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

Sachin Yallappa¹², Rizwana Imran¹, Ishtiakul Rizvi¹, Omar M. Aboumarzouk², Rupesh Bhatt¹, Prashant Patel¹

¹Department of Urology, Queen Elizabeth Hospital, University Hospital of Birmingham, Birmingham, ²The Urology Research and Training Unit, Queen Elizabeth University Hospital, Glasgow, UK

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 (RENA(L) 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

Access this article online

Quick Response Code: 

Website: www.urologyannals.com

DOI: 10.4103/UA.UA_11_18

How to cite this article: Yallappa S, Imran R, Rizvi I, Aboumarzouk OM, Bhatt R, Patel P. 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. Urol Ann 2018;10:270-9.
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 (RENA L) 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. Secondarily, 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.
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): ≥50% exophytic – 1 point, <50% exophytic – 2 points, entirely endophytic – 3 points
3. Nearestness 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.

The RENAL nephrometric score ranges continuously from 4 to 12. Complexity of renal masses according to RENAL score was then stratified into low, intermediate, and high.

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: ≥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.

The PADUA nephrometric score ranges continuously from 6 to 14. Complexity of renal masses according to PADUA score was then stratified into low, intermediate, 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), 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.
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.

### 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        | 24                 | 2        | -     |
| Mean BMI | 33.4±12.5 | 28.9±0.7           | 28.7±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 | 92        | 99                 | 0        |       |
| Mean OT (mins) | 172.5±31.8 | 150±0              | 175±2.3  | 0.917 |
| Mean IT (mins) | 35±0      | 37.5±3.5           | 57±1     | 0.032* |
| Mean blood loss (ml) | 130±70.7 | 135±30.2           | 150±45.9 | 0.487 |
| Mean postoperative eGFR at 6 months (ml/min) | 66±10.6 | 59±7.3             | 69±4.5   | 0.727 |
| Mean LOS | 6±1.4     | 5.5±2.1            | 9±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±3.4    | 29±5.7             | 28±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±1.8 | 168±1.4            | 181±3.0  | 0.483 |
| Mean IT (min) | 29.2±1.1 | 30.8±1.5           | 33.3±2.1 | 0.167 |
| Mean blood loss (ml) | 326±17.7 | 237±20.2           | 255±4.9  | 0.592 |
| Mean postoperative eGFR at 6 months (ml/min) | 56±3.5 | 70±5.3             | 71±4.5   | 0.412 |
| Mean LOS | 7±0.4     | 7.2±2.0            | 7.07±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
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, $r^2 = 0.253$.

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 = 0.035) and the component score, L (OR: 2.727, P = 0.011) 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, $r^2 = 0.153$.

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: 4.63, 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

| 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 |

**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 |

| 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 |

**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

| Complication | UVA | MVA | OT | EBL | Clavien–Dindo | eGFR (6 m) | Hospital LOS |
|--------------|-----|-----|----|-----|--------------|-----------|-------------|
| 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.
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 ($F_1, 135 = 3.736, P = 0.055$) 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 ($F_1, 84 = 3.767, P = 0.056$) 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: $A$ ($F_1, 91 = 3.977, P = 0.049$) 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, $N$ ($F_1, 132 = 5.901, P = 0.016$), $A$ ($F_1, 112 = 5.215, P = 0.024$), the PADUA component score: sinus line location ($F_1, 133 = 6.616, P = 0.011$), and relation to renal sinus ($F_1, 133 = 4.064, P = 0.046$) were significant. In the multivariate analysis, the PADUA component score: sinus line location ($F_1, 94 = 7.042, P = 0.009$) was a significant predictor controlling for other variables. In this model, $R^2 = 0.229$. 

**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.
Yallappa, et al.: Validation of nephrometric scores

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 (F1, 20 = 15.571, P = 0.001) was significant in predicting the eGFR difference. Sex (F1, 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. However, especially in case of complex renal tumors, the risks of postoperative complications are higher in PN compared with RN, despite the functional benefits. 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 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.

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. 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. 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. 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.

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 tumor 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.

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.

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) and the arterial-based complexity score.

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/collection 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. 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. 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. 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. 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. 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. 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 outcomes of postoperative complications. Ischemic time, and change of eGFR after surgery

**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 |
|-----------------------------|----|----------------|
| Ellison et al. | Yes | NA | Yes | Yes |
| Desantis et al. | No | Yes | No | No | No |
| Chen-Yu et al | Yes* | NA | No | NA | No |
| Simhan et al. | Yes | NA | Yes | NA | Yes |
| Borghesi et al. | Yes | Yes | Yes | No | No |
| Bylund et al. | Yes | Yes* | No | Yes | No |
| Ficarra et al. | NA | Yes | NA | Yes | NA |
| Zhang et al. | No | No | Yes | No | No |
| Long et al. | No | No | Yes | No | No |
| Present study | Yes | Yes | Yes | 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

**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 contribution 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.
Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Cancer Research UK. Kidney Cancer Incidence by Sex and UK Country, 2014. Available from: http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/kidney-cancer/incidence#ref-0. [Last accessed on 2018 May 28].
2. Hock LM, Lynch J, Balaji KC. Increasing incidence of all stages of kidney cancer in the last 2 decades in the United States: An analysis of surveillance, epidemiology and end results program data. J Urol 2002;167:57-60.
3. Russo P. Renal cell carcinoma: Presentation, staging, and surgical treatment. Semin Oncol 2000;27:160-76.
4. Huang WC, Elkin EB, Levey AS, Jang TT, Russo P. Partial nephrectomy versus radical nephrectomy in patients with small renal tumors – Is there a difference in mortality and cardiovascular outcomes? J Urol 2009;181:55-61.
5. Gill IS, Aron M, Gervais DA, Jewett MA. Clinical practice. Small renal mass. N Engl J Med 2010;362:624-34.
6. Clark AT, Breau RH, Morash C, Fergussion D, Doucette S, Cagianos I, et al. Preservation of renal function following partial or radical nephrectomy using 24-hour creatinine clearance. Eur Urol 2008;54:143-49.
7. Brookman-May S. Utility of nephrometric scores in kidney cancer surgery. Eur Urol Suppl 2016;15:57.
8. Simmons MN, Ching CB, Samplaksi MK, Park CH, Gill IS. Kidney tumor location measurement using the C index method. J Urol 2010;183:1708-13.
9. Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: A comprehensive standardized system for quantifying renal tumor size, location and depth. J Urol 2009;182:844-53.
10. Remzi M, Klatte T, Waldert M. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol 2010;58:462.
11. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: A new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205-13.
12. Van Poppel H, Da Pozzo L, Albrecht W, Matveev V, Bono A, Borkowski A, et al. A prospective, randomised EORTC intergroup phase 3 study comparing the oncologic outcome of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. Eur Urol 2011;59:543-52.
13. Scosyrev E, Messing EM, Sylvester R, Campbell S, Van Poppel H. Renal function after nephron-sparing surgery versus radical nephrectomy: Results from EORTC randomized trial 30904. Eur Urol 2014;65:372-7.
14. Schiavina R, Mari A, Antonelli A, Bertolo R, Bianchi G, Borghesi M, et al. A snapshot of nephron-sparing surgery in Italy: A prospective, multicenter report on clinical and perioperative outcomes (the RECORDr I project). Eur J Surg Oncol 2015;41:346-52.
15. Bylund JR, Gayheart D, Fleming T. Association of tumor size, location, R.E.N.A.L. PADUA and centrality index score with perioperative outcomes and postoperative renal function. J Urol 2012;188:1684-9.
16. Moreno-Alarcón C, Ramírez-Backhaus M, Pelechano-Gómez P, Ortíz-Rodríguez IM, Rubio-Brones J, Rodríguez-Torreblanca C, et al. Nephrometry scores: Interobserver reproducibility and perioperative factors prediction. Actas Urol Esp 2014;38:523-9.
17. Okhunov Z, Rais-Bahrami S, George AK, Wiinangkner N, Daby B, Montag S, et al. The comparison of three renal tumor scoring systems: C-index, P.A.D.U.A. and R.E.N.A.L. nephrometry scores. J Endourol 2011;25:1921-4.
18. Ficarra V, Novara G, Secco S, Macchi V, Porzionato A, De Caro R, et al. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol 2009;56:786-93.
19. Chang X, Liu T, Zhang F, Qian C, Ji C, Zhao X, et al. The comparison of R.E.N.A.L. PADUA and centrality index score in predicting perioperative outcomes and complications after laparoscopic radio frequency ablation of renal tumors. J Urol 2015;194:897-902.
20. Yeon JS, Son SJ, Lee YJ, Cha WH, Choi WS, Chung JW, et al. The nephrometry score: Is it effective for predicting perioperative outcome during robot-assisted partial nephrectomy? Korean J Urol 2014;55:254-9.
21. Samplaksi MK, Hernandez A, Gill IS, Simmons MN. C-index is associated with functional outcomes after laparoscopic partial nephrectomy. J Urol 2016;192:2559-63.
22. Spaliviero M, Poon BC, Kaelo CA, Guglielmetti GB, Di Paolo PL, Belhco Corradi R, et al. An arterial based complexity (ABC) scoring system to assess the morbidity profile of partial nephrectomy. Eur Urol 2016;69:72-9.
23. Schiavina R, Novara G, Borghesi M, Ficarra V, Ahlawat R, Moon DA, et al. PADUA and R.E.N.A.L. nephrometry scores correlate with perioperative outcomes of robot-assisted partial nephrectomy: Analysis of the Vattikuti Global Quality Initiative in Robotic Urologic Surgery (GQI-RUS) database. BJU Int 2017;119:456-63.
24. Ellison JS, Montgomery JS, Hafez KS, Miller DC, He C, Wolf JS Jr., et al. Association of RENAL nephrometry score with outcomes of minimally invasive partial nephrectomy. Int J Urol 2013;20:564-70.
25. Desantis D, Lavallée LT, Witiuk K, Mallick R, Kamal F, Fergussion D, et al. The association between renal tumour scoring system components and complications of partial nephrectomy. Can Urol Assoc J 2015;9:39-45.
26. Chen-Yu W, Yu-Chi C, Chung-Hsien C. External validation of RENAL nephrometry score to assess the perioperative parameter for laparoscopic partial nephrectomy in a single institution. Urol Sci 2017;28:14-8.
27. Simhan J, Smalldone MC, Tsai KJ, Caner DJ, Li T, Kutikov A, et al. Objective measures of renal mass anatomic complexity predict rates of major complications following partial nephrectomy. Eur Urol 2011;60:724-30.
28. Borghesi M, Della Mora L, Brunocilla E, Schiavina R, Rizzi S, La Manna G, et al. Warm ischemia time and postoperative complications after partial nephrectomy for renal cell carcinoma. Actas Urol Esp 2014;38:313-8.
29. Ficarra V, Bhayani S, Porter J, Buffi N, Lee R, Cestari A, et al. Predictors of warm ischemia time and perioperative complications in a multicenter, international series of robot-assisted partial nephrectomy. Eur Urol 2012;61:395-402.
30. Zhang ZY, Tang Q, Li XS, Zhang Q, Mayer WA, Wu JY, et al. Clinical analysis of the PADUA and the RENAL scoring systems for renal neoplasms: A retrospective study of 245 patients undergoing laparoscopic partial nephrectomy. Int J Urol 2014;21:40-4.
31. Long JA, Arnoux V, Fiard G, Autorino R, Descotes JL, Rambeaud JJ, et al. External validation of the RENAL nephrometry score in renal tumours treated by partial nephrectomy. BJU Int 2013;111:233-9.