Predictive Factors for Postoperative Renal Function After Off-Clamp, Non-Renorrhaphy Partial Nephrectomy

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Research Article

Keywords: Renal pedicle clamping, renorrhaphy, partial nephrectomy, estimated glomerular filtration rate, early recovery

Posted Date: September 8th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-871351/v1

Abstract

Background: There is limited information on perioperative renal function during off-clamp, non-renorrhaphy open partial nephrectomy.Therefore, this study aimed to clarify the chronological postoperative changes in renal function after off-clamp, non-renorrhaphy open partial nephrectomy.

Methods: Clinical records of 138 patients with renal tumors who underwent off-clamp, non-renorrhaphy open partial nephrectomy at our institution were reviewed. Off-clamp, non-renorrhaphy partial nephrectomy were performed using a soft coagulation system. Perioperativeestimated glomerular filtration rate (eGFR) preservation was calculated, and predictors were identified using multivariate regression analysis at 5 days, 1 month, and 3 months after surgery.

Results: The median operation time was 122 minutes, and the median volume of estimated blood loss was155 mL. The mean eGFR preservation at 5 days, 1 month, and 3 months after surgery was 95.3%, 91.0%, and 90.7%, respectively. Multivariate regression analysis revealed that estimated blood loss was an independent predictor of perioperative eGFR preservation at 5 days and 1 month after surgery, while age was an independent predictor of perioperative eGFR preservation at 3months after surgery.

Conclusion: Chronological changes in renal function after off-clamp, non-renorrhaphy open partial nephrectomy have been reported.Ourresults could bea reference in the era of robot-assisted partial nephrectomy.

Introduction

Partial nephrectomy has become the standard procedure for removing renal tumors. Robot-assisted partial nephrectomy (RAPN) has been established as a safe and minimally invasive procedure for tumors measuring < 40 mm [1–3]. Renal pedicle clamping and renorrhaphy are included in laparoscopic partial nephrectomy in most institutes. However, these operative procedures cause postoperative complications, such as renal function impairment or pseudoaneurysm, at a certain rate [4].

Preservation of estimated glomerular filtration rate [eGFR] and no chronic kidney disease [CKD] upgrading are important outcomes after RAPN [1, 3, 5, 6]. Although studies have reported eGFR preservation after on-clamp partial nephrectomy with renorrhaphy (open or laparoscopic), limited studies have reported that after off-clamp open partial nephrectomy without renorrhaphy. In particular, assessment of renal function impairment at very early time points (< 3 months after surgery) is lacking.

We retrospectively analyzed the perioperative data of 138 patients who underwent off-clamp open partial nephrectomy without renorrhaphy. The association between perioperative renal function preservation and tumor characteristics and patient characteristics was analyzed.

Results

Patient characteristics are described in Table 1. There were 92 (66.7%) were male patients and 46 (33.3%) female patients. The median age and tumor size were 63 years (range, 27–89 years) and 28 mm (range, 7–110 mm), respectively. Among the tumors, 41 (29.7%) were > 50% exophytic, 62 (44.9%) were < 50% exophytic, and 35 (25.4%) were entirely endophytic. The median nephrometry score was 7 (range, 4–10).

Table 1
Patient and tumor characteristics

No. patients	**138**
Sex (%)	
Male	92 (66.7)
Female	46 (33.3)
Median age (range)	63 (27—89)
Median BMI (range)	23.4 (14.6—38.9)
No. tumor laterality (%)	
Right	69 (50.0)
Left	69 (50.0)
Median tumor size, mm (range)	28 (7—110)
Median RENAL nephrometry score (range)	7 (4–10)
Exophytic/Endophytic properties	
> 50% exophytic	41 (29.7)
< 50% exophytic	62 (44.9)
Entirely endophytic	35 (25.4)
Location relative to the polar lines	
Entirely above the upper or below the lower polar line	46 (33.3)
Lesion crosses polar line	64 (46.4)
> 50% of mass is across polar line or mass crosses the axial renal midline or mass is entirely between the polar lines	28 (20.3)
Comorbidity, n (%)	
Hypertension	54 (39.1)
Diabetes mellitus	22 (15.9)
Dyslipidemia	17 (12.3)4
BMI Body Mass Index. The RENAL nephrometry score is the sum of the sectional scores (R, E, N, and L). RCC Renal cell carcinoma,	

The surgical results are described in Table 2. The median operation time was 122.5 min. The median estimated blood loss was 155 mL. There were no cases of conversion to nephrectomy or consequential

renal hilum clamping. The mean eGFR preservation at 5 days, 1 month, and 3 months after surgery was 95.3%, 91.0%, and 90.7%, respectively. The relationship between age and perioperative eGFR decline was shown in Fig. 1A and 1B. Statistically significant reduction in eGFR was detected only in patients aged over 80 (Fig. 1A).

Table 2
Surgical results and complications

Median operative time, min (range)	**122.5 (56-199)**
Median volume of estimated blood loss, mL (range)	155 (5-1070)
No. additional resections	0
No. conversion to nephrectomy	0
Intraoperative blood transfusion	0
Postoperative blood transfusion	0
Pathology (%)	
Clear cell RCC	92 (66.7)
Papillary RCC	13 (9.4)
Chromophobe RCC	10 (7.2)
Angiomyolipoma	17 (12.3)
Oncocytoma	2 (1.4)
Others	14 (10.1)
Mean eGFR preservation, % (SD)	
Five days after surgery	95.3 (14.9)
One month after surgery	91.0 (11.5)
Three months after surgery	90.7 (16.3
eGFR estimated glomerular filtration ratio, RCC renal cell carcinoma	

Tumor size, R, N, RENAL score, and estimated blood loss were identified predictors of perioperative eGFR preservation at 5 days after surgery. Multivariate analysis revealed that estimated blood loss was an independent predictor of perioperative eGFR preservation (Table 3).

Table 3
Predictors of perioperative eGFR preservation at 5 days after surgery. Univariate and multivariate analysis

	Univariate analysis			**Multivariate analysis**		
	Unstandardized regression coefficient B (95% CI)	Standardized regression coefficient β	*p* - value	Unstandardized regression coefficient B (95% CI)	Standardized regression coefficient β	*p* - value
Age†	-0.128 (-0.332, 0.077)	-0.105	0.219	-0.174 (-0.364, 0.017)	-0.143	0.074
BMI	-0.470 (-1.054, 0.114)	-0.136	0.114			
Tumour size†	-0.218 (-0.356, -0.081)	-0.261	0.02*	-0.101 (-0.247, 0.045)	-0.121	0.172
R	-6.417 (-11.209, -1.625)	-0.221	0.009*			
E	-0.926 (-2.487, 4.339)	-0.046	0.592			
N†	-3.752 (-6.615, -0.89)	-0.217	0.011			
L	-2.435 (-5.923, 1.054)	-0.118	0.17			
RENAL score†	-1.819 (-3.276, -0.362)	-0.207	0.015*	-1.112 (-2.559, 0.335)	-0.127	0.131
Operative time	-0.055 (-0.132, 0.023)	-0.118	0.168			
eBlood loss†	-0.024 (-0.033, -0.014)	-0.377	< 0.001*	-0.019 (-0.03, -0.008)	-0.3536	0.001*
HTN	-3.198 (-8.356, 1.96)	-0.105	0.222			
DM	-4.427 (-11.301, 2.446)	-0.109	0.205			
DL	-1.052 (-8.751, 6.647)	-0.023	0.787			

eGFR estimated glomerular filtration rate, BMI body mass index. eBlood loss estimated blood loss, R Radius, E exophytic and endophytic properties, N Nearness of the tumor to the collecting system or sinus, L location relative to the upper and lower polar lines, (R,E,N, and L were scored according to RENAL nephrometry scoring system), HTN hypertension, DM diabetes mellitus, DL dyslypidemia, CI confidential interval, † These factors were put in multivariate regression analysis, * p-value < 0.05 was considered statistically significant.

Tumor size, R, RENAL score, and estimated blood loss were identified as predictors of perioperative eGFR preservation at 1 month after surgery. Multivariate analysis revealed that age, tumor size, and estimated blood loss were independent predictors of the eGFR preservation (Table 4).

Table 4
Predictors of perioperative eGFR preservation at 1 month after surgery. Results of univariate and multivariate analysis.

	Univariate analysis			**Multivariate analysis**		
	Unstandardized regression coefficient B (95% CI)	Standardized regression coefficient β	*p* - value	Unstandardized regression coefficient B (95% CI)	Standardized regression coefficient β	*p* - value
Age†	-0.118 (-0.275, 0.039)	-0.127	0.140	-0.158 (-0.307, -0.008)	-0.17	0.039*
Sex	1.08 (-3.08, 5.239)	0.044	0.608			
BMI	-0.167 (-0.618, 0.285)	-0.063	0.467			
Tumour size†	-0.182 (-0.287, -0.077)	-0.283	0.001*	-0.121 (-0.235, -0.006)	-0.187	0.039*
R	-5.612 (-9.276, -1.948)	-0.252	0.003			
E†	0.441 (-2.204, 3.085)	0.028	0.742			
N	-2.187 (-4.425, 0.052)	-0.164	0.055			
L	-1.597 (-4.302, 1.107)	-0.1	0.245			
RENAL score	-1.277 (-2.404, -0.15)	-0.189	0.027*	-0.769 (-1.902, 0.364)	-0.114	0.182
Operative time	-0.045 (-0.105, 0.015)	-0.126	0.144			
eBlood loss†	-0.015 (-0.023, -0.007)	-0.306	0.000	-0.01 (-0.018, -0.002)	-0.209	0.018*
HTN	-2.576 (-6.567, 1.415)	-0.109	0.204			
DM	-1.976 (-7.393, 3.442)	-0.062	0.472			
DL	-2.421 (-8.496, 3.653)	-0.068	0.432			

Univariate analysis	Multivariate analysis
eGFR estimated glomerular filtration rate, BMI body mass index. eBlood loss estimated blood loss, R Radius, E exophytic and endophytic properties, N Nearness of the tumor to the collecting system or sinus, L location relative to the upper and lower polar lines, (R,E,N, and L were scored according to RENAL nephrometry scoring system), HTN hypertension, DM diabetes mellitus, DL dyslypidemia, CI confidential interval,† These factors were put in multivariate regression analysis, CI confidence interval, * p-value < 0.05 was considered statistically significant.	

Age, tumor size, R, N, and estimated blood loss were identified as predictors of perioperative eGFR preservation at 3 months after surgery. Multivariate analysis revealed that age was an independent predictor of perioperative eGFR preservation (Table 5).

Table 5
Predictors of perioperative eGFR preservation at 3 months after surgery. Results of univariate and multivariate analysis.

	Univariate analysis			**Multivariate analysis**		
	Unstandardized regression coefficient B (95% CI)	Standardized regression coefficient β	*p* - value	Unstandardized regression coefficient B (95% CI)	Standardized regression coefficient β	*p* - value
Age†	-0.228 (-0.449, 0.008)	-0.173	0.043*	-0.277 (-0.494, -0.059)	-0.209	0.013*
Sex	-1.981 (-7.853, 3.89)	-0.057	0.506			
BMI	-0.073 (-0.727, 0.580)	-0.019	0.824			
Tumour size†	-0.182 (-0.334, -0.03)	-0.199	0.019*	-0.277 (-0.494, 0.039)	-0.139	0.133
R	-6.019 (-11.274, -0.764)	-0.191	0.025*			
E	0.706 (-3.014, 4.426)	0.032	0.708			
N	-3.058 (-6.21, 0.094)	-0.162	0.057			
L	-1.474 (-5.292, 2.344)	-0.065	0.446			
RENAL score†	-1.472 (-3.075, -0.13)	-0.154	0.071	-1.113 (-2.764, 0.537)	-0.116	0.184
Operative time	0.01 (-0.075, 0.095)	0.02	0.817			
eBlood loss†	-0.014 (-0.025, -0.003)	-0.206	0.015*	-0.009 (-0.021, 0.003)	-0.128	0.156
HTN	-3.94 (-9.549, 1.67)	-0.118	0.167			
DM	-4.882 (-12.368, 2.604)	-0.11	0.199			
DL	-1.584 (-9.969, 6.8)	-0.032	0.709			

Univariate analysis	Multivariate analysis
eGFR estimated glomerular filtration rate, BMI body mass index. eBlood loss estimated blood loss, R Radius, E exophytic and endophytic properties, N Nearness of the tumor to the collecting system or sinus, L location relative to the upper and lower polar lines, (R, E, N, and L were scored according to RENAL nephrometry scoring system), HTN hypertension, DM diabetes mellitus, DL dyslypidemia, CI confidential interval, † These factors were put in multivariate regression analysis, * p-value < 0.05 was considered statistically significant.	

Discussion

We have reported on perioperative renal function preservation during off-clamp, non-renorrhaphy open partial nephrectomy within 3 months after surgery.

The advantage of the off-clamp technique in perioperative renal function preservation is controversial. Wen et al. have reported less decrease in renal function in off-clamp surgery compared to that in on-clamp surgery (weighted mean difference: 4.81 mL/min/1.73 m^2; 95% confidence interval: 3.53–6.08; $p < 0.00001$) [9]. Meanwhile, several studies have failed to show the advantages of off-clamp surgery in eGFR preservation over clamping surgery in pneumoperitoneum settings [10–13].

AS for the advantage of renorrhaphy, the non-renorrhaphy technique failed to benefit the preservation of perioperative renal function for ≥ T1b renal tumors in open partial nephrectomy compared with the cold ischemia technique [14]. In this study, the renal function was analyzed at 4 and 6 months after surgery. However, studies comparing single-layered and double-layered renorrhaphy have shown the benefits of single-layered renorrhaphy in eGFR preservation [4, 15, 16]. In these analyses, eGFR was assessed between the date of discharge and 1 month postoperatively. Considering these findings, it is possible that omission of renorrhaphy preserves renal function during the early postoperative period.

The RENAL score correlates with perioperative reduction in renal function during on-clamp partial nephrectomy [17]. In this study, split renal function was measured using diethylene triamine penta-acetic acid scintigraphy, which showed a significant decrease in ipsilateral renal function 6 months after surgery, with no significant change thereafter [17].

There are limited data on perioperative renal function during combined off-clamp and non-renorrhaphy partial nephrectomy. We have recently reported the surgical results of off-clamp, non-renorrhaphy open partial nephrectomy for ≥ T1b renal tumors [8]. The perioperative eGFR preservation at 1 month and 3 months after surgery was 88.9% and 87.3%, respectively [8]. In laparoscopic or robotic surgeries, perioperative eGFR preservation was 96.9–100% for highly selected patients [18, 19]. In our study, the eGFR preservation at 5 days, 1 month, and 3 months after surgery was 95.3%, 91.0%, and 90.7%, respectively. We believe our report will add some knowledge on the chronological recovery of renal function after off-clamp, non-renorrhaphy partial nephrectomy.

Estimated blood loss was an early predictor of perioperative eGFR preservation, but was replaced by age at 3 months after surgery. Within 1 month after surgery, we assumed that damage of renal parenchyma by soft coagulation directly contributed to the decrease in the eGFR. Impairment of the potential for renal function recovery by age may affect eGFR preservation > 3 months after surgery [20].

This study has some limitations. First, the study was a retrospective study. Second, the postoperative eGFR was analyzed only within 3 months after surgery.

In conclusion, we have analyzed perioperative changes in renal function after off-clamp, non-renorrhaphy open partial nephrectomy until 3 months after surgery. The perioperative eGFR preservation rates of 95.3%, 91.0%, and 90.7% at 5 days, 1 month, and 3 months after surgery, respectively, reported in our study may be used as reference in the era of RAPN.

Methods

Patients

Among 220 patients with renal tumors who underwent off-clamp, non-renorrhaphy open partial nephrectomy at our institute between 2013 and 2020, those with postoperative complications of urinoma or incomplete data were excluded. Therefore, clinical records of 138 patients were retrospectively analyzed.

Surgical Techniques

Complexity of renal tumors were analyzed according to R-E-N-A-L nephrometry scoring system [7]. Briefly, (R)adius (tumor size as maximal diameter), (E)xophytic and endophytic properties, (N)earness of the tumor to the collecting system or sinus, and (L)ocation relative to the upper and lower polar lines were scored on a 1, 2 or 3-point scale. RENAL score represents sum of R, E, N, and L scores. All patients underwent open partial nephrectomy retroperitoneally. Renal pedicle was not secured, and renal pedicle clamping and cortical renorrhaphy were omitted. We used monopolar SOFT COAG (VIO300D, ERBE, Germany) with a normal saline drip for hemostasis. Surgical techniques have been described previously [8]. In partial nephrectomy, the renal parenchyma was repeatedly separated bluntly using a spatula-shaped tip of a monopolar device, followed by soft coagulation of the separated renal parenchyma and bleeding blood vessels. To minimize blood loss, tumor resection was advanced by millimeter unit. Resection beds were sutured with 4 – 0 VICRYL® when the collecting system was opened. Urine leakage was ruled out by intravenous injection of indigo carmine solution. TachoSil® was placed on the resection surface to ensure hemostasis.

Assessment of renal function and perioperative reduction in renal function

The eGFR was calculated using the Eq. $186 \times (\text{Creatinine}/88.4)^{-1.154} \times (\text{Age})^{-0.203} \times (0.742 \text{ if female})$. Perioperative eGFR preservation at 5 days, 1 month, and 3 months after surgery was calculated as postoperative eGFR/preoperative eGFR × 100 (%).

Statistical analysis

The Student's t-test was used to analyze continuous variables. Univariate and multivariate regression analyses were performed to identify predictors of postoperative eGFR preservation. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using the SPSS version 24.

Declarations

Author contributions

Data collection: M.N., Y.A.; Writing - original draft preparation: M.N.; Writing - review and editing: M.N., S.K., T.T., Y.I., T.Y., Y.A., N.S., H.I., R.A., S.I., M.K., T.M., Y.S.; Supervision: S.K., Y.S.

Statement of Ethics

This study was approved by the Ethics Committee of NTT Medical Center, Tokyo (ID: 20-198), and was conducted in accordance with the Helsinki Declaration.

Informed consent was obtained in the form of opt-out on the web-site (https://www.nmct.ntt-east.co.jp/aboutus/ethic/research/). Those who rejected were excluded.

Conflict ofInterest Statement

The authors declare no competing interests.

Funding Sources

This research received no specific grantfrom any funding agency in the public, commercial, or

not-for-profit sectors.

Data Availability Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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Figures

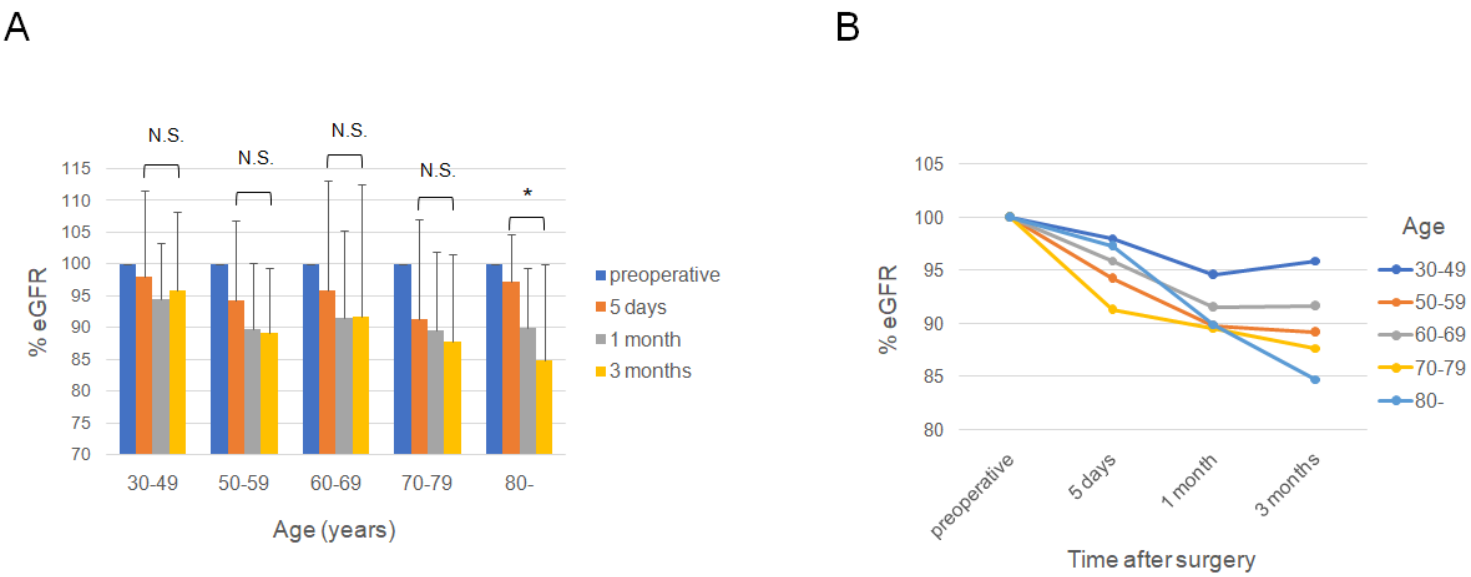

Figure 1

A) Relationship between age and eGFR change was shown. N.S. not significant. * $p < 0.05$. B) Chronological change of eGFR (mean) by age are plotted.