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The current role of pentafecta outcomes in open and laparoscopic partial nephrectomy for localized renal tumors

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Abstract. *Background: Partial nephrectomy (PN) is the standard treatment for managing clinical T1 renal masses. The "trifecta" and "pentafecta" metrics are commonly used to assess the complexity and success of PN procedures. The present study aimed to identify predictive factors associated with the achievement of pentafecta outcomes following PN.*
Methods. A prospective randomized study was conducted between May 2022 and May 2024, involving 70 patients with clinical T1–T2a N0M0 renal tumors suitable for partial nephrectomy. Participants were randomly assigned into two groups: Group A (n = 38) underwent open partial nephrectomy (OPN), and Group B (n = 32) underwent laparoscopic partial nephrectomy (LPN). Preoperative assessment included lab tests and imaging. All surgeries were performed via a transperitoneal approach under general anesthesia. OPN and LPN techniques followed standardized protocols, each performed by an experienced surgeon. Postoperative follow-up included clinical, laboratory, and imaging assessments at set intervals. Primary outcomes focused on predictors of pentafecta achievement; secondary outcomes included blood loss, operative time, hospital stay, pain scores, complications, recurrence, and renal function. Statistical analysis was performed using SPSS v26.0, with significance set at p < 0.05. The study was registered at ClinicalTrials.gov (Identifier: NCT06960135).
Results. Both surgical approaches yielded comparable oncological outcomes. However, patients in the LPN group experienced significantly lower intraoperative blood loss, shorter operative times, reduced opioid requirements, and lower postoperative pain scores (p < 0.05) compared to the OPN group. Additionally, the length of hospital stay was significantly shorter in the LPN group (p < 0.0001). A significant positive association was observed between glomerular filtration rate and the use of tumor enucleation (p = 0.0073), as well as between PADUA score and body mass index (p = 0.0004).
Conclusions. While LPN is associated with longer ischemia time, it offers significant benefits over OPN, including reduced blood loss, lower analgesia requirements, and shorter hospital stays.

Keywords: *laparoscopic, partial nephrectomy, trifecta, pentafecta achievement, renal tumors.*

Conflict of interest. The authors declare no conflict of interest.

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Сучасна роль показників "пентафекти" як критеріїв ефективності відкритої та лапароскопічної часткової нефректомії у пацієнтів з локалізованими пухлинами нирок

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Резюме. *Часткова нефректомія (ЧН) є стандартом лікування пацієнтів із клінічними Т1-пухлинами нирок. Показники «трифекта» та «пентафекта» широко застосовуються для оцінки складності та ефективності проведення ЧН. Метою цього дослідження було визначення прогностичних факторів досягнення пентафекти після часткової нефректомії.*

Методи. У період з травня 2022 до травня 2024 року проведено проспективне рандомізоване дослідження за участю 70 пацієнтів із пухлинами нирки стадії T1—T2a N0M0, придатними для часткової нефректомії. Пацієнтів випадковим чином розподілено на дві групи: група A (n = 38) — відкрита часткова нефректомія (ОЧН), група B (n = 32) — лапароскопічна часткова нефректомія (ЛЧН). Передопераційне обстеження включало лабораторні аналізи та візуалізацію. Усі операції виконувалися трансперитонеальним доступом під загальним наркозом за стандартизованими методиками. Первинна кінцева точка — предиктори досягнення пентафекти; вторинні — крововтрата, тривалість операції, госпіталізація, больовий синдром, ускладнення, рецидиви та функція нирок. Статистичний аналіз виконано в SPSS v26.0; рівень значущості — p < 0,05. Дослідження зареєстровано в ClinicalTrials.gov (ідентифікатор: NCT06960135).

Результати. Обидва хірургічні підходи забезпечили порівнянні онкологічні результати. Однак пацієнти групи ЛЧН мали достовірно меншу інтраопераційну крововтрату, коротший операційний час, нижчу потребу в опіоїдних анальгетиках та нижчі показники післяопераційного болю (p < 0,05) у порівнянні з групою ВЧН. Тривалість госпіталізації також була значно коротшою в групі ЛЧН (p < 0,0001). Було встановлено достовірно позитивну асоціацію між швидкістю клубочкової фільтрації та застосуванням енуклеації пухлини (p = 0,0073), а також між балом PADUA і індексом маси тіла (p = 0,0004).

Висновки. Попри довший час ішемії ЛЧН, цей метод має переваги над відкритою ЧН, зокрема меншу крововтрату, нижчі анальгетичні потреби та скорочену тривалість перебування в стаціонарі.

Ключові слова: *лапароскопія, часткова нефректомія, трифекта, пентафекта, пухлини нирки.*

Introduction. PN is widely considered the preferred treatment for clinical T1 (cT1) renal masses, primarily due to its superior preservation of kidney function compared to radical nephrectomy [1].

The trifecta metric includes three components: warm ischemia time (WIT) of ≤ 25 minutes or cold ischemia time (CIT) of ≤ 60 minutes, negative surgical margins, and the absence of perioperative major complications. The pentafecta expands upon these criteria by adding two additional parameters: preservation of ≥ 90% of the estimated glomerular filtration rate (eGFR) and no progression in the chronic kidney disease (CKD) stage within 12 months postoperatively [2].

Over the past decade, advances in surgical techniques and technology have positioned LPN as a viable alternative to OPN demonstrating comparable outcomes in terms of perioperative complications, oncological efficacy, and kidney function preservation [3].

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A critical determinant of postoperative kidney function is the extent of preserved parenchymal mass, assuming that ischemia duration is minimized [4]. In this context, tumor enucleation (TE) — a surgical technique involving blunt dissection along the tumor pseudocapsule — has gained attention. TE is thought to preserve more healthy renal parenchyma than conventional sharp dissection techniques, which typically remove tissue within a 2—5 mm margin around the tumor [5].

This study aims to evaluate pentafecta outcomes in patients undergoing OPN and LPN for localized renal tumors. Additionally, it seeks to identify clinical, surgical, and pathological factors that predict the likelihood of achieving pentafecta status.

Methods. A prospective, randomized study was conducted between May 2022 and May 2024, involving 70 patients of both sexes diagnosed with clinical T1 or T2a N0M0 renal tumors who were eligible candidates for partial nephrectomy. The study was approved by the Local Ethics Committee of South Valley University, Egypt (Ethical Approval Code: SVU-MED-URO016-2-22-5-400). Written informed consent was obtained from all participants or, when applicable, from their parent, legal guardian, or next of kin, for both participation in the study and publication of medical data and related images. The study was registered at ClinicalTrials.gov (Identifier: NCT06960135). Inclusion criteria required patients to have localized renal tumors suitable for nephron-sparing surgery. Exclusion criteria included: severe and irreversible coagulopathy, anatomically unfavorable tumor location, extensive encasement of the renal pedicle, diffuse invasion of the renal vein or central collecting system, adjacent organ invasion consistent with stage cT4 disease, regional lymphadenopathy (stage cTxN1), or anticipated preservation of less than 20% of total nephron mass.

Randomization. Random allocation of the cases into two groups was performed using a block randomization method in Stata, version 13.1, Stata Corp, for Microsoft Windows: group A (OPN) and group B (LPN group) (Fig. 1).

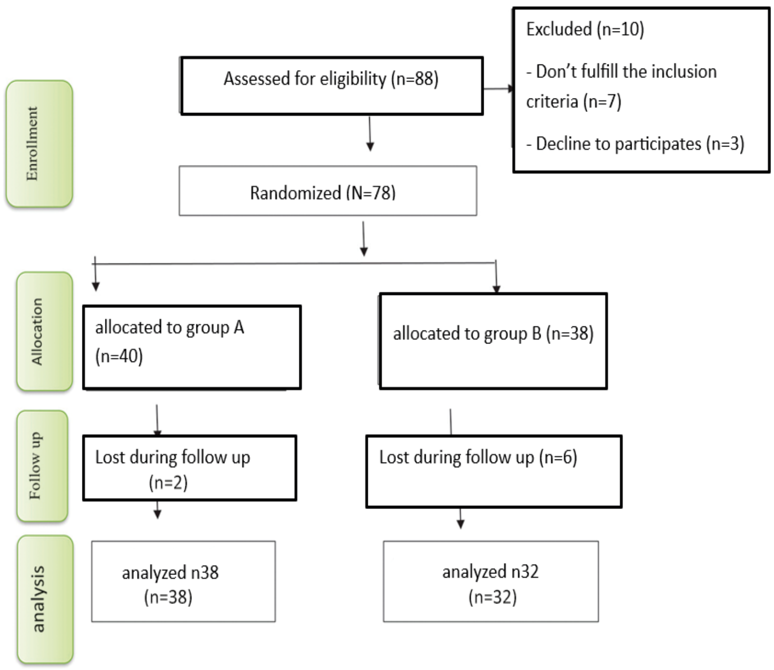

Fig. 1. CONSORT diagram for patient flow throughout the research

Participants were randomly assigned into two groups using block randomization: Group A (n = 38) underwent OPN, while Group B (n = 32) underwent LPN, with all procedures performed under general anesthesia. A transperitoneal approach was used in all cases.

Preoperative assessment. Physical examination, medical history, and laboratory investigations. Laboratory tests included complete blood count (CBC), serum creatinine, glomerular filtration rate (GFR), liver function tests, random blood glucose, blood grouping, coagulation profile, and urinalysis. Radiological evaluation included ultrasonography (US), computed tomography (CT), chest X-ray, and magnetic resonance imaging (MRI).

Surgical techniques. Group A – Open Partial Nephrectomy (OPN). An extraperitoneal flank incision was made over the 11th or 12th rib. In some patients, a transperitoneal Chevron incision was performed. The renal hilum was exposed, and the renal artery was occluded using a bulldog clamp. Tumor excision was then performed using cold scissors in a nearly bloodless field, followed by renal parenchymal repair using interrupted horizontal mattress sutures (0-polyglactin). The bulldog clamp was removed following repair, and warm ischemia time was recorded in minutes. Operative time was calculated from skin incision to skin closure.

Surgical techniques. Group B – Laparoscopic Partial Nephrectomy (LPN). Patients were positioned in a 45-degree modified lateral decubitus position with mild table flexion. A Veress needle was inserted periumbilically to establish pneumoperitoneum with carbon dioxide. After removal of the needle, a 12-mm trocar was inserted at the same site, and intra-abdominal pressure was maintained at 12–15 mmHg. A 30-degree endoscopic camera was used. Under direct vision, two additional trocars were placed: a 12-mm trocar in the ipsilateral midclavicular line (one finger breadth caudal to the camera port) and a 5-mm trocar (one finger breadth cephalic). Operative time was calculated from port entry to port exit.

The colon was mobilized along Toldt's fascia to fully expose the retroperitoneum. Dissection proceeded until the psoas muscle was visualized, revealing the ureter dorsal to the gonadal vein. The lower pole of the kidney was elevated and mobilized. The renal hilum was identified, and the arteries were meticulously dissected. The kidney was mobilized within Gerota's fascia and defatted, preserving peritumoral fat. Tumor excision or enucleation was performed using cold scissors. Renal parenchymal repair was completed with V-Loc sutures, and warm ischemia time was recorded.

To minimize the variability in surgical expertise and enhance the reliability of the findings, all OPNs were performed by a single surgeon, and all LPNs were performed by another single surgeon. Each surgeon had independently performed over 100 procedures using their respective approach prior to the start of this study. This standardization aimed to control for operator-dependent variability and reduce potential bias related to differences in surgical experience.

Follow-up. This included physical examination and laboratory testing, along with radiological imaging at 3, 6, and 12 months postoperatively, and annually for three years. Imaging included abdominal CT or MRI, and chest X-ray annually, with chest CT performed when clinically indicated. These imaging procedures were mainly performed to assess renal tumor recurrence or local metastases.

Outcome measures. The primary outcomes include predictors of pentafecta achievement among variables. The secondary outcomes included blood loss, surgery duration, length of hospital stay, intraoperative complications, VAS, analgesic requirements, complications following surgery, local recurrence, kidney function, distant metastases, contralateral kidney recurrence, and cardiovascular events, all of which have been documented, with monitoring based on the Clavien-Dindo grading system [6, 7].

Statistical analysis. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were presented as means and standard deviations (SD) and compared between the two groups using the unpaired Student's t-test. Categorical variables were summarized as frequencies and percentages and analyzed using the Chi-square test or Fisher's exact test, depending on the expected cell counts. Receiver operating characteristic (ROC) curve analysis was employed to evaluate diagnostic performance, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). A two-tailed p-value < 0.05 was considered statistically significant.

Results. *The patients' characteristics*. A total of 70 patients were enrolled between May 2022 and May 2024, with 38 undergoing OPN and 32 undergoing LPN. The two groups were comparable across preoperative demographic, clinical, and tumor-related variables.

As shown in Table 1, there were no statistically significant differences between groups in terms of age, sex distribution, smoking index, body mass index (BMI), Eastern Cooperative Oncology Group (ECOG) performance status, comorbidities (hypertension [HTN], diabetes mellitus [DM], chronic kidney disease [CKD], ischemic heart disease [IHD]), or baseline laboratory values. Tumor characteristics, including laterality, location, size, PADUA score, and clinical stage (T1a, T1b, T2a), were also not significantly different between the two groups.

Table 1

Preoperative demographic, disease history and laboratory data of the studied patients

		Open surgery (n =38)	Lap. approach (n =32)	P
Age (years)		61.63 ± 10.96	58.28 ± 16.03	0.098
Sex	Male	28 (73.68%)	18 (56.25%)	0.2928
	Female	10 (26.32%)	14 (43.75%)	
Smoking index		0.47 ± 0.5	0.48 ± 0.56	0.94
BMI		28.99 ± 3.98	30.91 ± 4.39	0.2036
ECOG score		0.21 ± 0.69	1 (6.25%)	0.6575
Disease history data				
CKD		8 (21.05%)	2 (6.25%)	0.2243
IHD		0	2 (6.25%)	0.2824
HTN		12 (31.58%)	12 (37.5%)	0.7229
DM		6 (15.79%)	16 (50.0%)	0.1586
Laboratory data				
Hb (g/dl)		12.84±1.37	13.39 ± 1.66	0.7274
Creatinine		1.15 ± 0.28	1.07 ± 0.42	0.1104
GFR (CKD-EPI)		67.69 ± 13.61	77.2 ± 33.57	0.3328

Continuation of Table 1

		Open surgery (n =38)	Lap. approach (n =32)	P
Tumor data				
Side	Left	20 (52.63%)	16 (50.0%)	0.8811
	Right	18 (47.37%)	16 (50.0%)	0.8811
Site	Lower polar	20 (52.63%)	10 (31.25%)	0.2143
	Mid polar	8 (21.05%)	14 (43.75%)	0.1586
	Upper polar	10 (26.32%)	8 (25.0%)	0.9319
Size (mm)		44.05 ± 23.13	38.38 ± 14.67	0.7525
PADUA score		7.47 ± 1.09	7.25 ± 1.09	0.5605
Clinical staging data				
t1a		22 (57.89%)	24 (75.0%)	0.2882
t1b		12 (31.58%)	6 (18.75%)	0.387
t2a		4 (10.52%)	2 (6.25%)	0.9039

Intraoperative outcomes and histopathological findings. Intraoperative parameters are summarized in Table 2.

Table 2

Intraoperative evaluation and histopathology data of the studied patients

		Open surgery (n = 38)	Lap. approach (n = 32)	P
Operative data				
Tumor Resection	Enucleation	0(0.0%)	28(87.5%)	0.0001
	Excision	38(100.0%)	4(12.5%)	0.0001
Ischemia time (min.)		8.17±7.05	16.94±3.8	0.0005
Pelvicalyceal injury		2(5.26%)	4(12.5%)	0.4609
Pleural injury		6(15.79%)	0(0.0%)	0.102
Blood loss (cc)		365.79±167.06	171.88±72.82	0.0001
Operative time (min.)		153.89±39.12	126.88±20.22	0.0179
Histopathology data				
Clear Cell RCC		24(63.16%)	32(100.0%)	0.0056
Chromophobe		6(15.79%)	0(0.0%)	0.102
Papillary RCC		8(21.05%)	0(0.0%)	0.0531
Surgical margin free		38(100%)	32(100%)	

Enucleation was performed significantly more often in the LPN group (87.5%) compared to none in the OPN group (P < 0.0001). Conversely, tumor excision was performed in all OPN cases and only 12.5% of LPN cases. Mean ischemia time was significantly longer in the LPN group (16.94 ± 3.8 minutes) compared to the OPN group (8.17 ± 7.05 minutes; P = 0.0005). The LPN group also had significantly lower estimated blood loss (171.88 ± 72.82 mL vs. 365.79 ± 167.06 mL, P < 0.0001) and shorter operative time (126.88 ± 20.22 minutes vs. 153.89 ± 39.12 minutes, P = 0.0179). Rates of pelvicalyceal and pleural injuries were not significantly different.

Histopathological evaluation showed clear cell renal cell carcinoma (CCRCC) as the most common subtype, with significantly more cases in the LPN group (100%) than in the OPN group (63.16%, P = 0.0056). All patients in both groups had negative surgical margins.

Postoperative outcomes. Postoperative clinical and laboratory outcomes are detailed in Table 3.

Table 3

Postoperative evaluation and lab. Investigations of the studied patients

Postoperative data				
Analgesia required	**Paracetamol**	38(100.0%)	32(100.0%)	–
	NSAID	38(100.0%)	0(0.0%)	–
	Opioid	24(63.16%)	0(0.0%)	0.0001
Clavien Dindo **1** **2**		1.05±0.22 36(94.74%) 2(5.26%)	32(100.0%) 32(100.0%) 0(0.0%)	0.3896 0.3666 –
VAS		8.16±0.67	3.94±0.83	0.0001
Hospital stays (day)		7.47±2.37	1.94±0.66	0.0001
Post operative investigations				
Post operative Hb (g/dl)		10.92±0.56	12.59±1.69	0.0272
Post. Week1 Creatinine		1.17 0.35	1.13 0.35	0.64
Post. Week1 GFR		71.1 16.3	70.3 17.5	0.85
Post. 3 months Creatinine		1.19 0.29	1.17 0.3	0.78
Post. 3 months GFR		68.9 12.5	69.1 13.2	0.95
Post. Year 1 Creatinine		1.22±0.3	1.22±0.44	0.7776
Post. Year 1 GFR		63.57±13.98	67.56±16.21	0.2732
GFR deficit>10%		13 (34.21%)	18(56.25%)	0.06
Pentafecta achievement		28(73.68%)	16(50.0%)	0.1575

Pain scores (VAS) and opioid analgesia requirements were significantly lower in the LPN group compared to the OPN group (VAS: 3.94 ± 0.83 vs. 8.16 ± 0.67; $P < 0.0001$; opioids: 0% vs. 63.16%; $P < 0.0001$). The length of hospital stay was significantly shorter in the LPN group (1.94 ± 0.66 days vs. 7.47 ± 2.37 days; $P < 0.0001$).

No statistically significant differences were observed in postoperative creatinine levels or GFR at one week, three months, or one year. The rate of GFR decline >10% was higher in the LPN group (56.25%) than in the OPN group (34.21%), but this difference did not reach statistical significance (P = 0.06). Pentafecta achievement rates were 73.68% in the OPN group and 50.0% in the LPN group (P = 0.1575).

Predictors of pentafecta achievement. As presented in Table 4, comparisons between patients who achieved pentafecta (n = 44) and those who did not (n = 26) revealed that patients in the failure group had significantly higher BMI (31.64 ± 3.42 vs. 28.82 ± 4.39; P = 0.0496), smoking index (P = 0.04), and higher prevalence of HTN (76.92% vs. 9.09%; P = 0.0004) and DM (69.23% vs. 9.09%; P = 0.0002). Postoperative kidney function measures (GFR at one week, three months, and one year; creatinine levels at three months and one year; and GFR deficit >10%) were significantly worse in the pentafecta failure group (Fig. 2, 3).

Operative approach, ischemia time, intraoperative blood loss, complications, and hospital stay were not significantly associated with pentafecta achievement.

Table 4

Analysis of variables among success and failure of pentafecta achievement groups

		Pentafecta achievement (n = 44)	Pentafecta failure (n = 26)	P
Age (years)		54.32±15.33	61.23±11.66	0.1555
Sex	**Male**	30(68.18%)	16(61.54%)	0.6995
	Female	14(31.82%)	10(38.46%)	0.6995
Smoking index		0.39 ±0.69	0.52 ±0.1	0.04
BMI		28.82±4.39	31.64±3.42	0.0496
Disease history data				
CKD		6(13.64%)	4(15.38%)	0.8905
IHD		0(0.0%)	2(7.69%)	0.1977
HTN		4(9.09%)	20(76.92%)	0.0004

Continuation of Table 3

		Pentafecta achievement (n = 44)	Pentafecta failure (n = 26)	P
DM		4(9.09%)	18(69.23%)	0.0002
PADUA score		7.36±1.07	7.38±1.15	0.9859
Operative data				
Tumor Resection	**Enucleation**	14(31.82%)	14(53.85%)	0.21
	Excision	30(68.18%)	12(46.15%)	0.21
Ischemia time (min.)		11.1±6.86	14.23±7.39	0.1926
Intraoperative complication		2(4.55%)	4(15.38%)	0.3029
Blood loss (cc)		304.55±189.44	230.77±91.02	0.2259
Operative time (min.)		136.82±37.06	158±27.88	0.0501
Histopathology data				
CCRCC		32(72.73%)	24(92.31%)	0.1713
Chromophobe		4(9.09%)	2(7.69%)	0.8905
Papillary RCC		8(18.18%)	0(0.0%)	0.1083
Post operative data				
Analgesia required				–
Paracetamol		44(100.0%)	26(100.0%)	–
NSAID		28(63.64%)	10(38.46%)	0.1575
Opioid		18(40.91%)	6(23.08%)	0.2967
Clavien Dindo	**1**	44(100.0%)	24(92.31%)	0.1977
	2	0(0.0%)	2(7.69%)	--
VAS		6.68±2.18	5.46±2.1	0.1131
Post operative Hb (g/dl)		11.48±1.15	12.03±1.85	0.5838
Post. Week1 Creatinine		1.08±0.3	1.19±0.5	0.25
Post. Week1 GFR		74.8±22.7	59.15±11.8	0.001
Post. 3 months Creatinine		1.09 ±0.3	1.34±0.6	0.02
Post. 3 months GFR		74.9 ±22.8	56.6±11.5	<0.0001
Post. Year 1 Creatinine		1.1±0.3	1.42±0.4	0.001
Post. Year 1 GFR		75.1±22.82	54.15±12.11	0.0012
GFR deficit>10%		0.45±1.88	24(92.31%)	<0.0001
Hospital stays (day)		5.36±3.13	4.23±3.45	0.2261

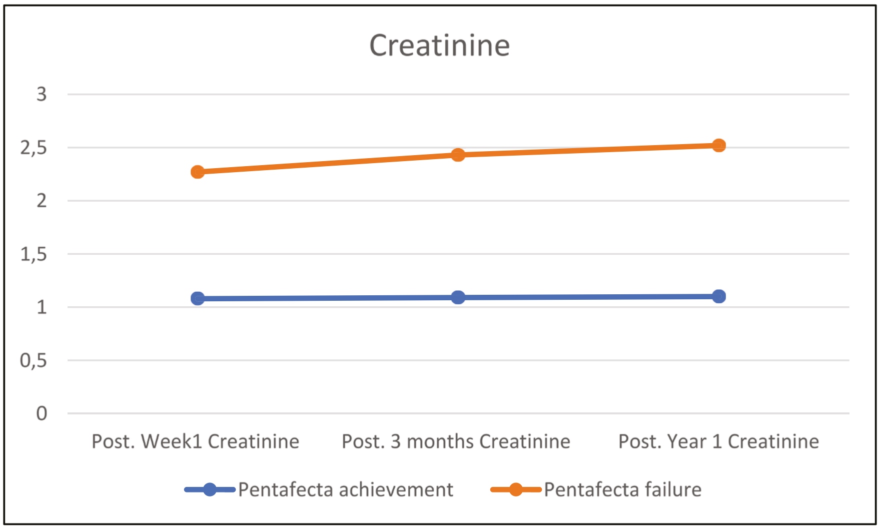

Fig. 2. Creatinine level during the follow-up period.

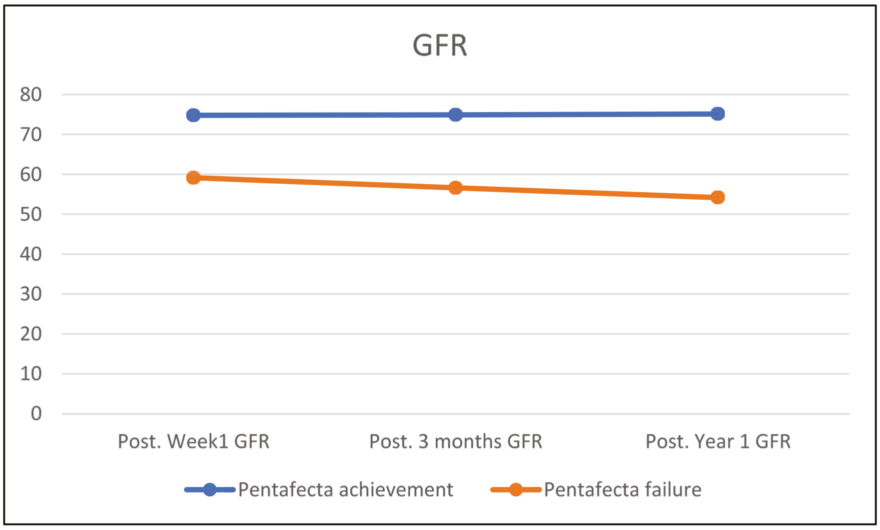

Fig. 3. eGFR changes during the follow-up period.

There was a significant negative correlation between pentafecta achievement and HTN and DM ($P<0.05$). There was a significant positive correlation between GFR and the performance of enucleation ($P = 0.0073$), indicating that enucleation preserves kidney function. There was a significant positive correlation between Padua score and BMI ($P = 0.0004$); however, non-significant associations were found with other parameters as seen in Table 5.

Table 5

Association between BMI, HTN, DM, enucleation, GFR, padua score and comorbidities with pentafecta achievement

	Unstandardized Coefficients		OR	T	P	95.0% CI for B	
	B	Std. Error				Lower bound	Upper bound
BMI	-0.01681	0.012565	0.983331	-1.3378	0.1907	-0.0424	0.00881
HTN	-0.50474	0.122878	0.603664	-4.1076	**0.0003**	-0.7553	-0.25413
DM	-0.40863	0.124896	0.664562	-3.2717	**0.0026**	-0.6633	-0.1539
GFR	0.01004	0.003162	1.010091	3.175	**0.0073**	0.00320	0.01687
pentafecta achieved	-0.3602	0.178398	0.697537	-2.0190	0.0646	-0.7456	0.02520
HTN	0.355945	0.319216	1.427529	1.11506	0.2737	-0.2959	1.00787
DM	0.000769	0.3155	1.000769	0.00243	0.9981	-0.6435	0.64510
BMI	0.1884	0.047038	1.207317	4.00529	**0.0004**	0.09233	0.28446

Results of all follow-up imaging procedures revealed no local recurrence or metastases.

Discussion. Renal tumors are among the most common neoplasms of the urinary system, second only to bladder cancer in prevalence. Due to their relatively low biological aggressiveness, these tumors typically demonstrate a subdued malignant potential [8].

In the present study, the preoperative characteristics — including age, sex, smoking index, BMI, ECOG score, comorbidities, and laboratory parameters — did not differ significantly between OPN and LPN groups. These findings align with Kang et al. [9]. who examined outcomes following robot-assisted partial nephrectomy (RAPN) for localized renal cell carcinoma (RCC). Their cohort had a median age of 50 years, a male predominance (70.7%), and notable rates of hypertension (29.3%) and diabetes mellitus (13.5%), with a median BMI of 25 kg/m^2. Similarly, Deka et al. [2] compared trifecta and pentafecta outcomes across OPN, LPN, and RAPN and reported comparable baseline characteristics.

While LPN is associated with a longer ischemia time, it is important to note that the mean ischemia duration in our study remained below the commonly accepted threshold of 30 minutes [1], which is used in defining favorable trifecta outcomes. Therefore, the prolonged ischemia observed in the LPN group may not have had a significant impact on Pentafecta outcomes. Nevertheless, a more detailed analysis with a larger sample size or a multi-institutional cohort would provide greater clarity on the potential influence of ischemia time on long-term functional outcomes and overall Pentafecta achievement.

Tumor-related variables, including tumor side, site, and size, also showed no statistically significant differences between the surgical groups or between cases achieving versus failing to achieve pentafecta outcomes. This is consistent with Porpiglia et al. [10] who reported no significant differences in tumor location or diameter between OPN and LPN groups.

Evaluation of disease complexity using the PADUA score similarly demonstrated no significant differences between the groups or between pentafecta achievers and non-achievers. Although Abdelhafez et al. [11]. found PADUA score differences to be significant across their study groups, our findings may reflect the inclusion of a broader clinical spectrum (cT1 and T2a tumors) with low complexity scores.

Clinical staging analysis revealed a nonsignificant increase in T1a and T1b tumors in the LPN group compared to the OPN group. T2a tumors were evenly distributed between groups. These results are consistent with Chang et al. [12] who observed no significant differences in clinical staging across surgical approaches.

In agreement with our result about operative data, Mehra et al. [13], reviewed fifty-five PN procedures: 28 OPN, 14 LPN, and 13 RAPN. OPN, LPN, and RAPN had similar median tumor size, nephrometry score, and preoperative creatinine. Blood loss was higher for OPNs than for LPNs. Our study disagrees with Soisrithong, Sirisreetreerux, et al. [14], which reported that the operative time was significantly shorter in the OPN group compared to the LPN and RPN groups.

Postoperative outcomes further supported the advantages of LPN. Patients undergoing LPN required significantly less analgesia – especially opioids and NSAIDs – and reported lower visual analog scale scores and decreased blood loss. No significant differences were observed between groups in terms of blood transfusion requirements, Clavien-Dindo complications, postoperative creatinine or GFR levels, or GFR deficit >10%.

Among patients failing to achieve pentafecta, significantly higher postoperative creatinine, lower GFR, and increased GFR deficit were observed. These findings are consistent with those of Ghavimi et al. [15] who reported similar eGFR trends across surgical modalities, with >10% GFR reductions observed in 59% of LPN and OPN cases and 52% of RAPN cases.

Histopathological comparisons revealed no significant differences in tumor subtype or margin status between surgical groups or pentafecta achievement groups. These results are in line with Mehra et al. [13] who found no significant difference in histologic subtypes (e.g., papillary RCC) across surgical modalities. It is worth noting that all cases included in the study were consecutively enrolled and randomized without any selection bias. The observed difference in CCRCC rates (100% in LPN vs. 63.16% in OPN) likely reflects random variation due to the small sample size, rather than a systematic bias in patient selection or treatment assignment. Histopathological outcomes were determined independently and postoperatively, thus not influencing surgical decision-making.

Hospital stay duration was significantly shorter in the LPN group, a finding supported by Mehra et al. [13] who reported median postoperative durations of 5, 6.5, and 10 days for OPN, LPN, and RAPN, respectively. However, pentafecta achievement rates did not differ significantly between groups, consistent with results from both Mehra et al. [13] and Deka et al. [2] who reported pentafecta rates of 71.6% for OPN, 82.6% for LPN, and 62.6% for RAPN.

In our study, there was a significant negative association between pentafecta achievement and HTN and DM. Also, there was a significant positive association between GFR and the performance of enucleation, indicating that enucleation preserves kidney function. Our study can be supported by Xu et al. [16] who found that TE was not only less traumatizing and beneficial for recovery but also better for kidney function protection.

Strengths and limitations of the study. This study provides valuable insights into the comparative performance of OPN and LPN regarding pentafecta outcomes. However, several limitations should be noted. While our analysis revealed a numerical trend favoring OPN descriptively, these differences did not reach statistical significance, due mainly to the limited sample size, which may have limited the ability to detect small but potentially meaningful differences between groups. Accordingly, future studies with larger sample sizes may help clarify whether the trend observed reflects a true clinical benefit of OPN. Specifically, based on a post-hoc power analysis with a medium effect size, a sample size of 51 in each group is needed to potentially detect the existing effect. Additionally, the follow-up period was limited, which necessitates making it longer in future research. Moreover, variations in surgeon expertise and technique could have influenced both operative outcomes and the achievement of pentafecta.

Conclusions. Both approaches show similar rates of pentafecta achievement, BMI and comorbidities such as HTN and DM negatively impact pentafecta outcomes, while the enucleation technique appears beneficial for preserving kidney function. These findings highlight the need for tailored surgical approaches to optimize outcomes in PN for localized renal tumors.

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Author contributions.

Aly M Abdel-Karim: Conceptualization and methodology;

Gamal Alsagheer: Validation and formal analysis;

Omar A.Bakeet: Writing – original draft preparation;

Mostafa AbdelRazek: Writing – review, editing and supervision.

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