A “3S+f” Nephrometry Score System to Predict the Clinical Outcomes of Laparoscopic Nephron-Sparing Surgery

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Background: When we treat renal cell carcinoma by laparoscopic nephron-sparing surgery (NSS), it is essential to use an evaluation system to predict clinical outcomes. Hitherto, there are more than a dozen nephrometry score systems. In this study, through assessing the correlations between nephrometry score systems and clinical outcomes, we aim to provide a novel nephrometry score system—the “3S+f” score system—to simplify the evaluation of technical complexity of partial nephrectomy.

Methods: We retrospectively collected the data of 131 patients who underwent NSS, which was performed by a single surgeon (SZ) from January 2013 to July 2018 at Peking University Third Hospital. The “3S+f” score system contains four parameters: “size, side, site, and fat”, all of which can be obtained from preoperative imaging data. We evaluated the correlations between the “3S+f” score and clinical outcomes, and compared R.E.N.A.L. score and PADUA score.

Results: All the three nephrometry score systems were related to some clinical outcomes in univariate analyses. In multivariate regression models, the “3S+f” score, the R.E.N.A.L. score, and the PADUA score were significantly associated with operative time (p = 0.016, p = 0.035, and p = 0.001, respectively) and warm ischemia time (all p < 0.008, p < 0.001, and p < 0.001, respectively). “3S+f” was also significantly related to extubation time > 5 days (p = 0.018). In predicting operative time > 120 min and extubation time >5 days from ROC curves, the AUCs of the “3S+f” score (0.717 and 0.652, respectively) were larger than both the R.E.N.A.L (0.598 and 0.554, respectively) and PADUA (0.600 and 0.542, respectively) score systems.

Conclusion: A novel nephrometry score system—the “3S+f” score system—shows equivalent correlation and the ability in predicting clinical outcomes when compared to the R.E.N.A.L. score system and the PADUA score system, which can describe renal tumors.

Keywords: nephrometry score system, renal tumor, laparoscopy, nephron-sparing surgery, “3S+f” nephrometry score system
INTRODUCTION

The incidence of renal cell carcinoma (RCC) has increased over the last few decades, partly because of the widespread application of imaging, and has become one of the most common malignant tumors in the urinary system today (1, 2). Since the 1960s, Robson et al. have established radical nephrectomy (RN) as the treatment of choice for localized RCC, and it became the gold standard therapy for RCC (3). However, with the increasing early detection of kidney cancer and surgical technology, nephron-sparing surgery (NSS) has attracted the attention of an increasing number of urologists (4, 5). Compared to RN, NSS can provide similar oncologic outcomes and better preservation of renal function in most patients with small renal tumors (6–8). NSS has become the treatment of choice for renal tumors <7 cm (T1a+T1b) according to European Association of Urology guidelines (9).

Different surgical methods involve numerous technical aspects such as tumor exposure, tumor resection, and renal reconstruction. Thus, assessing the surgical anatomy of renal tumors is essential. In 2009, the first system (R.E.N.A.L. nephrometry score) to quantify renal tumor anatomy was developed by Kutikov and Uzzo (10). So far, more than a dozen nephrometry score systems have been developed (11–13). Most of the systems contain several parameters, and the scores can be obtained from preoperative sectional imaging. However, due to their computational complexities, the vast majority of them are hardly applied into practice. Hence, we developed a novel nephrometry score system called “3S+f” which stands for “size, site, side, and fat”, to quantify the anatomical characteristics of renal masses, aiming to simplify the process of assessment.

In this article, we introduce the “3S+f” nephrometry score system in detail and compare the clinical outcomes with two other common nephrometry score systems: the R.E.N.A.L. (radius, exophytic/endothytic properties, nearness of tumor to collecting system or sinus, anterior/posterior, hilar tumor touching the main renal artery or vein and location relative to polar lines) score system and the PADUA (preoperative aspects and dimensions used for an anatomical classification) score system (10, 14).

METHODS

We collected patients’ data retrospectively via the medical record system of the Peking University Third Hospital. To avoid interference from different surgeons, we obtained data of consecutive patients who underwent NSS performed by a single surgeon (SZ) from January 2013 to July 2018. The inclusion criteria for patients were as follows (1): solitary renal mass; (2) laparoscopic nephron-sparing surgery (LNSS); (3) non-solitary kidney; (4) no previous rupture and bleeding of the tumor; and (5) not zero ischemia.

Patients’ epidemiological characteristics included sex, age, height, weight, body mass index (BMI), and comorbidity. Respective parameters and scores of the “3S+f” score system (intrarenal tumor diameter, tumor location, distance to artery/vein/collecting system, and perinephric fat), the R.E.N.A.L. score system (radius, exophytic/endothytic properties, nearness of tumor to collecting system or sinus, anterior/posterior, hilar tumor touching the main renal artery or vein and location relative to polar lines) and the PADUA score system (anterior or posterior face, longitudinal location, rim location; relationships with sinus; relationships with the urinary collecting system; percentage of tumor deepening into the kidney and maximal diameter in centimeters) were defined and calculated according to the described protocols for those systems from preoperative computed tomography (CT) or magnetic resonance imaging (MRI). American Society of Anesthesiologists (ASA) score and preoperative creatinine (Cr)/hemoglobin (Hb) were also recorded. Clinical outcomes included operative time (OT), warm ischemia time (WIT), estimated blood loss (EBL), reduction in Hb, increase in Cr during operation, postoperative length of stay (PLOS), extubation time (ET), and postoperative complication. Complications were classified according to Clavien–Dindo classification. We also collected information on tumor pathology and T stage as defined by TNM 8th classification (15).

Nephrometry Score Systems

The “3S+f” score consists of four simple separate variables: “size, site, side, and fat”. “Size” refers to the intrarenal diameter of the mass rather than tumor diameter (Figure 1A). Actually, after removing the tumor, the volume of renal reconstruction is determined by direct intrarenal tumor volume, indicating the operative complexity to a certain extent. We use the intrarenal diameter of the mass to simplistically represent the intrarenal volume of tumor. “Site” means tumor location (Figures 1B–D). In most circumstances, the location of tumor has the greatest correlation with the difficulty of the surgery. Suture is much easier when the tumor is located at the lateral/upper pole, compared to the medial/lower pole. While the renal hilar tumor is close to renal vessels, it is difficult to fix the position of an endothytic tumor, and a cystic tumor is easy to break. Resecting the tumor in these positions is technically challenging. “Side” signifies the distance of the tumor to the artery/vein/collecting system (Figure 1A). Many other nephrometry score systems also take this parameter into account. A mass being too close to the artery/vein/collecting system will greatly increase the difficulty of operation. “Fat” denotes the situation of perinephric fat (Figures 1E, F). Few nephrometry score systems include this variable. When adhesion exists in perinephric fat, the surgical procedure becomes very complicated and time-consuming. Meanwhile, the renal capsule becomes prone to tearing and bleeding, and could even cause extensive exfoliation of renal cause.
capsule and tissues adhering to perinephric fat. Perinephric fat that is sticky or thick as shown in the preoperative CT or MRI will be given 3 points, whereas little or no fat will be given 1 point. Fat classified in between thick fat and little fat will be given 2 points. The detailed scoring rules are shown in Table 1.

The “3S+f” score is further categorized into three groups: low, moderate, and high complexity according to total scores, corresponding to 4–6 points, 7–9 points, and 10–12 points, respectively; the same goes with the R.E.N.A.L. score. For the PADUA score, it is 6–7 points, 8–9 points, and 10–14 points.

**Statistical Analysis**

All data analyses were performed by SPSS version 23.0. Spearman correlation analysis was conducted between variables and clinical outcomes. Kruskal–Wallis test was used to evaluate the intergroup distribution differences of three score systems with OT, WIT, EBL, and ET. When finding a significant difference, Bonferroni-adjusted pairwise comparisons were conducted by Mann–Whitney tests. Then, multivariate regression models adjusted for age, sex, comorbidity, BMI, ASA score, and preoperative Cr were constructed to assess the associations between nephrometry score systems’ parameters and clinical outcomes. Multivariable linear regression models were created to evaluate the independent associations between each nephrometry score system and OT or WIT. Clinical outcomes, such as the EBL, ET, and complication, were treated as binary variables, and multivariate binary logistic regression models were designed to assess the abilities of nephrometry score systems’ parameters that predicted these clinical outcomes. According to our hospital’s experience, we defined 100 ml as the demarcation point for EBL and 5 days for ET. Furthermore, receiver operating characteristic (ROC) curves were plotted and areas under the curve (AUCs) were calculated by using a nonparametric distribution assumption for nephrometry score systems to predict OT > 120 min, WIT > 30 min, and ET > 5 days. Statistical significance was set as \( p < 0.05 \) two-sided.

**RESULTS**

A total of 131 consecutive patients were identified and enrolled in our research eventually, whose laparoscopic NSS was
performed by the same surgeon (SZ) from January 2013 to July 2018 at Peking University Third Hospital. The demographic and clinical characteristics are summarized in Table 2. Among the 131 patients, 60.31% were men and 39.69% were women. The mean age of the patients was 53.60 (18–80), and the mean body mass index (BMI) was 25.30 (16.52–35.91) kg/m². There were 66 (50.38%) patients who had comorbidities such as hypertension, diabetes, smoking history, and chronic renal disease. Sixty-nine (52.67%) patients’ masses were in the left kidney while 62 (47.33%) were in the right. The average ASA score was 1.76. The mean diameter of tumors was 3.07 cm. The mean (47.33%) were in the right. The average ASA score was 1.76. The mean (47.33%) were in the right. The average ASA score was 1.76.

### Table 2 | The demographic and clinical characteristics of the patients.

| Characteristics | Value (range or n %) |
|-----------------|-----------------------|
| **Sex**         |                       |
| Male            | 79 (60.3%)            |
| Female          | 52 (39.7%)            |
| **Age (years)** |                       |
|                 | 53.60 (18–80)         |
| **BMI (kg/m²)** |                       |
|                 | 25.30 (16.52–35.91)   |
| **Comorbidity** |                       |
| Yes             | 66 (50.38%)           |
| No              | 65 (49.62%)           |
| **ASA**         | 1.76                  |
| **Preoperative Cr (µmol/L)** | 84.19 (46–328) |
| **Preoperative Hb (g/L)** | 138.06 (86–168) |
| **Diameter (cm)** | 3.07 (1.00–9.10) |
| **Location**    |                       |
| Left            | 69 (52.67%)           |
| Right           | 62 (47.33%)           |
| **3S+f**        |                       |
| Low             | 22 (16.79%)           |
| Moderate        | 100 (76.33%)          |
| High            | 9 (6.67%)             |
| **R.E.N.A.L.**  |                       |
| Low             | 41 (31.30%)           |
| Moderate        | 74 (56.49%)           |
| High            | 16 (12.21%)           |
| **PADUA**       | 8.95                  |
| Low             | 30 (22.90%)           |
| Moderate        | 46 (35.11%)           |
| High            | 55 (41.98%)           |
| **OT (min)**    | 137.99                |
| **WIT (min)**   | 22.85                 |
| **EBL (ml)**    | 88.24                 |
| **ET (days)**   | 4.73                  |
| **PLOS (day)**  | 7.02                  |
| **Complication**|                       |
| No              | 121 (92.37%)          |
| I               | 5 (3.82%)             |
| II              | 4 (3.05%)             |
| III             | 1 (0.76%)             |
| **Increase in Cr (µmol/L)** | 11.20 (–9–69) |
| **Reduction in Hb (g/L)** | 14.95 (–21–394) |

**Histology**

- **Malignant**
  - Clear cell: 84 (64.12%)
  - Papillary cell: 8 (6.11%)
  - Chromophobe cell: 5 (3.82%)
  - Others: 4 (3.05%)

- **Benign**
  - Angiomyolipoma: 11 (8.40%)
  - Oxy: 10 (7.63%)
  - Oncocytoma: 5 (3.82%)
  - Others: 4 (3.05%)

**Surgery margin**

- Negative: 111 (84.73%)
- Positive suspiciously: 20 (15.27%)

**T stage**

- T1a: 108 (82.44%)
- T1b: 21 (16.03%)
- T2: 2 (1.53%)

ASA: American Society of Anesthesiologists; OT, operative time; WIT, warm ischemia time; EBL, estimated blood loss; ET, exflagitation time; PLOS, postoperative length of stay; Cr, creatinine; Hb, hemoglobin.

*Positive suspiciously: Cancer cells and suspicious but not certain cancer cells can be seen at the pathological specimen of margins.*

R.E.N.A.L. score and WIT (p < 0.001) but the R.E.N.A.L. score was not related to OT, EBL, or ET. The PADUA score, however,
was statistically significantly different with OT ($p = 0.002$), WIT ($p < 0.001$), and EBL ($p = 0.040$).

Furthermore, we analyzed the correlations of different nephrometry score systems for the malignant and benign masses (Supplementary Table 1), but there was no correlation between the nephrometry score system and the malignant or benign masses.

To further substantiate the relationships between nephrometry scores and clinical outcomes, we adjusted age, sex, comorbidity, BMI, ASA score, and preoperative Cr to construct the models of multivariable regression analyses. According to Table 5, all three nephrometry scores were significantly associated with OT and WIT. For every 1 point increase in the “3S+f” score, an increase in average OT of \(2.736, p = 0.040\) was observed, while the increase was 4.507 min (95% CI 0.319–8.694, \(p = 0.035\)) in the R.E.N.A.L. score and 7.365 min (95% CI 1.295–2.824, \(p < 0.001\)) in the PADUA score. Compared with the low-complexity groups, the high-complexity groups’ “3S+f” score ($p < 0.001$) and PADUA score ($p = 0.006$) were statistically significantly related to OT, while this was not found in the R.E.N.A.L. score. The \(r^2\) values for each scoring system model were 0.136 (“3S+f”), 0.125 (R.E.N.A.L.), and 0.174 (PADUA), indicating that none of these models can explain a high proportion of OT variability.

The proportion of WIT explained by each scoring system was also low: \(r^2 = 0.035 (“3S+f”), r^2 = 0.170 (R.E.N.A.L.), and r^2 = 0.170 (PADUA).\) For every 1 point increase in the “3S+f” score, there was an increased WIT of 1.517 min (95% CI 0.405–2.628, \(p = 0.008\)), and the increase was 1.995 min (95% CI 1.254–2.736, \(p < 0.001\)) in the R.E.N.A.L. score and 2.039 min (95% CI 1.295–1.824, \(p < 0.001\)) in the PADUA score. Compared with the low-complexity groups, the high-complexity groups’ three score systems (all \(p < 0.001\)) were all significantly related to WIT, and the moderate-complexity groups’ R.E.N.A.L. score system ($p < 0.001$) was significantly correlated with WIT.

None of these three systems were related to EBL > 100 ml. In predicting OT > 120 min and ET > 5 days, based on ROC curves, the AUCs of the “3S+f” score system (0.717 and 0.652, respectively) were larger than both R.E.N.A.L. (0.598 and 0.554, respectively) and PADUA (0.600 and 0.542, respectively) score systems. For predicting WIT > 30 min, the AUC of the “3S+f” score system (0.670) was also nearly equal to R.E.N.A.L. (0.732) and PADUA (0.701) score systems (Figure 2).

**DISCUSSION**

In the treatment of RCC, minimally invasive surgery has been developing rapidly in recent years. The main purposes are to preserve normal renal tissue as much as possible while ensuring complete tumor resection and to reduce perioperative complications. LNSS is now commonly performed to resect solitary kidney tumors. A retrospective study comparing open partial nephrectomy (OPN) with laparoscopic partial nephrectomy (LPN) in the treatment of T1 renal masses found that LPN had less blood loss, shorter surgical duration, and reduced hospital stay (16). Moreover, LPN had similar intraoperative complications (1.8% vs. 1%), similar positive surgical margin rates (1.6% vs. 1%), and similar 3-year oncologic and renal functional outcomes compared to OPN. Although LPN needs more WIT due to its operational difficulty and more postoperative hemorrhage, the advantages of LPN are still obvious. Preoperative assessment of renal mass is essential, but to translate the anatomy of renal tumor into visual data, a standard guide is still lacking, although more than a dozen nephrometry score systems were designed so far. Here, we

| TABLE 3 | Spearman correlation analysis between variables and clinical outcomes. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | OT              | WIT             | EBL             | Reduction in Hb | Increase in Cr  | PLOS            | ET              |
| Size            | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| Site            | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| Side            | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| Fat             | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| 3S+f            | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| R.E.N.A.L.      | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| PADUA           | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| Age             | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| BMI             | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |
| ASA             | Coefficient     |                 |                 |                 |                 |                 |                 |
| $p$             |                 |                 |                 |                 |                 |                 |                 |

ASA, American Society of Anesthesiologists; OT, operative time; WIT, warm ischemia time; EBL, estimated blood loss; ET, extubation time; PLOS, postoperative length of stay; Cr, creatinine; Hb, hemoglobin.
**TABLE 4 |** Kruskal-Wallis test of different nephrometry score systems’ categorized scores.

| Variables | I (Low) | II (moderate) | III (high) | H | p |
|-----------|---------|---------------|------------|---|---|
| **3S+f**  | n=22    | n=100         | n=9        |    |   |
| OT (min)  | 132.50 (102.00-148.25) | 128.50 (107.25-157.00) | 196.00 (150.00-243.00) | 12.486 | 0.002 |
| WIT (min) | 17.50 (15.00-24.50)    | 22.00 (18.75-27.25)    | 31.00 (27.00-40.00)    | 12.173 | 0.002 |
| EBL (ml)  | 20.00 (10.00-87.50)    | 50.00 (20.00-100.00)   | 100.00 (100.00-150.00) | 6.517  | 0.014 |
| ET (day)  | 5.00 (3.00-6.00)       | 6.00 (5.00-6.00)       | 6.00 (5.00-6.00)       | 4.463  | 0.107 |
| **R.E.N.A.L.** | n=41   | n=74          | n=16       |    |   |
| OT (min)  | 130.00 (105.00-151.00) | 127.00 (108.25-164.00) | 142.00 (134.00-159.75) | 3.687  | 0.158 |
| WIT (min) | 17.00 (14.00-22.00)    | 23.5 (19.00-29.00)     | 26.5 (22.00-32.50)     | 25.968 | <0.001 |
| EBL (ml)  | 20.00 (10.00-100.00)   | 50.0 (20.00-100.00)    | 100.00 (100.00-150.00) | 6.438  | 0.04 |
| ET (day)  | 7.00 (6.00-8.00)       | 5.0 (3.25-6.00)        | 5.00 (3.25-6.25)       | 1.706  | 0.426 |
| **PADUA** | n=30   | n=46          | n=55       |    |   |
| OT (min)  | 126.00 (103.50-150.50) | 123.00 (101.00-144.00) | 146.00 (122.00-183.50) | 12.372 | 0.002 |
| WIT (min) | 18.00 (15.00-21.50)    | 20.00 (14.25-26.00)    | 26.00 (22.00-30.50)    | 30.834 | <0.001 |
| EBL (ml)  | 20.00 (10.00-87.50)    | 50.00 (20.00-50.00)    | 50.00 (20.00-150.00)   | 6.438  | 0.04 |
| ET (day)  | 4.50 (3.00-6.00)       | 7.00 (6.00-8.00)       | 7.00 (6.00-8.00)       | 2.811  | 0.245 |

**TABLE 5 |** Multivariable binary regression analyses of nephrometry score systems and clinical variables.

| Variables | OR/Coefficient | 95% CI | p |
|-----------|----------------|-------|---|
| **OT**    |                |       |   |
| 3S+f      | 7.185          | 1.389-12.981 | 0.016 |
| I         | 1.661          | -16.927-29.249 | 0.860 |
| II        | 70.668         | 39.143-102.192 | <0.001 |
| III       | 4.507          | 0.319-8.694   | 0.035 |
| R.E.N.A.L. | 4.601        | -12.525-21.726 | 0.596 |
| I         | 22.676         | -2.988-48.340 | 0.083 |
| II        | 27.118         | 3.165-11.566  | 0.001 |
| III       | -3.096         | -22.226-16.034 | 0.749 |
| PADUA     | 7.365          | 3.165-11.566  | 0.006 |
| I         | 16.927-29.249  | 0.860 |
| II        | -12.525-21.726 | 0.596 |
| III       | -2.988-48.340  | 0.083 |
| **WIT**   |                |       |   |
| 3S+f      | 1.517          | 0.405-2.628  | 0.009 |
| I         | 3.730          | -0.007-7.454 | 0.050 |
| II        | 11.743         | 5.428-18.058 | <0.001 |
| III       | 1.995          | 1.254-2.736  | <0.001 |
| R.E.N.A.L. | 6.218        | 3.183-9.253  | <0.001 |
| I         | 10.444         | 5.896-14.992 | <0.001 |
| II        | 2.282          | 1.295-2.824  | <0.001 |
| III       | 8.647          | 5.152-12.142 | <0.001 |
| **EBL > 100 ml** |      |       |   |
| 3S+f      | 1.166          | 0.812-1.674  | 0.405 |
| I         | 0.707          | 0.220-2.272  | 0.560 |
| II        | 3.556          | 0.603-20.959 | 0.161 |
| III       | 1.176          | 0.908-1.522  | 0.219 |
| R.E.N.A.L. | 0.996        | 0.357-2.778  | 0.993 |
| I         | 2.253          | 0.556-9.125  | 0.255 |
| II        | 1.253          | 0.960-1.637  | 0.097 |
| III       | 0.843          | 0.224-3.165  | 0.800 |
| PADUA     | 2.347          | 0.707-7.788  | 0.163 |

*(Continued)*
validate the effectiveness of a novel nephrometry score system called the “3S+f” score system through a single-center, single-surgeon research that included 131 patients who underwent LNSS. We compared our score system with the most commonly used R.E.N.A.L. score system and PADUA score system.

OT is a clinical variable we are concerned about. In our study, the total scores of the “3S+f” score system is related to OT ($p = 0.001$) in Spearman correlation analysis. The results of Kruskal–Wallis tests also implied that the higher the “3S+f” score, the more OT would be needed, while the two other score systems simply conveyed a relation of total scores rather than the differences between categorical scores. The multivariable linear regression model and ROC curve also highlighted the differences between categorical scores. The multivariable linear regression model and ROC curve also highlighted the differences between categorical scores. The multivariable linear regression model and ROC curve also highlighted the differences between categorical scores. The multivariable linear regression model and ROC curve also highlighted the differences between categorical scores.

| Variables        | OR/Coefficient | 95% CI          | $p$  |
|------------------|----------------|-----------------|------|
| 3S+f I           | 1.484          | 1.071–2.066     | 0.018|
| 3S+f II          | 2.626          | 0.802–8.599     | 0.111|
| 3S+f III         | 10.952         | 1.736–69.090    | 0.011|
| 3S+f R.E.N.A.L. I| 1.125          | 0.906–1.395     | 0.286|
| 3S+f R.E.N.A.L. II| 1.292         | 0.542–3.084     | 0.563|
| 3S+f R.E.N.A.L. III| 1.714        | 0.485–6.055     | 0.402|
| 3S+f PADUA I     | 1.099          | 0.883–1.370     | 0.398|
| 3S+f PADUA II    | 1.168          | 0.423–3.223     | 0.765|
| 3S+f PADUA III   | 1.309          | 0.477–3.590     | 0.602|
| Complication     |                |                 |      |
| 3S+f I           | 0.997          | 0.752–1.322     | 0.985|
| 3S+f II          | 1.110          | 0.422–2.917     | 0.833|
| 3S+f III         | 0.716          | 0.140–3.659     | 0.688|
| 3S+f R.E.N.A.L. I| 1.194          | 0.969–1.471     | 0.095|
| 3S+f R.E.N.A.L. II| 2.258         | 0.972–5.246     | 0.058|
| 3S+f R.E.N.A.L. III| 1.160        | 0.331–4.061     | 0.817|
| 3S+f PADUA I     | 1.284          | 1.033–1.596     | 0.024|
| 3S+f PADUA II    | 1.332          | 1.052–3.539     | 0.506|
| 3S+f PADUA III   | 3.013          | 1.126–8.063     | 0.028|

OT, operative time; WIT, warm ischemia time; EBL, estimated blood loss; ET, extubation time.
In our ROC curves, PADUA had a stronger ability to predict OT > 30 min. In fact, in a series of studies, PADUA score was considered significantly related to WIT due to its detailed anatomical parameters (22–24). We did not emphasize the renal function in our study since no parameter was related with an increase in Cr in Spearman correlation analysis, but renal function was still related to nephrometry scores, which was approved by other researchers. Matthew et al. found that R.E.N.A.L. and C-index scores were associated with percent functional volume preservation (each \( p < 0.001 \)) and were also related with nadir and late percent glomerular filtration rate preservation in a 237-patient study (25). A study from Taiwan indicated that three scoring systems performed significant correlation with both early and late functional outcomes (\( p < 0.05 \)), and R.E.N.A.L. nephrometry and PADUA classification reported high correlation (−0.715 and −0.721), while C-index demonstrated moderate correlation (0.451) (26).

Evaluation of surgical complications is of great importance when evaluating outcomes of surgery. Although NSS is as effective as RN in long-term oncologic outcome, patients who underwent PN are at a higher risk of postoperative complications compared with those who underwent RN, especially for intrarenal tumors (6, 27–29). LNSS with more WIT increases the incidence of complications. However, we did not obtain results confirming that these three systems were associated with complications from our study. A novel anatomic classification system called Zhongshan score with R.E.N.A.L. and PADUA scores had a definite correlation with severe complications and surgical complications in a retrospective study of 789 patients who underwent NSS (13). In another study that assesses a zero ischemia index (ZII), R.E.N.A.L. and PADUA scores in predicting complexity, and outcomes of off-clamp partial nephrectomy, results showed that ZII (\( p = 0.020 \)), R.E.N.A.L. (\( p = 0.014 \)), and PADUA (\( p = 0.027 \)) scores were all related to surgical complications (12). Results of complication are also heterogeneous among different studies. A study that compared four established nephrometry systems—R.E.N.A.L., PADUA, NePhRO, and C-index—for their significance in predicting the surgical outcome of partial nephrectomy in a cohort of 305 patients found that none of them was related to severe complications (30). With the increasing LPN experience of
surgeons and more common use of techniques to reduce WIT (e.g., early unclamping, off-clamp partial nephrectomy, selective arterial clamping, and parenchymal clamping), we believe that improvement will be made in this issue. We also pay attention to PLOS and ET, which indicate patients' surgical damage and physical recovery to a certain degree. Also, PLOS and ET are associated with patients' expense that patients care about. Some studies may add LOS to their study, but no one has assessed ET as far as we are concerned (17). Although PLOS was not related to any variable in Spearman correlation analysis, we found that “3S+f” had high correlation (p = 0.025) with ET and a great ability (p = 0.018) to predict ET > 5 days. Every one score increase in the “3S+f” score system was associated with a 1.484-fold high risk of tending to ET > 5 days, which elucidated that more attention need to be paid on the drainage tube (used to remove blood or other fluids from the surgical wound) to care for patients who scored higher in the “3S+f” score system. We predicted that the extubation time may be better predicted with “3S+f” as it takes perinephric fat into consideration, which may be related to the degree of adhesion of the surgical areas.

Besides these evaluations of perioperative outcomes, we take the histology of the tumors into consideration as well, but found no association between each of the three nephrometry scores and the presence of malignancy. In fact, in addition to gender (female patients have more benign tumors) and tumor size (larger size correlated with malignancy), few tumor anatomic characteristics or patient features were found to be significant predictors for differentiating malignant and benign renal masses (31).

We have chosen four parameters as components of the “3S+f” score system, namely, “size, site, side, and fat”, and any of them contributes to the complexity of surgery in theory. The “3S+f” score system has only four parameters and all can be easily calculated from preoperative images. In this study, we chose patients who only underwent LNSS to eliminate the negative effect from different surgical methods. All surgeries were performed by the same surgeon (SZ), which is distinctive, and which many other studies failed to achieve. With only one surgeon, many biases can be eliminated. However, there are several limitations in our study. A small sample (131 patients) may not be enough to assess our system. The lack of different raters can also lead to biases. In addition, we only collected data from a single center. Also, our retrospective study may be affected by subjective factors when we reviewed the patients’ data. Furthermore, the assessment of SITE and FAT may suffer from subjective bias since these two indicators can hardly be quantified by using a rigorous objective method. We also found that “3S+f” and PADUA only differentiate tumors with low vs. high complexity and moderate vs. high complexity but not between tumors with low vs. moderate complexity. The same results can be demonstrated by the study of Okhunov et al., although their results revealed that nephrometry scores (R.E.N.A.L., PADUA, and C-index) could only differentiate tumors with low vs. moderate/high complexity but not between tumors with moderate vs. high complexity, which suggested that a two-tiered complexity classification may be more valid (20). Therefore, further exploration is required to validate the effectiveness of the “3S+f” score system in the future.

CONCLUSIONS

Our novel nephrometry score system—the “3S+f” score system—has simple components and is easy to calculate from preoperative cross-sectional imaging. Compared with R.E.N.A.L. and PADUA scores, it shows equivalent correlation and the ability to determine clinical outcomes, demonstrating that our system is reliable, to some degree, in predicting surgical complexity. Thus, we provide a new nephrometry score system to describe renal tumors suitable for NSS.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

SZ, ZQ, and LM contributed to the study design and administrative support, and were major contributors to the writing of the manuscript. SZ, ZQ, FZ, HZ, YH, and LM provided the study materials and patients. SZ, ZQ, LM, and LT were in charge of data analysis and interpretation. All authors contributed to data collection, manuscript writing, and final approval of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fonc.2022.922082/full#supplementary-material
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