± 31.1	87.5 [64.8–111.0]	0.023
STONE score	99	6.9 ± 1.2	7.0 [6.0–8.0]	<0.001
Operative time (minutes)	85	103.0 ± 40.8	96.0 [73.0–120.0]	<0.001
Ultrasound access time (minutes)	85	8.4 ± 8.2	5.0 [3.0–11.0]	<0.001
Hemoglobin change (g/dL)	82	−1.4 ± 1.5	−1.3 [−2.2 to −0.6]	0.022

Table 2: Sociodemographic and clinical characteristics of patients undergoing percutaneous nephrolithotomy (PCNL) at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

Variable	**Category**	**N (%)**
Sex	Female	33 (33.0)
	Male	67 (67.0)
Comorbidity	Yes	50 (50.0)
Hypertension	Yes	33 (33.0)
Diabetes mellitus	Yes	16 (16.0)
Retroviral infection	Yes	5 (5.0)
Binary CKD	eGFR < 60	20 (20.0)
	eGFR ≥ 60	80 (80.0)

CKD stage	Stage 1	47 (47.0)
	Stage 2	33 (33.0)
	Stage 3	15 (15.0)
	Stage 4	3 (3.0)
	Stage 5	2 (2.0)
Hydronephrosis Degree	None	26 (26.0)
	Mild	24 (24.0)
	Moderate	38 (38.0)
	Severe	11 (11.0)
Stone laterality	Right	63 (63.0)
	Left	37 (37.0)
Tract number	Single	85 (85.0)
	Multiple	15 (15.0)
Early stone clearance	Yes	73 (73.0)

5.2. Postoperative Complications

Postoperatively, complications occurred in 28% (Table 3 and 4). The majority were minor (Clavien-Dindo I/II: 17%). Major complications (Clavien-Dindo ≥III) occurred in 11% of patients. The most common complications were urine leak (11%) and fever (6%).

Table 3: Clavien–Dindo grading of postoperative complications following percutaneous nephrolithotomy (PCNL) at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024**.**

Variable	**Category**	**N (%)**
Clavien–Dindo	No complication	72 (72.0)
	Minor Complication	17 (17.0)
	Major Complication	11 (11.0)

Table 4: Postoperative complications following percutaneous nephrolithotomy (PCNL) at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

Variable	**Category**	**N (%)**

Fever	Yes	6 (6.0)
Bleeding	Yes	4 (4.0)
Nephrocutaneous fistula	Yes	1 (1.0)
Organ injury	Yes	1 (1.0)
Urosepsis	Yes	1 (1.0)
Tract tuberculosis	Yes	1 (1.0)
Urinary Leak	Yes	11 (11.0)
Perforation	Yes	3 (3.0)

5.3 Pattern of Renal Function

Renal function change was statistically significant over time ($F(4,190.5)=2.86$, $p=0.025$). Mean eGFR exhibited a transient postoperative decline at 72 hours, followed by a recovery that exceeded baseline values by 12 months (+5.68 mL/min/1.73 m², $p=0.034$ vs. baseline) (Table 5).

Table 5: Mean eGFR over time following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

Time point	Mean eGFR	SE	95% CI	Estimate (β)	p-value
Baseline	85.25	3.12	79.13–91.37		
72 hrs	82.19	3.24	75.85–88.54	−3.06	0.106
3 months	87.56	3.31	81.07–94.04	+2.31	0.302
6 months	88.56	3.42	81.86–95.26	+3.31	0.178
12 months	90.93	3.56	83.94–97.91	+5.68	0.034

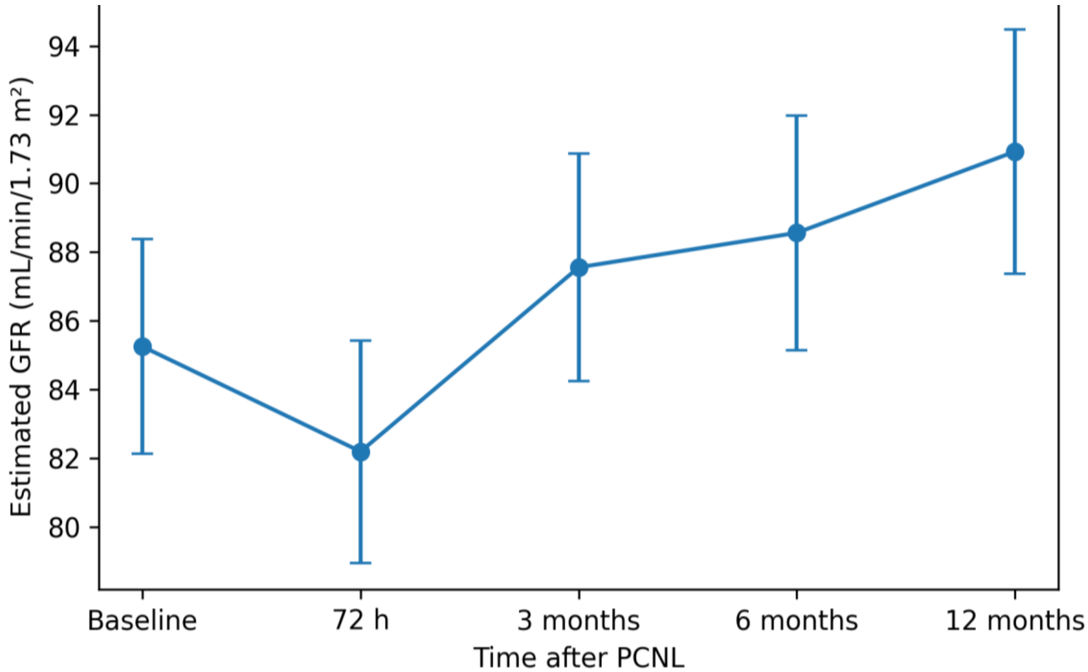

Figure 1: Unadjusted eGFR pattern following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

5.4. Predictors of Renal Function change

5.4.1 Factors affecting the mean eGFR

In the adjusted multivariable mixed-effects model (Table 6), older age (β= -0.40 per year, p=0.004) and the presence of comorbidities (β= -7.46, p=0.032) were associated with lower mean eGFR. As expected baseline CKD stage was associated with mean eGFR significantly, compared to stage 1, advanced stages were associated with progressively lower eGFR (e.g., Stage 5: β= -88.01, p<0.001). Operative factors (time, tract number, sheath size, stone clearance) did not show significant effect on the mean eGFR.

Table 6: Factors affecting mean eGFR following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

Predictor	**Level**	**β (SE)**	**95% CI**	**p-value**
Age	Year	−0.396 (0.136)	−0.662 to −0.129	**0.004**
Comorbidity	Present	−7.46 (3.47)	−14.27 to −0.66	**0.032**
Baseline CKD Stage	Stage 1	Reference		
	Stage 2	−32.30 (4.11)	−40.35 to −24.25	**<0.001**
	Stage 3	−55.41 (5.62)	−66.42 to −44.40	**<0.001**
	Stage 4	−85.68 (10.23)	−105.74 to −65.62	**<0.001**
	Stage 5	−88.01 (14.24)	−115.91 to −60.10	**<0.001**
Clavien Dindo	No	Reference		
	Major	+7.71 (3.70)	0.45 to 14.97	**0.037**
	Minor	−2.90 (3.84)	−10.43 to 4.64	0.451
Sex	F/M	−0.33 (2.90)	−6.01 to 5.35	0.91
Nephrostomy duration	hour	−0.041 (0.022)	−0.085 to 0.003	0.067
TIME	Baseline	Reference		
	72 Hrs	1.096 (22.258)	−42.536 to 44.727	0.961
	3 month	12.980 (21.698)	−29.551 to 55.510	0.55
	6 month	−1.322 (21.374)	−43.219 to 40.574	0.951
	12 month	5.056 (18.093)	−30.418 to 40.530	0.78
Sex	Female	−0.328 (2.899)	−6.010 to 5.353	0.91
BMI	< 18.5	Reference		
	18.5 – 24.9	2.641 (8.474)	−13.979 to 19.260	0.755
	25 – 29.9	−3.668 (6.358)	−16.136 to 8.801	0.564
	> 29.9	−4.404 (6.149)	−16.467 to 7.660	0.474
Early stone clearance	Complete	2.068 (4.720)	−7.184 to 11.320	0.661
Hydronephrosis	No	Reference		
	Mild	−2.789 (6.535)	−15.599 to 10.020	0.67
	Moderate	3.125 (4.585)	−5.861 to 12.112	0.495
	Severe	3.488 (4.746)	−5.814 to 12.790	0.462

Hgb_Change	per g/dl	−0.219 (1.111)	−2.405 to 1.967	0.844
Time_Surgery_Duration	Minute	−0.003 (0.049)	−0.099 to 0.094	0.955
STONE_Score		−0.562 (1.281)	−3.072 to 1.949	0.661
Number of Tract	1	Reference		
	2	1.479 (5.380)	−9.066 to 12.024	0.783
	3	2.788 (14.482)	−25.598 to 31.174	0.847
US Access Time	Minute	0.129 (0.190)	−0.242 to 0.501	0.496
Stone Score		−0.562 (1.281)	−3.072 to 1.949	0.661
Sheath Size	Mini	4.599 (7.394)	−9.892 to 19.090	0.534

** BMI, Operative time, tract number, sheath size, early stone clearance, stone score, and hemoglobin change were not significant independent predictors (all p > 0.05).*

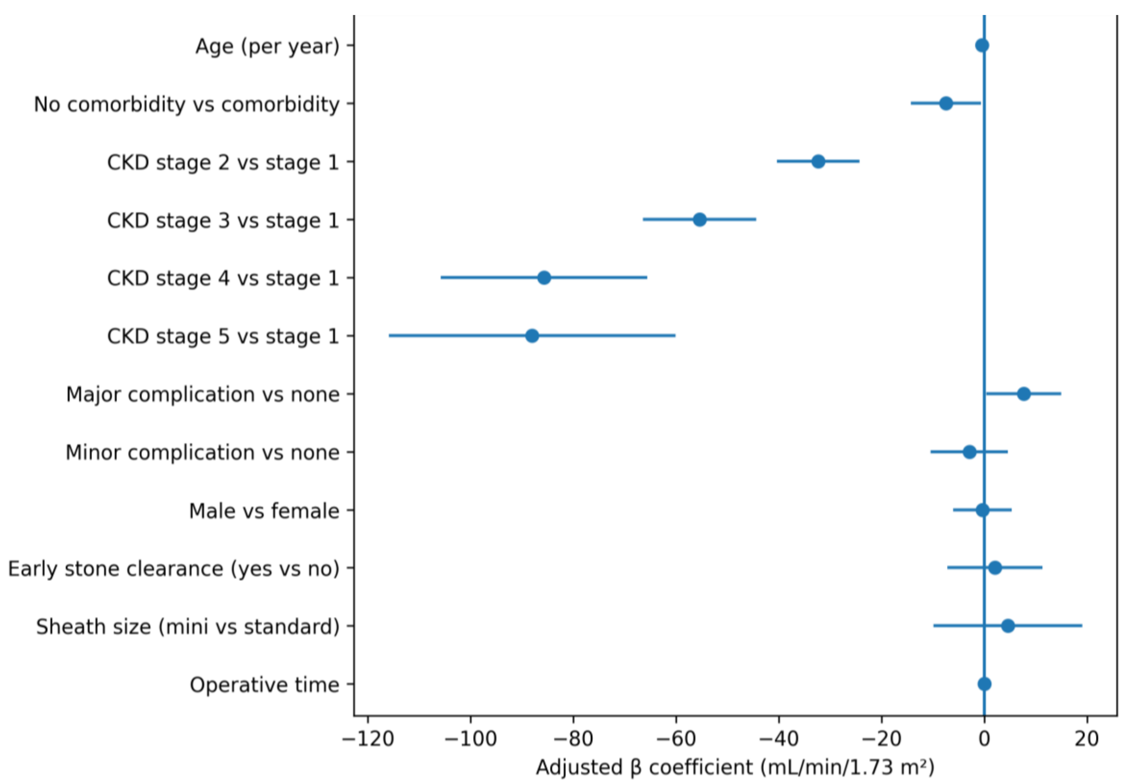

Figure 2: Factors affecting mean eGFR following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024. Points represent beta coefficients, and horizontal lines represent 95% confidence intervals.

5.4.2. Factors affecting eGFR change over time

The renal function pattern was modified by the severity of hydronephrosis. Compared with those with no hydronephrosis, significant lower eGFR was observed for patients with severe hydronephrosis at 3 and 6 months but this will return to baseline by 12 month. Similarly patients with Mild hydronephrosis show significant transient reduction

Time × HDN degree	**β (SE)**	**95% CI**	**p-value**
6 months × Severe HDN	−24.91 (8.31)	−41.19 to −8.62	0.003
6 months × Mild HDN	−13.74 (6.86)	−27.20 to −0.29	0.045
3 months × Severe HDN	−21.33 (8.30)	−37.60 to −5.07	0.01
72 hrs × Mild HDN	−13.36 (5.66)	−24.46 to −2.27	0.018

early and at 6 month which later reruns to baseline indicating no evidence of progressive renal deterioration (Table 7, Figure 2).

Table 7: Degree of Hydronephrosis effect on eGFR pattern following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

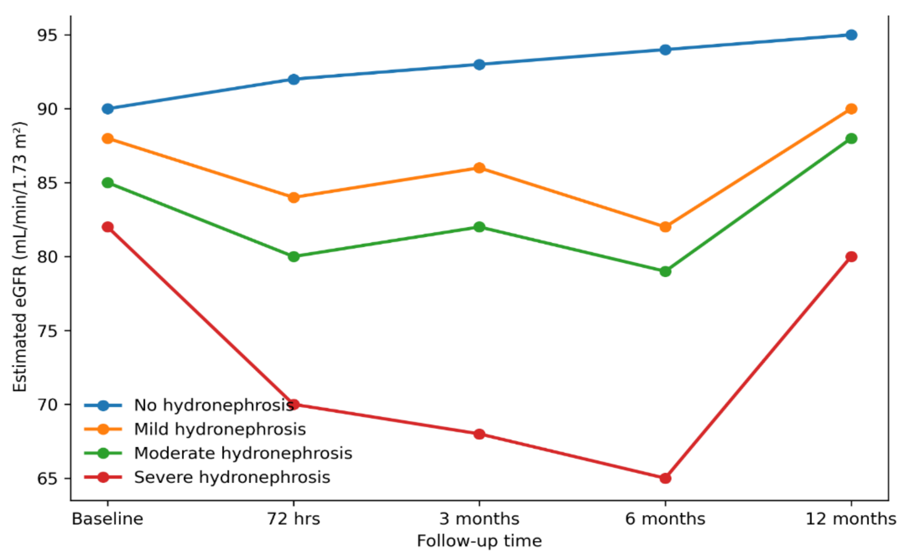

Figure 3: Degree of Hydronephrosis effect on eGFR pattern following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

CKD stage significantly modified the eGFR pattern in the mid and long term (Table 8, Fig 3). Patients with CKD stages 3 and 4 showed significant improvement at 3, 6, and 12

Follow-up time	**CKD Stage**	**β (SE)**	**95% CI**	**p-value**
3 months	Stage 2	+25.82 (12.60)	1.13 to 50.50	0.040
	Stage 3	+32.77 (6.93)	19.19 to 46.35	<0.001
	Stage 4	+20.74 (4.83)	11.26 to 30.21	<0.001
6 months	Stage 3	+27.22 (7.00)	13.50 to 40.94	<0.001
	Stage 4	+23.92 (5.44)	13.25 to 34.58	<0.001
12 months	Stage 3	+23.04 (7.63)	8.08 to 38.00	0.003
	Stage 4	+19.39 (5.81)	8.01 to 30.77	0.001
72 hours	All stages	—	—	>0.05

months compared to patients with CKD stage 1 over time which is likely due to recovery of obstructive component.

Table 8: effect of CKD stage on eGFR pattern following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

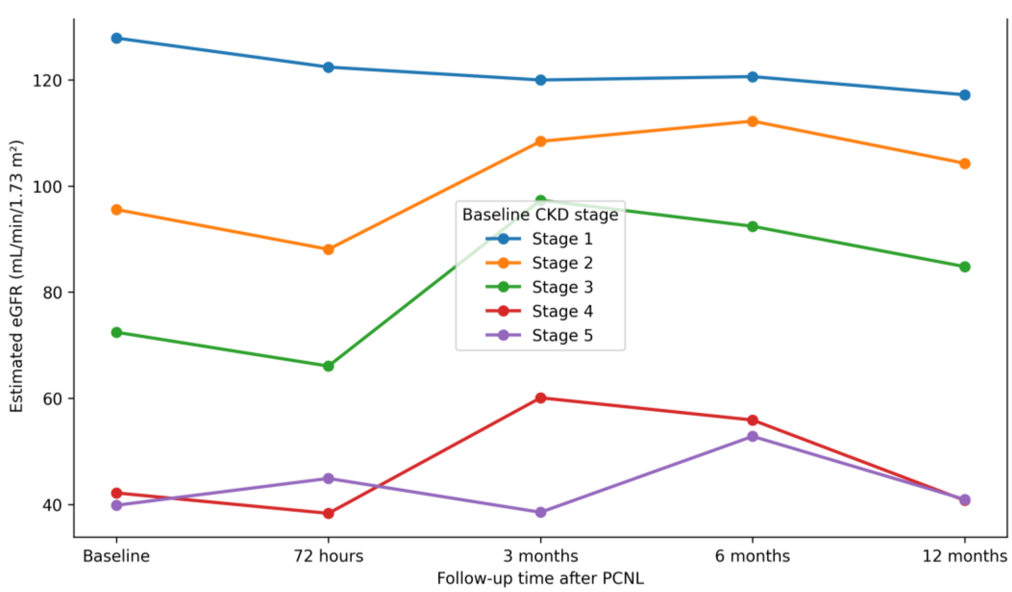

Figure 4: effect of CKD stage on eGFR pattern following PCNL at Tikur Anbessa Hospital from September 1, 2023 to October 30, 2024.

6. Discussion

The study tried to assess the renal function pattern and its determinants following PCNL. The main findings showed a biphasic pattern of an early transient decline followed by recovery and significant improvement at one year. The analysis identified factors like age, baseline renal function status, hydronephrosis and comorbidity to have an effect on the mean eGFR. Hydronephrosis severity and CKD stage were found to modify the eGFR pattern, while modern operative parameters showed no effect.

6.1 Longitudinal Renal Function pattern

The observed eGFR pattern of early drop which is non-significant followed by progressive recovery goes in line with the already known biphasic renal function pattern [4, 5, 11]. This early decline, also reported by Mukherjee et al. (eGFR: 95.2 → 89.3 mL/min/1.73 m^2) [4] and Hosseini et al. [5], is mainly attributed to reversible surgical trauma, hemodynamic changes and systemic neurohormonal responses rather than irreversible injury [6]. The subsequent recovery phase at 12 months underscores the therapeutic benefit of obstruction relief and stone removal. This result resembles other mid and long term studies by Basiri et al. and Fayad et al. who has documented functional recover by 3 months [11] and stabilization or improvement at one year [1, 7, 8, 12], reinforcing safety of PCNL.

6.2 Predictors of Longitudinal Renal Function

6.2.1 Factors affecting the mean eGFR

CKD emerged as the dominant determinant of mean eGFR which is in consistence with the available literature. Taking stage 1 as a reference, advanced CKD was associated with a stepwise reduction in eGFR, mirroring the report by Fayad et al. (2014) [8]. Age-related decline in eGFR (β =-0.40 per year, p=0.004) was observed which is an expected physiological condition [4, 11]. Having a comorbid illness was significantly associated with lower eGFR on average across follow-up (β =-7.46, p=0.032) [7, 8].

6.2.2 Factors affecting the eGFR pattern

A key finding of this study is the significant negative interaction between severe hydronephrosis and eGFR pattern. Patients with severe hydronephrosis experienced clinically meaningful and prolonged reductions in eGFR, particularly at intermediate follow-up intervals, with a delayed return to the baseline eGFR. Lee et al. (2025) also recently reported this finding by identifying hydronephrosis and stone complexity as predictor's of late renal deterioration [13]. This indicates that high-grade obstruction inflicts parenchymal damage that limits functional recovery, but there is still room for improvement of renal function in the long term if intervention is made to relieve obstruction and remove stones.

CKD Stage modifying he eGFR pattern is the other key finding of the study. Patients with CKD stages 3 and 4 demonstrated significant improvement in their eGFR at 3, 6, and 12 months compared to patients in CKD stage 1. This recovery in kidneys with impaired function support the safety of PCNL in this subgroup and provides a basis for its recommendation. İzol et al., also observed significant eGFR improvement in patients with CKD stages II–V at 1 and 12 months where the largest gain was among advanced CKD patients [7]. The recovery observed in the long term likely reflects reduction in intrarenal pressure, restoration of renal perfusion and resolution of chronic inflammation or infection emphasizing the renal protective effect of timely stone clearance.

6.3 Operative Factors and the Safety of Modern PCNL

In contrast to previous studies which showed multiple access tracts and bleeding to renal function deterioration [7, 8, 9], our study found no association between operative factors namely tract number, duration of procedure, sheath size, or early clearance and pattern of eGFR. The high prevalence of single-tract PCNL (85%) and low bleeding (4%) in our study may have limited the power to detect operative effects. This indirectly suggests avoidance of multiple tracts and meticulous hemostasis effectively neutralizes procedure-related risk, making patient baseline renal function status to be the dominant determinant of long term outcome.

6.4 Clinical and Contextual Implications

The study findings show that PCNL remains a secure treatment option for all patients who have different initial eGFR levels when their parenchymal damage is minimal. Patients who have severe hydronephrosis or advanced CKD need to receive counseling about their expected recovery time as protracted recovery might occur and extra monitoring after surgery may be needed.

In resource-limited settings like ours, where late presentation is common [2, 3, 14], timely PCNL remains a key strategy for renal preservation and it is good to understand that outcomes are dictated more by baseline disease severity than by surgical technique alone.

6.5 Strengths and Limitations

Strengths of this study include longitudinal assessment of renal function using mixed-effects modeling, which appropriately handles repeated measures and variable follow-up times, adjustment for multiple clinical and operative factors and robust handling of missing data through multiple imputation. Limitations include the study is done in a single-center, with moderate sample size and assessment of renal function was by using eGFR rather than direct radionuclide measurements. Additionally, follow-up beyond 12 months was not available, limiting assessment of very long-term renal outcomes.

7. Conclusion

PCNL is associated with a transient early postoperative decline in renal function, followed by recovery and long-term preservation or improvement in majority of patients. Baseline renal function status and hydronephrosis degree are the principal determinants of postoperative eGFR pattern. Operative factors exert minimal independent influence when renal-sparing techniques are employed. These findings confirm that PCNL is a safe procedure in preserving renal function across all CKD stages and highlights the importance of early intervention and obstruction relief to optimize long-term renal function outcomes.

8. Recommendations

8.1 For Clinical Practice

- PCNL should be considered a safe intervention across all CKD stages. PCNL should not be delayed or deferred in patients with impaired renal function due to obstructive stone disease for fear of procedure related worsening renal function.
- Prompt Intervention and Enhanced Surveillance for patients presenting with higher degree of hydronephrosis or advanced CKD. These patients warrant early Intervention and more frequent and prolonged postoperative monitoring of renal function beyond 12 months.
- The finding that operative factors did not independently predict long-term outcomes in a cohort with a high rate of single-tract access confirms the renal-sparing benefit of this approach. prioritize single-tract PCNL with meticulous hemostasis to minimize parenchymal trauma

8.2 For Future Research

- Future studies should aim for involvement of multiple centers and larger sample size with follow-up periods extending beyond 12 months.
- Subsequent studies should use more direct measures of split renal function to validate the eGFR findings and distinguish between functional changes in the treated versus contralateral kidney.

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Appendix

Data-extraction form for PCNL Outcome Study

A. Demographic Information

No.	Variable	Response Type / Options
	MRN	____________
1	ID	____________
2	Sex	☐ Male ☐ Female
3	Age	___ years
4	BMI	_____________
5	Co-morbidities	☐ None ☐ Hypertension ☐ Diabetes ☐ CKD ☐ Others: ___

B. Clinical History

No.	Variable	Response Type / Units
6	Baseline SCr	___ mg/dL
7	Baseline eGFR	_________
8	Hemoglobin	Preop___ g/dL, Postop_____g/dl

C. Stone Characteristics

No.	Variable	Response Options
9	Stone side	☐ Right ☐ Left ☐ Bilateral
10	Stone size (Largest diameter)	___________ mm
11	Stone Number	☐ Staghorn ☐ Partial staghorn ☐ Calyceal ☐ Pelvic ☐ Ureteric
12	STONE score	___________
13	Number of Stone	☐ Single ☐ Multiple
14	Degree of Hydronephrosis	☐ None ☐ Mild ☐ Moderate ☐ Severe

D. Intraoperative Data

No.	Variable	Response Type
15	Procedure date	DD/MM/YYYY
16	Number of tracts	___
17	Sheath Size	____fr
18	Time to get	___ min

	Ultrasound guided access	
19	Operation duration	___ min
20	Early Stone clearance	☐ Yes ☐ No (residual fragment present)

E. Postoperative Parameters

No.	Variable	Response Type
21	Hospital stay	___ days
22	Duration of Nephrostomy	___hrs
23	SCr at 72 hr	___ mg/dL
24	eGFR at 72 hr	___
25	Post-op complications	☐ No ☐ Yes, If Yes Clavien Dindo score: ________
26	Transfusion?	☐ Yes ☐ No

F. Follow-Up Data

No.	Variable	Response Type / Timepoint
27	SCr at 3 months	________ mg/dL
28	eGFR at 3 months	________
29	SCr at 6 months	______ mg/dL
30	eGFR at 6 months	______
31	SCr at 12 months	______ mg/dL
32	eGFR at 12 months	______