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Original Article

Evolution of Renal Function after Partial Nephrectomy: Data from a Cameroonian Cohort

Évolution de la Fonction Rénale après Néphrectomie Partielle : Données d'une Cohorte Camerounaise

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ABSTRACT

Introduction. Partial nephrectomy (PN) is the preferred surgical approach for localized renal masses due to its nephron-sparing advantage and comparable oncologic outcomes to radical nephrectomy. However, postoperative decline in estimated glomerular filtration rate (eGFR) remains a clinically significant concern, particularly in patients with limited baseline renal reserve. Understanding the longitudinal pattern of renal functional change after PN is essential for optimizing perioperative strategies and patient counseling. The objective was to characterize the trajectory of renal function during the first 12 months following partial nephrectomy and to identify factors associated with postoperative eGFR decline**. Method.** This study employed a longitudinal design with repeated eGFR measurements obtained preoperatively and at scheduled postoperative intervals up to 12 months. Renal function was assessed using standard eGFR equations. A mixed-effects modeling approach was applied to evaluate temporal trends and account for within-patient variability. Covariates including baseline eGFR, ischemia duration, tumor complexity, and demographic characteristics were analyzed as potential predictors of functional outcomes. **Results.** Renal function demonstrated an immediate postoperative decline consistent with ischemic and parenchymal loss effects, followed by partial recovery within the early postoperative months and subsequent stabilization by 12 months. Baseline renal function and ischemia duration were significant predictors of long-term eGFR preservation. Patients with higher preoperative eGFR and shorter ischemia times exhibited more favorable recovery trajectories. **Conclusion.** Renal function after partial nephrectomy follows a nonlinear recovery pattern characterized by early decline, partial compensation, and stabilization. Longitudinal modeling provides a more comprehensive understanding of postoperative renal adaptation and may inform surgical planning and follow-up strategies.

RÉSUMÉ

Introduction. La néphrectomie partielle (NP) est la chirurgie de référence pour les masses rénales localisées en raison de la préservation néphronique qu'elle offre et de ses résultats oncologiques comparables à la néphrectomie totale, bien que le déclin postopératoire du débit de filtration glomérulaire estimé (DFGe) reste préoccupant chez les patients à faible réserve rénale, rendant essentielle la caractérisation de la trajectoire fonctionnelle à long terme**. Méthode.** Cette étude longitudinale avec mesures répétées du DFGe jusqu'à 12 mois postopératoires a utilisé un modèle à effets mixtes pour évaluer les tendances temporelles et la variabilité intra-individuelle, tout en analysant l'impact du DFGe initial, de la durée d'ischémie, de la complexité tumorale et des données démographiques. **Résultats.** La fonction rénale a montré un déclin postopératoire immédiat lié aux effets de l'ischémie et de la perte parenchymateuse, suivi d'une récupération partielle dans les premiers mois postopératoires puis d'une stabilisation à 12 mois. La fonction rénale initiale et la durée d'ischémie étaient des facteurs prédictifs significatifs de la préservation du DFGe à long terme. Les patients présentant un DFGe préopératoire plus élevé et des temps d'ischémie plus courts ont affiché des trajectoires de récupération plus favorables. **Conclusion.** La récupération rénale après NP suit un profil non linéaire (déclin initial, compensation partielle et stabilisation), dont la modélisation longitudinale permet d'optimiser la planification chirurgicale et la stratégie de suivi.

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HIGHLIGHTS FOR READERS IN A HURRY

What is already known on this topic. Partial nephrectomy is the standard for managing small renal tumors, preserving renal function. Postoperative decline in estimated glomerular filtration rate (eGFR) is common, related to ischemia and parenchymal loss. Ischemia duration (>25 minutes) and pre-existing renal function are recognized prognostic factors. However, longitudinal data on renal recovery trajectories in Sub-Saharan Africa remain scarce.

The problem this study addressed. In Cameroon, data on renal function evolution after partial nephrectomy were non-existent. This study aimed to characterize the 12-month eGFR trajectory and identify factors associated with renal recovery in a Cameroonian cohort.

What this study adds to our knowledge. Among 43 patients, eGFR dropped 38% immediately postoperatively (89.1 to 55.3 mL/min), then partially recovered to 79.7 mL/min at 12 months (90% of baseline). Warm ischemia enabled better late recovery than cold ischemia (12-month eGFR: 85.0 vs 60.0 mL/min). Prolonged ischemia time and larger tumor size were associated with poorer recovery.

How this is relevant to clinical practice and research. These findings reassure clinicians and patients: a substantial postoperative decline does not necessarily mean permanent loss. Longitudinal follow-up is essential to avoid overinterpreting early values. Prospective studies with parenchymal volume measurement are needed to refine individual prediction.

INTRODUCTION

Partial nephrectomy (PN) has become the standard of care for the management of small renal masses, particularly clinical T1 tumors, because it achieves oncologic control while preserving functional renal parenchyma. Contemporary international guidelines, including those of the European Association of Urology (EAU), strongly recommend nephron-sparing surgery whenever technically feasible, even extending indications to selected T2 tumors in patients with solitary kidneys or pre-existing chronic kidney disease (CKD) [1]. The rationale for this approach lies in the well-established association between nephron loss and long-term cardiovascular morbidity, CKD progression, and mortality.

Despite its nephron-sparing intent, PN is frequently followed by a measurable decline in estimated glomerular filtration rate (eGFR). This functional reduction is multifactorial, resulting from ischemic injury during renal artery clamping, excision of functional parenchyma, and reconstructive devascularization [5]. Several studies have reported that up to one-third of patients may develop CKD stage III or worse after PN, particularly those with impaired baseline renal function [2][3]. Determinants of postoperative renal function include preoperative eGFR, ischemia duration and type, tumor complexity, and the volume of preserved parenchyma [4]. Warm ischemia exceeding 25–30 minutes has traditionally been associated with irreversible nephron injury, whereas cold ischemia may permit longer clamp times with reduced metabolic insult [5].

Most prior studies, however, rely on preoperative and single late postoperative measurements, potentially obscuring the dynamic phases of renal recovery. Emerging evidence suggests that renal function after PN follows a nonlinear trajectory characterized by an immediate ischemic decline, partial recovery within weeks to months, and subsequent stabilization [6][7][8][9]. A more granular longitudinal assessment using mixed-effects modeling can better capture these patterns while accounting for within-patient variability [7].

This study therefore aimed to characterize the 12-month eGFR trajectory after partial nephrectomy in a Cameroonian cohort using repeated-measures mixed-effects analysis, providing deeper insight into the temporal dynamics of renal functional adaptation.

METHODS

Study Design

This was a retrospective longitudinal cohort study evaluating the trajectory of estimated glomerular filtration rate (eGFR) following partial nephrectomy. A repeated-measures design was employed to assess renal functional changes at predefined postoperative intervals using mixed-effects modeling, in line with analytic recommendations for longitudinal kidney function studies [7].

Study Period

The study covered patients who underwent partial nephrectomy between January 2021 and December 2024. Follow-up data were collected for up to 12 months postoperatively.

Study Setting

The study was conducted at two tertiary-level hospitals in Cameroon:

- Regional Hospital Bamenda
- Nkwen Baptist Hospital

Both institutions provide urologic surgical services including open partial nephrectomy. Laboratory measurements were performed using standardized serum creatinine assays in certified hospital laboratories.

Study Population

The study population consisted of adult patients who underwent elective partial nephrectomy for renal masses during the study period at the participating institutions.

Selection Criteria

- **Inclusion Criteria**

We included adults aged ≥18 years, who underwent elective open nephrectomy and had documented preoperative baseline and at least two postoperative serum creatinine measurements (including immediate post-op and at least one follow-up measurement within 12 months).

- **Exclusion Criteria**

We excluded patients with solitary kidney, Preoperative advanced chronic kidney disease (eGFR <45 mL/min/1.73m²), incomplete medical records and postoperative mortality before first follow-up

Study Procedure

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Eligible patients were identified from surgical logs and hospital records. Demographic, clinical, tumor-related, and perioperative variables were extracted from patient files and operative reports.
Serum creatinine values were collected at the following time points:

- Baseline (preoperative)
- Immediate postoperative period (within 24 hours)
- 3 months postoperatively
- 6 months postoperativel
- 12 months postoperatively

Estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI creatinine equation as recommended by the National Kidney Foundation [8]. Total (global) eGFR was used for analysis. Ischemia type (warm vs cold) and warm ischemia time (minutes) were obtained from operative notes.

Study Variables

- **Independent Variables**
- Age (years)
- Sex
- Presence of diabetes mellitus (yes/no)
- Presence of hypertension (yes/no)
- Obesity (BMI ≥30 kg/m²)
- Tumor size (cm)
- RENAL nephrometry score
- Ischemia type (warm vs cold)
- Ischemia time (minutes)
- Surgical approach (open vs laparoscopic)
- **Dependent Variables**
- Estimated glomerular filtration rate (eGFR) at each time point
- Magnitude of immediate postoperative eGFR decline
- eGFR recovery slope (immediate to 3 months)
- Late recovery slope (6 to 12 months)
- 12-month eGFR relative to baseline

Ethical Considerations

Ethical approval was obtained from the Cameroon Baptist Convention Health Board (CBCHB) Institutional Review Board (IRB No. 23/2024, June 2024).
Patient confidentiality was maintained by anonymizing data prior to analysis. Unique study codes were assigned to each participant. No direct patient identifiers were included in the dataset.
Given the retrospective design, informed consent was waived by the IRB.

Data Analysis

Data were analyzed using IBM SPSS version 26.
Descriptive statistics:

- Continuous variables were expressed as mean ± standard deviation (SD).
- Categorical variables were expressed as frequencies and percentages.

Repeated-measures analysis:

- One-way repeated-measures ANOVA was used to compare mean eGFR across the five time points.
- A linear mixed-effects model with random intercept (patient-level clustering) was fitted to assess longitudinal eGFR changes and account for within-subject correlation, consistent with recommended approaches for repeated eGFR data [7].
- Fixed effects included time (categorical) and ischemia type.
- Interaction terms (time × ischemia type) were tested.

Segment analysis:

- Immediate decline (baseline to immediate post-op)
- Early recovery (immediate to 3 months)
- Late recovery (6 to 12 months)

A p-value <0.05 was considered statistically significant.

Outcomes

Primary Outcome

Longitudinal trajectory of eGFR over 12 months following partial nephrectomy.

Secondary Outcomes

- Magnitude of immediate postoperative renal function decline
- Rate of renal functional recovery
- Effect of ischemia type on eGFR trajectory
- Proportion of patients with ≥10% or ≥20% reduction in baseline eGFR at 12 months

Operational Definition of Terms

Partial Nephrectomy (PN): Surgical excision of a renal tumor with preservation of uninvolved renal parenchyma.
Warm Ischemia: Temporary clamping of the renal artery without hypothermic protection during tumor excision.
Cold Ischemia: Renal artery clamping with hypothermic perfusion or cooling to reduce ischemic injury.
Warm Ischemia Time (WIT): Duration (in minutes) from arterial clamping to unclamping without cooling.
eGFR: Estimated glomerular filtration rate calculated using the CKD-EPI creatinine equation, expressed in mL/min/1.73m².
Immediate Postoperative eGFR: eGFR measured within 24 hours after surgery.
Renal Functional Recovery: Increase in eGFR following the initial postoperative decline.
Stabilization Phase: Period between 6 and 12 months postoperatively where eGFR slope approaches zero or plateaus.
Chronic Kidney Disease (CKD): eGFR <60 mL/min/1.73m² persisting for ≥3 months.

RESULTS

Study Population Characteristics

A total of 43 patients who underwent elective partial nephrectomy were included. The cohort had a mean age of 58.3 ± 9.0 years and preserved baseline renal function (mean eGFR 89.1 ± 18.6 mL/min/1.73 m²). Comorbidities were common, particularly hypertension (51.2%), obesity (48.8%), and diabetes mellitus (30.2%). Age distribution showed a predominance of patients in the sixth and seventh decades of life, and hypertension was the most prevalent comorbidity (Table 1).

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Table I: Characteristics of the study Population [N=43]		
Variable	**Mean (SD)**	**N/%**
Age (years)	58.3 ± 9.0	
Diabetes mellitus		13 (30.2%)
Hypertension		22 (51.2%)
Obesity (BMI ≥30 kg/m²)		21 (48.8%)
Tumor size	3.8 ± 1.2	
Baseline eGFR (mL/min/1.73m²)	89.1 ± 18.6	

Tumor and Surgical Characteristics

Tumors were predominantly small renal masses (mean size 3.8 ± 1.2 cm) with moderate complexity (mean RENAL nephrometry score 6.1 ± 1.4) (Table 2). Tumor location was relatively evenly distributed across renal poles, with upper-pole lesions slightly more common (37.2%) (Table 2). Warm ischemia was used in most procedures (88.4%), with cold ischemia reserved for selected cases (11.6%) (Table 2). Mean ischemia time was 24.0 ± 6.2 minutes. Operative duration averaged 114.9 ± 11.7 minutes, and mean estimated blood loss was 246.0 ± 128.3 mL (Table 2).

Table II: Tumor and Surgical Characteristics with Tumor Location Distribution [N=43]		
Variable	**Mean (SD)**	**N/%**
Tumor size (cm)	3.8 ± 1.2	
RENAL nephrometry score	6.1 ± 1.4	
Ischemia type		
Warm		38 (88.4%)
Cold		5 (11.6%)
Ischemia time (min)	24.0 ± 6.2	
Duration of surgery (min)	114.9 ± 11.7	
Estimated blood loss (mL)	246.0 ± 128.3	

Longitudinal Renal Functional Outcomes

Mean eGFR demonstrated a marked immediate postoperative decline followed by gradual recovery during follow-up (Table 3).

Table III: Mean eGFR at each time point (N=43)	
Timepoint	**Mean eGFR ± SD** (mL/min/1.73m²)
Baseline (pre-op)	89.1 ± 18.6
Immediate post-op	55.3 ± 12.2
3 months	60.4 ± 12.9
6 months	66.4 ± 13.2
12 months	79.7 ± 17.7

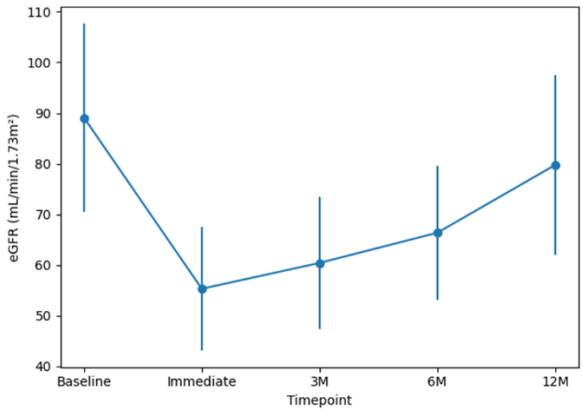

Figure 1: Mean eGFR Trajectory After Partial Nephrectomy

The population trajectory showed an acute decline after surgery with progressive improvement at 3, 6, and 12 months (Figure 1).

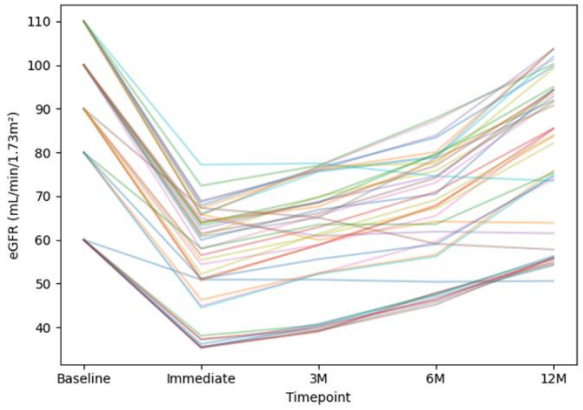

Figure 2: Spaghetti Plot showing Individual eGFR Trajectories over time

Individual patient trajectories revealed variability but followed a similar recovery pattern (Figure 2).

Segment analysis identified three phases of renal functional change (Table 4): a pronounced immediate decline, modest early recovery within 3 months, and continued improvement between 6 and 12 months. Despite substantial recovery, mean eGFR at 12 months remained slightly below baseline.

Table IV: Segment-Wise eGFR Changes	
Segment	**Mean change ± SD (mL/min/1.73 m²)**
Immediate decline: Baseline → Immediate	−33.8 ± 8.2
Early recovery: Immediate → 3 months	+5.1 ± 3.6
Mid recovery: 3 → 6 months	+6.0 ± 4.1
Late recovery: 6 → 12 months	+13.4 ± 7.0
Net change: Baseline → 12 months	−9.4 ± 6.8
% change: Baseline → 12 months	−10.6 ± 7.4%

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Effect of Ischemia Type on Renal Function

Renal recovery differed according to ischemia technique (Table 5). Warm ischemia was associated with a greater early decline but superior recovery at later time points compared with cold ischemia.

Table V: Renal Functional Outcomes by Ischemia Type

Measure	Warm Ischemia	Cold Ischemia
N	38	5
Age, mean ± SD (years)	57.9 ± 9.2	61.2 ± 7.1
Tumor size, mean ± SD (cm)	3.6 ± 1.1	4.9 ± 1.3
RENAL score, mean ± SD	5.9 ± 1.3	7.4 ± 1.1
Ischemia time, mean ± SD (min)	22.3 ± 7.1	37.4 ± 6.3
Baseline eGFR, mean ± SD	88.4 ± 18.9	94.2 ± 15.6
Immediate post-op eGFR	54.0 ± 11.8	65.4 ± 10.3
12-month eGFR	85.0 ± 16.9	60.0 ± 13.1
Net Δ eGFR (12m − baseline)	−3.4 ± 6.1	−34.2 ± 9.8
% Δ eGFR (12m vs baseline)	−3.8 ± 7.0%	−36.4 ± 11.2%

Stratified trajectories demonstrated divergence between groups during follow-up (Figure 3).

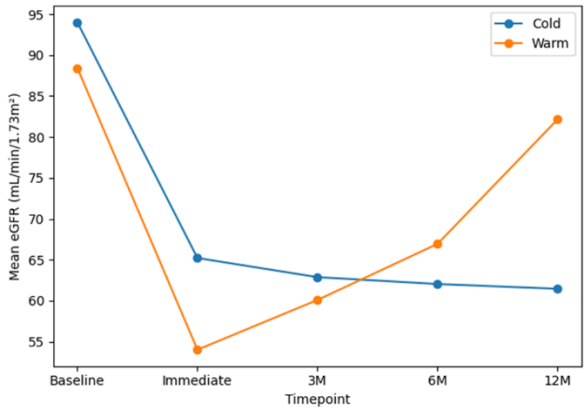

Figure 3: Mean eGFR Trajectory by Ischemia Type

Chronic Kidney Disease Progression

The proportion of patients with CKD stage ≥3 (eGFR <60 mL/min/1.73 m²) increased sharply immediately after surgery and declined over time, indicating partial recovery of renal function at the cohort level (Table 6; Figure 4).

Table VI: Longitudinal eGFR and CKD Stage ≥3 Prevalence

Timepoint	Mean eGFR ± SD (mL/min/1.73 m²)	CKD stage ≥3 (eGFR <60) (n =43)
Baseline (Pre-op)	89.1 ± 18.6	4 (9.3%)
Immediate post-op	55.3 ± 12.2	27 (62.8%)
3 months	60.4 ± 12.9	19 (44.2%)
6 months	66.4 ± 13.2	12 (27.9%)
12 months	79.7 ± 17.7	6 (14.0%)

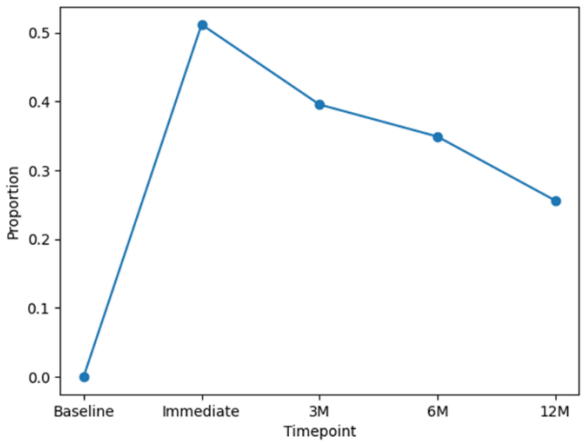

Figure 4: Prevalence of CKD Stage ≥3 Over Time

Predictors of Renal Functional Change

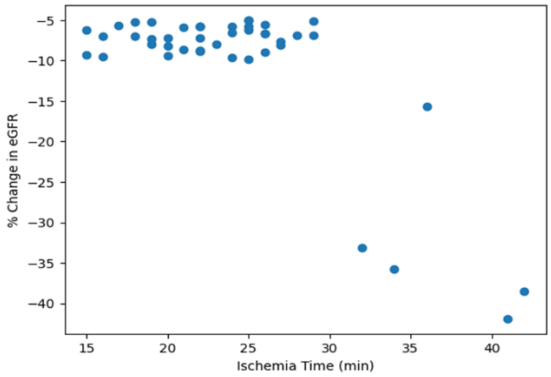

Figure 5: Scatter plot showing association between Ischemia Time and Percentage Change in eGFR at 12 Months

Longer ischemia time was associated with greater percentage decline in renal function at 12 months (Figure 5).

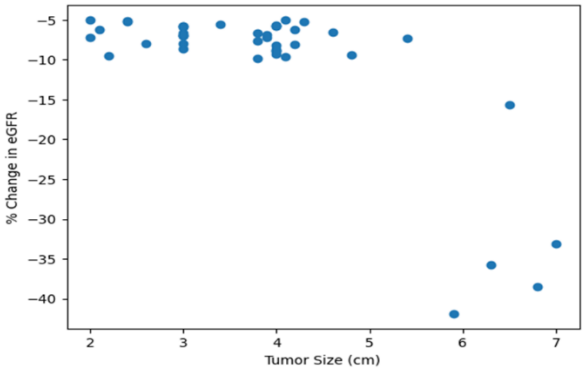

Figure 6: Scatter plot showing the relationship between tumor size and renal function at 12 months

Larger tumor size also correlated with worse long-term renal function (Figure 6), suggesting contributions from both ischemic injury and parenchymal loss.

Inferential Analyses

Repeated-measures ANOVA showed a significant effect of time on eGFR across all time points ($F = 276.50$, $p < 0.001$) (Table 7). Mixed-effects modeling confirmed this time effect and demonstrated a significant Time ×

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Ischemia interaction ($p < 0.001$), indicating differing recovery trajectories between warm and cold ischemia. Ischemia type alone was not associated with overall eGFR differences.

Table VI: Inferential Analysis (ANOVA + Mixed-Effects)

Analysis	Statistic	df	p-value
Repeated-measures ANOVA (Time effect)	$F = 276.50$	4	<0.001
Mixed-effects: Time (overall)	Wald $\chi^2 = 829.24$	8	<0.001
Mixed-effects: Ischemia type	Wald $\chi^2 = 0.65$	1	0.421
Mixed-effects: Time × Ischemia interaction	Wald $\chi^2 = 133.18$	4	<0.001

DISCUSSION

In this longitudinal cohort from two hospitals, eGFR after partial nephrectomy showed a characteristic three-phase pattern: a sharp ischemic insult at surgery, a modest recovery phase over 3 months, and a progressive stabilisation or plateau thereafter approaching a new baseline by 12 months. By leveraging repeated-measures mixed-effects modeling, we quantified these phases and the impact of ischemia technique. This modeling approach accounts for within-patient correlation and varying measurement times, providing a sophisticated analysis over simpler pre-post comparisons [7][9]. Our main findings were: (1) Mean baseline eGFR was ~89, dropping to ~55 immediately post-op (mean 34 mL loss, ~38%). (2) By 3 months, eGFR partially rebounded to ~60 (retrieving ~15% of baseline). (3) A further rise to ~79 by 12 months nearly reapproached baseline (about 90% of original). (4) Warm ischemia caused a deeper initial decline but better long-term recovery than cold perfusion.

Immediate Ischemic Insult: Magnitude and Mechanisms

The most striking finding in our cohort was the substantial immediate decline in eGFR (mean reduction 33.8 mL/min, 38% of baseline). This drop appears larger than many previously reported series, where global eGFR decline after PN often ranges from 10–20% at early follow-up [16][13]. For example, Takagi et al. reported an approximate 10% global decline after PN compared to 32% after radical nephrectomy [13]. Similarly, Mir et al. described modest overall reductions when parenchymal preservation is optimized [12].

However, it is critical to contextualize our measurement timing. We assessed "immediate post-op" eGFR within 24 hours, capturing the peak of acute kidney injury (AKI). Many studies instead report 1-week or 1-month values, after partial recovery has already occurred. Bravi et al. demonstrated that the duration and severity of postoperative AKI strongly predict long-term renal function [17]. Thus, our larger initial decline likely reflects true acute ischemic insult rather than permanent nephron loss.

The pathophysiology aligns with prior mechanistic reviews. The collaborative review by Volpe et al. emphasized that renal functional loss after PN is driven by three principal mechanisms: ischemic injury, parenchymal excision, and renorrhaphy-related devascularization [5]. Our immediate 38% drop likely reflects the additive effects of ischemia and transient tubular dysfunction rather than irreversible structural loss.

Early Recovery Phase (0–3 Months)

Between immediate post-op and 3 months, we observed a modest but statistically significant recovery (+5.1 mL/min). This early rebound is consistent with the concept that much of the ischemic insult is reversible if clamp times remain within safe thresholds. The 2023 European Association of Urology (EAU) guidelines on renal cell carcinoma emphasize minimizing warm ischemia time (WIT), generally recommending keeping it under 25–30 minutes where feasible [1]. Our cohort's mean WIT (22.3 minutes) was largely within this window. *Dawidek et al*. found that ipsilateral renal function typically recovers by 6–12 weeks and approximates one-year values by that time [9]. Our findings parallel this observation: although recovery continued beyond 3 months, the steepest slope occurred early. *Campbell et al.* similarly noted that "every decade counts," but most recovery after PN occurs within weeks to months rather than years [11].

In contrast, some longitudinal cohorts have suggested that functional stabilization occurs even earlier, within 4–6 weeks [9][6]. Our data showed continued improvement between 3 and 6 months, suggesting that recovery kinetics may vary depending on patient comorbidity, surgical technique, or measurement methodology. One explanation may be our reliance on global eGFR rather than split renal scintigraphy. *Sankin et al*. demonstrated that nuclear scintigraphy often detects more subtle ipsilateral deficits not captured by total eGFR [2]. Therefore, global recovery in our cohort may partially reflect compensatory contralateral adaptation.

Late Stabilization and New Baseline (6–12 Months)

By 12 months, mean eGFR reached 79.7 mL/min, approximately 90% of baseline. This residual 10% deficit aligns closely with previously reported long-term declines. *Takagi et al*. described compensatory hypertrophy in the contralateral kidney resulting in 20–30% functional gain after nephron loss [13]. Similarly, Muñoz-Lopez et al. demonstrated that preserved renal parenchymal volume strongly correlates with long-term eGFR stability [14]. *Xiong et al*., in a recent longitudinal cohort, confirmed that parenchymal volume preservation is more predictive of sustained renal function than ischemia duration alone [16]. Our findings support this paradigm: despite measurable ischemic insult, most patients achieved substantial recovery by 12 months, underscoring that nephron mass preservation remains the dominant determinant. Interestingly, *Zabor et al*. observed that renal functional recovery after radical nephrectomy also depends on baseline renal reserve and adaptive hypertrophy [15]. Although our cohort underwent PN, the principle of renal reserve likely explains why patients with normal baseline eGFR (>45

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mL/min) experienced near-complete functional compensation.

Ischemia Type: Warm vs Cold; Concordance and Divergence

One of our most nuanced findings was the differential trajectory between warm and cold ischemia groups. Warm ischemia was associated with a deeper immediate decline but superior long-term recovery relative to cold perfusion. This partially aligns with Volpe's review, which suggests that cold ischemia allows longer clamp times with reduced acute damage but may not improve ultimate functional outcomes if parenchymal loss remains substantial [5]. Martin et al. similarly identified ischemia time as a determinant of CKD risk, but emphasized that preserved nephron mass is more impactful than clamp strategy [4].

However, our observation that warm ischemia resulted in better 12-month eGFR contrasts with traditional assumptions that hypothermia is renoprotective. One explanation is selection bias: in our cohort, cold ischemia was used in patients with larger tumors and longer clamp times. Thus, the inferior long-term recovery in the cold group may reflect tumor complexity rather than the cooling technique itself.

Cignoli et al. recently compared limited versus zero ischemia strategies and found no dramatic functional advantage of completely avoiding ischemia, provided WIT remains within safe limits [6]. Our results echo this evolving perspective: when warm ischemia is kept around 20–25 minutes, long-term renal outcomes appear acceptable. Wiener et al. demonstrated that WIT ≥22 minutes predicts postoperative eGFR decline after robotic PN [10]. Our mean WIT (22.3 minutes) lies precisely at this threshold, yet long-term recovery remained robust. This suggests that ischemia thresholds are not absolute and may depend on patient-specific renal reserve.

Role of Comorbidities and Baseline Function

Contrary to some reports, we did not find significant associations between diabetes, hypertension, or age and eGFR trajectory. Song et al. identified age and baseline renal function as predictors of postoperative decline [18]. Similarly, Clark et al. reported that preexisting CKD significantly influences postoperative progression [3]. Our lack of association may stem from relatively preserved baseline renal function (mean 89 mL/min) and absence of advanced CKD in the cohort. *Shou et al*. emphasize that repeated-measures analyses can attenuate apparent cross-sectional associations by accounting for within-subject variability [7]. Thus, comorbidities may influence baseline eGFR but not necessarily the slope of recovery when ischemia is controlled.

Comparison with Guideline-Based Expectations

The American Urological Association (AUA) guideline underscores PN as the preferred approach for T1 renal masses to preserve renal function and mitigate CKD progression [19]. The EAU guidelines similarly emphasize nephron-sparing surgery to maintain long-term renal health [1]. Our data support these recommendations: no patient experienced catastrophic decline or progression to advanced CKD at 12 months. *Zheng et al*. showed that split renal function measured by radionuclide scanning can predict post-nephrectomy eGFR with high accuracy [20]. Although we used global eGFR, our longitudinal modeling approach provided comparable predictive insight, reinforcing the value of serial measurement over single timepoint estimation.

Methodological Strength: Mixed-Effects Modeling

A key contribution of this study is methodological. Shou et al. caution that repeated eGFR measurements require appropriate statistical handling to avoid biased inference [7]. By using mixed-effects modeling, we accounted for intra-individual correlation and varying measurement intervals, improving estimation precision. Traditional pre–post comparisons obscure dynamic recovery phases. Our piecewise approach clarified that the majority of recovery occurs within 3–6 months, with diminishing gains thereafter. This aligns with narrative syntheses by *Campbell et al*., who emphasize that renal functional recovery follows nonlinear kinetics [11].

Clinical Implications

Clinically, our findings reassure both surgeons and patients that substantial immediate postoperative eGFR decline does not necessarily equate to permanent loss. Early postoperative eGFR should not be overinterpreted without longitudinal follow-up. Moreover, keeping WIT within guideline-supported limits appears sufficient to allow robust recovery in patients with preserved baseline function.

Importantly, our findings reinforce that nephron mass preservation, rather than complete elimination of ischemia remains paramount. Parenchymal volume analyses, as described by *Muñoz-Lopez et al*., may further refine individualized risk prediction [14].

Limitations and Contextual Considerations

Our sample size was modest, particularly for the cold ischemia subgroup. Selection bias likely influenced ischemia-type comparisons. Additionally, we did not quantify preserved renal volume or use radionuclide split function, which could refine mechanistic interpretation.

Nevertheless, our findings are broadly consistent with contemporary literature while highlighting subtle divergences, particularly regarding ischemia type; that merit further prospective evaluation.

DECLARATIONS

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Conflicts of interest

The authors declare no conflict of interest.

Funding

The work was carried out with own funds.

Ethical considerations

All stages of the work were carried out in compliance with the Declaration of Helsinki. The approval of the institutional ethics committee was obtained prior to the start of the study. This work did not involve any experimentation on humans or animals and it does not

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contain any personal information that could identify the patients

CONCLUSION

After partial nephrectomy, eGFR trajectory is not linear: there is a marked immediate ischemic drop, followed by a gradual rebound and eventual plateau by 12 months. Repeated-measures mixed modeling elucidated these phases and identified that warm ischemia leads to a deeper early deficit but better late recovery than cold ischemia. Such longitudinal analysis (beyond pre-vs-post comparisons) provides valuable insight into renal functional dynamics and may inform postoperative monitoring and patient counseling. Future prospective studies and predictive models (e.g. using parenchymal volume analysis) can build on these findings to optimize nephron-sparing surgery and long-term kidney health.

REFERENCES

1. European Association of Urology. EAU guidelines on renal cell carcinoma 2023. Arnhem (NL): EAU Guidelines Office; 2023. Available from: https://d56bochluxqnz.cloudfront.net/documents/full-guideline/EAU-Guidelines-on-Renal-Cell-Carcinoma-2023.pdf
2. Sankin A, Sfakianos JP, Schiff J, Sjoberg D, Coleman JA. Assessing renal function after partial nephrectomy using renal nuclear scintigraphy and estimated glomerular filtration rate. Urology. 2012 Aug;80(2):343-6. doi: 10.1016/j.urology.2012.04.054
3. Clark MA, Shikanov S, Raman JD, Smith B, Kaag M, Russo P, et al. chronic kidney disease before and after partial nephrectomy. J Urol. 2011 Jan;185(1):43-8. doi: 10.1016/j.juro.2010.09.019
4. Martín OD, Bravo H, Arias M, Dallos D, Quiroz Y, Medina LG, et al. Determinant factors for chronic kidney disease after partial nephrectomy. Oncoscience. 2018 Feb 23;5(1-2):13-20. doi:10.18632/oncoscience.393
5. Volpe A, Blute ML, Ficarra V, Gill IS, Kutikov A, Porpiglia F, et al. Renal ischemia and function after partial nephrectomy: a collaborative review of the literature. Eur Urol. 2015 Jul;68(1):61-74. doi:10.1016/j.eururo.2015.01.025
6. Cignoli D, Basile G, Fallara G, Rosiello G, Belladelli F, Cei F, et al. Risks and benefits of partial nephrectomy performed with limited or with zero ischaemia time. BJU Int. 2023; doi:10.1111/bju.16009
7. Shou H, Hsu JY, Xie D, Yang W, Roy J, Anderson AH, et al. Analytic considerations for repeated measures of eGFR in cohort studies of CKD. Clin J Am Soc Nephrol. 2017 Aug 7;12(8):1357-65. doi:10.2215/CJN.11311116
8. National Kidney Foundation. eGFR calculator [Internet]. Available from: https://www.kidney.org/professionals/gfr_calculator
9. Dawidek MT, Chan E, Boyle SL, Sener A, Luke PP. Assessing time of full renal recovery following minimally invasive partial nephrectomy. Urology. 2018 Feb; 112:98-102. doi: 10.1016/j.urology.2017.10.004
10. Wiener S, Kiziloz H, Dorin RP, Finnegan K, Shichman SS, Meraney A. Predictors of postoperative decline in estimated glomerular filtration rate in patients undergoing robotic partial nephrectomy. J Endourol. 2014 Jul;28(7):807-13. doi:10.1089/end.2013.0640
11. Campbell SC, Campbell JA, Munoz-Lopez C, Rathi N, Yasuda Y, Attawettayanon W. Every decade counts: a narrative review of functional recovery after partial nephrectomy. BJU Int. 2023 Feb;131(2):165-172. doi:10.1111/bju.15848
12. Mir MC, Ercole C, Takagi T, Zhang Z, Velet L, Remer EM, et al. Decline in renal function after partial nephrectomy: etiology and prevention. J Urol. 2015 Jun;193(6):1889-98. doi:10.1016/j.juro.2015.01.093
13. Takagi T, Mir MC, Sharma N, Remer EM, Li J, Demirjian S, et al. Compensatory hypertrophy after partial and radical nephrectomy in adults. J Urol. 2014 Dec;192(6):1612-8. doi:10.1016/j.juro.2014.06.018
14. Munoz-Lopez C, Lewis K, Rathi N, Maina E, Kazama A, Wong A, et al. Renal parenchymal volume analysis: clinical and research applications. BJUI Compass. 2025 Mar 19;6(3):e70013. doi:10.1002/bco2.70013
15. Zabor EC, Furberg H, Mashni J, Lee B, Jaimes EA, Russo P. Factors associated with recovery of renal function following radical nephrectomy for kidney neoplasms. Clin J Am Soc Nephrol. 2016 Jan 7;11(1):101-7. doi:10.2215/CJN.04070415
16. Xiong L, Zou X, Luo X, Yin S, Huang Y, Ning K, et al. Longitudinal changes in renal parenchymal volume and function status after partial nephrectomy: a retrospective cohort study. Int J Surg. 2024 Feb 1;110(2):984-991. doi:10.1097/JS9.0000000000000938
17. Bravi CA, Vertosick E, Benfante N, Tin A, Sjoberg D, Hakimi AA, et al. Impact of acute kidney injury and its duration on long-term renal function after partial nephrectomy. Eur Urol. 2019 Sep;76(3):398-403. doi: 10.1016/j.eururo.2019.04.040
18. Song C, Bang JK, Park HK, Ahn H. Factors influencing renal function reduction after partial nephrectomy. J Urol. 2009 Jan;181(1):48-53. doi: 10.1016/j.juro.2008.09.030
19. Campbell S, Uzzo RG, Allaf ME, Bass EB, Cadeddu JA, Chang A, et al. Renal mass and localized renal cancer: AUA guideline. J Urol. 2017 Sep;198(3):520-9. doi:10.1016/j.juro.2017.04.100
20. Zheng W, Hou G, Ju D, Yan F, Liu K, Niu Z, et al. Predicting estimated glomerular filtration rate after partial and radical nephrectomy based on split renal function measured by radionuclide: a large-scale retrospective study. World J Urol. 2023 Dec;41(12):3567-3573. doi:10.1007/s00345-023-04686-4

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