

Validation of radius exophytic/endophytic nearness anterior/posterior location and preoperative aspects and dimensions used for an anatomical nephrometric scores in patients undergoing partial nephrectomy for renal cancer: A single-center experience and literature review

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Abstract

Introduction: Nephrometric scores are used to predict perioperative and postoperative complications, with no uniform results in the current literature.

Materials and Methods: A retrospective study of 141 patients in a single center who underwent open partial nephrectomy between June 2006 and 2016 for T1a and T1b renal tumor was conducted. Univariate and multivariate analyses were used to evaluate the correlations between preoperative aspects and dimensions used for an anatomical (PADUA) and radius exophytic/endophytic nearness anterior/posterior location (RENAL) scores and their components with pre-, peri-, and post-operative parameters. Linear regression (*F*-tests) and logical regression models were used to test for significance of the association and predictability of outcomes.

Results: Total RENAL score ($P = 0.032$), its components R ($P = 0.004$), E ($P = 0.022$), L ($P = 0.011$), and total PADUA score ($P = 0.016$) were significantly associated with ischemic time. In postoperative complications, the PADUA components: sinus line location ($P = 0.008$), lateral/medial rim score ($P = 0.029$), and collecting system score ($P = 0.006$) showed significance. None of the variables showed correlation with operation time and change in estimated glomerular filtration rate (eGFR). On multivariate analysis, sinus line location and gender ($P = 0.012$) showed significance in predicting eGFR changes and RENAL score component: A ($P = 0.049$) was significant in predicting estimated blood loss. Both RENAL and PADUA components were significantly associated with hospital length of stay.

Conclusion: Both RENAL and PADUA scores showed important correlation in predicting outcomes. We further demonstrated the importance of knowing the individual components of the scores, which can independently give outcome predictions. The scoring systems can still be improved and standardized for broad clinical use with larger cohort and multicenter-based studies.

Keywords: Nephrometric scores, preoperative aspects and dimensions used for an anatomical score, partial nephrectomy, radius exophytic/endophytic nearness anterior/posterior location score, renal cancer

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INTRODUCTION

In the United Kingdom, kidney cancer is the seventh most common cancer (2014), and around 12,500 new cases of kidney cancers are detected with 7839 (63%) in males and 4684 (37%) in females.^[1] Over the last decade, localized renal cell carcinoma (RCC) detection has increased by 3.7%/year.^[2] More than half of renal masses detected each year are <4 cm.^[3] Tumors ≤4 cm in diameter are defined as small renal masses (SRMs) and have contrast-enhancing features that are usually consistent with stage T1a RCC.^[4]

The main forms of treatment for these SRMs have been radical nephrectomy (RN) and nephron-sparing surgery namely partial nephrectomy (PN). The decision of selection of a particular procedure depends on the patient's characteristics, tumor complexity, and experience of the surgeon. PN with any type of approach, namely, laparoscopic, open, or robotic, is comparable outcomes with regard to oncological results as RN in Stage T1a (4 cm) and T1b (4–7 cm) tumor.^[5] There is also good evidence that PN preserves renal function.^[6] Renal insufficiency has shown to impact negatively in cardiovascular outcome, and hence, the current evidence suggests that in a localized renal carcinoma, whenever technically feasible, PN should be undertaken.^[7]

However, anatomical placement of a tumor plays a paramount role in deciding the surgical approach. To help this decision-making and standardize tumor anatomical elements, different nephrometric scoring (NS) systems were designed.^[7,8]

The objective of this study was to verify the radius exophytic/endophytic nearness anterior/posterior location (RENAL) and preoperative aspects and dimensions used for an anatomical (PADUA) scoring systems to a cohort of patients receiving PN. Primary outcome was to determine the correlation between nephrometric scores, PADUA and RENAL scores separately, with perioperative and postoperative outcomes. Secondly, the study was to determine the operation time (OT), estimated blood loss (EBL), hospital length of stay (LOS), and changes in estimated glomerular filtration rate (eGFR) after 6 months of operation as quantitative perioperative outcomes.

MATERIALS AND METHODS

Patient selection

Clinical and radiological data were extracted retrospectively for patients of all age, who underwent open PN between

June 2006 and June 2016, for T1a and T1b renal tumors, irrespective of technique used (minimally invasive technique or open technique) at our institution. All PNs were performed by two main consultant urologists with special interest in kidney cancer and extensive experience in PN. We excluded cases where PN was performed for emergency indications and for local recurrence. Of the initial study population of 179 patients in total, 38 patients were excluded from the study, which involved 20 patients due to a lack of digital imaging data and 18 due to a lack of various perioperative and postoperative data. The final study population consisted of 141 patients [Figure 1].

Data collection

Tumor assessment and nephrometric scores

Abdominal computerized tomography or magnetic resonance imaging data performed preoperatively in each patient was used to determine the nephrometric scores for each renal mass. If there were multiple masses in one patient, nephrometric scores were obtained for all masses and the mass with the highest score served as the reference score for that patient. Nephrometric scores were calculated by two urology trainees. These junior urology trainees were given a formal teaching session on scoring by a designated consultant urologist. They were deemed adequately trained to calculate the scores after interobserver agreement was achieved in five consecutive cases, which was done after assessing images on multiple cases. All nephrometric scores were numbered continuously as absolute values and categorically according to complexity level.

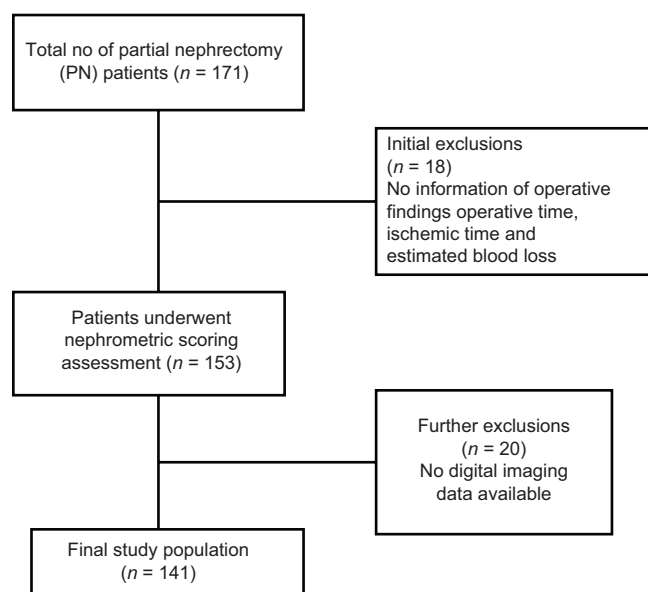


Figure 1: CONSORT diagram showing the flow of study population through the study

According to the RENAL scoring system, the following variables and scores were allocated for every tumor:

1. Tumor size (R): ≤ 4 cm – 1 point, 4.1–7 cm – 2 points, > 7 cm – 3 points
2. Tumor location into the parenchyma (E): $\geq 50\%$ exophytic – 1 point, $< 50\%$ exophytic – 2 points, entirely endophytic – 3 points
3. Nearness to the renal sinuses/collecting ducts in mm (N): ≥ 7 – 1 point, < 7 but > 4 – 2 point, ≤ 4 mm/touching the renal sinus – 3 points
4. Anterior – a/posterior – p (A)
5. Location relative to the polar line (L): Entirely above the upper or below the lower polar line – 1 point, lesion crosses polar line – 2 points, $> 50\%$ of mass is across polar line or mass crosses axial renal midline or mass is entirely between the polar lines – 3 points.^[9]

The RENAL nephrometric score ranges continuously from 4 to 12. Complexity of renal masses according to RENAL score was then stratified into low,^[4-6] intermediate,^[7-9] and high.^[10-12]

As per the PADUA scoring system, the following variables and scores were allocated for every tumour:

1. Tumor size: ≤ 4 cm – 1 point, 4.1–7 cm – 2 points, > 7 cm – 3 points
2. Tumor location into the parenchyma: $\geq 50\%$ exophytic – 1 point, $< 50\%$ exophytic – 2 points, entirely endophytic – 3 points
3. Tumor entirely above/below or crossing sinus line by $< 50\%$ – 1 point, $> 50\%$ between sinus line – 2 points
4. Rim location: Lateral – 1 point and medial – 2 points
5. Renal sinus involvement: Not involved – 1 point; involved – 2 points; longitudinal location: Upper or inferior pole – 1 point; middle pole – 2 points
6. Urinary collecting system involvement: Not involved – 1 point, dislocated or infiltrated – 2 points.^[10]

Designated consultant urologist evaluated the discrepancies between the two junior trainees' scoring, and a final score was agreed after discussion.

The PADUA nephrometric score ranges continuously from 6 to 14. Complexity of renal masses according to PADUA score was then stratified into low,^[6-7] intermediate,^[8-9] and high (≥ 10).

Along with the nephrometric scores, for each patient, preoperative characteristics of patient's gender, age, American Society of Anesthesiologists (ASA) score, and eGFR were collected from the hospital database. Perioperative details of OT, ischemic time (IT), ischemic

type-warm/cold/none, and EBL were collected from the operative notes.

Postoperative details of immediate and 6-month eGFR, surgical and medical complications (wound infection, postoperative collection, myocardial infarction, chest infection, pulmonary embolism, respectively) classified according to the Clavien–Dindo grading system (ranges from 1 to 5),^[11] unplanned intensive therapy unit, and hospital LOS were collected from discharge letters on the clinical portal.

Statistical analysis

For univariate analysis, when the outcome variable and the predictor both were continuous, linear regression (F -tests) was used to test for significance of the association. If the outcome was continuous but the predictor was categorical, F -tests were used to compare the means of different groups. If the outcome variable was binary, logistic regression was used to estimate the odds ratio (OR) and Chi-squared tests to test for significant association whether the predictor is continuous or categorical. For multivariate analysis, logistic regression was used to predict ischemia type and postoperative complications using RENAL and PADUA score components controlling for age, body mass index (BMI), sex, and ASA grade.

Linear regression analysis was used to build the prediction models, IT, postoperative eGFR, OT, blood loss, hospital LOS, and changes in 6-month postoperative eGFR. Total PADUA score or total RENAL score as a predictor in the multivariate analysis was not included as that would enhance the multicollinearity of the problem. All variables were considered statistically significant if $P < 0.05$.

The internal consistency of the individual component scores of the RENAL and PADUA systems was accessed using intraclass correlations with the average measure. All computations are performed using SPSS 22.

RESULTS

Patient demographics are shown in Tables 1 and 2 with separated RENAL and PADUA characteristics and outcomes corresponding to the complexity groups. The study population consisted of 141 patients with 93 men and 48 women, with a mean age of 56.1 ± 14.9 years. Mean BMI was calculated as 29.3 ± 6.4 kg/m² and eGFR (Modification of Diet in Renal Disease 7) was 75.4 ± 18.0 mL/min/1.7 m². Mean renal mass size was 3.4 ± 2.1 cm. The mean RENAL nephrometric score was 6.9 ± 2.2 and mean PADUA nephrometric score was 8.4 ± 1.1 .

Table 1: Preoperative characteristics and outcomes of the low-, intermediate-, and high-complexity groups in radius exophytic/endophytic nearness anterior/posterior location scoring

RENAL score	Low (4-6)	Intermediate (7-9)	High ≥ 10	P
Mean age at operation	57	56	40	-
Number of patients (%)	56 (40)	79 (56)	6 (<1)	-
Gender				-
Male	34	57	2	
Female	22	22	4	
Mean BMI	33.4 \pm 12.5	28.9 \pm 0.7	28.7 \pm 5.6	-
ASA grade				
Grade I	10	17	3	-
Grade II	34	50	3	
Greater than equal Grade III	12	12	0	
WHO performance grade				
0	17	17	2	
1	29	43	3	-
≥ 2	02	09	0	
Mean OT (mins)	172.5 \pm 31.8	150 \pm 0	175 \pm 2.3	0.917
Mean IT (mins)	35 \pm 0	37.5 \pm 3.5	57 \pm 1	0.032*
Mean blood loss (ml)	130 \pm 70.7	135 \pm 30.2	150 \pm 45.9	0.487
Mean postoperative eGFR at 6 months (ml/min)	66 \pm 10.6	59 \pm 7.3	69 \pm 4.5	0.727
Mean LOS	6 \pm 1.4	5.5 \pm 2.1	9 \pm 1.4	0.992
Clavien–Dindo grade				
Number of patients (%)				
Grade 1-2	26 (46)	22 (27)	3 (50)	0.607
Grade 3-5	4 (7)	5 (6)	0	

* $P < 0.05$, statistically significant value. ASA: American Society of Anesthesiologists, BMI: Body mass index, eGFR: Estimated glomerular filtration rate, LOS: Length of stay, OT: Operative time, IT: Ischemic time, RENAL: Radius exophytic/endophytic nearness anterior/posterior location

Table 2: Preoperative characteristics and outcomes of the low, intermediate, and high-complexity groups in preoperative aspects and dimensions used for an anatomical scoring

PADUA score	Low (6-7)	Intermediate (8-9)	High ≥ 10	P
Mean age at operation	57	59	50	-
Number of patients (%)	45 (32)	55 (39)	41 (29)	-
Gender				-
Male	28	40	25	
Female	17	15	16	
Mean BMI	31 \pm 3.4	29 \pm 5.7	28 \pm 7.1	-
ASA grade				
Grade I	6	6	6	-
Grade II	30	33	26	
Greater than equal Grade III	7	11	6	
WHO performance grade				
0	13	13	11	
1	26	28	23	-
≥ 2	5	9	4	
Mean OT (min)	158 \pm 1.8	168 \pm 1.4	181 \pm 3.0	0.483
Mean IT (min)	29.2 \pm 1.1	30.8 \pm 1.5	33.3 \pm 2.1	0.167
Mean blood loss (ml)	326 \pm 17.7	237 \pm 20.2	255 \pm 4.9	0.592
Mean postoperative eGFR at 6 months (ml/min)	56 \pm 3.5	70 \pm 5.3	71 \pm 4.5	0.412
Mean LOS	7 \pm 0.4	7.2 \pm 2.0	7.07 \pm 1.4	0.839
Clavien–Dindo grade				
Number of patients (%)				
Grade 1-2	23 (51)	16 (29)	12 (29)	0.379
Grade 3-5	3 (6)	3 (5)	3 (7)	

* $P < 0.05$, statistically significant value. ASA: American Society of Anesthesiologists, BMI: Body mass index, eGFR: Estimated glomerular filtration rate, LOS: Length of stay, OT: Operative time, IT: Ischemic time, PADUA: Preoperative aspects and dimensions used for an anatomical

Perioperative and postoperative complications are shown in Table 3. Forty-five patients had complications grading between 1 and 5 on Clavien–Dindo classification. Nine patients had grade >2 complications on Clavien–Dindo classification. Details are provided in Tables 1 and 2, in comparison with different complexity scores of RENAL

and PADUA, respectively. In our series, two patients had cardiac arrest and death in the immediate postoperative period, one patient had RN secondary to postoperative bleed and failed embolization, three patients had embolization secondary to postoperative bleed, and two patients had urine leak requiring ureteric stent insertion.

Primary outcomes results

In the univariate analysis of IT, total RENAL score (F1,119 = 4.717, P = 0.032), Categorized RENAL score (F2, 110 = 15.807, P = 0.000), the component score, R (F1, 119 = 8.410, P = 0.004), the component score, E (F1, 109 = 5.416, P = 0.022), and the component score, L (F1, 105 = 6.650, P = 0.011) were significantly associated with ischaemic time [Figures 2 and 3]. Among the PADUA score components, total PADUA score (F1, 112 = 5.982, P = 0.016) was significantly associated with IT.

In multivariate analysis (to build a prediction model), the RENAL component scores R (F1, 85 = 0.024), E (F1, 85 = 6.648, P = 0.012), and L (F1, 85 = 5.775, P = 0.018) were significant predictors. The control variables age, BMI, sex, and ASA grade were not significant. In this model, r² = 0.253.

In the univariate analysis of ischemic type (warm/cold or none), categorized total RENAL score (P = 0.035) and the RENAL component score, N (OR: 1.678, P = 0.040) were

significant. With multivariate analysis controlling for other variables, the RENAL component score E (OR: 5.506, P = 0.032) and the PADUA component score, collecting system score (OR: 7.684, P = 0.016), and age (OR: 0.938, P = 0.031) were significant in predicting the probability of ischemic use.

Using the Clavien–Dindo score in a continuous scale as a measure of postoperative complications, the univariate analysis showed PADUA component score: sinus line location (F1, 139 = 7.311, P = 0.008), lateral/medial rim score (F1, 139 = 4.858, P = 0.029), and collecting system score (F1, 139 = 7.882, P = 0.006) were significant. The ASA grade (F3, 174 = 3.675, P = 0.013) was also significant. With a multivariate analysis using linear regression, only the PADUA component score: lateral/medial rim score (F1, 103 = 5.450, P = 0.022) was significant. In this model, r² = 0.153.

When postoperative complications were measured in binary (yes/no), the univariate analysis showed the RENAL component score, N (OR: 0.576, P = 0.006), categorized PADUA score (P = 0.046), PADUA score component: sinus line location (OR: 0.392, P = 0.011), lateral/medial rim score (OR: 2.727, P = 0.020), relation to renal sinus (OR: 463, P = 0.027), and collecting system score (OR: 0.141, P = 0.000) were significant. Using multivariate analysis controlling from age, sex, ASA grade, and BMI, only the PADUA component score: lateral/medial rim score (OR: 10.328, P = 0.004) and collecting system score (OR: 0.119, P = 0.001) were significant.

Association of postoperation eGFR was analyzed using univariate analysis. This showed the RENAL component score L (F1, 58 = 4.662, P = 0.035) and age (F1, 82 = 8.465, P = 0.005) were significant. None of the predictors considered here are significant in the

Table 3: Peri- and post-operative complications observed in the present series

Complications	All patients (n=45)
Severe abdominal pain; ileus/constipation	8
Postoperative temperature spike	4
Urine leak	2
Urinary tract infection	1
Acute kidney injury	8
Blood transfusion	4
Renal artery thrombosis	4
Hospital-acquired pneumonia	9
Pulmonary embolus	1
Fast atrial fibrillation	2
Postoperative infection	1
RN	1
Secondary bleeding requiring embolization	3
High blood pressure	1
Sepsis needing ITU admission	2
Cardiac failure and death	2

RN: Radical nephrectomy, ITU: Intensive Therapy Unit

Table 4: P values of univariate and multivariate analysis showing correlation between radius exophytic/endophytic nearness anterior/posterior location and its components with various outcomes

	IT		OT		EBL		Clavien–Dindo complication		eGFR (6 m)		Hospital LOS	
	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA
Total RENAL score	0.032*	-	0.931	-	0.627	-	0.704	-	0.490	-	0.549	-
Total RENAL score (categorized)	0.000*	-	0.917	-	0.487	-	0.607	-	0.727	-	0.992	-
R	0.004*	0.024*	0.870	0.950	0.183	0.762	0.298	0.248	0.998	0.883	0.608	0.458
E	0.022*	0.012*	0.588	0.153	0.661	0.266	0.595	0.999	0.917	0.268	0.814	0.281
N	0.401	0.633	0.884	0.697	0.672	0.981	0.423	0.908	0.332	0.051	0.016*	0.214
A	0.116	0.052	0.985	0.809	0.085	0.049*	0.891	0.585	0.618	0.122	0.024*	0.109
L	0.011*	0.018*	0.800	0.605	0.957	0.123	0.306	0.818	0.991	0.137	0.278	0.558

*Statistically significant P value. UVA: Univariate Analysis, MVA: Multivariate analysis, eGFR: Estimated glomerular filtration rate, R: Tumor size, E: Tumor location into the parenchyma, N: Nearness to the renal sinuses/collecting ducts, A: Anterior-a or posterior-p tumor location, L: Location relative to the polar line, EBL: Estimated blood loss, OT: Operative time, IT: Ischemic time, LOS: Length of stay, RENAL: Radius exophytic/endophytic nearness anterior/posterior location

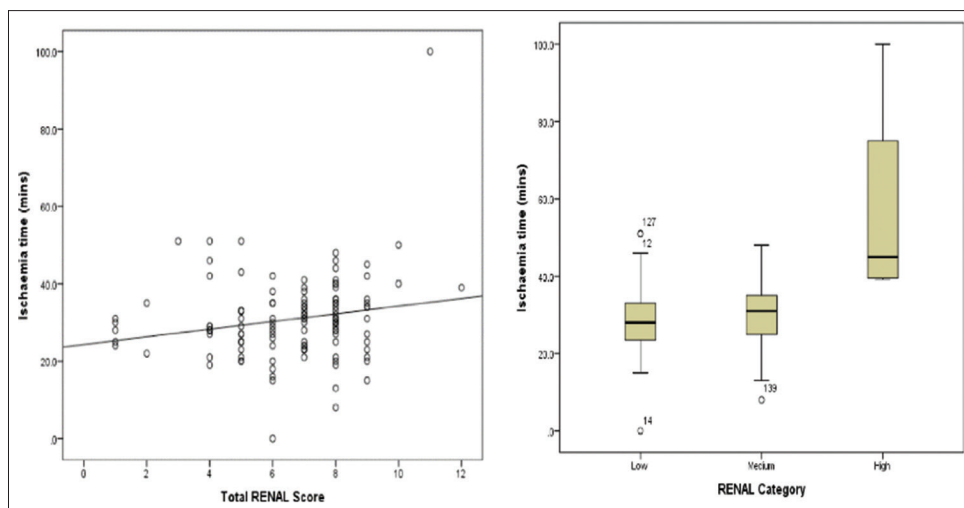


Figure 2: Ischaemic time increased with the total RENAL score. This is more evident with boxplots of ischemic time against the categories of the RENAL score

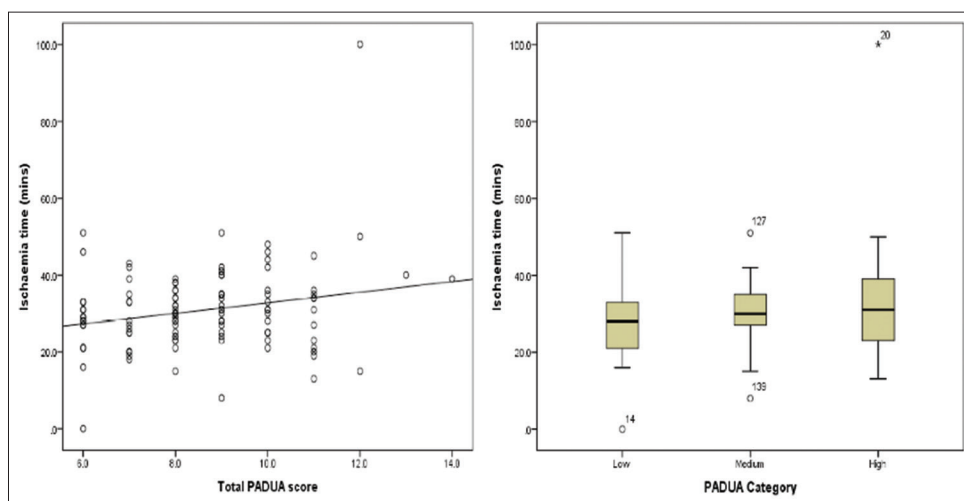


Figure 3: Ischemic time increased with the total preoperative aspects and dimensions used for an anatomical score; however, this is poorly evident on boxplots of ischemic time against the categories of the preoperative aspects and dimensions used for an anatomical score

multivariate analysis. Tables 4 and 5 shows *P* values of univariate and multivariate analyses showing correlation between RENAL, PADUA, and its components with various outcomes respectively. Table 6 shows *P* values of univariate and multivariate analyses showing correlation between age, sex, BMI, and ASA grade with various outcomes.

Secondary outcomes results

In the univariate analysis of OT, none of the variables were significant. Only age ($F1, 135 = 3.736, P = 0.055$) was close to the significance level. Similarly, none of the predictors are significant in the multivariate analysis. The PADUA component score lateral/medial rim score ($F1, 84 = 3.767, P = 0.056$) was close to the significance level. In this model, $r^2 = 0.148$.

Univariate analysis of the predictors with the EBL showed none of the variables were significant. The multivariate analysis showed the RENAL score component: A ($F1, 91 = 3.977, P = 0.049$) was significant in predicting EBL when controlled for other variables. In this model, $r^2 = 0.079$.

In the univariate analysis of hospital LOS, the RENAL component score, N ($F1, 132 = 5.901, P = 0.016$), A ($F1, 112 = 5.215, P = 0.024$), the PADUA component score: sinus line location ($F1, 133 = 6.616, P = 0.011$), and relation to renal sinus ($F1, 133 = 4.064, P = 0.046$) were significant. In the multivariate analysis, the PADUA component score: sinus line location ($F1, 94 = 7.042, P = 0.009$) was a significant predictor controlling for other variables. In this model, $r^2 = 0.229$.

Table 5: P values of univariate and multivariate analysis showing correlation between preoperative aspects and dimensions used for an anatomical and its components with various outcomes

	IT		OT		EBL		Clavien–Dindo complication		eGFR (6 m)		Hospital LOS	
	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA
Total PADUA score	0.016*	-	0.753	-	0.712	-	0.483	-	0.749	-	0.779	-
Total PADUA score (categorized)	0.167	-	0.483	-	0.592	-	0.379	-	0.412	-	0.839	-
R	0.004*	-	0.870	-	0.183	-	0.298	-	0.998	-	0.608	-
E	0.022*	-	0.588	-	0.661	-	0.595	-	0.917	-	0.814	-
Sinus line location	0.431	0.579	0.287	0.392	0.692	0.984	0.008*	0.579	0.170	0.170	0.011*	0.011*
Lateral/medial rim score	0.147	0.545	0.142	0.056	0.770	0.996	0.029*	0.545	0.884	0.884	0.249	0.249
Relation to renal sinus	0.102	0.950	0.844	0.721	0.512	0.795	0.406	0.884	0.889	0.889	0.046*	0.046*
Collecting system score	0.970	0.229	0.547	0.436	0.337	0.808	0.006*	0.098	0.771	0.771	0.094	0.094

*Statistically significant P value. UVA: Univariate Analysis, MVA: Multivariate Analysis, eGFR: Estimated glomerular filtration rate, R: Tumor size, E: Tumor location into the parenchyma, EBL: Estimated blood loss, OT: Operative time, IT: Ischemic time, LOS: Length of stay, PADUA: Preoperative aspects and dimensions used for an anatomical

Table 6: P values of univariate and multivariate analysis showing correlation between age, sex, basal metabolic index, and anesthesiologist grade with various outcomes

	IT		OT		EBL		Clavien–Dindo complication		eGFR (6 m)		Hospital LOS	
	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA	UVA	MVA
Age	0.066	0.135	0.055	0.126	0.204	0.723	0.573	0.618	0.875	0.680	0.164	0.291
Sex	0.626	0.740	0.084	0.185	0.549	0.925	0.380	0.994	0.597	0.012*	0.160	0.471
BMI	-	-	0.728	-	0.399	-	0.886	-	0.647	-	0.665	-
ASA grade	0.799	-	0.722	0.334	0.796	0.963	0.013*	-	0.737	0.562	0.772	0.504

*Statistically significant P value. UVA: Univariate analysis, MVA: Multivariate analysis, eGFR: Estimated glomerular filtration rate, BMI: Basal metabolic index, EBL: Estimated blood loss, OT: Operative time, IT: Ischemic time, LOS: Length of stay

To measure the changes in 6-month postoperative eGFR, the difference between preoperative eGFR and the eGFR after 6 months of the operation was calculated. Univariate analysis showed that none of the predictor variables was significantly associated with the difference. However, the multivariate analysis revealed that the PADUA component score sinus line location ($F_{1, 20} = 15.571$, $P = 0.001$) was significant in predicting the eGFR difference. Sex ($F_{1, 20} = 7.727$, $P = 0.012$) was also significant predictor in the multivariate model. In this model, $r^2 = 0.558$.

The intraclass correlations for RENAL score and the PADUA scores were 0.459 ($P = 0.000$) and 0.597 ($P = 0.000$), respectively, showing significant consistency of the responses of these scores.

DISCUSSION

For stage T1a and T1b renal tumors, PN has become a standard therapeutic modality in the present time, specifically providing equivalent oncological results and decreased renal impairment when compared to RN.^[12,13] However, especially in case of complex renal tumors, the risks of postoperative complications are higher in PN compared with RN, despite the functional benefits.^[14] Hence, it is very important to have a cautious assessment of the tumour's anatomy before surgery and to understand

the balance of the possible adverse outcomes of PN with its expected functional benefits, which would assist urologists in selecting the best surgical approach for each patient^[15] as well as counseling the patient toward expected outcomes. Multiple studies have been conducted, mostly retrospective, to validate the predictability of perioperative and postoperative complications along with reproducibility of different NS systems. Although the scoring systems have shown satisfactory reproducibility, the prediction of perioperative and postoperative complications has not shown uniform results.^[11,16,17]

Kutikov and Uzzo *et al.* introduced integrated anatomical categorization system, RENAL scoring, to give a common nomenclature to describe renal tumors based on various criteria that were considered separately by different surgeons preoperatively and to standardize the findings of these tumors on cross-sectional imaging. At introduction, RENAL scoring was also intended to be used in comparing outcomes and developing metrics for treatment decision-making. It is based on five critical and reproducible anatomical features of renal masses.^[9] These components are scored according to a three-point scoring system, as explained earlier in the data collection area of this report.

Ficarra *et al.* introduced and demonstrated PADUA scoring classification in a prospective cohort who underwent PN.^[18] The main objective was to propose a standardized and

original classification system of renal tumors along with other parameters to assess the ability to predict the risk of overall complications in patients who had PN and to outline a complication risk group of patients according to the different score.^[10] When compared to RENAL, PADUA scoring uses the sinus borders in its evaluation based on the first slides that show the presence of adipose tissue, on axial images providing an advantage over the later which requires coronal reconstructions to define the polar lines limiting the sinus.^[19]

The first and second components in PADUA are similar to RENAL score, i.e., diameter of the tumor and the exophytic/endophytic properties of the tumor. It is also scored with 3-point scale for diameter and exophytic/endophytic properties similar to RENAL NS, 1- and 2-point scale depending on the location of tumour to the sinus crossing lines, relation to the lateral and medial rim of the kidney and relation to the renal sinus and collecting duct. Essentially when analyzed closely, both include most of the same tumor components, however, differ in definitions of some components such as location in relation to polar lines^[10]

These two systems have been commonly used by nephrectomists for preoperative evaluation and few studies have compared the two, presenting the reliability of both systems.^[19,20]

Since the introduction of these scoring systems, there have been few more scoring systems developed to estimate perioperative outcomes after PN including the centrality index (C-index)^[21] and the arterial-based complexity score.^[22,23]

In the present single-institutional retrospective study, we noted that RENAL and PADUA nephrometric scores and their individual components showed varied association with PN perioperative and postoperative outcomes.

On postoperative complication evaluation using Clavien–Dindo scoring classification and analyzing the data for grade >2 complications, the current study noted PADUA components; sinus line location in relation to the tumor, tumor location to lateral or medial rim, and tumor association to the collecting system showed significant association. Not surprisingly, the ASA grade also showed significance. On linear regression, only tumor location to lateral or medial rim was significant for grade >2 complications.

When all postoperative complications were measured in binary (yes/no) without using Clavien–Dindo classification,

RENAL component score “N”-nearness of the tumor to the sinus/collecting system showed significance along with PADUA components of sinus line location, location to lateral or medial rim, and association of collecting system. However, on controlling the variables, tumor location to lateral or medial rim was significant along with collecting system score.

Ellison *et al.*^[24] reported the data of 298 laparoscopic PN and robot-assisted PN (RAPN) patients; their outcomes were correlated with RENAL scoring and found to have significant correlations between the score and major postoperative complications ($P < 0.001$). Desantis *et al.*^[25] reported PADUA score having significant correlation with surgical (OR 1.31, $P = 0.02$) and overall (OR 1.12, $P = 0.04$) complications at ≤ 30 days of surgery. This retrospective study included a cohort of 118 patients with clinically localized renal tumors and who underwent PN in a single institution. The study, however, failed to show such correlations from RENAL score. Chen-Yu *et al.*^[26] evaluated 53 patients who had laparoscopic PN and reported RENAL score to be a valuable predictor of postoperative complications however failed to mention any statistical value in the article. This article also highlighted radius or nearness to the collecting system as independent predictors of major complication $P = 0.016$ and $P = 0.011$, respectively. Similarly, Simhan *et al.*^[27] evaluated 390 patients who had open PN or RAPN and reported significant correlation of higher complexity groups of RENAL scores to major complication rates ($P = 0.009$).

In our study, both RENAL and PADUA scores showed significant association with the IT. In particular, the total RENAL score categorized RENAL score and components of RENAL score specifically tumor size (R), tumor location into the parenchyma (E), and location of the tumor relative to the polar line (L) showed significant association. Total PADUA score also showed significant association; however, its components failed to show any association. On multivariate analysis, RENAL components: R, E, and L were significant predictors of IT.

Borghesi *et al.*^[28] studied 96 patients outcome, which were treated with open or laparoscopic PN, with both PADUA and RENAL scores. Both scores were reported showing significant correlation with longer warm IT (WIT) and higher postoperative complications in complex renal tumors. Bylund *et al.*^[15] in a retrospective study of 162 patients who underwent PN (irrespective of the technique used), evaluated the correlations between nephrometric scores, namely, the PADUA score, RENAL score, C-index, and

surgical outcomes. The authors demonstrated a statistically significant correlation with WIT ($P < 0.001$). Notably, the total PADUA score performed slightly better than the other systems for WIT and also correlated with the absolute change of eGFR after surgery [Table 7].

Ficarra *et al.*,^[29] in a retrospective, multi-institutional study with a cohort of 347 patients who underwent RAPN, reported that PADUA stratification was independently correlated with a WIT of >20 min after multivariable analyses and adjusted for effects of surgeon experience. The same group also showed independent association with perioperative complications. This study only assessed the outcome variables with PADUA system.

Zhang *et al.*^[30] reported the data of 245 patients treated with laparoscopic PN. The outcomes were correlated with RENAL and PADUA scoring. RENAL score was significantly correlated with WIT ($P = 0.03$); however, PADUA failed to show any correlation ($P = 0.22$). There was no significant association of RENAL score to any grade of complications ($P = 0.44$) neither was PADUA score ($P = 0.26$).

Long *et al.*^[31] in a retrospective study evaluated 177 patients, who underwent open PN and laparoscopic PN. Patient outcomes were correlated with RENAL scoring. After multivariate analysis reported RENAL scoring as an independent predictor of WIT ($P = 0.03$) and conversion to RN ($P = 0.008$). This study did not predict the occurrence of major complications ($P = 0.91$).

In the present study, neither scores nor any of the variables had any significant association with operative

time. Similarly, no association with any variables was noted in EBL on univariate analysis; however, the anterior location of the tumor (A), component of RENAL score on multivariate analysis, showed significance in predicting EBL. Components of RENAL scores N, A, and PADUA components sinus line location relation to renal sinus showed a significant association with hospital LOS. Again, sinus line location on adjusted multivariate analysis was a significant predictor of hospital LOS. On univariate analysis, none of the variables showed any significant association to change of postoperative eGFR; sinus line location of PADUA showed association on multivariate analysis as a predictor of change of eGFR.

Limitations of the study

We acknowledge that our presented data have limitations. This study being retrospective had limitations inherent to retrospective analyses such as recall bias and interviewer/observer bias. The study was in a small cohort of patients treated in a fixed period of time, thus lacked power calculation and limited statistical power of the analyses. All the patients in this cohort were operated in a single center, which would limit the external validity important to establish definitive associations of the nephrometric scores with outcome parameters and complications. We also appreciate that the study may have a resultant bias as 21% of patients (38/179) were excluded due to unavailability of digital images and other perioperative and postoperative data, which highlights missing of valuable information of one in every five patients.

CONCLUSION AND RECOMMENDATIONS

RENAL and PADUA scores were significant in correlating postoperative complications, IT, and LOS. From our experience, we noted that not only it is important to know the complexity score in predicting outcomes, it is also important to know the individual component of the score which can also give outcome predictions. We contemplate that these scoring systems can still be improved to help the broad clinical use for standardization, selection of patients for surgery, and prediction of the outcomes after surgery and involve patients in making informed decision.

We recommend further studies as prospective, multicenter, and larger cohort study to aid external validation. Similarly, with increase in minimal access techniques for PN, namely, laparoscopic and robotic, the nephrometric scores will also need separate validation in corresponding homogenous cohort.

Table 7: Correlation (yes/no) of nephrometric scores to outcomes of postoperative complications, ischemic time, and estimated glomerular filtration rate in different studies

	Postoperative complications		IT		Change in eGFR	
	RENAL	PADUA	RENAL	PADUA	RENAL	PADUA
Ellison <i>et al.</i>	Yes	NA	Yes		Yes	
Desantis <i>et al.</i>	No	Yes	No	No	No	No
Chen-Yu <i>et al.</i>	Yes*	NA	No	NA	No	NA
Simhan <i>et al.</i>	Yes	NA	Yes	NA	Yes	NA
Borghesi <i>et al.</i>	Yes	Yes	Yes	Yes	No	No
Bylund <i>et al.</i>	Yes	Yes**	No	Yes	No	Yes
Ficarra <i>et al.</i>	NA	Yes	NA	Yes	NA	No
Zhang <i>et al.</i>	No	No	Yes	No	No	No
Long <i>et al.</i>	No	No	Yes	No	No	No
Present study	Yes	Yes	Yes	Yes	No	Yes

*Article as has mentioned any statistical significant value. **Shows better statistical significance than other scoring system. NA: Not assessed, eGFR: Estimated glomerular filtration rate, IT: Ischemic time, PADUA: Preoperative aspects and dimensions used for an anatomical, RENAL: Radius exophytic/endophytic nearness anterior/posterior location

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Conflicts of interest

There are no conflicts of interest.

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