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Objective Measures of Renal Mass Anatomic Complexity Predict Rates of Major Complications Following Partial Nephrectomy

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Abstract

Background—The association between tumor complexity and postoperative complications after partial nephrectomy (PN) has not been well characterized.

Objective—We evaluated whether increasing renal tumor complexity, quantitated by nephrometry score (NS), is associated with increased complication rates following PN using the Clavien-Dindo classification system (CCS).

Design, setting, and participants—We queried our prospectively maintained kidney cancer database for patients undergoing PN from 2007 to 2010 for whom NS was available.

Interventions—All patients underwent PN.

Measurements—Tumors were categorized into low- (NS: 4–6), moderate- (NS: 7–9), and high-complexity (NS: 10–12) lesions. Complication rates within 30 d were graded (CCS: I–5), stratified as minor (CCS: I or 2) or major (CCS: 3–5), and compared between groups.

Results and limitations—A total of 390 patients (mean age: 58.0 ± 11.9 yr; 66.9% male) undergoing PN (44.6% open, 55.4% robotic) for low- (28%), moderate- (55.6%), and high-

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complexity (16.4%) tumors (mean tumor size: 3.74 ± 2.4 cm; median: 3.2 cm) from 2007 to 2010 were identified. Tumor size, estimated blood loss, and ischemia time all significantly differed ($p < 0.0001$) between groups; patient age, body mass index (BMI), and operative time were comparable. When stratified by CCS, minor and major complication rates for all patients were 26.7% and 11.5%, respectively. Minor complication rates were comparable (26.6 vs 24.9 vs 32.8%; $p = 0.45$), whereas major complication rates differed (6.4 vs 11.1 vs 21.9%; $p = 0.009$) among tumor complexity groups. Controlling for age, gender, BMI, type of surgical approach, operative duration, and tumor complexity, prolonged operative time (odds ratio [OR]: 1.01; confidence interval [CI], 1.0–1.02) and high tumor complexity (OR: 5.4; CI, 1.2–24.2) were associated with the postoperative development of a major complication. Lack of external validation is a limitation of this study.

Conclusions—Increasing tumor complexity is associated with the development of major complications after PN. This association should be validated externally and integrated into the decision-making process when counseling patients with complex renal tumors.

Keywords

Partial nephrectomy; Nephrometry; Complications

1. Introduction

In accordance with the American Urological Association (AUA) and European Association of Urology guidelines for the management of the clinical T1 renal mass, partial nephrectomy (PN) is a preferred surgical approach for amenable small renal masses with functional and oncologic outcomes comparable with radical nephrectomy (RN) [1,2]. Although underutilization has been reported due to various factors such as increased technical difficulty, diffusion of laparoscopy, and selective referral patterns [3–5], support for increased use of PN has increased [6] in an effort to maximize nephron preservation and reduce the morbidity and mortality associated with development of chronic kidney disease [7].

The benefit of renal function preservation following PN must be weighed against the increased risk of postoperative complications when compared with RN [8]. Reported complication rates following PN, regardless of surgical technique, range from 4.5% to 28% [1,8–11], with higher rates observed in patients undergoing complex PN [12–14]. However, lack of standardized reporting methods has resulted in an existing body of complications literature that is difficult to interpret [15]. In an attempt to homogenize outcomes reporting for the assessment of case mix, grading schemes such as the Clavien-Dindo classification system (CCS) [16] have been validated to standardize the description of surgical complications. Similarly, in an effort to standardize renal tumor anatomic characterization, the RENAL nephrometry score (NS) [17], followed by Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) and C-Index [18,19] classifications, were designed to objectify and quantify salient renal mass anatomic attributes and facilitate the rigorous assessment of surgical outcomes for renal procedures. Here we assess whether increased tumor complexity as quantified by NS is associated with increased complication rates following PN stratified by the CCS.

2. Materials and methods

Our prospectively maintained institutional kidney cancer database, approved by our institutional review board, was queried to identify all patients from 2007 to 2010 undergoing PN with available cross-sectional imaging for assessment. NSs (www.nephrometry.com;

Appendix A) were calculated and input prospectively before the completion of each procedure since 2009 [17]. All score assignments were performed by at least two investigators with conflicting data reviewed. NSs were totaled and categorized into low- (NS: 4–6), moderate- (NS: 7–9), or high-complexity (NS: 10–12) groups for risk stratification.

Surgical technique and approach (robotic vs open) was at the discretion of the primary surgeon and determined on a case-by-case basis. Robotic procedures employed a three-arm technique with port location tailored to the location of the renal tumor and hilum [20]. Open approaches were generally performed extraperitoneally through the 11th or 12th ribs as previously described [21]. Demographic, clinical, and operative data included patient age, gender, body mass index (BMI), age-adjusted Charlson comorbidity index (CCI) score, American Society of Anesthesiologists (ASA) score, Eastern Cooperative Oncology Group (ECOG) performance status, tumor size, procedure type, estimated blood loss (EBL), ischemia time, operative duration, pathologic data, and hospital length of stay (LOS). Complications within 30 perioperative days were prospectively collected according to the CCS format [16] (Appendix B) and then retrospectively confirmed by chart review. Urine leak was defined as a radiographically proven extravasation of urine and/or elevation of drain fluid creatinine greater than twice serum creatinine at 2-wk follow-up. Ileus was defined as the need for placement of a nasogastric tube.

2.1. Statistical analyses

Demographic, clinical, and procedural characteristics were compared between tumor complexity groups. Continuous variables were analyzed by Wilcoxon tests, and noncontinuous variables were examined by chi-square analyses. To account for the number of patients in which multiple postoperative complications occurred, complications were reported as both the absolute number of complications incurred irrespective of the patient and the proportion of patients developing a specific complication. These were further stratified into minor (CCS 1 or 2) or major (CCS 3–5) groups by organ system and compared between tumor complexity groups using chi-square tests. A multivariable logistic regression using stepwise selection was used to identify independent predictors of major complications. All analyses were performed using SAS v.9.2 statistical software (SAS, Cary, NC, USA) with a p value <0.05 considered statistically significant.

3. Results

Table 1 presents the demographic and clinical data for the cohort ($n = 390$) meeting the inclusion criteria. Mean patient age was 58.0 ± 11.9 yr (median: 59.0 yr; 66.9% male), with a mean tumor size of 3.74 ± 2.4 cm (median: 3.2 cm) and a mean follow-up of 20.6 ± 15.2 mo (median: 19.0 mo). Most patients ($n = 216$; 55.4%) underwent open PN; 174 (44.6%) underwent robotic-assisted laparoscopic PN. Stratified by NS classification, 109 (28.0%), 217 (55.6%), and 64 (16.4%) patients underwent PN for a low-, moderate-, or high-complexity lesion, respectively. Although there were significant differences regarding patient gender ($p = 0.01$), there were no differences observed in age, race, ECOG performance status, ASA score, BMI, tumor laterality, CCI, or duration of follow-up between groups. When considering procedural variables, although operative duration was similar regardless of anatomic complexity, EBL, ischemia time, pathologic tumor size, and LOS all demonstrated significant variation ($p < 0.0001$) between groups with the highest values observed in complex lesions. When analyzing anatomic characteristics, proximity to the renal hilum was more common in moderate (16.1%) and highly complex (28.1%) lesions and rarely seen in patients with low-complexity (2.8%) scores ($p < 0.001$).

The proportion of patients incurring minor (CCS 1 or 2) and major (CCS 3–5) complications undergoing PN was 26.7% ($n = 104$) and 11.5% ($n = 45$), respectively. When stratified by nephrometric complexity, there were no differences in the proportion of patients incurring a minor complication ($p = 0.45$) (Table 2). In contrast, a significantly increased proportion of patients incurring major complications was observed in those undergoing PN for highly complex anatomic lesions (21.9%) compared with those with moderate- (11.1%) and low-complexity (6.4%) lesions ($p = 0.009$). Thirty-five patients (54.7%) in the high NS group suffered from a postoperative complication (minor or major) within 30 d of surgery ($p = 0.01$). The incidence of complications within 30 d of surgery by CCS type was examined and categorized by organ system affected (Table 3). Urine leak was the most common complication incurred (10.8%), followed by ileus (4.9%), and anemia requiring blood transfusion (3.3%). Data were further analyzed by assessing the proportion of patients incurring complications classified by organ system and stratified by tumor complexity groups (Table 4). The most frequently occurring complications were genitourinary (25.1%), pulmonary (6.9%), and gastrointestinal (5.9%). When complications stratified by organ system were compared by complexity groups, the percentage of genitourinary complications significantly differed between groups ($p < 0.0001$) and corresponded with increasing tumor complexity. In contrast, although small but significant differences were observed between complexity groupings for other organ system complications (pulmonary, gastrointestinal, other), no clear trends corresponding to anatomic tumor complexity were observed.

To assess for independent predictors of major complications, we started with a full logistic regression model including age, gender, BMI, CCI, ASA score, solitary kidney status, surgical approach, EBL, ischemia time, operative duration, presence of hilar tumors, and nephrometry complexity groups. A stepwise selection procedure was used to look for the most significant predictors of major complications (Table 5). Operative duration (odds ratio [OR]: 1.01, confidence interval [CI], 1.0–1.02; $p = 0.0004$), BMI (OR: 0.92; CI, 0.8–0.99, $p = 0.04$), female gender (OR: 2.9; CI, 1.1–7.6; $p = 0.03$), and high-complexity nephrometry category (OR: 5.4; CI, 1.2–24.2; $p = 0.03$) were significantly associated with an increased risk of incurring a major complication.

4. Discussion

Recent evidence has suggested a reduction in the risk of chronic kidney disease and cardiovascular morbidity following PN with equivalent oncologic outcomes when compared with patients undergoing RN for clinically localized renal cell carcinoma [22,23]. However, contemporary series report postoperative complication rates following PN ranging from 19.2% to 24.9% [1,24], and these risks must be considered when counseling patients presenting with a new diagnosis of an enhancing renal mass. Interpretation of the current body of evidence is limited by inconsistent reporting of surgical outcomes and a lack of standardized methods to assess case mix [15].

When assessing the comparative effectiveness of differing procedures for the same primary disease process, it is essential to control for anatomic complexity to account for differences in clinical outcomes. Although intuitive that a more complex procedure may increase risk of adverse events, the clinical usefulness of these data is limited by the lack of standardized quantification of tumor anatomic complexity. In an attempt to rigorously evaluate and standardize anatomic complexity reporting, the RENAL NS was developed to describe salient renal tumor anatomy objectively and facilitate the comparison of treatment outcomes [17]. Subsequently, scoring systems such as PADUA [18], which assesses complexity through anatomic characterization, and C-Index [25], which employs geometric equations to assess tumor centrality, have also been reported.

Early efforts have successfully correlated tumor complexity assessed with standardized reporting methods with urine leak [12] and perioperative outcomes [26]. In the first report using NS, Bruner et al investigated the association between anatomic complexity and urine leak in a matched cohort analysis of patients undergoing PN. These authors demonstrated that with each unit increase in total NS, the risk of postoperative urine leak increased by 35% [12]. In a retrospective account of 297 patients, Waldert et al demonstrated an association between tumor complexity quantitated by PADUA and overall complication rates measured by CCS [26]. Similarly, in a retrospective review of 62 patients undergoing robotic PN, Mottrie et al reported a relationship between PADUA score and overall complication frequency [27]. In comparison with the present study, neither group was able to correlate tumor complexity with complication severity using standardized criteria or provide organ-specific complication data for comparison.

In a comprehensive review, Donat et al reported a startling disparity in the quality of contemporary surgical complication reporting in urologic oncology [15]. These findings highlight the inability to compare the morbidity of surgical techniques and outcomes accurately, concluding that improved use of standardized guidelines to report surgical outcomes is essential to facilitate the evaluation of case mix [15]. Of available contemporary externally validated complication reporting schemes, the CCS represents a widely used grading system that stratifies postoperative complications by severity of therapeutic intervention required [16]. Although the CCS has been used to report standardized outcomes following complex oncologic procedures such as radical cystectomy [28], its use for patients undergoing PN remains limited.

Relating anatomic complexity to surgical outcome using a standardized methodology facilitates preoperative counseling and enables patients to make clinical trade-off decisions confidently. In this study, we demonstrate that tumor anatomic complexity determined by NS is significantly associated with major (CCS: 3–5) postoperative complications following PN. Patients with complex renal tumors (NS: 10–12) were 5.4 times more likely to sustain a major complication following PN. Although these findings are consistent with previous series describing the increased risk of specific complications following PN for complex tumors [12–14], our series represents the first to correlate anatomic complexity with severity and frequency of postoperative complications incurred in a rigorously standardized fashion. Rates of minor complications requiring minimal intervention (CCS: 1 or 2) in our cohort were similar regardless of tumor complexity, but the proportion of patients developing major complications requiring a secondary intervention (CCS: 3–5) was significantly increased in the high anatomic complexity group. This suggests that major complications (as determined by CCS) after PN are affected by procedure complexity posed by the anatomic attributes of the tumor excised. Not surprisingly, when subclassified by organ system, there was a significant association between high tumor complexity and the development of genitourinary complications when compared with low and moderate complexity lesions, of which urine leak and hemorrhage requiring blood transfusion were the most common. Although there were other small but significant differences observed when comparing organ system complications (pulmonary, gastrointestinal, and miscellaneous) by complexity group, it appears from these data that nongenitourinary organ system complication rates are likely influenced by additional patient factors such as competing medical risks and prior surgical history. We also observed that in our cohort, increasing operative time, female gender, and decreasing BMI were associated with increased major complication risks. Although the association of female gender and decreasing BMI is likely an artificial finding with minimal clinical relevance, our findings support previous observations that increasing time under anesthesia may affect postoperative sequelae [29].

Although limited by retrospective methodology as well as lack of external validation, our findings demonstrate that high tumor complexity can be directly correlated to the risk of major postoperative complications requiring a secondary intervention. Specifically, methods of using ischemia differed between open and robotic procedures, introducing bias to our findings. Furthermore, the association between postoperative complications and surgical modality approached significance, likely influenced by robotic learning curve as well as differences in patient selection that were difficult to assess due to small sample size. Most importantly, whereas high-complexity stratification was associated with increased risk of complications in our cohort, intermediate complexity was not, indicating that further investigation is necessary to validate our nephrometric complexity stratification scheme.

In summary, taking into consideration the attendant risks of cardiovascular morbidity, chronic kidney disease, and overall mortality associated with the performance of RN for clinically localized renal tumors, the AUA guidelines currently recommend that a nephron-sparing approach is preferred when oncologically feasible via either minimally invasive or open techniques [1]. Although we strongly advocate this principle, for patient counseling purposes it must be clearly delineated that the nephron-preserving benefits of PN for anatomically complex lesions come with significant additional risks in excess of 20% of a major complication requiring a secondary intervention.

5. Conclusions

We report complication rates using the CCS and objectifying tumor complexity using the RENAL NS. Standardized reproducible reporting of surgical outcomes is essential to facilitate the assessment of case mix. Tumor anatomic complexity, quantitated by NS, is a significant predictor of major complications following PN necessitating secondary interventions stratified by the CCS. This association should be validated externally and integrated into the decision-making process when counseling patients with complex renal tumors.

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Table 1

Patient demographics and tumor characteristics

	All patients <i>n</i> = 390	Low complexity group (NS: 4-6)	Moderate complexity group (NS: 7-9)	High complexity group (NS: 10-12)	<i>p</i> value
Demographic data mean ($\pm$ SD)					
Age, yr	58.0 ($\pm$ 11.9)	57.7 ($\pm$ 12.4)	57.9 ($\pm$ 11.9)	58.9 ($\pm$ 10.8)	0.87
Gender, <i>n</i> (%)					
Male	261 (66.9)	83 (76.2)	132 (60.8)	46 (71.2)	0.014
Female	129 (33.1)	26 (23.9)	85 (39.2)	18 (28.1)	
Race					
White (%)	331 (84.9)	90 (82.6)	188 (86.6)	53 (82.8)	0.17
African American (%)	44 (11.3)	13 (11.9)	20 (9.2)	11 (17.2)	
Other (%)	15 (3.9)	6 (5.5)	9 (4.2)	0	
CCI	2.6 ($\pm$ 2.2)	2.5 ($\pm$ 2.4)	2.6 ($\pm$ 2.2)	3.0 ($\pm$ 2.0)	0.20
ECOG $\geq$ 1 (%)	39 (10%)	7 (6.4)	23 (10.6)	9 (14.1)	0.29
ASA score $\geq$ 3 (%)	117 (30%)	36 (33.0)	59 (27.2)	22 (34.4)	0.48
BMI, kg/m ²	30.4 ($\pm$ 6.7)	30.5 ($\pm$ 6.5)	30.2 ($\pm$ 6.8)	30.9 ($\pm$ 6.4)	0.27
Type of procedure					
Robotic PN (%)	174 (44.6)	83 (76.2)	81 (37.3)	10 (15.6)	<0.000
Open PN (%)	216 (55.4)	26 (23.9)	136 (62.7)	54 (84.4)	1
Preoperative tumor size, cm	3.47 ($\pm$ 2.1)	2.5 ($\pm$ 1.0)	3.6 ($\pm$ 1.9)	4.8 ($\pm$ 3.0)	<0.0001
Patients with solitary kidney (%)	31 (7.9)	8 (7.3)	13 (6.0)	10 (15.6)	0.04
Follow-up, mo	20.6 ($\pm$ 15.2)	19.2 ($\pm$ 12.2)	21.4 ($\pm$ 17.4)	20.0 ($\pm$ 11.4)	0.84
Operative data mean ($\pm$ SD)					
EBL, ml	206 ($\pm$ 264)	135 ($\pm$ 152)	210 ($\pm$ 251)	314 ($\pm$ 392)	<0.0001
Ischemia time, min	31.2 ($\pm$ 12.3)	27.8 ($\pm$ 13.2)	30.7 ($\pm$ 11.5)	37.9 ($\pm$ 11.5)	<0.0001
Operative time, min	197 ($\pm$ 64)	198 ($\pm$ 83)	196 ($\pm$ 53)	201 ($\pm$ 62)	0.83
Hospital length of stay, d	4.7 ($\pm$ 3.5)	3.8 ($\pm$ 3.1)	4.9 ($\pm$ 3.4)	5.6 ($\pm$ 4.0)	<0.0001
Pathologic tumor size, cm	3.74 ($\pm$ 2.4)	2.8 ($\pm$ 1.3)	3.8 ($\pm$ 2.2)	5.2 ($\pm$ 3.6)	<0.0001
Tumor characteristics (%)					
Tumor complexity					
Low complexity (NS: 4-6)	109 (28.0)				

	All patients <i>n</i> = 390	Low complexity group (NS: 4–6)	Moderate complexity group (NS: 7–9)	High complexity group (NS: 10–12)	<i>p</i> value
Moderate complexity (NS: 7–9)	217 (55.6)				
High complexity (NS: 10–12)	64 (16.4)				
Tumor mass location					
a	199 (51.0)	57 (52.3)	113 (52.1)	29 (45.3)	
p	159 (40.7)	41 (37.6)	90 (41.5)	28 (43.8)	0.59
x	32 (8.3)	11 (10.1)	14 (6.5)	7 (10.9)	
h (hilar) tumor	56 (14.3)	3 (2.8)	35 (16.1)	18 (28.1)	<0.001

NS = Nephrometry score, SD = standard deviation; CCI = age-adjusted Charlson comorbidity index score, ECOG = Eastern Cooperative Oncology Group, ASA = American Society of Anesthesiologists, BMI = body mass index; PN = partial nephrectomy; EBL = estimated blood loss.

Table 2Complication data reported by patient^{*}

	Low- complexity group (NS: 4–6) <i>n</i> = 109	Moderate- complexity group (NS: 7–9) <i>n</i> = 217	High- complexity group (NS: 10–12) <i>n</i> = 64	<i>p</i> value
Any complication: CCS: 1–5; <i>n</i> = 149	36 (33.0)	78 (35.9)	35 (54.7)	0.011
Minor complications: CCS: 1 or 2; <i>n</i> = 104	29 (26.6)	54 (24.9)	21 (32.8)	0.45
Major complications: CCS: 3, 4, or 5; <i>n</i> = 45	7 (6.4)	24 (11.1)	14 (21.9)	0.009

NS = nephrometry score; CCS = Clavien-Dindo classification system.

^{*} Total number of patients per NS category with complication stratified by CCS class (%).

Table 3

Incidence of individual complication by Clavien-Dindo classification system type within 30 d of surgery categorized by organ system

	All patients <i>n</i> = 390 pts		Low-complexity group NS: 4–6; <i>n</i> = 109 (%)		Moderate-complexity group NS: 7–9; <i>n</i> = 217 (%)		High-complexity group NS: 10–12; <i>n</i> = 64 (%)	
	CCS 1–5	Minor (CCS 1–2)	Major (CCS 3–5)	Minor (CCS 1 or 2)	Major (CCS 3–5)	Minor (CCS 1 or 2)	Major (CCS 3–5)	
Genitourinary								
Urinary leak	42 (10.8)	–	2 (1.8)	9 (4.1)	13 (6.0)	8 (12.5)	10 (15.6)	
Embolization								
Pseudoaneurysm	4 (1.0)	–	–	–	2 (0.9)	–	2 (3.1)	
Urinary tract infection	10 (2.6)	1 (0.9)	–	4 (1.8)	–	5 (7.8)	–	
Dialysis	1 (0.25)	–	–	–	–	–	1 (1.6)	
Lymphocele	1 (0.25)	–	–	–	1 (0.5)	–	–	
Pyelonephritis	1 (0.25)	–	–	1 (0.5)	–	–	–	
Perinephric abscess	6 (1.5)	2 (1.8)	–	–	1 (0.5)	–	3 (4.7)	
Acute kidney injury*	4 (1.0)	2 (1.8)	–	1 (0.5)	–	1 (1.6)	–	
Perinephric hematoma	5 (1.3)	1 (0.9)	–	2 (0.9)	–	2 (3.1)	–	
Wound infection	9 (2.3)	5 (4.6)	–	3 (1.4)	–	1 (1.6)	–	
Wound seroma	2 (0.51)	1 (0.9)	–	1 (0.5)	–	–	–	
Transfusion	13 (3.3)	–	–	7 (3.2)	–	6 (9.4)	–	
Cardiovascular tachycardia	2 (0.51)	1 (0.9)	–	–	–	1 (1.6)	–	
Hypertension	2 (0.51)	–	–	2 (0.9)	–	–	–	
Atrial fibrillation	6 (1.5)	1 (0.9)	–	4 (1.8)	–	1 (1.6)	–	
Cardiac catheterization	2 (0.51)	–	2 (1.8)	–	–	–	–	
Congestive heart failure	1 (0.25)	–	–	1 (0.5)	–	–	–	
Angina	1 (0.25)	1 (0.9)	–	–	–	–	–	
Dysrhythmia requiring pacemaker	1 (0.25)	–	1 (0.9)	–	–	–	–	
Death	3 (0.76)	–	3 (2.8)	–	–	–	–	
Pulmonary								
Pneumonia	9 (2.3)	3 (2.8)	–	3 (1.4)	–	3 (4.7)	–	
Respiratory failure/intubation	4 (1.0)	–	3 (2.8)	–	–	–	1 (1.6)	

All patients n = 390 pts		Low-complexity group NS: 4-6; n = 109 (%)		Moderate-complexity group NS: 7-9; n = 217 (%)		High-complexity group NS: 10-12; n = 64 (%)	
	CCS 1-5	Minor (CCS 1-2)	Major (CCS 3-5)	Minor (CCS 1 or 2)	Major (CCS 3-5)	Minor (CCS 1 or 2)	Major (CCS 3-5)
Atelectasis	6 (1.5)	4 (3.7)	-	2 (0.9)	-	-	-
Pneumothorax	2 (0.5)	-	-	1 (0.5)	-	1 (1.6)	-
Pleural effusion	6 (1.5)	4 (3.7)	1 (0.9)	-	-	-	1 (1.6)
Thromboembolic							
Deep Vein Thrombosis	4 (1.0)	-	1 (0.9)	2 (0.9)	-	-	1 (1.6) 21
Pulmonary Embolism	4 (1.0)	-	-	1 (0.5)	2 (0.9)	1 (1.6)	-
Gastrointestinal							
<i>Clostridium difficile</i> infection	3 (0.76)	1 (0.9)	-	1 (0.5)	-	1 (1.6)	-
Ileus	19 (4.9)	11 (10.1)	-	4	-	4 (6.3)	-
Pancreatitis	1 (0.25)	-	-	1 (0.5)	-	-	-
Electrolyte/Metabolic							
Rhabdomyolysis	1 (0.25)	-	-	-	-	-	1 (1.6)
Hyperkalemia	1 (0.25)	-	-	1 (0.5)	-	-	-
Other systems							
Oropharyngeal Swelling	1 (0.25)	1 (0.9)	-	-	-	-	-
Gouty flare	1 (0.25)	-	-	1 (0.5)	-	-	-
Delirium	1 (0.25)	-	-	1 (0.5)	-	-	-
Fever of unknown origin	2 (0.51)	1 (0.9)	-	-	-	1 (1.6)	-
Corneal abrasion	2 (0.51)	2 (1.8)	-	-	-	-	-
Neuropathic leg pain	1 (0.25)	1 (0.9)	-	-	-	-	-

CSS = Clavien-Dindo classification system; NS = Nephrometry score.

* Defined according to the Acute Dialysis Quality Initiative definition reported originally in 2004 as a serum creatinine increase to 1.5-fold or glomerular filtration decrease >25% from baseline on discharge from hospital [30].

Table 4
Proportion of patients (percentage) incurring complications by organ system stratified by nephrometric complexity

	Total proportion of patients (%) incurring complication	All patients	Low complexity NS: 4-6	Moderate complexity NS: 7-9	High complexity NS: 10-12	p value
<i>n</i>		390	109	217	64	-
Genitourinary		98 (25.1)	13 (11.9)	51 (23.5)	27 (42.2)	<0.0001
Cardiovascular		18 (4.7)	9 (8.3)	10 (4.6)	2 (3.1)	0.14
Pulmonary		27 (6.9)	11 (10.0)	15 (6.9)	5 (7.8)	0.0005
Thromboembolic		8 (2.1)	1 (0.9)	7 (3.2)	3 (4.7)	0.62
Gastrointestinal		23 (5.9)	11 (10.0)	8 (3.7)	6 (9.4)	0.006
Metabolic		2 (0.51)	0	1 (0.5)	0	0.38
Other		8 (2.1)	3 (2.8)	2 (0.9)	2 (3.1)	0.004

NS = nephrometry score.

Table 5

Multivariate analysis using stepwise selection procedure to look for the most significant predictors of major complications *

Predictor	Multivariate* OR (CI)	p value
Age	1.04 (0.9–1.1)	0.07
BMI	0.92 (0.8–0.99)	0.04
Gender		
Male	1.0	–
Female	2.9 (1.1–7.6)	0.03
Type of procedure		
Open PN	1.0	–
Robotic PN	0.2 (0.05–1.0)	0.0502
Operative time	1.01 (1.0–1.02)	0.0004
Moderate NS (7–9)	0.75 (0.17–3.2)	0.69
High NS (10–12)	5.4 (1.2–24.2)	0.03

OR = odds ratio; CI = confidence interval; BMI = body mass index; PN = partial nephrectomy;

NS = nephrometry score.

* Clavien-Dindo classification system 3–5.

Appendix A

Description of the RENAL nephrometry score [17]*

	1 point	2 points	3 points
(R)adius (maximal diameter in centimeters)	≤ 4	>4 but <7	≥7
(E)xophytic properties	≥50%	<50%	Entirely endophytic
(N)earness of the tumor to the collecting system or sinus (millimeters)	≥7	>4 but <7	≤4
(A)nterior/Posterior	No points given. Mass assigned a descriptor of a, p, or x		
(L)ocation relative to the polar lines* Suffix "h" assigned if the tumor touches the main renal artery or vein	Entirely above the upper or below the lower polar line	Lesion crosses polar line	>50% of mass is across polar line <i>or</i> mass crosses the axial renal midline <i>or</i> mass is entirely between the polar lines

* Web tool for point-of-service use can be found at www.nephrometry.com.

Appendix B

Examples of Clavien-Dindo complications related to partial nephrectomy [16]

CCS grade	Definition	Examples
Grade 1	Deviation from normal postoperative course without need for pharmacologic treatment	Ileus, urinary leak managed expectantly, fever of unknown origin
Grade 2	Deviation from normal postoperative course with need for pharmacologic treatment	Atrial fibrillation, wound infection requiring antibiotics, urinary tract infection, blood transfusion
Grade 3A	Requiring surgical/endoscopic/radiologic intervention without anesthesia	Nephrostomy tube placement under ultrasound, perinephric drain placement for urinary leak, pulmonary embolism requiring inferior vena cava filter
Grade 3B	Requiring surgical/endoscopic/radiologic intervention with anesthesia	Placement of internalized JJ stent for urinary leak
Grade 4A	ICU admission due to complication; single organ dysfunction	Dialysis <i>or</i> respiratory failure/intubation
Grade 4B	ICU admission due to complication; multiorgan dysfunction	Dialysis <i>and</i> respiratory failure/intubation
Grade 5	Death of patient	–

ICU = intensive care unit.