ORIGINAL RESEARCH
Urooncology

Doi: 10.4274/jus.galenos.2025.2025-5-5
J Urol Surg

Robot-assisted Partial Nephrectomy for Complex (PADUA score >10) Renal Masses

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What's known on the subject? and What does the study add?

The preoperative aspects and dimensions used for an anatomical (PADUA) score predicts anatomical complexity and complication risk in partial nephrectomy, but large-scale data on robot-assisted surgery for highly complex tumors are limited. This study demonstrates that robot-assisted partial nephrectomy is feasible and safe even for tumors with PADUA ≥10, providing valuable outcome data from a large single-surgeon cohort.

Abstract

Objective: To evaluate the perioperative outcomes of robot-assisted partial nephrectomy (RAPN) in patients with complex renal masses, stratified by preoperative aspects and dimensions used for an anatomical (PADUA) score, and to assess the utility of the PADUA classification in surgical planning and risk prediction.

Materials and Methods: We retrospectively analyzed 354 patients who underwent RAPN between April 2008 and February 2023 using Da Vinci Si and Xi systems. Tumors were classified as complex (PADUA ≥10) or non-complex (PADUA <10) based on preoperative imaging. Demographic data, perioperative outcomes, and renal function parameters were compared between groups. Complications were graded using the Clavien-Dindo system.

Results: Of the 354 patients, 124 (35%) had PADUA scores ≥10 (group A), and 230 (65%) had scores <10 (group B). Group A patients were significantly younger (p=0.003) and had had larger tumors, had longer operative and warm ischemia times, had higher blood loss, and had longer hospital stays (all p<0.01). Despite increased complexity, positive surgical margin rates were similar between groups. Postoperative declines in hemoglobin, hematocrit, and estimated glomerular filtration rate, along with increased creatinine levels, were significant (p<0.001). High PADUA scores correlated with increased surgical difficulty and complication risk, supporting its role as a preoperative risk stratification tool. Despite technical challenges, RAPN provided effective oncologic control, with complication and margin rates consistent with those reported in prior studies.

Conclusion: RAPN is a safe and effective treatment for complex renal tumors when guided by detailed preoperative assessment using the PADUA score. A multidisciplinary approach and experienced surgical technique are critical for optimizing outcomes in high-complexity cases.

Keywords: Endourology, radiology, urooncology

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Received: 08.05.2025 **Accepted:** 11.07.2025 **Epub:** 24.07.2025

Cite this article as: Doğanca T, Tuna MB, Pirdal BZ, Argun ÖB, Tüfek İ, Öbek C, Kural AR. Robot-assisted partial nephrectomy for complex (PADUA score >10) renal masses. J Urol Surg. [Epub Ahead of Print]

Introduction

Renal cell carcinoma (RCC) is an entity that accounts for almost 90% of all kidney cancers and has significant clinical importance in current uro-oncology practice (1). Although surgery has a paramount role in the treatment of RCC, a multidisciplinary approach is needed to achieve satisfactory curative results. A primary step of this approach is to recognize the tumor through preoperative radiological evaluation, choose the correct surgical approach, and predict possible complications and outcomes.

We have long been aware of the survival benefit that partial nephrectomy provides the patient compared to radical nephrectomy, without sacrificing oncological survival outcomes (2-6). For this reason, fewer radical nephrectomies and more partial nephrectomies are performed today; however, determining the appropriate technique and approach in partial nephrectomy becomes important.

The preoperative aspects and dimensions used for an anatomical (PADUA) classification system has long been considered a guide to ensure accurate evaluation at this step (7).

Because the T-stage of the classical tumor, node, metastasis classification system evaluates the tumor only in terms of its relationship with major anatomical structures and its size, it may not predict aspects important for surgery. A risk classification based only on size as suggested by the classical T classification would be insufficient for the planning of this delicate surgery. The location of the mass in the vertical and horizontal planes of the kidney, its percentage within the parenchyma, and its proximity to the renal hilus and collecting system are undoubtedly important. In addition to standard scoring systems, the PADUA system also takes into account other anatomical and pathological features of the tumor (7). It does not seem wise to make a risk assessment based solely on tumor size when comparing a small but risky mass (in terms of its relationship with these critical structures) and a large mass that partial excision would not be challenging.

Revealing the tumor characteristics objectively may make more personalized approaches for the treatment of patients possible. Partial nephrectomy, which was initially performed with an open surgical approach due to its difficulties in terms of surgical technique, could also be performed laparoscopically and subsequently robot-assisted over time (7-9), the disadvantages of these closed methods versus open surgery are that they require operation almost exclusively under warm ischemia when ischemia is mandatory (7,9,10). Therefore, it is important to accurately evaluate the complexity of the masses preoperatively in robot-assisted surgery. In this study, we aim to present perioperative data according to the PADUA scores of the tumors in patients who underwent robot-assisted partial nephrectomy (RAPN) due to renal mass.

Materials and Methods

Between April 2008 and February 2023, a total of 354 patients had undergone RAPN. Demographic (Table 1), clinical (Table 2), preoperative, and peroperative outcomes (Table 3) of the patients were collected retrospectively. All of the procedures were performed with Da Vinci Si and Xi surgical systems (Intuitive Surgical, Sunnyvale, CA, USA).

Age, body mass index (BMI), American Society of Anesthesiologists (ASA) scores, and biochemical evaluations of the patients as well as PADUA scores of the masses were recorded. Main intraoperative data: operation time, warm ischemia time, estimated amount of blood loss. Postoperative data: hospital stay, duration of drain and Foley catheter insertion, surgical margin positivity, data on tumor pathology, serum creatinine levels, hematocrit, and estimated glomerular filtration rate (eGFR). As a biochemical evaluation, these were kept as values. The eGFR calculation method was recorded 1 month after surgery using the appropriate calculation formula.

Patients were evaluated with computed tomography or magnetic resonance imaging in the preoperative period and their PADUA scores were recorded. Two groups were created based on PADUA scores above and below 10, and masses above 10 were considered complex masses. Postoperative complications were recorded according to the Clavien-Dindo grading system (11). Ethics committee approval was obtained for the study from Acibadem University Ethics Committee (approval no: ATADEK 2023-19-643, date: 30.11.2023).

Operation Technique

All patients were operated on by a single surgeon. During the specified period, Da Vinci S-HD was used for the first year, Da Vinci Si for the next 5 years, and Da Vinci Xi was used for the next 9 years. The patients were positioned in the modified flank position, with the affected kidney on top, and flexion was applied to the table. Partial nephrectomy was performed using a 5-port approach. Excision of the masses was performed by enucleation a combination of these techniques, depending on the condition of the mass. V-Loc and polyglactin sutures were used for suturing the resection bed, repairing the collecting system if it was opened, and parenchymal suturing. A hemostatic agent (human gelatin-thrombin matrix sealant) was used in almost all patients.

Statistical Analysis

Statistical analysis was performed using SPSS version 21 (IBM Corp., Armonk, NY, USA). In descriptive analyses, the numbers and percentages were classified as categorical variables, and normality of the continuous variables was demonstrated via the Kolmogorov-Smirnov test. The comparisons between the groups

were evaluated using the Mann-Whitney U test for continuous variables and the chi-squared test for categorical variables. Differences between the two paired groups were tested using the Wilcoxon test. A p-value below 0.05 was considered significant.

Results

Of our study cohort, 124 patients (35%) had a PADUA score ≥10 (group 1), and 230 patients (65%) had a PADUA score <10 (group 2). Group 1 (PADUA score ≥10) had a significantly lower mean age when compared to group 2 (PADUA score 10) (p=0.003). No significant difference was found in terms of sex, BMI and surgical margin positivity between group 1 (PADUA score ≥10) and group 2 (PADUA score 10). Tumor size, operation time, blood loss, need for collecting system repair, the ischemia time, and hospitalization time were significantly higher in group 1 (PADUA score ≥10) when compared to group 2 (PADUA score <10) (p<0.001, p=0.002, p=0.001, p<0.001, p<0.001, p<0.001, p=0.005, respectively).

Three hundred and fifty-four patients who underwent partial nephrectomy were included in the study. 69.1% (n=244) of the patients were male; the mean age of the patients was 53.4±13.1. The mean BMI was 27.9±4.6. Descriptive of demographic categories of patients shown in Table 1.

32.5% of the patients were ASA 1, 63% (n=223) were ASA 2, and 4.5% were ASA 3. The operated kidney of 51.7% (n=183) of the study group was on the left side. The mean PADUA score of the study group was 8.6±1.7, and the median was 9 (7-10). The most common pathology result was RCC in 83% (n=293). When RCC subtypes were examined, it was observed that 69% (n=202) clear cell was the most common. When their pathological stages were examined, it's shown that 73.1% (n=259) were T1a, 26.3% (n=93) T1b, 0.6% (n=2) T2a. The Fuhrman nuclear grading distribution in the study cohort was as follows: Grade 1 was identified in 45 cases (15.4%), grade 2 in 207 cases (70.6%), grade 3 in 40 cases (13.7%), and grade 4 in 1 case (0.3%). This distribution reflects a predominance of intermediate-grade tumors (grade 2) within the sample population. Clinical and pathological characteristics of the study population are shown in Table 2.

It was found that the preoperative hemoglobin, hematocrit, and eGFR values of the patients decreased after the surgery, whereas the creatinine values increased. (p<0.001, four instances) (Table 4).

Table 1. Descriptive of demographic categories of patients

Categories (n=354)	n (%)	Mean ± standard deviation	Median (25-75. interquartile range)
Gender			
Male	244 (69.1)		
Female	110 (30.9)		
Age		53.4±13.1	53 (43.3-64)
Height, cm		172.3±8.7	173 (166-178)
Weight, kg		82.9±15.6	83 (73-92)
Body mass index, kg/cm^2		27.9±4.6	27 (25-30)

Table 2. Clinical and pathologic characteristics of the study population

Categories (n=354)	n (%)	Mean ± standard deviation	Median (25-75. interquartile range)
ASA		1.72±0.54	2 (1-2)
1	115 (32.5)		
2	223 (63)		
3	16 (4.5)		
Laterality			
Right	171 (48.3)		
Left	183 (51.7)		
Follow-up time, month		64.9±39.3	64 (34-92.8)
PADUA score		8.6±1.7	9 (7-10)

Table 2. Continued			
Categories (n=354)	**n (%)**	**Mean ± standard deviation**	**Median (25-75. interquartile range)**
Pathology			
RCC	293(83)		
Oncocytoma	23 (6.5)		
AML	22 (6.2)		
Others (kist, nephrocalcinosis, adenoma, infarct, epithelial and stroma tm, liposarcoma)	16 (4.5)		
RCC sub-type			
Clear cell	202 (69)		
Papillary	57 (19.4)		
Chromofob	23 (7.8)		
Others	11 (3.7)		
Pathologic state			
T1a	259 (73.1)		
T1b	93 (26.3)		
T2a	2 (0.6)		
Fuhrman grade			
1	45 (15.4)		
2	207 (70.6)		
3	40 (13.7)		
4	1 (0.3)		
ASA: American Society of Anesthesiologists, RCC: Renal cell carcinoma, AML: Angiomyolipoma, PADUA: Preoperative aspects and dimensions used for an anatomical			

Table 3. Comparison of demographic and clinical characteristics of patients according to PADUA score			
Categories (n=354)	PADUA score		p
	≥10 (124)	<10 (230)	
Age (mean ± standart deviation)	50.6±12.7	54.9±12.9	**0.0031**
Gender			
Male [n (%)]	81 (65.3)	163 (70.9)	0.2822
Female [n (%)]	43 (34.7)	67 (19.1)	
BMI, kg/cm^2 [n (%)]	28 (25-32)	27 (25-30)	0.0971
Follow-up time, month [median (25-75. interquartile range)]	58.5 (28.8-88.5)	67 (36.5-94)	0.1501
Tumor size [median (25-75. interquartile range)]	40 (30-49.5)	27 (22-37.5)	**<0.001**
Time of operation [median (25-75. interquartile range)]	109 (82-134.8)	91 (70-121.5)	**0.002**[1]
Amount of bleeding, cc [median (25-75. interquartile range)]	200 (77.5-400)	100 (50-200)	**0.001**[1]
Collecting system entry			
Yes [n (%)]	81 (65.3)	56 (24.3)	**<0.001**[2]
No [n (%)]	43 (34.7)	174 (75.7)	
Ischemia			
Yes [n (%)]	115 (92.7)	180 (78.3)	
No [n (%)]	9 (7.3)	50 (21.7)	**<0.001**[2]
Ischemia time (n=295) [median (25-75. interquartile range)]	21 (19-24)	19 (15-20)	**<0.001**
Surgical margin			
Positive [n (%)]	2 (1.7)	3 (1.4)	0.818[2]
Negative [n (%)]	116 (98.3)	215 (98.6)	
Hospitalization time [median (25-75. interquartile range)]	109 (82-134)	91 (70-121)	**0.005**[1]
[1]: Mann-Whitney U test, [2]: Chi square test, BMI: Body mass index, PADUA: Preoperative aspects and dimensions used for an anatomical			

Table 4. Comparison of laboratory values before and after operation			
Categories (n)	Pre-operation	Post-operation	p[1]
	Median (25-75. interquartile range)	Median (25-75. interquartile range)	
Hb (344)	14.3 (13.3-15.4)	12.4 (11-13.5)	**<0.001**
HCT (344)	42.6 (39.9-45)	37.2 (33.3-39.6)	**<0.001**
eGFR (248)	93 (79.6-104)	91.7 (76.2-104)	**<0.001**
Creatinine 1 (350)	0.86 (0.73-1.00)	0.88 (0.76-1.05)	**<0.001**
eGFR 2 (338)	94 (79.7-105)	91.8 (77-104)	**<0.001**
[1]: Wilcoxon test, eGFR: Estimated glomerular filtration rate, Hb: Hemoglobin, HCT: Hematocrit			

Discussion

PADUA classification, is a system designed to quantify the anatomical characteristics of renal tumors in patients who are candidates for nephron-sparing surgery (7,12,13). It is an anatomy-based nephrometry scoring system used from preoperative imaging to delineate renal mass characteristics and their relationship to adjacent structures (7,12). The primary purpose of the PADUA score is to predict the risk of surgical and medical perioperative complications in patients undergoing open partial nephrectomy (7,12). It is also intended to help clinicians stratify patients suitable for nephron-sparing surgery into subgroups with different complication risks. It can be used as a standardized tool to test the comparability between groups of patients undergoing partial nephrectomy with different surgical approaches. The PADUA classification evaluates five anatomical aspects of the tumor plus its maximal diameter, including: Longitudinal (polar) location, exophytic rate, renal rim, renal sinus, urinary collecting system. The anterior or posterior face of the kidney can also be indicated with a letter ('a' or 'p') (7,12).

The PADUA score can predict the risk of overall complications. In the study where the score was initially developed, multivariate analysis showed that a PADUA score between 8 and 9 identified patients with a 14-fold higher risk of complications compared to those with scores of 6 or 7 (7). Patients with a score ≥10 had a 30-fold higher risk of complications compared to those with scores of 6 or 7 (7). Renal tumors with a PADUA score ≥10 are usually defined as having high surgical complexity (8,13). The median PADUA score in a large multicenter study of patients undergoing PN for complex tumors was 10 (13). In this study, 73.4% of these complex tumors were adjacent to the renal sinus, 81.5% were compressing or infiltrating the urinary collecting system, and 30% were completely endophytic (13).

Comparisons with the RENAL nephrometry score indicate that the two systems are highly correlated (12). They assign almost the same points for maximal tumor size, with a slight difference for tumors, Key differences lie in the definition of sinus lines and the evaluation of the relationship with the urinary collecting system or renal sinus; in PADUA, these are scored separately (1-2 scale), unlike RENAL's single three-tiered variable. Studies suggest, both systems are similarly effective in predicting the risk of overall complications (7,12).

Studies evaluating partial nephrectomy for highly complex renal tumors defined by PADUA score ≥10 have provided important insights.

A single-center study comparing laparoscopic partial nephrectomy (LPN) and open partial nephrectomy (OPN) for tumors with PADUA score ≥10 found that while operation time, conversion to radical nephrectomy, and positive surgical margins were similar between the two groups, LPN was associated with significantly lower estimated blood loss, intra-operative and post-operative transfusion rates, drainage time, and pain score at post-operative day. There was a statistically significant difference in overall complication rate, in favor of the laparoscopic approach, although no significant difference in grade ≥3 post-operative complications was detected (8).

A large multicenter prospective observational study (RECORD2 project) evaluated patients treated with OPN, LPN, and RAPN for complex tumors (PADUA score ≥10) (8,13). They found that the robotic approach was associated with significantly lower estimated blood loss and a higher trifecta rate compared to both LPN and OPN. RAPN also had a significantly lower postoperative complication rate and transfusion rate than OPN. Multivariable analysis identified lower preoperative hemoglobin and the open versus robotic surgical approach as significant predictive factors of overall postoperative surgical complications. The PADUA score was found to be a predictor of major (Clavien ≥3) postoperative surgical complications. The surgical approach was an independent predictor of postoperative complications, with OPN carrying a 3.91-fold increased risk compared to RAPN (13).

Our study underscores the critical role of the PADUA classification system in characterizing tumor complexity. Tumors classified as group A are associated with higher PADUA scores, signifying their increased complexity due to factors such as larger size, proximity to vital renal structures, and multifocality. As anticipated, we observed that surgical procedures for group A were inherently more challenging, necessitating advanced surgical skills and meticulous planning to achieve optimal results.

Despite the greater complexity of tumor A, it is noteworthy that the surgical approach employed in our study yielded favorable outcomes. Surgical success, as defined by complete tumor resection with negative margins and preservation of renal function, was achieved in a substantial proportion of cases. This highlights the expertise of the surgical team and the adaptability of the chosen technique to manage even the most challenging tumors. Our findings revealed that group A tumors, which were characterized by larger sizes and higher PADUA scores, were associated with a higher incidence of complications. Notably, increased blood loss and prolonged hospital stays were more common in this group. These results are consistent with the established notion that larger tumors often necessitate more extensive surgical resections, potentially leading to increased blood loss. Moreover, the extended hospital stays for group A tumors may reflect the need for closer postoperative monitoring and management of complications. Our findings are consistent with those of Ficarra et al. (7), who reported that higher PADUA scores were associated with increased intraoperative blood loss and prolonged hospital stay. In contrast to previous studies suggesting increased positive surgical margins in complex renal masses, our series demonstrated comparable margin-negative rates regardless of PADUA score.

The disparities in complications between group A and group B tumors underscore the importance of individualized surgical planning. While the surgical technique employed in our study demonstrated its effectiveness, it is crucial for clinicians to recognize that the approach to complex tumors may require additional precautions and resources to mitigate potential complications. This includes meticulous hemostasis techniques, access to blood products, and postoperative care protocols tailored to the specific needs of patients with more complex tumors.

Study Limitations

While the PADUA score was initially validated in patients undergoing OPN, further external validation is noted as needed Studies have since evaluated its use in minimally invasive techniques. Some studies using the PADUA score for complex tumors also mention limitations, such as the retrospective nature of the study, small cohort size, procedures being performed by highly experienced surgical teams, and non-randomized surgical approach selection. Despite limitations, these studies indicate that the PADUA score is a valuable tool for assessing tumor complexity and predicting outcomes in partial nephrectomy, particularly for complex lesions.

It is essential to acknowledge certain limitations of our study, including its retrospective nature and the potential for selection bias in patient cohort assignment. Furthermore, our analysis primarily focused on short-term surgical outcomes, and long-term follow-up is warranted to assess factors such as recurrence rates and overall survival.

Conclusion

Our study sheds light on the intricate relationship between tumor complexity, surgical technique, and patient outcomes. While group A tumors, classified as more complex by the PADUA scoring system, posed greater challenges during surgery and were associated with increased complications, the chosen surgical approach proved effective in achieving favorable outcomes. This emphasizes the need for a tailored, multidisciplinary approach in the management of renal tumors, especially when dealing with more complex cases. As we continue to refine surgical techniques and incorporate evolving technologies, the ultimate goal remains to optimize outcomes and enhance the quality of life for patients with renal tumors, irrespective of their complexity.

Ethics

Ethics Committee Approval: Ethics committee approval was obtained for the study from Acibadem University Ethics Committee (approval no: ATADEK 2023-19-643, date: 30.11.2023).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: T.D., M.B.T., Ö.B.A., İ.T., A.R.K., Concept: T.D., M.B.T., Design: T.D., M.B.T., Data Collection or Processing: T.D., M.B.T., B.Z.P., Analysis or Interpretation: T.D., M.B.T., B.Z.P., Ö.B.A., İ.T., C.Ö., A.R.K., Literature Search: T.D., M.B.T., Writing: T.D., M.B.T.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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