Comparison of robot-assisted partial nephrectomy with soft coagulation and double-layer technique for complex and non-complex tumors

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Running title

RAPN suturing technique for complex tumors

Objectives

To compare the postoperative outcomes of robot-assisted partial nephrectomy when only the inner layer is sutured (single-layer technique with soft coagulation) with those when sutures are placed in the inner and outer layers (double-layer technique) in patients with and without complex renal tumors.

Methods

This retrospective three-institution study included 371 patients with renal tumors who underwent robot-assisted partial nephrectomy with a double-layer technique or a single-layer technique with soft coagulation. Tumors that were cT1b, completely embedded, located in the renal portal, or had a RENAL score of ≥10 were considered complex. Relevant data were collected from hospital records. Propensity score matching was performed to minimize selection bias.

Results

Propensity score matching created 83 patient-pairs with non-complex tumors and 32 with complex tumors. Regardless of tumor complexity, there was no significant difference in operation time, console time, warm ischemia time, positive surgical margin rate, or length of hospital stay between the double-layer and single-layer groups. Although Clavien–Dindo grade I–II urinomas not requiring intervention were significantly more common in the single-layer group regardless of tumor complexity, there was no significant between-group difference in rate of decline in renal function or grade III–IV complications.

Conclusion

Single-layer suturing with soft coagulation achieves renal function and perioperative outcomes comparable to those of double-layer suturing regardless of complexity.

Keywords
partial nephrectomy, renal tumors, robotic-assisted, complex tumors, soft coagulation

Introduction

The double-layer technique (DLT) is the standard reconstruction method after tumor resection by partial nephrectomy. However, Bahler et al. proposed a single-layer technique (SLT), whereby only the inner layer is sutured with omission of cortical sutures[1], thereby reducing ischemia time, cortical damage, and postoperative decline in renal function. Moreover, SLT reportedly has the advantage of reducing operation and ischemia times[2,3].

Some Japanese reports have described an SLT that uses soft coagulation without suturing the renal parenchyma and has advantages over DLT in terms of a shorter warm ischemia time (WIT) and fewer postoperative complications[4–6]. However, no significant differences in postoperative outcomes between SLT and DLT in robot-assisted partial nephrectomy (RAPN) have been identified.

Recent reports on RAPN for complex tumors indicate satisfactory short-term surgical outcomes but the long-term results remain unclear[7,8]. Furthermore, there appear to be no published comparisons of perioperative outcomes and postoperative complications between SLT and DLT in patients with complex tumors.

In this report, we compare the perioperative outcomes and postoperative complications of RAPN with SLT using soft coagulation and those of standard RAPN with DLT in patients with and without complex tumors.

Material and Methods

Study Design and Patient Selection

This retrospective study included patients who underwent RAPN with standard DLT or RAPN with SLT at any of three institutions affiliated with Tokushima University Hospital between February 2013 and February 2022. Six patients with bilateral tumors, eight with a single kidney, one with multiple tumors, and three in whom T3a disease was suspected intraoperatively and prompted conversion to nephrectomy were excluded. Ten patients who were lost to follow-up within the first 6 months and had missing data were also excluded. Data were obtained for the remaining 371 patients, including age, sex, body mass index (BMI), presence of hypertension or diabetes, and tumor size. Preoperative computed tomography (CT) was used to evaluate RENAL nephrometry scores and to determine whether the tumor was in the renal portal area. Perioperative data, including operation time, console time, WIT, estimated blood loss, and length of hospital stay, were also collected. Preoperative and postoperative renal function (at 1, 3, and 6 months) was assessed by the estimated glomerular filtration rate (eGFR), which was calculated using the Modification of Diet in Renal Disease (MDRD) modified for Japanese patients as outlined by The Japanese Society of Nephrology (eGFR=194×serum creatinine mg/dL$^{-1.094}$×age$^{-0.287}$×0.739 [if female])[9]. Postoperative complications were evaluated using a modified Clavien–Dindo classification[10]. A complex tumor was defined as >4 cm in diameter, completely embedded, located in the renal portal, or with a RENAL score of ≥10. This study aimed to compare the perioperative outcomes and postoperative complications between RAPN with SLT and standard RAPN with DLT in patients with and without complex tumors. The study was performed retrospectively using anonymized patient data and approved by the Tokushima University Hospital Institutional Review Board.

Surgical Techniques

All surgeries were performed by urologic surgeons experienced in robotic surgery. The technique chosen (DLT vs. SLT) was determined primarily by the surgical facility; DLT was performed at two centers and SLT in the remaining center.

A transabdominal or retroperitoneal approach was selected depending on the tumor location. The tumor margin was identified intraoperatively using an ARIETTA 70 ultrasound probe (Hitachi, Tokyo, Japan); the renal artery was then clamped and the tumor removed with a robotic shear blade. The resection surface was reconstructed using one of the following suture techniques. We do not generally place ureteral stents preoperatively. However, depending on the surgeon's preference, a few patients may have a ureteral catheter placed preoperatively, but the catheter is removed at an end of the surgery. All patients undergo drainage, but the drain is removed on postoperative day 3, 4, or 5 if there is no increase in drainage volume after the urethral balloon is removed on postoperative day 2.

Single-layer technique

After removal of the tumor, hemostasis of the cut surface was achieved by soft coagulation (VIO 300D; Erbe Elektromedizin GmbH, Tubingen, Germany). If the urinary tract had been opened, it was closed using 3-0 Biosyn™ sutures (Medtronic, Dublin, Ireland). With hemostasis controlled by soft coagulation, the renal artery was unclamped and additional hemostasis was achieved with ligature sutures (3-0 Biosyn) or soft coagulation as needed. In principle, parenchymal sutures were omitted and absorbable hemostat (Tacho Sil; CSL Behring Japan, Tokyo, Japan) was applied to the resection surface at the end of the procedure.

Double-layer technique

After the tumor had been removed, the resection bed was repaired with internal running sutures (15 cm 3-0 V-Loc 180 CV23; Covidien, New Haven, CT, USA). The same type of suture was used for closure when the urinary tract had been opened. After the inner suture had been completed, a series of outer-layer sutures (30 cm 2-0 V-Loc 180 GS21; Covidien) were stitched to the renal parenchyma and absorbable (Tacho Sil) hemostat was applied to the suture surface. Soft coagulation can be used for hemostasis in cases of severe bleeding even with DLT, but the time spent using soft coagulation is very short.

Statistical analysis

To minimize the influence of preoperative characteristics in the DLT and SLT groups, we performed a propensity score-matched analysis. Propensity scores were obtained by multivariate logistic regression using the covariates of age, sex, BMI, tumor size, RENAL score, history of diabetes, or hypertension, and preoperative renal function as factors affecting intraoperative tumor resection, reconstruction of the resection bed and postoperative decline in renal function. Using estimated propensity scores, patients who had undergone RAPN with SLT were matched 1:1 without replacement to patients who had undergone RAPN using DLT by the nearest-neighbor method with a caliper of 0.2. Independent t-tests or Pearson's chi-square tests were used to compare covariate differences before and after matching. The findings indicated that matching improved the balance between the two groups. Continuous variables were examined using the Student's t-test and unordered categorical variables using the chi-square test. The Mann–Whitney U test was used to adjust for ordered categorical variables. All statistical tests were performed using SPSS version 28.0 software (IBM Corp., Armonk, NY, USA). All tests were two-tailed, and a p-value ≤0.05 was considered statistically significant.

Results

DLT was performed in 207 of the 371 patients who had undergone RAPN; 261 of these patients had non-complex tumors and 110 had complex tumors. Sixty-one of the complex tumors were renal portal, 50 were T1b, and 18 were completely embedded (some contained more than one of these features). DLT was performed in 38 of the complex cases (in the renal hilum, n=18; cT1b, n=18; completely embedded, n=6; RENAL score ≥10, n=6). Figure 1 shows the study flow chart. Table 1 shows the characteristics of patients with non-complex tumors before and after matching; 169 had undergone RAPN with DLT and 92 RAPN with SLT. Preoperative renal function and RENAL scores differed significantly between the groups. After using 1:1 propensity score matching to adjust for patient variables, 83 patients per group were matched; the matching achieving a good balance of key characteristics between the two groups. There was no significant difference in age (p=0.64), sex (p=0.87), BMI (p=0.92), tumor size (p=0.63), preoperative renal function (p=0.72), RENAL score (p=0.5) and presence of diabetes or hypertension (p=1.0, p=0.75).

Table 2 shows the characteristics of patients with complex tumors before and after matching in the SLT and DLT groups. Thirty-eight had undergone RAPN with DLT and 72 had undergone RAPN with SLT. There was no significant between-group difference before propensity score matching. Matching resulted in 32 patient-pairs per group, with no significant difference in age (p=0.28), sex (p=0.79), BMI (p=0.35), tumor size (p=0.92), preoperative renal function (p=0.93), RENAL score (p=0.86) and presence of diabetes or hypertension (p=1.0, p=0.77). Perioperative data are shown in Table 3. In non-complex cases, there was no significant difference in operation time (195 vs. 187 min), WIT (21.2 vs. 22.7 min), positive surgical margin rate (p=0.53), estimated blood loss (43 vs 71 ml) or hospital stay (11.2 vs. 11.6 days) between the DLT and SLT groups. In complex cases, there was no significant difference in operation time (246 vs. 241 min), WIT (29.4 vs. 29.8 min), positive surgical margin rate (p=0.5), estimated blood loss (96 vs 92 ml) or hospital stay (11.4 vs. 12.0 days) between the DLT and SLT groups; however, console time (166 vs. 187 min) tended to be longer in the SLT group although the difference was not statistically significant (p=0.08).

Table 4 shows postoperative renal function according to tumor complexity. There was no significant difference in the rate of decline in renal function between the SLT and DLT groups at 1, 3, and 6 months postoperatively.

Table 5 shows the postoperative complications according to Clavien–Dindo grade. Grade I–II urinomas not requiring intervention were significantly more common in the SLT group regardless of tumor complexity. Figure 2 shows the changes in conservatively treated grade II urinomas over time. There was no significant between-group difference related to tumor complexity. There were also no cases of urinoma requiring ureteral stenting in the DLT group. No patients in the SLT group developed pseudoaneurysms requiring embolization; however, pseudoaneurysms developed in two non-complex cases and in two complex cases in the DLT group. There was no significant between-group difference in development of pseudoaneurysms, regardless of tumor complexity.

Discussion

RAPN is the main treatment for localized renal cell cancers, and several reports suggest that SLT is useful when performing this procedure[4–7]. Some studies found no significant difference in long-term renal function between SLT and DLT in patients who underwent RAPN, and the choice between the techniques mainly comes down to the surgeon's preference. However, RAPN remains challenging in so-called complex cases, including tumors that are ≥cT1b, completely embedded, or RENAL ≥10.

In this study, we compared postoperative outcomes between SLT with soft coagulation and standard DLT for both complex and non-complex tumors. There was no significant difference in WIT between these techniques regardless of tumor complexity. Other studies found that SLT was associated with a shorter WIT, which was attributed to omission of sutures in the renal parenchyma[2,3]. This inconsistency may reflect our policy concerning SLT, whereby hemostasis with soft coagulation is achieved by direct application of electrodes, resulting in tissue contraction and protein denaturation. Therefore, prolongation of clotting time by soft coagulation is inevitable when the resection bed is large. Furthermore, given that achieving hemostasis by SLT depends predominantly on this step, we clamp the renal artery until complete hemostasis has been achieved by soft coagulation and expect WIT to be longer with SLT in complex cases.

Pseudoaneurysms and urinomas are typical complications of RAPN. Singh and Gill proposed two mechanisms for development of pseudoaneurysms after partial nephrectomy: first, inadvertent vascular injury during tumor resection; second, vascular injury during suturing of the renal parenchyma[11]. Additionally, postoperative weaning is said to increase blood flow to the surgical layer, leading to extravascular blood pooling and aneurysm formation[12]. Previous studies suggest that a retroperitoneal approach, exposure of a buried tumor, or a renal sinus could influence development of pseudoaneurysm[13–15]. Pseudoaneurysms requiring arterial embolization after RAPN reportedly occur in 1.0% of cases[16,17] and were detected in 2% of non-complex cases in our DLT group but in none in our SLT group. However, in our complex cases, the incidence of pseudoaneurysms was 6% in the DLT group and 0% in the SLT group.

Tachibana et al. found that the risk of pseudoaneurysm was lower with SLT than with DLT during open partial nephrectomy[18]. Similarly, in patients undergoing RAPN for cT1a disease, the risk of pseudoaneurysm was lower when SLT with soft coagulation was used[4–7]. Early unclamping may help prevent pseudoaneurysm after partial nephrectomy because Kondo et al. reported that early unclamping allowed surgeons to identify arterial bleeding from the resection bed before suturing the renal parenchyma and control it by adding an internal suture[14,19]. However, early unclamping may be difficult when RAPN with DLT is performed in complex cases because of extensive suturing of the renal parenchyma but may be useful in non-complex cases and in RAPN with SLT.

Clavien–Dindo grade III or higher urinomas were detected in 4% of patients with non-complex tumors and 3% of those with complex tumors in the SLT group and in none in the DLT group. Furthermore, in the SLT group, 16% of patients with non-complex tumors and 15% with complex tumors developed grade I–II asymptomatic urinoma that resolved spontaneously over time.

Urinoma is a common complication after open or laparoscopic partial nephrectomy with a reported incidence of 10%–17%[20–22]. However, the advent of robotic surgery with its magnified stereoscopic view has ensured the feasibility of inner suturing for urinary tract closure. Unlike after open or laparoscopic partial nephrectomy, urinoma after RAPN is relatively rare, in the range of 0.6%–3% overall[23] and 4%–6% for tumors >7 cm[24,25]. Most studies have found no significant difference in incidence of urinoma between SLT and DLT after RAPN[1,3,26].

There are several possible reasons for our high incidence of urinoma after SLT with soft coagulation. First, the hemostatic manipulation associated with soft coagulation may have destroyed the thread used to suture the open urinary tract intraoperatively. Second, thermal damage arising from soft coagulation may have delayed healing of the closed urinary tract tissue. We take several measures to prevent urinoma in RAPN using SLT. If the urinary tract is open during tumor resection, we place a metal clip near the open area as a landmark to ensure closure of the open urinary tract at the time of the inner suture after tumor resection. Additionally, the renal medulla is close to the urinary tract, so we avoid soft coagulation in the medullary areas because of the risk of tissue necrosis due to thermal damage. If the medullary areas are bleeding, we perform hemostasis with inner sutures if possible. Preoperative imaging simulations, such as virtual partial nephrectomy images, can predict the area of urinary patency and help prevent urinoma[27,28].

However, all grade I–II urinomas healed spontaneously within 3–6 months (Figure 2). Furthermore, healing was achieved with the help of ureteral stents in all four patients with grade ≥III urinomas. Therefore, unlike pseudoaneurysm, urinoma is a relatively mild postoperative complication.

We found no significant between-group difference in postoperative renal function regardless of tumor complexity. Although it is generally believed that WIT impacts renal function post-partial nephrectomy, several studies have found no difference in postoperative renal function according to the WIT. Masson-Lecomte et al. prospectively compared the outcomes of 220 RAPNs and 45 LPNs and found RAPN to be superior in terms of WIT; however, postoperative renal function did not differ significantly between the procedures[26]. Simmons et al. found that parenchymal atrophy was minimal (range 0%–2%) after partial nephrectomy with a WIT of <40 min[29].

Cortical damage caused by the techniques used for hemostasis may affect post-partial nephrectomy renal function. Nakamura et al. reported lower rate of decline in renal function 1 month postoperatively after SLT with soft coagulation compared with standard DLT. They attributed these differences to the elimination of parenchymal suturing when soft coagulation is utilized[6]. In standard RAPN with DLT, the segmental arteries flowing to the renal cortex may be obstructed by the sutures, resulting in renal ischemia that may affect postoperative renal function. However, cortical damage caused by soft coagulation may also affect postoperative renal function, although Fujisaki et al. reported that thermal denaturation of the kidney caused by soft coagulation in pigs extended only about 4 mm from the incision surface, regardless of coagulation time[30].

This study had several limitations. First, we compared outcomes between different institutions and multiple surgeons. SLT with soft coagulation was only performed in one institution, and contrast-enhanced CT was performed in all patients in the SLT group at 1 month postoperatively but not in all patients in the DLT group, which may have contributed to the higher incidence of grade I–II urinoma after soft coagulation. Therefore, the generalizability of our findings may be limited. Second, each institution decided whether to perform RAPN in complex cases. Institutions that mainly perform RAPN with DLT may choose nephrectomy over RAPN for T1b or hilar cases, considering that the renal parenchyma would not be sutured after tumor resection. In such cases, WIT would have taken longer if RAPN with DLT was performed. Therefore, the possibility of selection bias that may impact on WIT in the DLT group in complex cases cannot be excluded. Third, the small sample size may have resulted in a lack of statistical power to detect potential differences. Finally, the study had a retrospective design. Therefore, our present findings and long-term outcomes require prospective investigation in the future

In conclusion, RAPN with SLT using soft coagulation and standard RAPN with DLT achieve comparable renal function and perioperative outcomes independent of tumor complexity. Pseudoaneurysm, which is a potentially serious complication, was not observed in the SLT group regardless of tumor complexity, suggesting that RAPN with SLT using soft coagulation is safe.

Abbreviations & Acronyms

DLT = double-layer technique
SLT = single-layer technique
WIT = warm ischemia time
RAPN = robot-assisted partial nephrectomy
CT = computed tomography
eGFR = estimated glomerular filtration rate
MDRD = Modification of Diet in Renal Disease
BMI = Body mass index
LPN=Laparoscopic partial nephrectomy

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Disclosure

Keito Shiozaki, Kazuyoshi Izumi, Yutaro Sasaki, Yoshito Kusuhara, Tomoya Fukawa, Yasuyo Yamamoto, Kunihisa Yamaguchi, Masayuki Takahashi, Hirofumi Izaki, Yasuo Kawanishi and Hiroomi Kanayama all declare that they have no conflicts of interest.
The Institutional Review Board of Tokushima University Hospital approved this study (approval number 4170).
Informed consent was not required for this retrospective study of anonymized data.
Registry and the Registration No. of the study: N/A
Animal studies: N/A.

Author contributions

We can confirm that all authors revised the manuscript, approved the version of the manuscript submitted for publication, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Figure 1. Flow chart showing the patient enrolment process

Figure 2. Clavien–Dindo grade I–II postoperative urinoma after performing the single-layer technique with soft coagulation

(a) Contrast-enhanced computed tomography image (excretory phase) obtained 1 month postoperatively showing relatively large urine leakage.
(b) Plain computed tomography image obtained 6 months postoperatively showing almost complete resolution of leakage of urine.

Table 1. Patient characteristics before and after matching for non-complex tumors

Table 2. Patient characteristics before and after matching for complex tumors

Table 3. Postoperative outcomes post-matching according to tumor complexity

Table 4. Renal functional outcomes post-matching according to tumor complexity

Table 5. Major postoperative complications

Figure 1. Flow chart showing the patient enrolment process

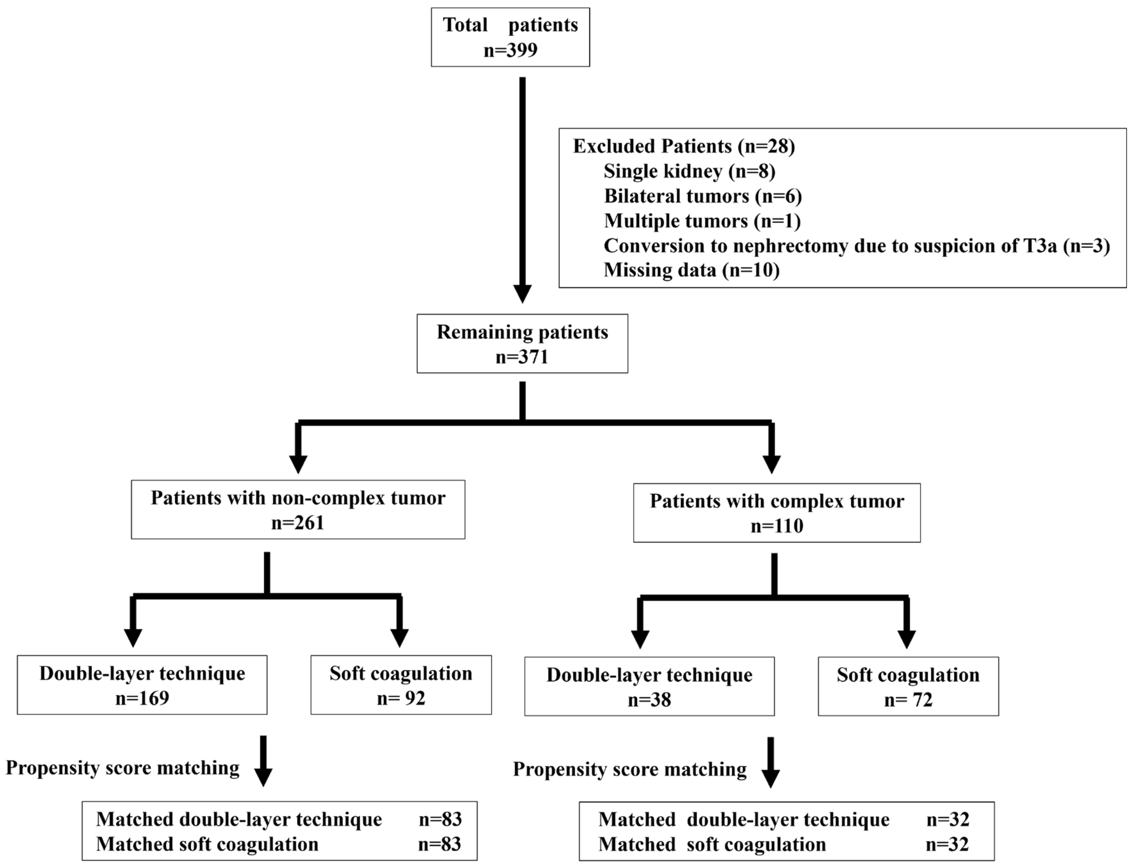
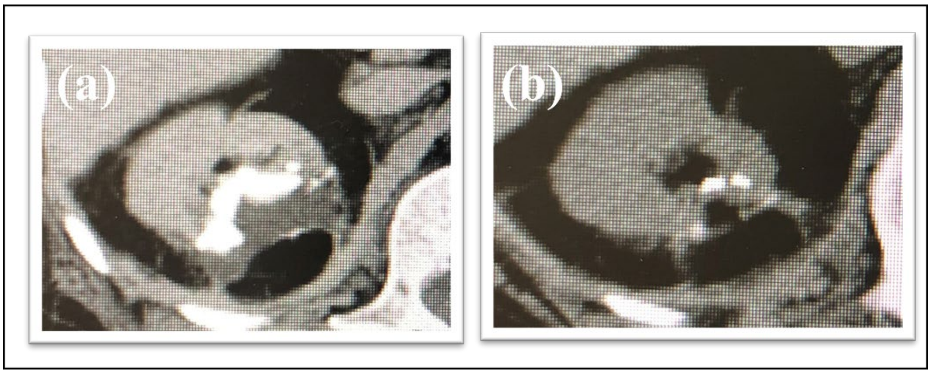


Figure 2. Clavien–Dindo grade I–II postoperative urinoma after performing the single-layer technique with soft coagulation



(a) Contrast-enhanced computed tomography image (excretory phase) obtained 1 month postoperatively showing relatively large urine leakage.
(b) Plain computed tomography image obtained 6 months postoperatively showing almost complete resolution of leakage of urine.

Table 1. Patient characteristics before and after matching for non-complex tumors

Variable	Pre-matching			Post-matching		
	Double layer technique (n=169)	Soft coagulation (n=92)	*P*	Double layer technique (n=83)	Soft coagulation (n=83)	*P*
Age, mean (SD)	65.5±11	67.2 ±11	0.27	66.3±10.3	67.1±11.7	0.64
Male, n (%)	120 (71.0)	55 (59.7)	0.06	52 (62.6)	51 (61.4)	0.87
BMI (kg/m^2), mean (SD)	24.4±3.5	23.6±3.7	0.12	23.8±3.5	23.8±3.7	0.92
Clinical tumor size (mm), mean (SD)	24.5±7.7	22.4±9.2	0.69	22.1±7.2	22.7±9.4	0.63
Preoperative eGFR (ml/min/1.73m^2), mean (SD)	68.7±19	76.2±23	<0.05	74.1±19	73.0±20	0.72
R.E.N.A.L. nephrometry score, mean (SD)	5.9±1.5	6.4±1.5	<0.05	6.2±1.5	6.3±1.5	0.5
Low 4-6, n (%)	105 (62.1)	50 (54.3)		46 (55.3)	47 (56.7)	
Moderate 7-9, n (%)	54 (31.9)	42 (45.6)		37 (39.7)	36 (43.3)	
High 10-12, n (%)	0 (0)	0 (0)		0 (0)	0 (0)	
Presence of diabetes, n (%)	33 (19.5)	21 (22.8)	0.53	18 (21.6)	18 (21.6)	1.0
Presence of hypertension, n (%)	93 (55.0)	55 (59.7)	0.45	49 (59.0)	51 (61.4)	0.75

BMI=body mass index; eGFR=estimated glomerular filtration rate.

Table 2. Patient characteristics before and after matching for complex tumors

Variable	Pre-matching			Post-matching		
	Double layer technique (n=38)	Soft coagulation (n=72)	*P*	Double layer technique (n=32)	Soft coagulation (n=32)	*P*
Age, mean (SD)	66.7 ± 12.4	65.8 ± 12.7	0.73	65.8 ± 12.7	69.3 ± 13.4	0.28
Male, n (%)	27 (71.0)	45 (62.5)	0.37	21 (65.6)	22 (68.7)	0.79
BMI (kg/m^2), mean (SD)	24.9 ± 3.4	24.0 ± 3.2	0.16	24.8 ± 3.7	24.1 ± 2.7	0.35
Clinical tumor size (mm), mean (SD)	37.0 ± 13	38.9 ± 15	0.53	37.9 ± 13.5	38.2 ± 13.7	0.92
Preoperative eGFR (ml/min/1.73m^2), mean (SD)	72.2 ± 19	72.8 ± 18	0.88	73.7 ± 21	74.1 ± 20	0.93
R.E.N.A.L. nephrometry score, mean (SD)	8.0 ± 1.3	8.5 ± 1.4	0.92	8.1 ± 1.3	8.2 ± 1.5	0.86
Low 4-6, n (%)	5 (13.1)	8 (11.1)		3 (9.3)	4 (12.5)	
Moderate 7-9, n (%)	27 (71.0)	41 (56.9)		23 (71.9)	21(65.7)	
High 10-12, n (%)	6 (15.8)	23 (32.0)		6 (18.8)	7 (21.8)	
Presence of diabetes, n (%)	6 (15.7)	18 (25.0)	0.26	6 (18.7)	6 (18.7)	1.0
Presence of hypertension, n (%)	29 (76.3)	44 (61.1)	0.1	23 (71.8)	24 (75.0)	0.77

BMI=body mass index; eGFR=estimated glomerular filtration rate.

Table 3. Postoperative outcomes post-matching according to tumor complexity

Variable	Non-complex tumor cases			Complex tumor cases		
	Double layer technique (n=83)	Soft coagulation (n=83)	*P*	Double layer technique (n=32)	Soft coagulation (n=32)	*P*
Transperitoneal approach, n (%)	45 (54.2)	47 (56.6)	0.68	18 (56.2)	13 (40.0)	0.21
Operative time (min), mean (SD)	195±45	187±49	0.30	246±56	241±58	0.34
Console time (min), mean (SD)	125±38	135±47	0.14	166±46	187±47	0.08
Warm ischemia time (min), mean (SD)	21.2±6.4	22.7±10	0.29	29.4±11	29.8±15	0.89
Positive surgical margin, n (%)	4 (4.8)	5 (6.0)	0.53	1 (3.1)	0 (0)	0.5
Hospital stay	11.2±2.5	11.6±4.3	0.39	11.4±2.4	12.0±2.5	0.29
Estimated blood loss (ml), mean (SD)	43±49	71±148	0.1	96±130	92±133	0.89
Transfusion, n (%)	0 (0)	1 (1)	0.31	1 (3)	1 (3)	1
Histopathology, n (%)						
Clear cell	63 (75.9)	62 (74.9)		29 (90.7)	23 (71.8)	
Papillary	11 (13.2)	6 (7.2)		1(3.1)	5(15.6)	
Chromophobe	1 (1.2)	4 (4.8)		0(0)	2(6.3)	
Other malignant	0 ()	2 (2.4)		1(3.1)	0(0)	
Benign	8 (9.7)	9 (10.7)		1(3.1)	2(6.3)	
Pathology stage						
pT1a, n (%)	75(90.3)	74 (89.1)		14 (43.8)	19 (59.4)	
pT1b, n (%)	0 (0)	0 (0)		16 (50.0)	11 (34.3)	
pT2, n (%)	0 (0)	0 (0)		0(0)	0 (0)	
pT3, n (%)	0 (0)	0 (0)		1 (3.1)	0 (0)	
Benign, n (%)	8 (9.7)	9 (10.9)		1 (3.1)	2 (6.3)	

Table 4. Renal functional outcomes post-matching according to tumor complexity

Time point	Variable	Non-complex tumor cases			Complex tumor cases		
		Double layer technique (n=83)	Soft coagulation (n=83)	*P*	Double layer technique (n=32)	Soft coagulation (n=32)	*P*
Preoperative	**eGFR (ml/min/1.73m²), mean (SD)**	**74.1±19**	**73.0±20**	**0.72**	**73.7±21**	**74.1±20**	**0.93**
Postoperative 1-month	**eGFR (ml/min/1.73m²), mean (SD)**	**69.4±19**	**68.3±21**	**0.74**	**64.0±19**	**65.9±17**	**0.68**
	Change in postoperative eGFR (%), mean (SD)	**-6.0±11**	**-6.8±10**	**0.64**	**-12.6±10**	**-9.4±14**	**0.31**
Postoperative 3-month	**eGFR (ml/min/1.73m²), mean (SD)**	**66.8±17**	**67.5±20**	**0.81**	**63.7±20**	**65.0±16**	**0.78**
	Change in postoperative eGFR (%), mean (SD)	**-9.8±11**	**-7.6±10**	**0.49**	**-13.7±11**	**-11.1±11**	**0.36**
Postoperative 6-month	**eGFR (ml/min/1.73m²), mean (SD)**	**67.5±17**	**65.3±19**	**0.44**	**61.3±19**	**63.4±17**	**0.64**
	Change in postoperative eGFR (%), mean (SD)	**-7.9±12**	**-10.2±12**	**0.21**	**-16.5±11**	**-13.0±12**	**0.25**

eGFR=estimated glomerular filtration rate.

Table 5. Major postoperative complications

Complication	Management method	Non-complex tumor cases: Double layer technique (n=83)	Non-complex tumor cases: Soft coagulation (n=83)	Non-complex tumor cases: *P*	Complex tumor cases: Double layer technique (n=32)	Complex tumor cases: Soft coagulation (n=32)	Complex tumor cases: *P*
Clavien-Dindo Grade 1-2							
Urinoma, n (%)	Conservative management	1 (1)	13 (16)	<0.05	0 (0)	5 (15)	<0.05
Pseudoaneurysm, n (%)	Conservative management	1 (1)	0 (0)	0.3	0 (0)	0 (0)	1
Clavien-Dindo Grade 3-5							
Urinoma, n (%)	Placement of ureteral stent	0 (0)	3 (4)	0.24	0 (0)	1 (3)	0.5
Pseudoaneurysm, n (%)	Arterioembolization	2 (2)	0 (0)	0.49	2 (6)	0 (0)	0.2