



Partial nephrectomy in solitary kidneys: comparison between open surgery and robotic-assisted laparoscopy on perioperative and functional outcomes (UroCCR-54 study)

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Abstract

Purpose The management of solitary kidney tumors is a surgical challenge, requiring irreproachable results on both oncological and functional outcomes. The goal of our study was to compare the perioperative results of robotic-assisted partial nephrectomy (RAPN) to open surgery in this indication.

Methods We led a multicentric study based on the prospectively maintained French national database UroCCR. Patients who underwent partial nephrectomy on a solitary kidney between 1988 and 2020 were included. Clinical and pathological data were retrospectively analyzed. The main outcome of the study was the analysis of the variation of the estimated glomerular filtration rate (eGFR) calculated according to MDRD at 3, 6, 12, and 24 months depending on the chosen surgical approach. The secondary outcomes were the comparison of Trifecta success, perioperative complications, and length of hospital stay.

Results In total, 150 patients were included; 68 (45%) in the RAPN group and 82 (55%) in the open surgery group. The two groups were comparable for all data. The variation of eGFR at 3, 6, 12, or 24 months was comparable without any significant difference between the 2 groups ($p=0.45$). Trifecta was achieved in 40% of the patients in the RAPN group and 33% in the open group ($p=0.42$). A significant difference was observed for the length of stay, 5 days for the robot group versus 9 days for the open surgery group ($p<0.0001$).

Conclusion In our study, the surgical approach did not modify functional results and we noted a significant decrease in hospital stay and complications in the RAPN group. RAPN is a safe and efficient method for management of kidney tumors in solitary kidneys.

Keywords Single kidney · Solitary kidney · Open partial nephrectomy · Robotic-assisted partial nephrectomy · Nephron sparing surgery · Trifecta

Introduction

The best in vivo model to study the impact of surgery on kidney function is the solitary kidney. The consideration of partial nephrectomy (PN) as the gold standard for imperative indications had led an increase in conservative management of kidney tumors by PN [1, 2]. Partial nephrectomy must fulfill 2 mandatory objectives: a maximum preservation of renal function and cancer control by obtaining a

tumorectomy with safe margins and a minimal complication rate.

Achieving these two objectives requires good visibility, exposure, and mobility. Therefore, the two main current approaches used are the open approach (lombotomy or laparotomy) and the robotic-assisted laparoscopic approach. Standard laparoscopy has almost been given up on, and is only performed by a few trained surgeons.

Open partial nephrectomy (OPN) has been considered the gold standard for PN for long decades and especially for solitary kidney. Advances in surgical and technological techniques led us to the development of robotics at the end of the 2000s. Although the surgical gesture remains identical, robotic-assisted surgery made the possibility of treating

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more difficult tumors over the past ten years and to extend RAPN to solitary kidneys [3–10].

The objective of our study was to compare the functional and perioperative results of partial nephrectomy in solitary anatomical kidney between open partial nephrectomy (OPN) and robotic-assisted partial nephrectomy (RAPN).

Patients and methods

Study population

We conducted a retrospective, multicenter study on all patients treated by partial nephrectomy for single tumor on a solitary kidney included in the French national prospectively maintained kidney cancer database UroCCR (NCT03293563). A signed consent was obtained from all the patients after clear information and an ethical board approbation was obtained for this study. The data collection and analysis were authorized by the National Information science and Liberties Commission (CNIL) under number DR-2013-206.

The inclusion criteria were: age > 18 years, presence of a single anatomical kidney (congenital or acquired), localized renal tumor on the solitary kidney, open surgical approach, or robot-assisted laparoscopic approach.

The exclusion criteria were mainly: simple laparoscopic approach, renal graft tumor, metastasis at diagnosis, absence of a single anatomical kidney.

Data and endpoints

Pre-, intra-, and postoperative clinicopathological data were collected. The RENAL morphometric score was used to evaluate the case complexity [11]. Renal function was monitored at 3, 6, 12, and 24 months postoperatively by measuring plasma creatinine ($\mu\text{mol/L}$) and estimated glomerular filtration rate (eGFR) according to MDRD. The primary endpoint was the postoperative variation of eGFR at 3, 6, 12, and 24 months. The secondary endpoints were the occurrence of perioperative complications and Trifecta achievement rate defined by negative surgical margins, warm ischemia time (WIT) ≤ 25 min, and the absence of intra, and/or postoperative complications [12].

Statistical analysis

The statistical analysis was performed using R software version 3.6.1. Population characteristics and perioperative outcomes between the 2 groups were compared using the Chi-2 test, Student's t test or Fisher's exact test.

Univariate and multivariate analysis was performed using linear regressions to assess predictive factors of renal

function alteration at 3 months. A p value of < 0.05 was considered statistically significant.

Results

Patient characteristics

A total number of 167 patients with anatomical solitary kidney that have undergone PN between November 1988 and March 2020 were retrieved from the UroCCR database. Seventeen patients were excluded from our study for metastatic disease ($n = 10$), pure laparoscopic approach ($n = 4$), kidney graft tumor ($n = 1$), and too much missing data ($n = 2$). Finally, 150 patients were included in our study, 68 (45%) in the OPN group and 82 (55%) in the RAPN group. The first RAPN took place in 2011, in the OPN group 25 patients (40%) were treated before 2011 and 37 (60%) after.

Both groups were comparable for clinical data. The mean age at diagnosis was 63.5 years [55; 70.2] with a sex ratio of 2:1 between men and women. The mean BMI was 27.7 [25.3; 31.3].

Tumor characteristics

There were no significant differences between the two groups regarding tumor characteristics. The mean tumor size was 3.6 ± 1.9 cm in the RAPN group and 3.7 ± 2 cm in the OPN group ($p = 0.78$).

When concerning the RENAL score, the two groups were comparable even if there was a trend for low complexity tumors (score between 4 and 6) which seemed more frequent in the OPN group with 35% of patients versus 21% in the RAPN group without this result being significant.

We found comparable histological data between the two groups. Most of the specimens were pT1a tumors, with 56% and 67%, respectively, in the robot and open group. Also, 16% of the tumors in the robot group were pT3a versus 6% in the open group. Surgical margins were positive in 10.8% of tumors in the RAPN group versus 9.1% in the open group, without significant difference ($p = 0.77$). All details are reported on Table 1.

Functional results (Table 2)

Preoperative renal function was significantly different in the two groups: $66.9 \text{ ml/min} \pm 18.1$ in RAPN group versus 57.0 ± 16.3 in OPN group ($p = 0.02$).

eGFR at 3, 6, 12, and 24 months decreased by 15.5%, 11.9%, 20.3% and 20.0%, respectively, in the RAPN group

Table 1 Tumor and histological characteristics

	RAPN (<i>N</i> =82)	OPN (<i>N</i> =68)	<i>p</i> value
Radiological tumor size (mean ± SD) (cm)	3.6 ± 1.9	3.7 ± 2.0	0.78
Pathological tumor size (mean ± SD) (cm)	3.2 ± 1.8	3.7 ± 2.5	0.15
RENAL score (<i>N</i> =117) (mean ± SD)	7.4 ± 2.0	7.9 ± 2.0	0.19
4–6 (<i>N</i> , %)	11 (21%)	23 (35%)	0.09
7–9 (<i>N</i> , %)	29 (59%)	28 (43%)	0.17
9–12 (<i>N</i> , %)	12 (23%)	14 (22%)	0.84
pT stage (<i>N</i> , %)			
T1a	41 (56%)	42 (67%)	0.06
T1b	16 (23%)	13 (21%)	0.76
T2a	2 (3%)	3 (5%)	0.67
T2b	0 (0%)	1 (2%)	0.47
T3a	11 (16%)	4 (6%)	0.1
Fuhrman grade (<i>N</i> , %)			
Grade 1	3 (4%)	1 (2%)	0.62
Grade 2	39 (57%)	37 (61%)	0.70
Grade 3	22 (32%)	21 (34%)	0.80
Grade 4	4 (6%)	2 (3%)	0.68
Histological type (<i>N</i> , %)			
Clear cell RCC	57 (77%)	53 (85%)	0.99
Papillary type 1	4 (5%)	3 (5%)	0.99
Papillary type 2	1 (1%)	1 (2%)	0.71
Chromophobe	3 (4%)	4 (6%)	0.50
Oncocytoma	2 (3%)	0 (0%)	0.99
Angiomyolipoma	1 (1%)	0 (0%)	0.46
Simple cyst	0 (0%)	1 (2%)	0.50
Clear cell papillary carcinoma	6 (8%)	0 (0%)	0.03
Positive margins (<i>N</i> =129) (<i>N</i> , %)	8 (10.8%)	5 (9.1%)	0.77

RAPN robot-assisted partial nephrectomy, OPN open partial nephrectomy, RCC renal cell carcinoma

Table 2 Variation of renal function (eGFR) at 3, 6, 12 and 24 months

	RAPN	OPN	<i>p</i> value
Preoperative eGFR (ml/min) (mean ± SD)	66.9 ± 18.1	57.0 ± 16.3	0.002
Delta 3 months (ml/min) (mean ± SD)	−10.38 ± 13.1 (−15.5%)	−5.5 ± 18.2 (−9.6%)	0.79
Delta 6 months (ml/min) (mean ± SD)	−7.93 ± 19.1 (−11.9%)	−6.3 ± 21.1 (−11.0%)	0.76
Delta 12 months (ml/min) (mean ± SD)	−13.6 ± 15.6 (−20.3%)	−6.2 ± 22.6 (−10.9%)	0.23
Delta 24 months (ml/min) (mean ± SD)	−13.4 ± 17.3 (−20.0%)	−9.3 ± 16.6 (−16.3%)	0.45

Significant with a *p* < 0.005 value is highlighted in bold

RAPN robot-assisted partial nephrectomy, OPN open partial nephrectomy, eGFR estimate Glomerular filtration rate

versus 9.6%, 11%, 10.9%, and 16.3% in the OPN group without significant difference (*p* = 0.45).

Postoperatively, 4 patients (2.7%) required dialysis, 3 of these patients were in the OPN group.

A change in CKD stage at 3 months was found in 28.9% of the cases of the entire cohort. In the RAPN group, 25.4% of patients progressed to a higher CKD stage versus 26.4% in the OPN group without significant difference (*p* = 0.93).

Among the entire cohort and in univariate analysis, five factors were significantly associated with the alteration of renal function at postoperative month 3 (POM 3). These factors were age (*p* = 0.008), preoperative eGFR (*p* < 0.0001), WIT (*p* = 0.001), surgery time (*p* = 0.003), and LOS time (*p* = 0.0014).

In multivariate analysis, operating time and blood loss were no longer significantly associated with POM-3 eGFR decrease (Table 3).

Table 3 Predictive factors of postoperative month 3 eGFR change in univariate and multivariate analysis

	Univariate analysis		Multivariate analysis	
	Odds ratio	<i>p</i> value	Odds ratio	<i>p</i> value
Surgical approach	OR: 7.11 [−0.980 to 15.2]	0.084	NA	NA
Age	OR: 0.64 [0.46–0.89]	0.008	OR: 0.58 [0.39–0.85]	0.006
Preoperative eGFR	OR: 2.00 [1.68–2.41]	<0.001	NA	NA
RENAL score	OR: 0.16 [0.01–1.67]	0.122	NA	NA
Blood loss	OR: 0.99 [0.98–1.00]	0.052	NA	NA
Clamping type	OR: −1.52 [−16.5 to 13.4]	0.881	NA	NA
WIT	OR: 0.46 [0.29–0.72]	0.001	OR:0.59[0.36–0.96]	0.032
Surgery time	OR: 0.92 [0.88–0.97]	0.003	OR:0.98[0.92–1.05]	0.597
Length of stay	OR: 0.22 [0.12–0.47]	0.001	OR:0.40[0.17–0.92]	0.033
Diabetes	OR: −8.64 [−18.2 to 0.907]	0.075	NA	NA
Tumor size	OR: 0.15 [0.014–1.6]	0.115	NA	NA

Significant with a $p < 0.005$ values are highlighted in bold

RAPN robot-assisted partial nephrectomy, OPN open partial nephrectomy, eGFR estimate Glomerular filtration rate, WIT warm ischemia time, NA not available

Surgical technique

Among the open approaches, 67% were performed by lobotomy and 33% by subcostal approach. In the RAPN group, a transperitoneal approach was used in 94% of the cases.

Postoperative course

We observed significant differences in the management of ischemia. Off clamp was used in 15% in the OPN group and 27% in the RAPN ($p = 0.07$). In the OPN group, a pedicle clamping (artery and vein) was performed in 50% of the cases versus 2% in the RAPN group ($p = 0.02$). Main and superselective arterial clamping were respectively used in 80% and 17% of the cases in the RAPN group compared to 46% and 0% in the OPN group ($p = 0.02$).

There was no significant difference between the two groups in terms of clamping time, operating time, and blood loss. Although not statistically significant, it can be noted that blood loss was on average higher in the OPN group than in the RAPN group with respectively 510 ml versus 329 ml.

The mean hospital length of stay (LOS) was 5 ± 5.6 days in the RAPN group versus 9.6 ± 6.4 days in the OPN group ($p < 0.001$). Since the introduction of the robot as surgery approach in 2011, the mean LOS was 5 ± 5.6 days in RAPN group versus 8.2 ± 5.8 days in OPN group ($p < 0.05$).

A total number of 18 (21.9%) complications were reported in the RAPN group including 8 intraoperative compared to 25 (36.7%) in the open group including 8 intraoperative ($p = 0.047$). Regarding postoperative complications, 7 (9%) minor complications (Clavien–Dindo < 3) were reported in the RAPN group as compared to 11 (16%) in the OPN group ($p = 0.15$) and major complications (CD ≥ 3)

occurred in 3 (4%) cases in the RAPN group versus 6 (9%) in the OPN group ($p = 0.30$).

The achievement of Trifecta was obtained for 33 (40.2%) and 23 (33.8%) patients in the RAPN group and in the OPN group, respectively ($p = 0.418$). Complete data are reported in Table 4.

Discussion

The diagnosis of a kidney mass on a solitary kidney is both a surgical and medical challenge. The management of these patients requires imperative nephron sparing surgery and pushing the limits of technical feasibility in some cases. The "gold standard" management of these tumors in such situation has remained OPN to ensure the best possible safety and renal function [13]. However, RAPN has been shown to be a feasible, reliable, and effective procedure even for complex renal tumors [14].

Compared with the gold standard, we were able to confirm the safety of the RAPN technique in patients with a single anatomical kidney. The results were comparable in terms of renal function impairment in both arms. There was no significant difference in postoperative GFR variation between the two groups and only 1 patient required postoperative dialysis in the RAPN group and none of them was on dialysis at the end of follow-up.

To our knowledge, this is the largest study on single kidney RAPNs in the literature and the largest series comparing RAPN and OPN in solitary kidney. However, although both groups were comparable on clinical data, medical history and radiological tumor characteristics (size and renal score), there was a slight difference on preoperative renal function

Table 4 Surgical characteristics and postoperative data

	RAPN (N=82)	OPN (N=68)	p value
Surgical approach (N, %)			
Open			
Lombotomy	–	46 (67.6%)	
Sub-costal	–	22 (32.3%)	
Robotic			
Transperitoneal	77 (93.9%)	–	
Retropéritoneal	5 (6%)	–	
Type of clamping (N, %)			
Off-clamp	22 (27%)	10 (15%)	0.07
Main artery	48 (58%)	24 (35%)	0.02
Selective	10 (12%)	0 (0%)	0.02
Parenchymal	0 (0%)	2 (3%)	0.210
Pedicle	2 (3%)	26 (38%)	< 0.001
Biological hemostatic agent (N, %)	20 (24%)	27 (40%)	0.04
WIT (mean ± SD) (min)	16.2 ± 9.5	19.6 ± 13.9	0.13
Surgery time (mean ± SD) (min)	173.9 ± 83	159.7 ± 63	0.29
Blood loss (mean ± SD) (ml)	329 ± 434	510 ± 745	0.07
Length of stay (mean ± SD) (jour)	5 ± 5.6	9.6 ± 6.4	< 0.001
No complication (N=150) (N, %)	64 (78%)	43 (63.2%)	0.047
Intraoperative complications (N, %)			
Hemorrhage	3 (3.7%)	4 (3.7%)	0.70
Vascular wound	0	1 (0.5%)	0.12
Pleural breach	0	3 (4.4%)	0.27
Laparo-conversion	5 (6.1%)	0 (0%)	0.03
Surgical revision (N=136) (N, %)			
Upper urinary tract stenting	1 (1.2%)	1 (1.7%)	0.86
Hemostasis	0	1 (1.7%)	0.26
Radical nephrectomy	0	1 (1.7%)	0.26
Embolization	0	1 (1.7%)	0.26
Postoperative transfusion (N, %)	5 (6%)	7 (11%)	0.39
Acute kidney injury requiring transient dialysis (N, %)	1 (1.2%)	3 (4.5%)	0.32
Clavien (CD) Score (N, %)			
Clavien 1	1 (1.2%)	5 (7.3%)	0.09
Clavien 2	6 (7.3%)	6 (8.8%)	0.76
Clavien 3a	0 (0%)	0 (0%)	0.99
Clavien 3b	0 (0%)	2 (2.9%)	0.20
Clavien 4a	1 (1.2%)	1 (1.5%)	0.82
Clavien 4b	1 (1.2%)	3 (4.4%)	0.26
Clavien 5	1 (1.2%)	0 (0%)	0.45
Minor complications (CD < 3) (N, %)	7 (9%)	11 (16%)	0.15
Major complications (CD ≥ 3)	3 (4%)	6 (9%)	0.31
Trifecta achievement (N=150) (N, %)	33 (40.2%)	23 (33.8%)	0.418

Significant with a $p < 0.005$ values are highlighted in bold

RAPN robot-assisted partial nephrectomy, OPN open partial nephrectomy, WIT warm ischemia time, CD Clavien–Dindo

which was significantly better in the RAPN group (66.9 ml/min ± 18.1 vs 57.0 ml/min ± 16.3) ($p = 0.002$).

We found several factors predictive of eGFR impairment at 3 months. The main factor was the preoperative GFR

value, which can influence postoperative GFR. It was significantly associated with poorer post-operative renal function regardless of the approach ($p < 0.001$). These results are consistent with the data in the literature. Indeed, Verhoest

et al. and Pignot et al. found in their single kidney cohort preoperative eGFR as a predictor of impaired renal function [15, 16].

The preoperative eGFR difference observed between our two groups may have induced a limitation in the interpretation of the postoperative renal function results although the delta eGFR at 3, 6, 12, and 24 months were comparable between the two groups.

A meta-analysis by Cacciamani et al. evaluated the impact of ischemia on the results of RAPN. According to them, the short- and long-term renal function of patients operated on with off-clamp and superselective clamping appeared to be superior to patients who underwent conventional arterial clamping [17]. In our series, it is noteworthy that clamping techniques were really different between RAPN and OPN. However, Zero-ischemia technique was only applied in 27% of the cases of the RAPN group and clamping technique by itself was not a significant predictor of postoperative kidney function in multivariate analysis. Nevertheless, WIT was also a predictor of worsening renal function in our study. Since the Campbell's "every minute counts" dogma concerning warm ischemia, we have seen the emergence of the technique of early declamping, supraseductive clamping and even off-clamp [18]. This is also in line with the data from the literature suggesting that each additional minute of warm ischemia correlates with a loss of GFR as long as blood loss remains reasonable [19–21]. We found a wide variety of clamping techniques ranging from off-clamp to full pedicle clamping. Nevertheless, the number of patients using off-clamp and selective clamping was too small to make a comparison with other clamping techniques. However, several studies have shown the interest of off-clamp in preserving renal function as long as the bleeding remains reasonable. A recent meta-analysis evaluated the impact of clamping on the results of robotic partial nephrectomy. According to them, the short- and long-term renal function of patients operated on with off-clamp and supra-selective clamping appeared superior to that of patients who had conventional arterial clamping [17]. In our study, the statistical analysis was unable to confirm this specific aspect due to small effective.

The interest of our series which only concerns "ischemia-sensitive" patients since they are solitary kidneys and therefore different from the majority of other series in the literature in the evaluation of the impact of ischemia.

In our study, we also investigated whether the RENAL score or tumor size could influence eGFR in the postoperative period. Indeed, Pierquet et al. found a tumor size > 4 cm, as a predictive factor of eGFR reduction in a group of patients with a solitary kidney [22]. These factors were not significant in our study.

Some authors evaluated the impact of resected tumor volume or preserved parenchymal volume. Lane et al. and Thomson et al., found that the amount of parenchymal

volume preserved was a determining and independent factor in the postoperative evolution of renal function [23, 24].

The conversion rate from RAPN to OPN was quite high in our study, in fact it was 6%. Among the 5 patients involved, there were 2 patients with complex tumors (RENAL score 9 and 10), 2 patients with multioperated abdomen and 1 patient for a technical issue. This rate appears to be relatively high compared to current practice and the literature on elective RAPN where conversion rates vary from 0.1 to 2.1% [25, 26]. Our results are probably different because of the type of patients we included, many of them had prior surgery or prior ablative treatments and tumor were mostly difficult with 22% RENAL score > 9 and 48% RENAL score between 7 and 9.

'Trifecta' was a secondary endpoint of our study. It was reached in 40% of the cases in the RAPN group and 33% of the cases in the open group. Arona et al. reported a significantly higher 58% Trifecta achievement in a series of 74 single kidney RAPN patients [27]. The difference in the performance of the trifecta can be explained by the fact that this is a large series, but multicentric with multiple operators and in a rare situation therefore limited experience and trifecta influenced by the rate of positive margins.

Hung et al. evaluated the achievement of 'Trifecta' over 12 years, based on 534 partial nephrectomies performed by a single surgeon [28]. They found an improvement in the rate of Trifecta over the years despite the increase in tumor size and surgical complexity.

In our series, there were 10.8% and 9.1% positive surgical margins in the RAPN and OPN groups, respectively, with no significant difference. This rate is slightly higher than elsewhere in the literature with 2–8% of PSM reported [29]. This difference is probably related to tumor size and complexity; both of them being quite high in our study. The mean tumor size was 3.6 cm (upper extremity was 10 cm) in the RAPN group and 3.7 in the OPN group (upper extremity was 8 cm) ($p=0.78$). Moreover, there is more low complex tumor (RENAL Score between 4 and 6) in the OPN vs RAPS group (35% vs 21%) which was not significant. Zargar et al. who also present a series of complex single kidney tumors and high levels of PSM (10%) [30]. The maximalist nephron sparing aim may explain about this point. In fact, maximal sparing justifies going as close as possible to the tumor with a minimal margin and a higher risk of positive margins. The enucleation technique can be used for this purpose by finding the cleavage plane between the healthy renal parenchyma and the tumor.

LOS was shorter in the RAPN group with 5 ± 5.6 days versus 9.6 ± 6.4 days in the OPN group ($p < 0.001$). This results were comparable to other studies published in literature [27, 31] excluding Gul et al. who found an average length of stay of 1 day [32]. Regarding the postoperative complications, we also had a relatively low rate with 22%

Table 5 Literature review on solitary kidney partial nephrectomy

Study	Study population	Year of publication	Surgical technique	Tumor size (median) (cm)	RENAL score (mean)	Blood loss (ml)	WIT (min)	All complications (%)	Positive margins (%)	Length of Hospital stay (days)	Pre op eGFR (ml/min)	Post op eGFR (ml/min)	Follow-up (months)
UroCCR	54	2021	RAPN (82)	3.6 (1.7–5.5)	7.4 (5–9)	329	16.2	22	10.8	5	67 (49–85)	–13.4	24
Gul et al. [26]	35	2018	OPN (68) RAPN (35)	3.7 (1.7–5.7) 2.7 (2–3.8)	7.9 (5–10) 6 (5–9)	510 113	19.6 16 (11–21)	36.70 20	9.1 0	9.5 1	57 (41–73) 61 (53–70)	–9.3 –5	24 24
Arora et al. [22]	74	2018	RAPN (74)	2.3 (1.8–3.7)	6 (5–9)	150	15	24	5.4	NA	61 (50–72)	–8	36
Zargar et al. RENAL 4–8 [25]	63	2014	RAPN (30)	2.5	6	200	15	30	6.7	3	NA	82% preservation	8
Zargar et al. RENAL SCORE 9–12 [25]	62	2014	RAPN (10)	4.5	9.5	225	22.7	10	10	4	NA	80.3% preservation	4
Panumat-rassamee et al. [29]	67	2013	RAPN (15) LPN (52)	3.2 (2.5–5.3) 2.8	7 5.6	150 250	15 (0–24) 19 (15–34)	33 42	0 3.8	3 4	50 (42–63) 60 (46–73)	–12 –11	6 16
Hilyer et al. [25]	26	2013	RAPN (26)	4.3 (2.9–5)	5.5	225	17 (12–28)	11	3.8	3	59 (44–73)	–15	6
Lane et al. [28]	196	2008	OPN (169) LPN (30)	3.8 (2.8–4.8) 2.8 (2.5–3.9)	> T1b = 44% (74) > T1b = 20% (6)	300 (200–450) 200 (100–300)	21 29	34 70	1 6.7	5 3	51.4 (40–65) 47.7 (35–57)	–12 –17	24 24
Fergany et al. [8]	400	2006	OPN (400)	NA	NA	NA	38	52	NA	NA	NA	NA	120

Significant with a $p < 0.005$ values are highlighted in bold

NA not available.

in RAPN group and 37% in OPN group, most of them were Clavien 1 or 2.

We conducted an actual literature overview on partial nephrectomy on solitary kidney (Table 5). There are few studies on this topic and we found only 3 studies comparing laparoscopic and open approaches. Lane et al. compared perioperative, functional and oncological results between OPNs and laparoscopic partial nephrectomy (LPN) [33]. Panumatrassamee et al. compared RAPN and LPN [34]. Zargar et al. are the only ones to have compared RAPN and OPN [30]. They compared 40 RAPN to 85 OPN patients, OPN cases were more complex according to RENAL score, and there were no differences in terms of complications, eGFR modification or trifecta accomplishment. The evaluation of perioperative, functional, and oncologic outcomes using robotic technique has also been studied by Arona et al., Hillyer et al., and Gul et al. reporting respectively on 74, 35, and 26 patients [27, 31, 32]. The main criteria for comparison between the studies were average tumor size, average RENAL score, average WIT and blood loss. The main criteria were comparable except for Gul et al. who found an average length of stay of 1 day [32]. All three concluded to less blood loss, shorter LOS and lower complication rates for the robotic approach. Regarding renal function, the results between the different studies are similar. The average follow-up is different, ranging from 3 months to a maximum of 10 years. Thus, the interpretation of the results on renal function cannot be done in the same way given this large variation in the duration of follow-up.

The main limitation of our study is its retrospective character and the large period of inclusion. In this period of inclusion, there has been a great evolution in extrasurgical and anesthesiology practices and the development of a new surgical approach in the last decade: robotic-assisted laparoscopy. Enhanced recovery after surgery protocols took off at the beginning of the 2010s with a change in practices, for example, the use of transfusion decreased and the length of stay were reduced.

Regarding the functional analysis, we can presume that the 6-month eGFR is clinically representative of the long-term renal function. Finally, another limitation is represented by the fact that almost half of the patients were treated in one of the centers (Bordeaux University Hospital), which could induce a selection bias.

Conclusion

In our study, the surgical approach did not alter the short- and long-term functional outcomes for partial nephrectomies on a single anatomical kidney. There was a significant reduction in the length of stay and complications rate in favor of the robotic approach. Robotic-assisted laparoscopic surgery

is a minimally invasive, safe, and effective technique for the management of renal tumors in case of solitary kidney. Larger effectives and longer follow ups may lead to updated recommendations, before considering the robotic approach as the standard of care of conservative management of all renal tumors.

Author contributions YB: protocol development, data management, data analysis, manuscript writing. FA: data collection, data analysis. KB, MR, PP, CL, FB, JBB, AV, HL, XD, PB, JAL, CC: data collection. AL: data management; data analysis. JCB: protocol development; data collection, manuscript editing. EA: protocol development; data management, data analysis, manuscript writing, manuscript editing.

Declarations

Conflict of interest KB, PhP, and JCB are proctors for Intuitive Surgical. The other authors have no relevant financial or non-financial interests to disclose.

Informed written consent Informed written consent was collected for each patient which were all included into the French kidney cancer network database UroCCR (CNIL-DR 2013-206; NCT number 03293563).

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