Original Article

Predictors of Postoperative Complications in Partial Nephrectomy: A Risk-Stratified Analysis of Urine Leak and Hemorrhage Across Open and Robotic Approaches

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Abstract

Objective: To describe postoperative urine leak and hemorrhage following open and robotic partial nephrectomy (PN) and to explore potential risk factors in a retrospective cohort.

Methodology: This retrospective cohort study included adults undergoing open or robotic PN between January 2020 and August 2025 at Department of Urology, Pakistan Kidney and Liver Institute & Research Center, Lahore. Demographic, tumor, and perioperative variables were compared descriptively between surgical approaches. Postoperative urine leak and hemorrhage were analyzed using univariate methods. Multivariable analysis was performed on an exploratory basis due to the low number of outcome events using IBM SPSS v27.

Results: A total of 117 patients were analyzed, including 15 (12.8%) robotic and 102 (87.2%) open PN cases. Tumors managed with open PN were significantly larger (median 4.75 vs. 3.8 cm; p = 0.015) and associated with higher ASA scores. Urine leaks occurred in 8 patients (6.8%) and postoperative hemorrhage in 5 patients (4.3%), with no statistically significant difference between approaches. All urine leaks were managed conservatively or with ureteric stenting. There was no consistent independent association between any variable and any of the complications.

Conclusion: Hemorrhage and urine leak rates postoperatively were minimal for both open and robotic PN. Findings should be taken as descriptive due to variations in tumor complexity and small event numbers. To reduce complications postoperatively, surgical skill and careful patient selection are still essential.

Keywords: Partial Nephrectomy; Hemorrhage; Urine Leakage

Introduction

The conventional surgical procedure for localized renal tumors is partial nephrectomy (PN), which preserves renal function while providing oncologic management comparable to radical nephrectomy.[1-3] In comparison to the open approach, improvements in minimally invasive surgery during the past 20 years, especially laparoscopic and robotic-assisted approaches, have decreased surgical morbidity and enhanced perioperative recovery.[4,5] Despite these developments, postoperative problems like bleeding and urine leaks are still clinically significant because they can lengthen hospital stays, affect renal function, and raise healthcare costs.[6–9] Even though it is less frequent in modern technique, urine leaks are still a difficult consequence after PN. While more recent trials estimate leak rates ranging from 1% to 4%, depending on criteria such tumor complexity, collecting system involvement, and surgical expertise,[9,11] early open PN series reported leak rates as high as 17%.10 Although less common, postoperative hemorrhage can counteract the advantages of nephron-sparing surgery by requiring blood transfusion, angioembolization or re-intervention.[12] Surgical planning, postoperative care optimization, and perioperative risk stratification all depend on an understanding of the factors that contribute to these problems.[13,14]

Tumor size, anatomical complexity, ischemia time, length of surgery, and surgical technique may affect the incidence of complications following PN, according to earlier research; nevertheless, published results are still mixed.[15–17] Furthermore, the majority of the data that is currently accessible comes from high-volume facilities in established healthcare systems, where robotic surgery is the most common procedure. There is also little data from resource-constrained environments where robotic programs are still in their early stages of adoption and open PN is still very important.

The Pakistan Kidney and Liver Institute & Research Center began using minimally invasive urologic surgery in April 2023 with the installation of a robotic surgical equipment. This provided a unique opportunity to evaluate perioperative outcomes during the early phase of robotic PN implementation while open PN remained the predominant approach.

Accordingly, the primary objective of this study was to evaluate the incidence of postoperative urine leak and hemorrhage following open and robotic PN and to explore potential predictors of these complications in a tertiary care center transitioning to robotic surgery. By integrating procedural comparison with exploratory risk factor analysis, this study aims to contribute locally relevant evidence to the global literature on nephron-sparing surgery outcomes.

Methodology

This retrospective comparative cohort study was conducted in the Department of Urology, Pakistan Kidney and Liver Institute & Research Center, Lahore covering the period from January 2020 and August 2025. All consecutive adult patients (≥18 years) who underwent open or robotic partial nephrectomy (PN) for renal masses during this period were eligible. Therefore, no a priori sample size calculation was performed. Formal sample size calculation was not feasible, as this was a retrospective, consecutive cohort reflecting real-world practice during early robotic program implementation rather than a hypothesis-driven comparative trial. Patients with complete clinical, operative, and pathological records were included, while those converted from robotic to open PN, or with incomplete documentation or less than three months of follow-up, were excluded. A non-probability consecutive sampling method was used, incorporating all eligible cases; therefore, no formal sample size calculation was performed. Selection bias may have been introduced because robotic PN was carried out selectively depending on the complexity of the case and the availability of the surgeon.

A standardized collection form was used to retrieve the data from the hospital's electronic medical record system, and two investigators independently confirmed the data's accuracy. Demographic information, such as age, sex, body mass index, comorbidities (diabetes, hypertension, chronic kidney disease), and ASA physical status score, as well as tumour characteristics, such as size, laterality, location, and exophytic/endophytic nature, as well as surgical parameters, such as approach, operative and ischaemia times, estimated blood loss, suture and haemostatic techniques, and intraoperative complications, were gathered, as were postoperative outcomes, such as haemorrhage, haemoglobin drop, hospital stay, Clavien-Dindo grade, and 30-day readmission. Dedicated uropathologists verified oncologic factors, including surgical margin status, tumour stage, and histopathological subtype, in accordance with ISUP/WHO criteria. At discharge, eGFR was used to measure renal function.

The incidence and predictors of postoperative urine leak and haemorrhage following PN were the main outcomes that were measured. The duration of hospitalisation, postoperative renal function, and the severity of complications were secondary endpoints. IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA), was used to analyse the data. While categorical variables were shown as frequencies and percentages, continuous variables were shown as mean ± standard deviation (SD) or median with interquartile range (IQR). For continuous data, the independent t-test or Mann-Whitney U test was employed, whereas for categorical data, the Chi-square or Fisher's exact test was used to compare groups. Binary logistic regression models were exploratory in nature due to the rarity of both postoperative hemorrhage and urine leak, with the understanding that inference of effect

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estimates is limited by limited statistical power from small sample size. As a result, $p < 0.05$ was established as the threshold for statistical significance; however, interpretation also gave importance to effect size and confidence intervals. The Institutional Review Board of PKLI & RC granted ethical approval for this study (Approval No. PKLI-IRB/AP/0073/2025, dated 29 July 2025), with a waiver of informed consent because it was a retrospective study.

Results

Baseline Characteristics

A total of 117 patients were included, of whom 15 (12.8%) underwent robotic and 102 (87.2%) underwent open partial nephrectomy. The unequal group sizes reflect institutional practice patterns and the gradual adoption of robotic partial nephrectomy during the study period. Baseline characteristics and clinical variables are summarized in Table 1.

Table 1. Demographic, Clinical, and Tumor Characteristics by Surgical Approach (n = 117)

Variable	Robotic (n = 15)	Open (n = 102)	p-value
Age (years)	55.27 ± 16.16	52.56 ± 13.69	0.486
Body Mass Index (kg/m^2)	27.7 (4.3)	27.9 (3.0)	0.867
Sex			
Male	11 (73.3%)	77 (75.5%)	0.857
Female	4 (26.7%)	25 (24.5%)	
Hypertension, n (%)	3 (20.0%)	13 (12.7%)	0.445
Diabetes Mellitus, n (%)	4 (26.7%)	12 (11.8%)	0.117
Chronic Kidney Disease, n (%)	0 (0%)	2 (2.0%)	0.584
Baseline Hemoglobin (g/dL)	11.0 (3.0)	11.5 (3.0)	0.921
Baseline GFR (mL/min/1.73m^2)	83.3 (30.0)	84.7 (35.1)	0.782
Tumor Size (cm)	3.8 (1.4)	4.75 (2.3)	0.015
Tumor Location			
Upper pole	0 (0%)	29 (28.4%)	0.070
Mid pole	5 (33.3%)	17 (16.7%)	
Lower pole	9 (60.0%)	42 (41.2%)	
Upper & mid pole	0 (0%)	9 (8.8%)	
Lower & mid pole	1 (6.7%)	5 (4.9%)	
Tumor Depth			
Exophytic	12 (80.0%)	85 (83.3%)	0.940
Endophytic	1 (6.7%)	5 (4.9%)	
Mixed	2 (13.3%)	12 (11.8%)	
ASA Score			
I	6 (40.0%)	12 (11.8%)	0.01
II	2 (13.3%)	49 (48.0%)	
III	7 (46.7%)	41 (40.2%)	

Note:
Values are presented as mean ± standard deviation or median (interquartile range) for continuous variables, and frequency (percentage) for categorical variables.
p-values for continuous data were obtained using t-test or Mann–Whitney U test as appropriate; categorical variables were compared using Chi-square or Fisher's exact test. Bold indicates statistically significant result ($p < 0.05$).

Table 2. Comparison of Operative, Postoperative, and Complication Parameters Between Robotic and Open Partial Nephrectomy

Variable	Robotic (n = 15)	Open (n = 102)	p-value
Operative Parameters			
Operative Time (minutes)	165 (72)	120 (85)	0.071
Warm Ischemia Time (minutes)	18.0 (2.0)	18.0 (3.0)	0.394
Hemoglobin Drop (g/dL)	1.0 (1.0)	1.0 (1.0)	0.774
Intraoperative Complications			
Intraoperative Bleeding, n (%)	0 (0%)	4 (3.9%)	0.435
Postoperative Urine Leak			
Occurrence, n (%)	1 (6.7%)	7 (6.9%)	0.978
POD of Diagnosis (Median)	2 (1–3)	2 (1–3)	0.880
Management – Stent / Conservative, n	1/0	5 / 2	0.830
Resolution Time (days)	1–5	1–5	0.645
Postoperative Hemorrhage			
Occurrence, n (%)	0 (0%)	5 (4.3%)	0.381
POD of Diagnosis (Median)	1–2	1–2	0.857
Blood Transfusion, n (%)	0 (0%)	5 (4.3%)	0.381
Intervention – Conservative / Embolization, n	0 / 0	3 / 2	0.681
Clavien–Dindo Classification			
Grade II, n (%)	0 (0%)	5 (4.9%)	0.679
Grade IIIb, n (%)	1 (6.7%)	6 (5.9%)	
Postoperative Recovery			
Length of Stay (days)	2.0 (1.0)	3.0 (1.0)	0.768
eGFR at Discharge (mL/min/1.73m^2)	83.3 (59.9)	64.4 (32.8)	0.142
Readmission Within 30 Days, n (%)	0 (0%)	5 (4.3%)	0.381

Note:
Values are presented as mean ± standard deviation or median (interquartile range) for continuous variables, and frequency (percentage) for categorical variables.
p-values for continuous data were obtained using t-test or Mann–Whitney U test as appropriate; categorical variables were compared using Chi-square or Fisher's exact test. Bold indicates statistically significant result ($p < 0.05$).

Both groups were comparable in age, sex distribution, BMI, and comorbidities, with no significant differences in hypertension, diabetes, or baseline renal function (all $p > 0.05$). Patients undergoing open partial nephrectomy had significantly larger tumors and higher ASA scores, indicating that open surgery was preferentially selected for more complex and higher-risk cases. Tumor location and depth showed no significant variation between groups.

Operative and Postoperative Outcomes

Operative and postoperative parameters are presented in Table 2. Collecting system involvement was more frequent in open procedures (34.3% vs. 13.3%), though not statistically significant ($p = 0.103$). Urine leaks occurred in 8 patients (6.8%), including 1 (6.7%) in the robotic group and 7 (6.9%) in the open group ($p = 0.978$). In the robotic group, the single leak was managed with ureteric stenting. Among open cases, five leaks required ureteric stenting and two resolved with conservative management. All leaks were resolved without long-term sequelae. Most urine leaks resolved conservatively within 2–4 days. Postoperative hemorrhage occurred in 4.3% of patients, respectively, with

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no significant difference between surgical approaches. According to the Clavien–Dindo classification, 89.7% of patients experienced no postoperative complications, and complication grades did not differ between groups (p = 0.679). Median hospital stay and renal function at discharge were also comparable.

Overall, both surgical techniques demonstrated low complication rates and similar short-term recovery profiles.

Predictors of Postoperative Complications

Given the low incidence of postoperative events in this cohort (8 urine leaks and 5 hemorrhages), exploratory regression analyses were attempted to assess potential associations between patient-, tumor-, and procedure-related variables and postoperative complications. However, the small number of outcome events resulted in statistically unstable estimates, with evidence of overfitting and complete or quasi-complete separation.

No variable demonstrated a reliable independent association with either urine leak or postoperative hemorrhage. Effect estimates were imprecise and associated with wide confidence intervals, precluding meaningful interpretation. Accordingly, regression findings were not used for inferential purposes and are presented only as descriptive, hypothesis-generating observations.

Given these limitations, postoperative urine leak and hemorrhage in this series are more appropriately characterized using descriptive analyses rather than multivariable predictive modeling. Detailed regression coefficients are therefore not presented due to model instability arising from sparse outcome events.

Discussion

In this retrospective cohort of 117 patients undergoing partial nephrectomy, both open and robotic approaches were associated with low rates of postoperative urine leak and hemorrhage. Baseline demographic and clinical characteristics were largely comparable between groups; however, tumors managed with open partial nephrectomy were significantly larger and associated with higher ASA scores. During the study period, patients with more difficult or high-risk diseases were given preference for open surgery, which is indicative of institutional case selection practices.

These findings are consistent with previously published data demonstrating that tumor complexity and patient risk profile, rather than surgical approach alone, frequently guide procedural selection. Bic et al. reported a similar tendency for open partial nephrectomy to be favored in anatomically challenging tumors, which in turn was associated with higher observed complication rates.[18] Our results support the concept that crude comparisons between approaches must be interpreted cautiously when baseline tumor characteristics differ.

Operative and early postoperative outcomes were broadly comparable between the two approaches. Although operative time tended to be longer in robotic cases, ischemia duration, hemoglobin drop, length of hospital stay, and renal function at discharge did not differ significantly. Overall complication rates were low, with nearly 90% of patients experiencing no postoperative complications, and Clavien–Dindo grades were similar between groups. These findings align with existing literature reporting acceptable perioperative safety profiles for both open and minimally invasive nephron-sparing surgery when performed in appropriately selected patients.

Postoperative urine leaks occurred in 6.8% of patients, with nearly identical rates between robotic and open partial nephrectomy. All leaks were managed conservatively or with ureteric stenting and resolved without long-term sequelae. Although reported leak rates in large multicenter series are often lower, particularly in robotic cohorts, differences in patient selection and tumor complexity likely account for this variation. In the present study, collecting system involvement was more frequent among open cases, which may partially explain the observed leak rate. Mahmud et al. reported lower overall leak rates but excluded more advanced tumors and complex collecting system involvement, limiting direct comparability.[6]

Postoperative hemorrhage was observed in 4.3% of patients, occurring exclusively in the open group, though without a statistically significant difference between approaches. Embolization and transfusion were rare, indicating uniform postoperative care and efficient intraoperative hemostasis. Open surgery and transfusion have been found to be predictors of postoperative problems in earlier research, such as that conducted by Bertolo et al.[17] Higher rates of bleeding have also been recorded. Rather than variations solely attributed to surgical methods, the decreased bleeding rate in the current group may be due to institutional experience and cautious perioperative management.

There were no statistically significant independent predictors of bleeding or urine leaks found using exploratory regression analysis. This is probably because multivariable models are unstable due to the low frequency of outcome occurrences. In exploratory multivariable modeling, these correlations were not robust, despite nonsignificant trends toward increased complication risk on univariate evaluation being shown by longer operating length and rising age. Regression results were therefore interpreted with caution and considered to be hypothesis generating rather than confirmatory.

In the early stages of robotic partial nephrectomy implementation, this study provides locally pertinent data from a high-volume tertiary care facility in Pakistan. Although robotic surgery did not show statistical

superiority, trends toward similar safety and recovery indicate that it is feasible in individuals who are carefully chosen. Crucially, the low rates of complications in both methods highlight how important surgical skill, patient selection, and consistent perioperative procedures are to achieving the best possible results. The small robotic subgroup, the single-center, retrospective design, and the short 30-day follow-up, which may restrict the identification of more complications that were rare, are some of the shortcomings. The low frequency of postoperative complications limited reliable multivariable modeling, and regression analyses were therefore interpreted cautiously. The marked imbalance between robotic and open cases limits direct comparative inference and underscores that findings should be interpreted descriptively. To better characterize predictors of postoperative problems and to shed light on the changing role of robotic technology in nephron-sparing surgery, future prospective, multicenter studies incorporating tumor complexity indexes and longer follow-up are required.

Conclusion

The incidence of postoperative complications were low for both open and robotic partial nephrectomy. Rather than outcome differentiation, the choice of surgical method was influenced by the intricacy of the tumor. Because of the small number of events and the early deployment of robotic programs, the results should be figured out descriptively.

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Authors' Contribution Statement

NBN contributed to the conception, design, acquisition, analysis, interpretation of data, drafting of the manuscript, critical review of the manuscript, and final approval of the version to be published. AR, NZ, SM, and SI contributed to the acquisition, analysis, interpretation of data, and drafting of the manuscript. MKG, SA, AMA, and SI contributed to the acquisition, analysis, and interpretation of data. All authors are accountable for their work and ensure the accuracy and integrity of the study.

Conflict of Interest

Authors declared no conflict on interest

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None

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.