RESEARCH PAPER

Comparative Outcomes of Robotic vs. Laparoscopic Nephrectomy in Renal Tumors

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Abstract

Background: Minimally invasive nephrectomy is widely used for the management of renal tumors. Robotic surgery may offer technical advantages over conventional laparoscopy, but its comparative clinical benefits remain under evaluation.

Objective: To compare perioperative, postoperative, renal functional, and oncological outcomes of robotic versus laparoscopic nephrectomy in patients with renal tumors.

Methods: This retrospective comparative observational study was conducted at IKD/HMC peshawar from June 2024 to June 2025 included 190 adult patients undergoing robotic or laparoscopic nephrectomy for renal tumors, with 95 patients in each group. Demographic and clinical information including age, gender, body mass index, hypertension, diabetes mellitus, smoking status, preoperative hemoglobin, serum creatinine, estimated glomerular filtration rate, tumor size, tumor laterality, clinical stage, and tumor complexity were recorded.

Results: Robotic nephrectomy was associated with longer operative time than laparoscopic nephrectomy (172.4±42.6 vs. 156.8±39.2 minutes, p=0.009), but significantly lower blood loss (146.7±91.4 vs. 211.5±118.6 mL, p<0.001) and shorter warm ischemia time (18.6±5.2 vs. 23.4±6.1 minutes, p<0.001). Blood transfusion (4.2% vs. 12.6%, p=0.037) and conversion to open surgery (2.1% vs. 8.4%, p=0.049) were also lower with robotics. Postoperative complications occurred in 14.7% versus 28.4% (p=0.021), while eGFR decline was 9.2±6.4% versus 13.6±8.1% (p<0.001). Robotic patients had earlier ambulation (18.7±6.2 vs. 24.3±7.8 hours, p<0.001) and shorter hospital stay (3.4±1.3 vs. 4.8±2.0 days, p<0.001). Positive surgical margins were comparable between groups (4.2% vs. 6.3%, p=0.516).

Conclusion: Robotic nephrectomy provided advantages in blood loss, warm ischemia time, transfusion requirement, postoperative complications, renal function preservation, and recovery, although operative time was longer.

Keywords: Renal tumors; Robotic nephrectomy; Laparoscopic nephrectomy; Partial nephrectomy

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Introduction

Renal tumors are an important urologic malignancy with renal cell carcinoma being the most common adult malignant renal tumour [1]. The primary curative

treatment is surgical removal, where the extent of the removal (partial versus radical) depends on the size, location, complexity, renal function, and characteristics of the patient and tumor [2]3]. Most of the current recommendations are that partial nephrectomy be considered for most T1 tumours when it is technically possible, as it helps to not sacrifice renal parenchyma to maintain oncological control [4]. Minimally invasive surgery is becoming more and more popular than open surgery due to the decreased blood loss, post-operative pain, hospital stay and recovery time [5]. Partial and radical nephrectomy are now performed in a conventional laparoscopic manner [6]. The technical challenges of laparoscopic surgery are, however, the limited instrument mobility, 2D visualization, and the challenges of intracorporeal suturing, especially when dealing with complex renal tumors [7]. To address some of these limitations, the introduction of robot assisted surgery has been developed that offers three-dimensional magnified visualization, articulated instruments, tremor filtering, and precision surgery [8]. Due to these technical benefits, the use of robotic nephrectomy is becoming more prevalent in modern-day urology.

Based on previous studies, it is suggested that the use of robotic assistance in partial nephrectomy would decrease the warm ischemia time, conversion to open or radical surgery, blood loss and postoperative decrease in renal function compared to conventional laparoscopy [9][10]. More recently, another comparative study also found that patients undergoing RPN experienced fewer postoperative complications, achieved higher trifecta rates, fewer hospital days, and better renal functional preservation [11]. However, overall, positive surgical margin rates and oncological outcomes seem similar for both techniques [12]. In the case of radical nephrectomy, the same safety and oncological outcome has been shown with both robotic and laparoscopic procedures [13]. However, in more complicated tumors, robotic surgery may provide benefits in terms of a more dexterous tool and decreased conversion to laparotomy, blood loss and transfusion needs, but also increased operative time and increased health care costs [14][15]. However, at this time, there is not enough evidence to support the superiority of any one of these minimally invasive techniques and the selection of approach continues to be dependent on the complexity of the tumor, surgeon experience, resources available at the hospital, and patient factors [16]. Because of the more resource intensive nature of robotic surgery, direct comparison to traditional laparoscopy continues to be clinically relevant in this era of ever-growing adoption of robotic surgery.

Objective

To compare perioperative, postoperative, renal functional, and oncological outcomes of robotic versus laparoscopic nephrectomy in patients with renal tumors.

Methodology

This retrospective comparative observational study was conducted at IKD/HMC peshawar from June 2024 to June 2025. A total of 190 adult patients who underwent minimally invasive nephrectomy for renal tumors were included. Patients were categorized according to surgical approach into robotic-assisted nephrectomy and conventional laparoscopic nephrectomy groups. Both partial and radical nephrectomy cases were included according to tumor characteristics and clinical indications. Patients aged ≥18 years with radiologically suspected or histologically confirmed renal tumors undergoing elective robotic or laparoscopic nephrectomy were included. Patients undergoing open nephrectomy, emergency surgery, surgery for non-neoplastic renal disease, bilateral procedures, or those with incomplete clinical or operative records were excluded.

Data Collection

Demographic and clinical information including age, gender, body mass index, hypertension, diabetes mellitus, smoking status, preoperative hemoglobin, serum creatinine, estimated glomerular filtration rate, tumor size, tumor laterality, clinical stage, and tumor complexity were recorded. Operative variables included type of nephrectomy, surgical approach, operative time, estimated blood loss, warm ischemia time for partial nephrectomy, intraoperative complications, blood transfusion, and conversion to open or radical surgery. Postoperative outcomes included change in hemoglobin and renal function, postoperative complications according to the Clavien–Dindo classification, intensive care admission, analgesic requirement, time to ambulation, length of hospital stay, readmission, and 30-day mortality. Histopathological findings including tumor type, pathological stage, Fuhrman/WHO-ISUP grade where applicable, and surgical margin status were also documented. Outcomes were compared between robotic and laparoscopic groups.

Statistical Analysis

Data were entered and analyzed using SPSS version 26.0. Continuous variables such as age, tumor size, operative time, blood loss, warm ischemia time, serum creatinine, eGFR, and hospital stay were expressed as mean±SD or median with interquartile range according to data distribution. Categorical variables were presented as frequency and percentage. The Shapiro–Wilk test was used to assess normality. Independent-samples t-test or Mann–Whitney U test was used to compare continuous variables, while Chi-square or Fisher's exact test was applied for categorical variables. A p-value ≤0.05 was considered statistically significant.

Results

Baseline characteristics were comparable between robotic and laparoscopic groups. Mean age was 56.8±11.4 vs. 58.1±10.9 years (p=0.424), BMI 27.6±4.1 vs. 27.1±4.3 kg/m² (p=0.413), and preoperative eGFR 83.6±18.7 vs. 81.9±19.4 mL/min/1.73m² (p=0.539). Male gender (64.2% vs. 67.4%), hypertension (49.5% vs. 53.7%), diabetes (30.5% vs. 33.7%), smoking (25.3% vs. 28.4%), tumor size (4.8±1.9 vs. 5.1±2.0 cm), right-sided tumors (51.6% vs. 54.7%), T1 disease (80.0% vs. 76.8%), and partial nephrectomy (65.3% vs. 57.9%) also showed no significant differences.

Table 1. Baseline Clinical and Tumor Characteristics

Variable	Robotic Nephrectomy (n=95)	Laparoscopic Nephrectomy (n=95)	p-value
Age, years, mean±SD	56.8±11.4	58.1±10.9	0.424
Male, n (%)	61 (64.2)	64 (67.4)	0.644
BMI, kg/m², mean±SD	27.6±4.1	27.1±4.3	0.413
Hypertension, n (%)	47 (49.5)	51 (53.7)	0.563
Diabetes mellitus, n (%)	29 (30.5)	32 (33.7)	0.641
Current smoking, n (%)	24 (25.3)	27 (28.4)	0.624
Tumor size, cm, mean±SD	4.8±1.9	5.1±2.0	0.291
Right-sided tumor, n (%)	49 (51.6)	52 (54.7)	0.661
Clinical stage T1, n (%)	76 (80.0)	73 (76.8)	0.596
Partial nephrectomy, n (%)	62 (65.3)	55 (57.9)	0.296
Radical nephrectomy, n (%)	33 (34.7)	40 (42.1)	0.296
Preoperative eGFR, mL/min/1.73 m², mean±SD	83.6±18.7	81.9±19.4	0.539

Robotic nephrectomy had longer operative time than laparoscopy (172.4±42.6 vs. 156.8±39.2 minutes, p=0.009) but lower blood loss (146.7±91.4 vs. 211.5±118.6 mL, p<0.001) and shorter warm ischemia time (18.6±5.2 vs. 23.4±6.1 minutes, p<0.001). Transfusion (4.2% vs. 12.6%, p=0.037) and conversion to open surgery (2.1% vs. 8.4%, p=0.049) were significantly lower with robotics. Intraoperative complications were 5.3% vs. 11.6% (p=0.118), while conversion from partial to radical nephrectomy was 4.8% vs. 14.5% (p=0.072).

Table 2. Comparison of Perioperative Outcomes

Outcome	Robotic Nephrectomy (n=95)	Laparoscopic Nephrectomy (n=95)	p-value
Operative time, minutes, mean±SD	172.4±42.6	156.8±39.2	0.009
Estimated blood loss, mL, mean±SD	146.7±91.4	211.5±118.6	<0.001
Warm ischemia time, minutes, mean±SD*	18.6±5.2	23.4±6.1	<0.001
Intraoperative complication, n (%)	5 (5.3)	11 (11.6)	0.118
Blood transfusion, n (%)	4 (4.2)	12 (12.6)	0.037
Conversion to open surgery, n (%)	2 (2.1)	8 (8.4)	0.049

Conversion from partial to radical nephrectomy, n (%)	3 (4.8)	8 (14.5)	0.072

*Warm ischemia time assessed among partial nephrectomy patients: robotic n=62 and laparoscopic n=55.

Robotic surgery resulted in a smaller hemoglobin drop (1.5±0.8 vs. 2.0±1.0 g/dL, p<0.001), lower eGFR decline (9.2±6.4% vs. 13.6±8.1%, p<0.001), earlier ambulation (18.7±6.2 vs. 24.3±7.8 hours, p<0.001), and shorter hospital stay (3.4±1.3 vs. 4.8±2.0 days, p<0.001). Postoperative eGFR was 75.9±18.5 vs. 70.8±19.1 mL/min/1.73m² (p=0.063). Overall complications were significantly lower with robotics (14.7% vs. 28.4%, p=0.021), while major complications (4.2% vs. 10.5%), ICU admission (5.3% vs. 12.6%), readmission (5.3% vs. 9.5%), and mortality (1.1% vs. 2.1%) were not significantly different.

Table 3. Postoperative and Renal Functional Outcomes

Outcome	Robotic Nephrectomy (n=95)	Laparoscopic Nephrectomy (n=95)	p-value
Postoperative hemoglobin drop, g/dL, mean±SD	1.5±0.8	2.0±1.0	<0.001
Postoperative eGFR, mL/min/1.73 m², mean±SD	75.9±18.5	70.8±19.1	0.063
eGFR decline, %, mean±SD	9.2±6.4	13.6±8.1	<0.001
Any postoperative complication, n (%)	14 (14.7)	27 (28.4)	0.021
Clavien–Dindo grade ≥III, n (%)	4 (4.2)	10 (10.5)	0.096
ICU admission, n (%)	5 (5.3)	12 (12.6)	0.079
Time to ambulation, hours, mean±SD	18.7±6.2	24.3±7.8	<0.001
Hospital stay, days, mean±SD	3.4±1.3	4.8±2.0	<0.001
30-day readmission, n (%)	5 (5.3)	9 (9.5)	0.268
30-day mortality, n (%)	1 (1.1)	2 (2.1)	0.561

Histopathological and oncological outcomes were comparable between groups. Clear-cell RCC occurred in 69.5% vs. 67.4%, papillary RCC in 15.8% vs. 17.9%, chromophobe RCC in 8.4% vs. 7.4%, and other histologies in 6.3% vs. 7.4%. Pathological pT1 disease was present in 75.8% vs. 72.6%, high WHO/ISUP grade in 22.1% vs. 25.3%, positive margins in 4.2% vs. 6.3%, and complete tumor excision in 95.8% vs. 93.7%, with no statistically significant differences between robotic and laparoscopic approaches.

Table 4. Histopathological and Oncological Outcomes

Outcome	Robotic Nephrectomy (n=95)	Laparoscopic Nephrectomy (n=95)	p-value
Clear-cell RCC, n (%)	66 (69.5)	64 (67.4)	0.756
Papillary RCC, n (%)	15 (15.8)	17 (17.9)	0.699
Chromophobe RCC, n (%)	8 (8.4)	7 (7.4)	0.790
Other histology, n (%)	6 (6.3)	7 (7.4)	0.776
Pathological stage pT1, n (%)	72 (75.8)	69 (72.6)	0.620
Pathological stage ≥pT2, n (%)	23 (24.2)	26 (27.4)	0.620
High WHO/ISUP grade, n (%)	21 (22.1)	24 (25.3)	0.608
Positive surgical margin, n (%)	4 (4.2)	6 (6.3)	0.516

Complete tumor excision, n (%)	91 (95.8)	89 (93.7)	0.516

Discussion

This study aimed to compare the perioperative, postoperative, renal functional and oncologic results between robotic and conventional laparoscopic nephrectomy in 190 patients who had renal tumors. There were no significant differences between groups at baseline, including age, BMI, comorbidities, size of the tumor, clinical stage or renal function before the surgery, which would have suggested important baseline imbalance to account for the difference in outcomes. The demographics and tumor types in the two treatment groups were also well matched for previous studies that compared the two techniques for partial nephrectomy [17]. The Mean operative time (172.4±42.6 minutes vs 156.8±39.2 minutes; p=0.009) for robotic nephrectomy was longer than laparoscopic surgery. However, estimated blood loss was significantly lower with robotics (146.7±91.4 vs. 211.5±118.6 mL, p<0.001), while transfusion requirements were also reduced (4.2% vs. 12.6%, p=0.037). A prior study also found that robotic radical nephrectomy might take longer than laparoscopy to perform, but result in similar perioperative results [18]. A few other prior studies in renal tumor surgery have shown lower blood loss for robotic surgery, in support of the ability to achieve more precise and hemostatic control with robotic instrumentation. Warm ischemia time was significantly less for the robotic approach compared to partial nephrectomy (18.6±5.2 vs. 23.4±6.1 minutes, p<0.001) among patients who had undergone partial nephrectomy. Similarly, in patients with intermediate- and high-complexity renal tumors, previous studies reported that robotic partial nephrectomy had a shorter warm ischemia time, 23.5 minutes compared to 27.5 minutes (p<0.001) [19]. This could possibly have to do with the ability of better visualization, articulated instruments and better efficiency of suturing when performing tumor removal and renal reconstruction, during the period of ischemia. Also, renal function was found to be better following robotic surgery. This was associated with a significantly lower performance of the eGFR after laparoscopic nephrectomy (13.6±8.1% decline) compared to robotic nephrectomy (9.2±6.4% decline, p<0.001), while absolute postoperative eGFR values were not significantly different (75.9±18.5 vs. 70.8±19.1 mL/min/1.73m², p=0.063). Previous studies also revealed a lower decline in eGFR at early postoperative period after RP compared to LP, which was 14.9 vs. 21.0 mL/min/1.73m² (p=0.011), with similar long-term renal function [20]. The results indicate that the renal functional benefit associated with the use of robotics could be greatest during the immediate postoperative period.

In addition, robotic surgery had a positive impact on patients' recovery. There were no significant differences between the numbers of overall complications for the robotic and laparoscopic procedures (14.7% vs 28.4%, respectively; p=0.021). Patients undergoing robotics had earlier ambulation (18.7±6.2 vs. 24.3±7.8 hours, p<0.001) and shorter hospitalization (3.4±1.3 vs. 4.8±2.0 days, p<0.001). In the past, robotic partial nephrectomy was also found to have fewer postoperative complications (2 compared to 8 in the laparoscopy group) and the blood loss was smaller in the robotic group with trend to faster postoperative recovery [21]. Another previous study found that significantly more patients achieved trifecta with robotic surgery, suggesting that robotic surgery may have significant perioperative benefits for technically challenging renal tumors. Conversions to open surgery were significantly lower with robotics (2.1% vs. 8.4%, p=0.049) but conversion from partial to radical nephrectomy were numerically lower (4.8% vs. 14.5%, p=0.072). This discovery could mean more flexibility with techniques during challenging minimally invasive procedures. Lower or infrequent conversion rates have been also reported for robotic surgery, but without statistical significance, in previous studies, especially in complex renal tumors [19][21]. However, although these peri-operative parameters differed, there were no significant differences in oncological outcomes. Positive surgical margins were found in 4.2% of the robotic cases, and in 6.3% of the laparoscopic cases, while the complete tumor resection rate was achieved in 95.8% and 93.7% of the robotic and laparoscopic groups, respectively. The other differences were also negligible, including histological subtype, pathological stage or tumor grade. Previous studies also failed to show any significant differences in pathological results, recurrence or overall, progression-free or cancer-specific survival between robotic versus laparoscopic surgery [22]. Previous large population based studies have also found no survival benefit to robotic compared to laparoscopic radical nephrectomy. There were a number of limitations in this study. It was performed in one centre and only included 190 patients, so the results might not be applicable to other centres. It is also a retrospective, observational study, which could have a selection bias and cannot conclude that the surgical approach and the outcome are causally related. Treatment selection may have been due to surgeon experience, tumor complexity,

institutional preference, and availability of robotic technology. Furthermore, long-term renal function, recurrence, cancer-specific survival, overall survival and cost-effectiveness were not assessed. More large-scale, prospective studies with extended follow up are suggested.

Conclusion

It is concluded that robotic nephrectomy was associated with lower blood loss, shorter warm ischemia time, fewer transfusions, lower conversion to open surgery, fewer postoperative complications, better preservation of renal function, earlier ambulation, and shorter hospital stay compared with laparoscopic nephrectomy, although operative time was longer. Oncological outcomes, including surgical margin status and complete tumor excision, were comparable between the two approaches. Robotic nephrectomy may therefore provide perioperative and recovery advantages while maintaining similar oncological effectiveness in appropriately selected patients with renal tumors.

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