Published in final edited form as:

Clin Genitourin Cancer. 2018 June ; 16(3): 191–196. doi:10.1016/j.clgc.2017.11.006.

The Impact of Patient and Surgical Characteristics on Renal Function Following Partial Nephrectomy

Andrew G. Winer¹, Emily C. Zabor², Michael J. Vacchio³, A. Ari Hakimi³, Paul Russo³, Jonathan A. Coleman³, Edgar A. Jaimes^{4,5}

¹Department of Urology, SUNY Downstate Medical Center, Brooklyn, NY, USA

²Department of Epidemiology and Biostatistics, Memorial Sloan Kettering Cancer Center, New York, USA.

³Urology Service at the Department of Surgery, Memorial Sloan Kettering Cancer Center, New York, USA.

⁴Department of Medicine, Nephrology Division, Weill-Cornell Medical College, New York, New York, USA

⁵Department of Medicine, Renal Service, Memorial Sloan Kettering Cancer Center, New York, USA.

Abstract

Background—To identify patient and disease characteristics which have an adverse impact on renal function following partial nephrectomy.

Methods—We conducted a retrospective review of 387 patients who underwent partial nephrectomy (PN) for renal tumors between 2006 and 2014. A line plot with a lowess smooth was generated to visually assess renal function over time. Univariable and multivariable longitudinal regression analyses incorporated a random intercept and slope to evaluate the association between patient and disease characteristics with renal function following surgery.

Correspondence: Edgar A. Jaimes, MD, Department of Medicine, Renal Service, Memorial Sloan Kettering Cancer Center, 1275 York Ave, New York, NY 10065, jaimese@mskcc.org, Tel: 212-639-5109, Fax: 212-639-5243.

Author's Contribution:

A Winer: Protocol/project development, Data collection or management, Data analysis, Manuscript writing/editing

E Zabor: Protocol/project development, Data collection or management, Data analysis, Manuscript writing/editing

M Vacchio: Protocol/project development, Data collection, Data analysis

A Hakimi: Manuscript editing

P Russo: Manuscript editing

J Coleman: Manuscript editing

E Jaimes: Protocol/project development, Data analysis, Manuscript editing

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Disclosure of Potential Conflicts of Interest: None

Research involving Human Participants and/or Animals: None, retrospective chart review

Informed consent: None, Retrospective review

Results—Median age was 60 years and the majority of patients were male (65.9%) and white (88.6%). On univariable analysis, advanced age at surgery, larger tumor size, male sex, longer ischemia time, history of smoking and hypertension were significantly associated with lower preoperative estimated glomerular filtration rate (eGFR). On multivariable analysis, independent predictors of reduced renal function following surgery included advanced age, lower preoperative eGFR, and longer ischemia time. Length of time from surgery was strongly associated with improvement in renal function among all patients.

Conclusion—Independent predictors of post-operative decline in renal function include advanced age, lower pre-operative eGFR and longer ischemia time. A substantial number of subjects had recovery in renal function over time following surgery which continued past the 12 month mark. These findings suggest that patients undergoing partial nephrectomy can experience long-term improvement in renal function. This improvement is most pronounced among younger patients with higher pre-operative eGFR.

Keywords

renal cell carcinoma; RCC; GFR; renal function; chronic kidney disease; nephrectomy

Introduction:

Renal cell carcinoma (RCC) has an annual estimated incidence of 64,000 cases in the United States¹. Five year relative survival rates have increased from 50% in 1975-1977 to 73% in 2003, largely due to the increasing utilization of abdominal imaging for unrelated indications, leading to a stage migration towards diagnosis of smaller, lower stage tumors^{2,3}. Historically, radical nephrectomy (RN) has been the standard of care for renal masses. However, a growing body of evidence has indicated that following radical kidney surgery, patients are more likely to be diagnosed with chronic kidney disease (CKD) or end-stage renal disease (ESRD) - medical conditions that are associated with increased cardiovascular morbidity and risk of non-cancer related death^{4,5}. Optimizing perioperative renal function has therefore become a key secondary goal in the surgical management of kidney tumors. Nephron sparing surgery (NSS) for renal cortical tumors has been shown to have superior renal functional outcomes while providing equivalent oncologic outcomes in appropriately selected patients⁶. Putative baseline clinical demographic factors that impact post-operative renal function in patients undergoing extirpative renal surgery include pre-operative eGFR, age at surgery, tumor size, and the presence of medical comorbidities such as diabetes and hypertension^{7,8}. In a comparison between patients undergoing donor nephrectomy (DN) versus RN for a renal cortical tumor, at a mean follow up of 15 months post-surgery, RN patients were more likely to have low eGFR, proteinuria, and de novo elevated creatinine levels than those who underwent DN⁹. These findings support the notion that non-surgical factors as well as vulnerabilities affecting cancer patients play a role in subsequent renal function. Other lifestyle factors such as smoking may also have an impact on renal function, with some studies suggesting that current or former smokers are susceptible to CKD¹⁰.

The aim of this study was to investigate the natural history of renal function following surgery and to identify independent predictors of reduced post-operative renal function.

Patients and Methods:

After IRB approval was obtained, data on 513 patients who underwent either partial nephrectomy (PN) or radical nephrectomy (RN) for kidney neoplasms at Memorial Sloan Kettering Cancer Center between 2006 and 2014 were collected from a kidney cancer surgical database for a single surgeon (JC) who obtains extensive peri-operative medical data on each patient. All surgeries were performed with a minimally invasive approach and thus the tumor excision was completed under warm ischemia in the shortest amount of time possible to safely remove the tumor and repair the renal parenchymal defect. Patients were excluded for having two separate surgeries within one year (n=11), transitional cell carcinoma (n=3), receipt of chemotherapy (n=52), or not having any post-operative eGFR measurements (n=8). As the number of patients receiving RN in this dataset was small (n=52), analysis was limited to patients who received PN. The final sample size for analysis was 387 patients with a total of 4,026 estimated glomerular filtration rate (eGFR) measurements.

Serum creatinine values were collected at the pre-operative visit and at all post-operative visits. Patients were seen for follow-up visits in the clinic every 3 to 6 months post-operatively, on average. We used serum creatinine to calculate eGFR values using the CKD-EPI formula¹¹ as follows: $eGFR = 141 * \min(Scr/\kappa, 1)^\alpha * \max(Scr/\kappa, 1)^{-1.209} * 0.993^{Age} * 1.018$ [if female] * 1.159 [if black], where Scr is serum creatinine (mg/dL), κ is 0.7 for females and 0.9 for males, α is -0.329 for females and -0.411 for males, $\min$ indicates the minimum of Scr/κ or 1, and $\max$ indicates the maximum of Scr/κ or 1. If patients had more than one measurement on the same date, the multiple measurements were averaged for analysis.

To explore trends in the data, we plotted the trajectory of each patient's eGFR from their immediate post-operative visit up to 5 years post-operatively, and used a lowess (locally weighted scatterplot smoothing) smooth to look at trends in the data overall. We analyzed the association between patient and disease characteristics with pre-operative eGFR using the Wilcoxon rank sum test when continuous and Fisher's exact test when categorical. The primary endpoint was post-operative eGFR over time. We fit linear mixed models to the data, incorporating a random intercept and random slope for each patient. Each model included a fixed effect for the factor of interest as well as a fixed effect for time. This model accounts for the correlation between multiple observations of eGFR within a patient, and allows each patient in the data to have an individual intercept and slope. A multivariable model incorporated factors selected based on a combination of clinical and statistical considerations.

A p-value <0.05 was considered statistically significant. All analyses were conducted using R version 3.1.0 (R Core Development Team, Vienna, Austria) including the 'nlme' package.

Results:

Of the 387 patients included in our analysis, 64 (16.5%) had eGFR ≥ 90 , 213 (55.0%) had eGFR 60-89, and 110 (28.4%) had eGFR < 60 pre-operatively. Patient and disease

characteristics by pre-operative eGFR are presented in Table 1. Median age was 60.1 (min = 23.0, max = 85.3) and the majority of patients were male (65.9%) and white (88.6%). There were differences in age ($p < .001$), sex ($p = 0.001$), smoking status ($p = 0.005$), hypertension ($p < .001$), pre-operative diastolic blood pressure (DBP) ($p = 0.007$), tumor size ($p < .001$), and ischemia time ($p < .001$) by pre-operative eGFR.

Longitudinal post-operative eGFR trajectories for each patient are plotted in Figure 1. Median follow-up time was 24 months (range: 0-68). Included patients had a median of 9 eGFR measurements during follow-up (range: 2-76). On average, patients experienced an initial decline in eGFR after surgery, followed by a slight increase and stabilization. In order to further investigate the trend in post-operative eGFR over time, we fit a linear mixed model that included a fixed effect for time and a random intercept and slope for each patient and found that each one month increase in time was significantly associated with a 0.11 (95% confidence interval (CI): 0.07, 0.15) unit increase in eGFR ($p < .001$), indicating that there is a significantly increasing trend in post-operative eGFR over time.

On univariable analysis (Table 2), older age ($p < .001$), male versus female sex ($p = 0.040$), ever smoker status ($p = 0.001$), higher ASA stage ($p < .001$), hypertension ($p < .001$), higher pre-operative SBP ($p = 0.003$), larger tumor size ($p = 0.002$), and longer ischemia time ($p < .001$) were associated with decreased post-operative eGFR over time. Only higher preoperative eGFR ($p < .001$) was associated with increased post-operative eGFR over time. Forty patients were missing data on ischemia time, so multivariable analysis is among 347 patients with complete data. On multivariable analysis incorporating age, smoking status, hypertension, tumor size, ischemia time, pre-operative eGFR, and months from surgery as fixed effects (Table 3), only older age ($p < .001$) and longer ischemia time ($p = 0.015$) remained significantly independently associated with decreased post-operative eGFR over time. Higher pre-operative eGFR ($p < .001$) and months from surgery ($p < .001$) remained significantly associated with increased post-operative eGFR over time.

Discussion:

The long-term effects of extirpative renal surgery on post-operative kidney function along with the extent to which pre-existing clinical factors affect this recovery, remain poorly understood. In the present analysis of 387 patients who underwent PN at a referral cancer center, we found that increases in post-operative renal function occurred in a substantial number of patients, which continued past the 12-month post-surgical mark. This increase was most pronounced in younger patients with higher pre-operative eGFR. While baseline medical characteristics such as advanced age, larger tumor size, male sex, history of smoking, hypertension and longer ischemia time were significantly associated with lower pre-operative eGFR, only advanced age, lower pre-operative eGFR and longer ischemia time were independently predictive of decreasing renal function after surgery. These results stand in contrast to several previous studies that have reported baseline risk factors such as diabetes, gender and T stage to be independently influential on postoperative renal function^{12,13}. Given that many patients present with several of the aforementioned comorbidities, one may postulate that each individual disease may not predict post-surgical renal recovery, but rather the overall renal injury that occurs as a result of these diseases and

surgical variables are the critical factors. This combined effect may be reflected in a lower pre-operative eGFR, which, in conjunction with age and longer ischemia time, are ultimately among the most important clinical variables to consider when counseling patients.

The present study revealed that after an initial decline, renal function appears to stabilize and gradually increase over ensuing months post-operatively on average. Intriguingly, improvements in renal function continued past the 12 month period, which was also demonstrated in a similar report by Chung et al who showed improvements in renal function up to 5-years post-operatively⁷. Furthermore, a recent analysis from our institution¹⁴ evaluating a unique subset of RN patients demonstrated that overall, 49% of patients experienced a recovery to baseline eGFR following an initial postoperative decrease, and this renal recovery was significantly more likely to occur in patients whose preoperative eGFR was $\geq 60\text{ml/min per } 1.73\text{ m}^2$. The previous study, however, strictly evaluated RN patients. The current investigation illustrates that renal recovery occurs in PN patients as well, continues past the first post-operative year and is affected by baseline co-morbidities and surgical ischemia time.

Interrupting the flow of blood to the kidney is often necessary during PN, particularly because it allows the surgeon to work in a relatively bloodless field, thus providing the ability to safely remove the entire tumor and repair the renal parenchymal defect. An untoward consequence of clamping the arterial blood supply to the kidney is the potential loss of otherwise healthy nephrons. Although previous studies have demonstrated that renal parenchymal tissue is quite tolerant to ischemia¹⁵, it is clear that longer ischemia time during PN is associated with renal functional decline¹⁶. The degree and timing of renal functional recovery is currently unclear, however, it has been previously shown that renal function decreases immediately after PN and often partially recovers to a new baseline between 3 weeks to 3 months post-operatively¹⁷. In contrast, our results suggest that this functional recovery may persist past the 12-month mark. Furthermore, a recent collaborative review of the literature on ischemia time suggests, similar to our findings, that renal functional recovery after PN is closely associated with the preoperative eGFR as well as the amount of healthy kidney preserved¹⁸. Thus, limiting the ischemia time and maximizing healthy renal tissue represents important modifiable surgical factors that should be considered in order to optimize post-operative renal functional recovery.

A growing body of evidence suggests that reductions in GFR caused specifically by surgery (CKD-S) may be a separate entity that impacts long-term renal function and survival differently than that caused by medical comorbidities (CKD-M) alone. In the present study, we found that surgical patients with extensive pre-existing hypertension on univariate analysis and a lower starting eGFR on multivariable analysis were more likely to experience decreases in renal function over time as compared to younger, healthier counterparts who enjoyed improvements in renal function post-operatively. A report by Lane et al¹⁹ demonstrated a median decline in renal function of 4.7% annually for patients with CKD-M compared to 0.7% for those with CKD-S. Postoperative GFR was not associated with reduced survival for patients with normal preoperative renal function, suggesting that the clinical impact of CKD-S may be less pronounced than that of CKD-M. Potential reasons for this difference are that given the chronic nature of CKD-M, these patients likely have

decreased renal reserve, which in turn increases the diseased nephron's susceptibility to surgical injury followed by persistent damage after surgery imparted by pre-existing medical conditions such as hypertension and diabetes. Furthermore, several reports comparing renal functional outcomes between patients undergoing donor nephrectomy (DN) and renal surgery for RCC found that the DN group experience significant improvements in eGFR post-operatively compared to the RCC group^{9,20}. Compared with DN patients, those with RCC are more likely to present with baseline CKD risk factors such as diabetes, hypertension, and increased age. In fact, large series have shown that up to one-third of patients with RCC present with some degree of CKD preoperatively²¹⁻²³. This suggests that post-nephrectomy renal function is a complex and multifactorial process that is largely predicated on baseline renal function and the amount of preserved healthy renal tissue. While some debate persists within the medical community regarding the clinical impact of CKD-M as compared to that of CKD-S, our study demonstrates that the simultaneous presence of both has a cumulative impact on overall kidney function after surgery.

Previous studies have evaluated the relationship between smoking and RCC oncologic outcomes^{24,25}. However, few reports have explored the impact of tobacco use on renal functional recovery after surgery for renal tumors. The rate of smoking in our study was consistent with previous reports at 55% for former and current smokers²⁵. We found that tobacco use measured at baseline was significantly associated with reduced pre-operative eGFR, but was not an independent risk factor for compromised renal function post-operatively. One may postulate that if smoking use in this cohort was followed over time it may have been significantly associated with decreased post-operative renal function. Similarly, Heldt et al found that tobacco use by kidney donors was associated with decreased post-transplant renal function, further underscoring the nephrotoxic properties of cigarette smoking²⁶. These results reaffirm the notion that factors which alter baseline renal function, including cigarette smoking, will subsequently impact the ability of the kidney to recover after surgical insult but may not serve as independent risk factors.

Several important limitations to this study are worth noting. Primarily, the retrospective nature of this investigation leaves unmeasured confounders difficult to address. Our study design, with a lack of control group for comparison, does not address some important unmeasured variables (renal anatomy, case complexity, referral bias, etc.), as there is selection bias in a single center/single surgeon cohort, which cannot be accounted for here. Additionally, clinical variables change throughout the course of time, therefore the use of a single time point to define the presence or absence of a medical ailment can under-represent the true prevalence within the study population..

Ultimately, we found that on average subjects experienced an increase in renal function following kidney surgery, which continued past 12 months. Independent predictors of reduced renal function after surgery included advanced age, lower pre-operative eGFR and longer ischemia time. These findings suggest that patients undergoing PN can experience long-term improvement in renal function, in particular younger patients with higher pre-operative eGFR.

Acknowledgments:

We would like to acknowledge the research support staff that helped organize and maintain the data; namely Nicole Benfante.

Funding Source: Sidney Kimmel Center for Prostate and Urologic Cancers, Byrne Research Fund and NIH/NCI Cancer Center Support Grant P30 CA008748 (EAJ)

Abbreviations:

RCC	renal cell carcinoma
eGFR	estimated glomerular filtration rate
PN	Partial nephrectomy
RN	Radical nephrectomy
DN	Donor nephrectomy
ASA score	American society of anesthesiology score
CKD	chronic kidney disease
CKD-M	chronic kidney disease medical
CKD-S	chronic kidney disease surgical
ESRD	end stage renal disease
NSS	Nephron sparing surgery

References

1. Siegel R, Ma J, Zou Z & Jemal A Cancer statistics, 2014. CA: a cancer journal for clinicians 64, 9–29, doi:10.3322/caac.21208 (2014). [PubMed: 24399786]
2. Russo P Renal cell carcinoma: presentation, staging, and surgical treatment. Seminars in oncology 27, 160–176 (2000). [PubMed: 10768595]
3. Patard JJ, Rodriguez A, Rioux-Leclercq N, Guille F & Lobel B Prognostic significance of the mode of detection in renal tumours. BJU international 90, 358–363 (2002). [PubMed: 12175389]
4. Capitanio U et al. Nephron-sparing techniques independently decrease the risk of cardiovascular events relative to radical nephrectomy in patients with a T1a-T1b renal mass and normal preoperative renal function. European urology 67, 683–689, doi:10.1016/j.eururo.2014.09.027 (2015). [PubMed: 25282367]
5. Mariusdottir E, Jonsson E, Marteinsson VT, Sigurdsson MI & Gudbjartsson T Kidney function following partial or radical nephrectomy for renal cell carcinoma: a population-based study. Scandinavian journal of urology 47, 476–482, doi:10.3109/21681805.2013.783624 (2013). [PubMed: 23597159]
6. Kim JM, Song PH, Kim HT & Park TC Comparison of Partial and Radical Nephrectomy for pT1b Renal Cell Carcinoma. Korean journal of urology 51, 596–600, doi:10.4111/kju.2010.51.9.596 (2010). [PubMed: 20856643]
7. Chung JS et al. Trends in renal function after radical nephrectomy: a multicentre analysis. BJU international 113, 408–415, doi:10.1111/bju.12277 (2014). [PubMed: 23937424]

8. Jeon HG et al. Small tumour size is associated with new-onset chronic kidney disease after radical nephrectomy in patients with renal cell carcinoma. *European journal of cancer* (Oxford, England: 1990) 50, 64–69, doi:10.1016/j.ejca.2013.08.018 (2014).
9. Etafy M, Saleh F, Abdel Aal MA, Gawish M & Morsy G Comparison of renal function following donor nephrectomy versus radical nephrectomy for renal tumor. *Saudi journal of kidney diseases and transplantation : an official publication of the Saudi Center for Organ Transplantation, Saudi Arabia* 26, 238–242 (2015).
10. Nakamura K et al. Smoking increases the risk of all-cause and cardiovascular mortality in patients with chronic kidney disease. *Kidney international*, doi:10.1038/ki.2015.212 (2015).
11. Levey AS et al. A new equation to estimate glomerular filtration rate. *Annals of internal medicine* 150, 604–612 (2009). [PubMed: 19414839]
12. Kim SH et al. A Study of Relationship of Atheroembolic Risk Factors with Postoperative Recovery in Renal Function after Partial Nephrectomy in Patients Staged T1-2 Renal Cell Carcinoma During Median 4 Year Follow-up. *Cancer research and treatment: official journal of Korean Cancer Association*, doi:10.4143/crt.2014.297 (2015).
13. Leslie S, Goh AC & Gill IS Partial nephrectomy--contemporary indications, techniques and outcomes. *Nature reviews. Urology* 10, 275–283, doi:10.1038/nrrol.2013.69 (2013). [PubMed: 23588406]
14. Zabor EC et al. Factors Associated with Recovery of Renal Function following Radical Nephrectomy for Kidney Neoplasms. *Clinical journal of the American Society of Nephrology : CJASN* 11, 101–107, doi:10.2215/cjn.04070415 (2016). [PubMed: 26500248]
15. Parekh DJ et al. Tolerance of the human kidney to isolated controlled ischemia. *Journal of the American Society of Nephrology : JASN* 24, 506–517, doi: 10.1681/asn.2012080786 (2013). [PubMed: 23411786]
16. Lane BR et al. Factors predicting renal functional outcome after partial nephrectomy. *The Journal of urology* 180, 2363–2368; discussion 2368–2369, doi:10.1016/j.juro.2008.08.036 (2008). [PubMed: 18930264]
17. Porpiglia F et al. The effects of warm ischaemia time on renal function after laparoscopic partial nephrectomy in patients with normal contralateral kidney. *World journal of urology* 30, 257–263, doi:10.1007/s00345-011-0729-5 (2012). [PubMed: 21769680]
18. Volpe A et al. Renal Ischemia and Function After Partial Nephrectomy: A Collaborative Review of the Literature. *European urology* 68, 61–74, doi:10.1016/j.eururo.2015.01.025 (2015). [PubMed: 25703575]
19. Lane BR, Campbell SC, Demirjian S & Fergany AF Surgically induced chronic kidney disease may be associated with a lower risk of progression and mortality than medical chronic kidney disease. *The Journal of urology* 189, 1649–1655, doi:10.1016/j.juro.2012.11.121 (2013). [PubMed: 23201493]
20. Lee SH et al. Comparison of postoperative estimated glomerular filtration rate between kidney donors and radical nephrectomy patients, and risk factors for postoperative chronic kidney disease. *International journal of urology : official journal of the Japanese Urological Association* 22, 674–678, doi: 10.1111/iju.12784 (2015). [PubMed: 26012527]
21. Lucas SM et al. Renal function outcomes in patients treated for renal masses smaller than 4 cm by ablative and extirpative techniques. *The Journal of urology* 179, 75–79; discussion 79–80, doi: 10.1016/j.juro.2007.08.156 (2008). [PubMed: 17997440]
22. Zini L et al. Cancer-specific and non-cancer-related mortality rates in European patients with T1a and T1b renal cell carcinoma. *BJU international* 103, 894–898, doi:10.1111/j.1464-410X.2008.08252.x (2009). [PubMed: 19076131]
23. Huang WC et al. Chronic kidney disease after nephrectomy in patients with renal cortical tumours: a retrospective cohort study. *The Lancet. Oncology* 7, 735–740, doi:10.1016/S1470-2045(06)70803-8 (2006). [PubMed: 16945768]
24. Tsivian M, Moreira DM, Caso JR, Mouraviev V & Polascik TJ Cigarette smoking is associated with advanced renal cell carcinoma. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 29, 2027–2031, doi:10.1200/jco.2010.30.9484 (2011). [PubMed: 21502558]

25. Ehdaie B, Furberg H, Zabor EC, Hakimi AA & Russo P Comprehensive assessment of the impact of cigarette smoking on survival of clear cell kidney cancer. *The Journal of urology* 191, 597–602, doi:10.1016/j.juro.2013.08.081 (2014). [PubMed: 24018238]
26. Heldt J et al. Donor Smoking Negatively Affects Donor and Recipient Renal Function following Living Donor Nephrectomy. *Advances in Urology* 2011, 929263, doi:10.1155/2011/929263 (2011). [PubMed: 21912540]

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Clinical Practice Points

Importantly, we found that a substantial number of subjects experienced an increase in renal function following kidney surgery, which continued past 12 months. Independent predictors of reduced renal function after surgery included advanced age, lower pre-operative eGFR and longer ischemia time. These findings suggest that patients undergoing partial nephrectomy can experience long-term improvement in renal function, in particular younger patients with higher pre-operative eGFR and shorter renal artery clamp time. We feel that our results have significant clinical relevance given the importance of medical optimization, risk stratification and proper patient selection in the peri-operative management of renal tumors

Figure 1.
Individual patient trajectories of eGFR over time (gray dotted lines) overlaid with a lowess smooth (solid black line)

Table 1.

Patient and disease characteristics by pre-operative eGFR

	Pre-operative eGFR (mL/min/1.73 m ²)			p-value [*]
	90 (n=64)	60 – 89 (n=213)	< 60(n=105)	
Age, Med (min, max)	52.3 (23.0, 78.3)	58.4 (30.7, 84.5)	66.6 (37.9, 85.3)	<.001
BMI, Med (min, max)	28.0 (16.2, 54.5)	29.3 (16.8, 59.1)	29.5 (21.2, 47.5)	0.105
Sex, N (%)				0.001
Female	34 (53.1)	71 (33.3)	27 (24.5)	
Male	30 (46.9)	142 (66.7)	83 (75.5)	
Race, N (%)				0.022
Other	14 (21.9)	21 (9.9)	9(8.2)	
White	50 (78.1)	192 (90.1)	101 (91.8)	
Smoking status, N (%)				0.005
Never	39 (60.9)	126 (59.2)	44 (40)	
Ever	23 (35.9)	83 (39)	60 (54.5)	
NA	2 (3.1)	4 (1.9)	6 (5.5)	
Pack years ^{**} , Med (min, max)	12 (0, 50)	20 (0.14, 120)	18 (1, 132)	0.477
ASA, N (%)				0.168
1	3 (4.7)	16 (7.5)	4 (3.6)	
2	32 (50)	79 (37.1)	36 (32.7)	
3	28 (43.8)	114 (53.5)	66 (60)	
4	1 (1.6)	3 (1.4)	4(3.6)	
NA	0 (0)	1 (0.5)	0 (0)	
Diabetes, N (%)	10 (15.6)	30 (14.1)	17 (15.5)	0.904
Hypertension, N (%)	21 (32.8)	105 (49.3)	78 (70.9)	<.001
Pre-op SBP, Med (min, max)	124 (93, 172)	130 (97.5, 182)	132 (80, 185.5)	0.076
Pre-op DBP, Med (min, max)	77 (62, 93.5)	78.67 (52, 102)	74 (55, 93)	0.007
Tumor size (cm), Med (min, max)	2 (0.7, 8.6)	2.6 (0.3, 17)	3.15 (0.7, 12)	<.001
Ischemia time [†] (mins), Med (min, max)	19.03 (0, 42)	21 (0, 64)	24 (0, 73)	<.001

* p-value from Fisher's exact test when categorical and Wilcoxon rank sum test when continuous

** Among ever smokers

[†] 40 patients missing ischemia time

BMI = body mass index; ASA = American Society of Anesthesiologists; SBP = systolic blood pressure; DBP = diastolic blood pressure

Table 2.

Univariable linear mixed effects regression for the association between patient and disease characteristics with eGFR following surgery. Estimates presented are for the fixed effect of the factor of interest.

	Estimate (95% CI)	p-value
Age	-0.92 (-1.04, -0.79)	<.001
BMI	0.03 (-0.27, 0.32)	0.859
Sex		0.040
Female	1.00	
Male	-4.23 (-8.28, -0.19)	
Race		0.359
Other	1.00	
White	-2.83 (-8.90, 3.24)	
Smoking status		0.001
Never	1.00	
Ever	-6.88 (-10.75, -3.00)	
Pack years *	-0.08 (-0.20, 0.03)	0.155
ASA		<.001
1	1.00	
2	-5.89 (-14.16, 2.38)	
3	-11.94 (-20.04, -3.83)	
4	-24.85 (-39.99, -9.70)	
Diabetes	-1.94 (-7.37, 3.49)	0.482
Hypertension	-12.71 (-16.36, -9.06)	<.001
Pre-op SBP	-0.19 (-0.32, -0.06)	0.003
Pre-op DBP	0.18 (-0.06, 0.43)	0.146
Tumor size (cm)	-1.36 (-2.21, -0.52)	0.002
Ischemia time [†] (mins)	-0.43 (-0.61, -0.26)	<.001
Pre-op eGFR (mL/min/1.73 m ²)	0.87 (0.81, 0.93)	<.001
Months from surgery	0.11 (0.07, 0.15)	<.001

* Among ever smokers

[†] 40 patients missing ischemia time

SE = standard error; BMI = body mass index; ASA = American Society of Anesthesiologists; SBP = systolic blood pressure; DBP = diastolic blood pressure

Table 3.

Multivariable linear mixed effects regression for the association between patient and disease characteristics with eGFR following surgery, among n = 347 patients who underwent partial nephrectomy. Estimates presented are for the fixed effect.

	Estimate (SE)	p-value
Age	-0.46 (-0.56, -0.36)	<.001
Smoking status		0.872
Never	1.00	
Ever	0.18 (-1.99, 2.34)	
Hypertension	-0.36 (-2.65, 1.92)	0.754
Tumor size (cm)	-0.18 (-0.70, 0.34)	0.492
Ischemia time (mins)	-0.13 (-0.24, -0.03)	0.015
Pre-op eGFR (mL/min/1.73 m ²)	0.72 (0.65, 0.79)	<.001
Months from surgery	0.11 (0.07, 0.15)	<.001

SE = standard error