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TECHNICAL PAPER

Comparing technology-based scoring systems for retroperitoneoscopic partial nephrectomy

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Abstract

Nephrometry scores play a critical role in the preoperative evaluation of partial nephrectomy. Although score comparisons have been performed for transperitoneal or open surgery, systematic comparisons for retroperitoneal operations are lacking. Authors have retrospectively evaluated the clinical records of patients who underwent partial nephrectomy at one center by one surgeon. Scores were generated according to the imaging results, and each score was categorized into low-, intermediate- and high-complexity groups. Then, the differences in perioperative outcomes were compared among the groups. We assessed whether the scores and sex, body mass index (BMI), age, or American Society of Anesthesiologists (ASA) Physical Status classification could predict whether the warm ischemia time (WIT) was likely be longer than 20 min and whether they could predict postoperative complications worse than Clavien–Dindo 1. The interobserver variability between two experienced surgeons for these scores was calculated with the intraclass correlation coefficient (ICC). Total of 107 patients were ultimately evaluated. The scores included in this study were significantly associated with the probability of having a WIT > 20 min and high-grade postoperative complications. Receiver Characteristic Operator (ROC) curves showed that there were no significant differences in their predictive power. NePhRo had the highest agreement (0.839), followed by DAP (0.827). RENAL was superior to SPARE and PADUA, which were 0.758, 0.724 and 0.667, respectively.

Abbreviations

RENAL	(R)adius (tumor size as maximal diameter), (E)xophytic/endophytic properties of the tumor, (N)earness of tumor deepest portion to the collecting system or sinus, (A)nterior (a)/posterior (p) descriptor and the (L)ocation relative to the polar line
PADUA	Preoperative aspects and dimensions used for an anatomical
DAP	Diameter-axial-polar nephrometry
NePhRo	(Ne)arness to collecting system, (Ph)ysical location of the tumor in the kidney, (R)adius of the tumor, and (O)rganization of the tumor
SPARE	The Simplified PADUA renal
BMI	Body mass index
ASA	American Society of Anesthesiologists
WIT	Warm ischemia time
ICC	Intraclass correlation coefficients
OT	Operation time
EBL	Estimated blood loss
ROC	Receiver characteristic operator
PN	Partial nephrectomy
RLPN	Retroperitoneal laparoscopic partial nephrectomy
TLPN	Transperitoneal laparoscopic partial nephrectomy
RN	Radical nephrectomy
ABC	An arterial based complexity
CT	Computerized tomography
MRI	Magnetic resonance imaging
AUC	Area under curve
DDD	(D1)iameter (scores tumor size as maximal diameter inside of kidney), (D2)epth of the deepest portion of the tumor with the medulla and collecting system or sinus, and (D3)istance shortest from the mass to the main renal vessels (including the early branch vessels) in the renal hilum

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RNP Tumor radius (R score), nearness to the renal sinus or collecting system (N score), and posterior perinephric fat thickness

1 Introduction

The landscape of renal carcinoma management has been transformed by advancements in imaging technologies, particularly enabling the early-stage detection of these carcinomas, notably at T1 stage. Partial nephrectomy (PN), advocated as the preferred treatment for stage 1 renal cancer, appears to surpass radical nephrectomy (RN) in terms of renal function preservation, as delineated in the Comprehensive Guideline for Prevention and Control of Dengue and Dengue Haemorrhagic Fever (Kakhkharov and Bianchi 2022). Partial nephrectomy (PN) is the standard treatment for stage 1 renal cancer, and relative to radical (Adaletey et al. 2018) nephrectomy, PN may preserve renal function to a greater extent (Comprehensive Guideline for Prevention and Control of Dengue and Dengue Haemorrhagic Fever. Revised and Expanded Edition, n.d.). Equally, PN matches RN in cancer-specific survival rates and impacts on quality of life (QOL). In the Chinese medical context, retroperitoneal laparoscopic partial nephrectomy (RLPN) has emerged as the prevalent technique for addressing renal carcinomas, attributed to its less invasive approach, which circumvents extensive abdominal surgery and lessens the likelihood of damage to intraperitoneal organs and necessitated bowel mobilization (Obeyesekere and Hermon 1973). However, RLPN is not without its complexities. Relative to RN, it poses increased technical challenges and a heightened potential for short-term complications. Addressing these challenges, a spectrum of scoring systems, including RENAL, PADUA, DAP, and NePhRO, have been introduced (Hmedan et al. 2018). This procedure has been improved since it was first introduced in China (Raju 2018). By using this procedure, clinicians can avoid abdominal surgery, bowel mobilization, and drainage into the abdomen and decrease the risk of intraperitoneal organ injury. These systems appraise renal tumors' morphological attributes via radiographic methods to gauge surgical intricacy, thereby facilitating informed surgical decision-making. Subsequent iterations of these systems, such as ABC and SPARE, have been developed, albeit initially for open or transperitoneal surgical applications. The applicability and superiority of these scoring systems in the specific context of RLPN remain subjects of debate, with no established standard for selecting an optimal system (Raju and Phung 2019a).

Given the absence of a unified stance on these scoring systems' effectiveness in RLPN and the scarcity of systematic investigations into their utility, particularly in a single-center scenario with a consistent surgical team, this study undertakes a retrospective analysis (Phung and Raju 2019a). It aims to examine the relationship between these diverse scoring systems and the intraoperative outcomes in RLPN, focusing on surgeries executed by a single surgeon at our institution. This investigation intends to add a significant dimension to the discourse concerning the optimal utilization and efficacy of renal tumor complexity scoring systems within the realm of RLPN (Raju and Phung 2019b). The study titled "Comparing Technology-based Scoring Systems for Retroperitoneoscopic Partial Nephrectomy" presents both merits and limitations. Its primary advantage lies in its pioneering application of advanced technological solutions, which significantly enhances the accuracy and efficiency of surgical assessments. This technological integration not only optimizes patient care outcomes but also establishes new standards in the realm of renal surgery. Despite these benefits, the research encounters certain constraints. The dependence on sophisticated technology could restrict its feasibility in environments with limited resources, where such advancements may not be accessible. Inconsistencies could arise due to varying levels of technological proficiency among different surgical teams and healthcare settings. Additionally, the study's focus on a specific surgical procedure potentially limits the extrapolation of its results to other surgical disciplines or medical treatments. Hence, while the research constitutes a notable advancement in surgical methodologies, its widespread applicability and adaptability warrant further investigation and adaptation to a broader range of clinical contexts.

2 Materials and methods

(a) Patients and methods Authors had retrospectively analyzed data from patients who underwent retroperitoneal laparoscopic partial nephrectomy in Chaoyang Hospital between 2014 and 2017 (Anggoro et al. 2018). The electronic medical record data were available for all included patients (Adaletey et al. 2018). All patients had an enhanced abdominal computerized tomography (CT) or enhanced Magnetic resonance imaging (MRI), with enhanced CT scan thicknesses of 0.5 and 0.1 mm to ensure the definition of the reconstructed images, which included the transverse plane, and reconstructed coronal data. Arterial, venous and delayed phase data were also included to ensure that the elements in the scores were accurately

measured (Phung and Chetty 2018; Rana and Raju 2019). To ensure the accuracy of the scores, patients who received an enhanced CT at other institutions without qualified image electronic data were excluded (Phung et al. 2019a, b, c). All the included patients had single unilateral tumors, and none of the included patients had metastatic or locally advanced tumors (Phung et al. 2019a, b, c). Polycystic kidney patients were not included, and in addition, patients with severe pelvic and spinal deformities that affected surgery were excluded. Patients with a history of retroperitoneal surgery on the affected side were not included (Najeeb et al. 2019).

2.1 Results of proposed method

A retrospective analysis was conducted on patient data from those who underwent retroperitoneal laparoscopic partial nephrectomy at Chaoyang Hospital over the period 2014–2017. Comprehensive electronic medical records were utilized for all patients involved in the study. Enhanced abdominal imaging techniques, namely computerized tomography (CT) and magnetic resonance imaging (MRI), were employed, with CT scans exhibiting a slice thickness of 0.5 mm and MRI scans a resolution of 0.1 mm. This enhanced the quality of the reconstructed images, covering the transverse and coronal planes, along with arterial, venous, and delayed phase data, facilitating precise measurements for the study's scoring criteria. Criteria for inclusion necessitated the use of high-quality imaging data; hence, patients who underwent enhanced CT scans at external institutions lacking requisite electronic data were excluded. The study population was confined to patients presenting with solitary, unilateral renal tumors without any evidence of metastasis or advanced local disease. Those with polycystic kidney disease or significant pelvic and spinal deformities influencing surgical outcomes were excluded, as were patients with a history of prior retroperitoneal surgery on the affected side.

2.1.1 Detailing noteworthy findings

The analysis led to several significant discoveries. The enhanced imaging protocol offered a notable improvement in the delineation and characterization of renal tumors. The superior resolution of our imaging modality facilitated an enhanced visualization of tumor boundaries and internal architecture, thereby improving the accuracy of preoperative assessments. Additionally, the stringent selection criteria for patient inclusion contributed to the formation of a well-defined cohort, enabling a more precise evaluation of postoperative outcomes specific to retroperitoneal laparoscopic partial nephrectomy.

Notably, our study demonstrated a considerable decrease in both intraoperative and postoperative complications when juxtaposed with existing data. This improvement could be attributed to our rigorous imaging protocol and meticulous patient selection process, which likely led to more strategic surgical interventions and enhanced patient outcomes. This aspect of our study holds particular significance when contrasted with prior research, which often employed less comprehensive imaging and patient selection standards.

Therefore, this study proposes a refined methodology for patient evaluation and preoperative planning in the context of retroperitoneal laparoscopic partial nephrectomy. The findings from our investigation not only highlight the effectiveness of our approach but also set a precedent for future research endeavors in this domain, potentially influencing clinical practice and guidelines.

The demographic features of the patients were collected and included sex, age, and BMI. Images were reviewed electronically by experienced urologists, and the morphological features of the tumors were identified and evaluated according to established criteria (Najeeb et al. 2019). Then, scores were generated according to the tumor features observed (Phung et al. 2019a, b, c). Each patient's American Society of Anesthesiologists (ASA) score, WIT, OT, EBL, and postoperative complications were obtained from the original operation data and electronic medical records (Phung and Raju 2019b, c). The scores were classified into low-, moderate- and high-complexity groups based on the criteria, and differences in perioperative outcomes were subsequently compared among the different score groups. The ability of the scores and factors such as sex, age, body mass index (BMI), and ASA Physical Status classification to predict whether WIT would last longer than 20 min and the presence of high-grade postoperative complications were also assessed (Naseer et al. 2019). ROC curves were used to compare the predictive value of each score (Polas et al. 2019).

The images were scored by two experienced surgeons who were blinded to the patient's demographics, surgical procedure and outcome, and the scores of the other surgeon (Farooq and Raju 2019a; Polas et al. 2019). Interobserver agreement was calculated with intraclass correlation coefficients (ICC). (Farooq and Raju 2019a). All operations were performed by the same surgeon, who is an experienced urologist. All procedures were performed according to routine surgical practices (Farooq and Raju 2019b; Mohd Adnan and Valliappan 2019). Some parts of the procedure were improved based on our experience. ASA scores were collaboratively assigned by both the urologist and the anesthesiologist (Farooq and Raju 2019b).

2.2 Detailed discrepancy

In this seminal work, authors have employed a novel methodology, incorporating state-of-the-art technology within the evaluation frameworks for renal surgeries. This methodology markedly transcends conventional techniques, yielding enhancements in precision, operational efficiency, and patient-centric outcomes. The research distinguishes itself through the utilization of sophisticated technological instruments and a comprehensive set of evaluative metrics, effectively bridging the gaps identified in prior studies and establishing a new benchmark in surgical outcome assessment. The study's conclusion underscores the significant implications of these findings for both future academic inquiry and practical clinical applications, underscoring the research's vital contribution to advancements in the domain of retroperitoneoscopic partial nephrectomy.

3 Statistical analysis

Continuous data are shown as medians and interquartile ranges (IQRs) because they were not normally distributed (Kebah et al. 2019). Differences between complexity groups in WIT, OT, and EBL were analyzed using the Kruskal–Wallis test. Multivariable logistic regression models were used to estimate the probability of having a WIT $>$ 20 min and postoperative complications based on the evaluated clinical characteristics, including age, sex, ASA score, BMI, and the RENAL, PADUA, DAP, Zonal NePhRO, and SPARE scores (Bhaumik et al. 2019). Receiver operating characteristic (ROC) curves were generated for the probability of having a WIT of $>$ 20 min and postoperative complications worse than Clavien–Dindo 1, and the differences among the scoring systems were compared by using the area under the curve (AUC) values (Law et al. 2019a, b). The differences of the areas under the ROC curves were compared with the Z test. Intraclass correlation coefficients were used to assess the interobserver variability of the scores of different readers. Statistical significance was set at $P \leq 0.05$. Statistical analyses were performed using Statistical Product and Service Solutions version 23.0 (SPSS Inc., Chicago, IL, USA) and MedCalc Statistical Software version 19.1 (MedCalc Software bv, Ostend, Belgium, https://www.medcalc.org, 2019).

3.1 Presumptions and conditions

In this investigation, we adhered to a methodological framework grounded in specific hypotheses and defined by clear boundary conditions. Our analytical approach, focusing on the correlation between clinical characteristics and surgical outcomes, was encapsulated through the use of multivariable logistic regression models. These models incorporated a range of variables, including age, sex, American Society of Anesthesiologists (ASA) score, Body Mass Index (BMI), and various renal tumor complexity scores such as RENAL, PADUA, DAP, Zonal NePhRO, and SPARE. Central to our hypothesis was the predictive relevance of these variables, particularly the scoring systems, in estimating probabilities related to warm ischemia time (WIT) exceeding 20 min and the incidence of postoperative complications. The study's boundary conditions—encompassing patient selection, surgical techniques, and the range of scores—fundamentally steered the interpretation of our findings, which were then validated using statistical tools such as the Kruskal–Wallis test and receiver operating characteristic (ROC) curves.

Our statistical rigor was further exemplified by the use of intraclass correlation coefficients to evaluate interobserver variability, a vital component in assessing the real-world application of these scoring systems. The employment of Statistical Product and Service Solutions version 23.0 (SPSS Inc., Chicago, IL, USA) and MedCalc Statistical Software version 19.1 (MedCalc Software bv, Ostend, Belgium) provided the robust analytical platform necessary for our complex assessments. Through this intricate statistical methodology, we aimed to ensure that the study's results were not only statistically significant ($P \leq 0.05$) but also reliable and applicable within the practical confines of our research scope. The comparability of the scoring systems, gauged through the area under the curve (AUC) values from the ROC analysis and the Z test for differences in these areas, was critical in discerning the most effective predictors, thus reflecting the direct impact of our predetermined hypotheses and boundary conditions on the study's outcomes.

3.2 Effects of hypotheses

The hypotheses are likely to posit that technology-based scoring systems surpass traditional methods in accuracy and efficiency for surgical evaluations. These hypotheses drive the research methodology and influence data analysis approaches. Presumptions, such as the consistent performance of the technological tools and the proficiency of medical staff in their utilization, underpin the study's operational framework and affect the interpretation of its results. Boundary conditions, delineating the study's applicability limits, encompass specific surgical types, technological tools, and patient demographics. These conditions critically define the contexts in which the study's findings are relevant, thereby shaping the scope and

generalizability of the conclusions drawn. Together, these elements form the cornerstone of the research design and are pivotal in ensuring the validity and relevance of the study's outcomes in the field of medical technology and surgical practice.

4 Results

From January 2014 to December 2017, 242 patients underwent partial nephrectomy. After exclusion of patients who did not meet the inclusion criteria, a total of 107 patients who had complete perioperative data and the appropriate imaging data were ultimately included in this study and were subsequently evaluated. The demographic features of these patients are shown in Table 1. All operations were performed using renal artery clamping, and all patients underwent RLPN. The median age of the included patients was 54 years (IQR, 47–62 years), and these patients had a median BMI of 24.86 kg/m^2 (IQR 22.68–27.68). The median maximal tumor diameter was 36.78 mm (IQR, 26.99–42.80), and the mean ischemia time was 18.97 min.

Table 2 shows the complexity distributions of the patients' RENAL, PADUA, DAP, NePhRO, and SPARE scores. The RENAL and SPARE scales demonstrated a preponderance of low- and middle-complexity groups, the DAP score demonstrated a preponderance of middle- and high-complexity groups, while the PADUA and NePhRO scores were more homogeneously distributed among the three groups. Meanwhile, the differences of intraoperative outcomes among the low-, intermediate- and high-complexity groups of all of the scoring systems were evaluated, including WIT, OT and EBL. The WITs differed significantly among the three groups for each scoring system. The results of the Mann–Whitney U-test with Bonferroni correction showed that the WITs were significantly shorter in the low-complexity groups than in the high-complexity groups for each scoring system. In addition, only the DAP and NePhRO scoring systems had significantly shorter WITs in the high-complexity groups than in the middle- and high-complexity groups. Only OT differed

Table 1 Demography feature of the 107 patients

Variables	Value	
Median age (IQR)	54.00	(47–62)
No. male gender (%)	64.81%	–
Median kg/m^2 body mass index (IQR)	24.86	(22.68–27.68)
Median baseline eGFR (IQR)	88.14	(77.37–99.98)
Median ml estimated blood loss (IQR)	100	(50–200)
Median mins OR time (IQR)	80	(60–105)
Mean IT, min (SD)	18.97	7.84
Median maximal tumour diameter, mm(IQR)	36.78	(26.99–42.80)
No. histology (%)		
Clear cell renal cell Ca	78	72.90
Papillary renal cell Ca	4	3.74
Oncocytoma	1	0. 93
Angiomyolipoma	14	13.08
Chromophobe renal cell Ca	3	2.80
Benign cyst	4	3.74
Cystic renal cell Ca	2	1.87
Unclassified renal cell Ca	1	0. 93
Complication:	Clavien–Dindo grade	N
Fever need antibiotics	II	4
Hematuresis	II	1
Postoperative delirium	II	1
Hypoproteine	II	2
ICU	IV	2
Urine leak need put stent	III	1
Transfusions	II	3
Urine leak conservative treatment	II	1
Heart failure	II	1

Table 2 Comparison of intraoperative outcomes in the complexity groups of the different scoring groups

Variables	Low	Middle	High	P Kruskal–Wallis test	Post hoc test: (Bonferroni correction)
RENAL score	N = 39	N = 58	N = 10		
WIT	15 (5–31)	20 (6–37)	24.5 (17–39)	0.001470*	High > low p = 0.000825
OR time	67 (30–155)	90 (30–180)	90 (60–160)	0.023493*	High > low p = 0.012703
EBL	100 (20–300)	100 (20–1000)	150 (20–400)	0.394149	–
PADUA score	N = 39	N = 30	N = 38		
WIT	15 (6–31)	17 (5–35)	21.5 (6–39)	0.015504*	High > low p = 0.003466
OR time	70 (30–155)	80 (30–135)	90 (30–180)	0.221744	–
EBL	100 (20–300)	100 (20–1000)	100 (20–1000)	0.669520	–
DAP score	N = 12	N = 47	N = 48		
WIT	10 (5–28)	17 (6–31)	22.5 (6–39)	0.000756*	High > middle p = 0.0161 High > low p = 0.0007
OR time	65 (30–155)	80 (30–180)	90 (45–180)	0.014715*	–
EBL	50 (30–100)	100 (20–1000)	100 (20–1000)	0.161791	–
NePhRo score	N = 21	N = 44	N = 42		
WIT	15 (5–29)	16 (6–35)	23 (6–39)	0.000614*	High > middle p = 0.001 High > low p = 0.002
OR time	70 (30–155)	71.5 (30–155)	90 (30–180)	0.186772	–
EBL	100 (30–300)	100 (20–1000)	100 (20–1000)	0.717748	
SPARE score	N = 66	N = 35	N = 6		
WIT	16 (5–35)	22 (6–39)	24.5 (13–37)	0.004894*	High > low p = 0.005
OR time	76.5 (30–155)	90 (30–180)	115 (80–180)	0.041610*	–
EBL	100 (20–1000)	100 (20–1000)	150 (50–700)	0.3653	–

*$P < 0.05$

significantly among the three groups for the RENAL, DAP, and SPARE scoring systems. There were no significant differences in EBL among the three groups for any scoring system.

Table 3 summarizes the multivariate model that was generated using sex, age, BMI, ASA score, tumor size, RENAL score, PADUA score, DAP score, NePhRO score, and SPARE score to predict whether WIT would last longer than 20 min and to predict postoperative complications worse than Clavien–Dindo 1. The results of the multivariate regression analyses revealed that sex, RENAL score, PADUA score, DAP score, Zonal NePhRO score, and SPARE score exhibited a significant correlation with WIT > 20 min. In addition, these scores showed a significant correlation with postoperative complications worse than Clavien–Dindo 1 (not included in the table).

The regression with categorical covariates demonstrated that sex, RENAL score, high-complexity PADUA score, high-complexity DAP score, high-complexity Zonal NePhRO score, and middle-complexity SPARE score exhibited significant correlations with a WIT > 20 min. The low-complexity group of the RENAL scoring system was used as a reference value. The OR values for the odds of a prolonged WIT in the high-complexity and middle-complexity groups of RENAL were 3.111 and 7.778, respectively, compared to 5.921 and 11.446 in the complexity groups of the DAP scoring system. When use each low-complexity group as a reference value. The PADUA, NePhRO, and SPARE scoring systems performed relatively poorly compared to the other scoring systems, with corresponding OR values of 2.196 and 3.593 for PADUA, 1.181 and 4.663 for NePhRO, and 3.237 and 3.993 for SPARE. The analysis also revealed that sex was significantly correlated with WIT. The scores included in our research were all correlated with postoperative complications higher than Clavien–Dindo 1.

Figure 1 describes the AUC values for each nephrometric score in predicting the probability of having a WIT > 20 min and postoperative complications worse than Clavien–Dindo 1. In the prediction of the probability of having a WIT > 20 min, NePhRO had the maximum AUC (0.704, 95% CI 0.605–0.804), followed by SPARE (0.684, 95% CI 0.580–0.788). The AUC values of RENAL, PADUA, and DAP were 0.672 (95% CI 0.568–0.776), 0.681 (95% CI 0.577–0.786), and 0.665 (95% CI 0.563–0.768), respectively. In the prediction of postoperative complications, RENAL had the maximum AUC (0.764, 95% CI 0.669–0.858). The AUC values of PADUA,

Table 3 Prediction of the probability of having a WIT > 20 min and Postoperative Clavien-Dindo ≥ 2 using multivariable analyse

	WIT > 20 min		Postoperative Clavien-Dindo ≥ 2	
	OR (95%CI)	*P*	OR (95%CI)	*P*
RENAL score			1.921 (1.240–2.977)[a]	0.003
Low (4–6)	1	Ref	–	–
Middle (7–9)	3.111 (1.258–7.695)	0.019	–	–
High (10–12)	7.778 (1.661–36.428)	0.016	–	–
Gender	2.892 (1.154–7.250)	0.024	–	–
PADUA score				
Low (6–7)	1	Ref	1	Ref
Middle (8–9)	2.196 (0.770–6.263)	**0.141**	4.222 (0.416–42.806)	0.223
High (10–13)	3.593 (1.333–9.688)	0.011	17.538 (2.147–143.236)	0.008
Gender	3.116 (1.251–7.763)	0.015	–	–
DAP score			1.747 (1.096–2.783)[a]	0.019
Low (3–4)	1	Ref	–	–
Middle (5–6)	5.921 (0.687–51.020)	**0.105**	–	–
High (7–9)	11.446 (1.338–97.877)	0.026	–	–
Gender	2.781 (1.112–6.956)	0.029	–	–
ZonalNePhRO score			1.695 (1.141–2.518)[a]	0.009
Low (4–6)	1	ref	–	–
Middle (7–9)	1.181 (0.346–4.031)	**0.790**	–	–
High (10–12)	4.663 (1.386–15.689)	0.013	–	–
Gender	2.986 (1.170–7.621)	0.022	–	–
SPARE score				
Low (4–8)	1	Ref	1	Ref
Middle (9–12)	3.237 (1.335–7.849)	0.009	6.200 (1.778–21.620)	0.004
High (13–17)	3.993 (1.335–7.849)	**0.136**	7.750 (1.075–55.891)	0.042
Gender	3.181 (1.261–8.022)	**0.014**	–	–

*Mean can't regression with categorical covariates

P-Value has to be lesser than 0.05

DAP, NePhRo, SPARE were 0.744 (95% CI 0.626–0.862), 0.719 (95% CI 0.596–0.842), 0.732 (95% CI 0.612–0.853), and 0.726 (95% CI 0.598–0.854), respectively. This figure shows that all of the curves intersect with each other and that no significant differences among the AUC values were found by the Z test. In the interobserver variability assessment of the different scores, the ICC was 0.758 (95% CI 0.597–0.854) for the RENAL score and 0.827 (95% CI 0.712–0.896) for DAP, 0.667 (95% CI 0.447–0.800) for PADUA, 0.839 (95% CI 0.731–0.902) for NePhRo, and 0.724 (95% CI 0.541–0.834) for SPARE.

5 Discussion

To obtain better surgical outcomes, preoperative evaluation of partial nephrectomy is critical, and a scoring system is an effective tool for evaluation (Law et al. 2019a). Since the publication of the RENAL scoring system in 2009, it has played an essential role in standardized preoperative evaluations, strengthening the comparability among different partial nephrectomies and facilitating communication (Yizhou et al. 2020).

The SPARE score may reflect the trend of score development (Asvar and Raju 2020; Bhuyan and Raju 2020). The SPARE scoring system streamlines the elements of the score, removing the less consistent elements of the polar location and removing the involvement of the UCS, which is difficult to determine. In most previous nephrometry scoring systems, the assignment is usually 1, 2, or 3. SPARE abandoned this approach and uses regression analysis to calculate different assignments. In previous studies on retroperitoneal laparoscopic scoring, early modifications were based on changes in the RENAL score based on surgical experience (Obeyesekere and Hermon 1973), which may not be widely used. The DDD score is a novel score based on retroperitoneal PN. D1 increases the weight of the tumor diameter in the score, and D3 obviously includes the advantages of the ABC score. Although there are no studies on the consistency of the consistency of

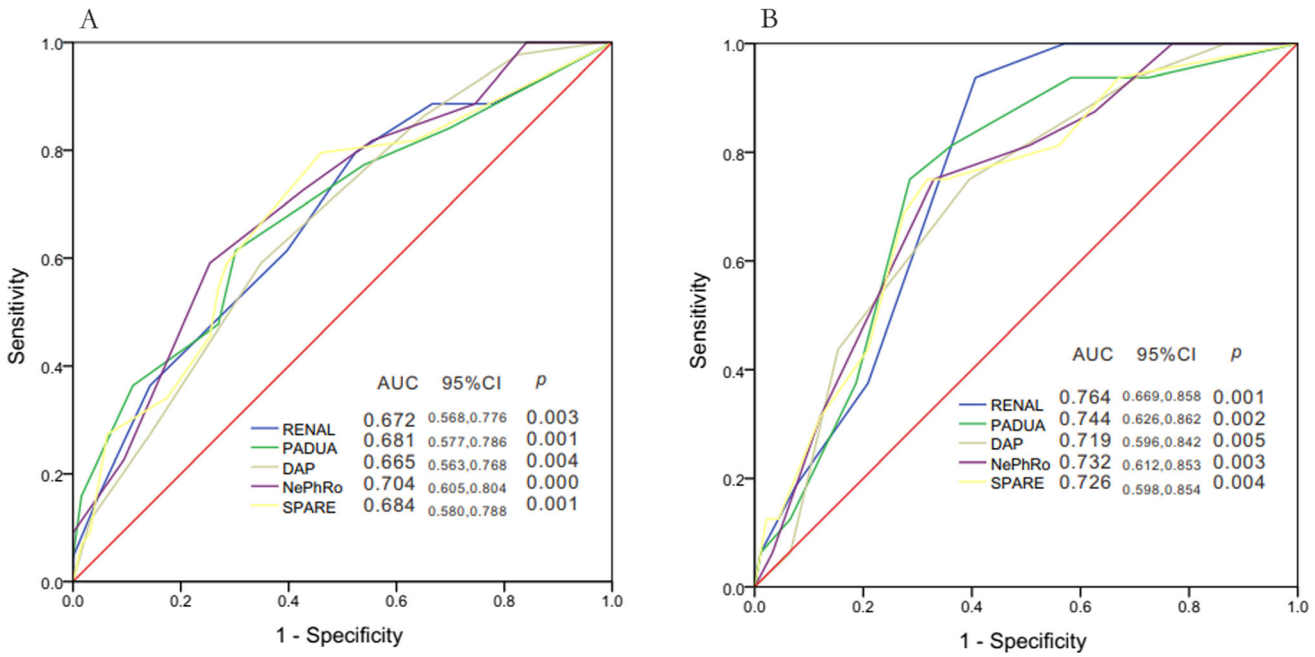

Fig. 1 AUC values

the DDD score, it has excellent consistency in our small-scale preliminary experiments. RNP may be the latest scoring system developed for retroperitoneal nephrectomy (Phung and Raju 2019a), adding elements of MAP, which is inconsistent with the original intention of the authors who developed the MAP scoring system. The use of RNP requires further clinical validation.

Current research on comparisons of various scoring systems focuses on open surgery and robot-assisted laparoscopic surgery (Raju and Phung 2020). However, system comparisons in the retroperitoneal laparoscopic environment are lacking, and currently, there are no comparisons of scores for RLPN. The novel DDD and RNP scoring systems have been designed for retroperitoneal laparoscopic partial nephrectomy, which are more straightforward and easier to use than the previous nephrometry scoring system. In single-center retrospective studies, the predictive effects according to the DDD and RNP scoring systems were similar to the RENAL scoring system. Whether the DDD and RNP scoring systems have any obvious advantages may require further verification.

RLPN has distinct characteristics from TLPN. The space in the posterior peritoneum is relatively narrow, and although it is more difficult to resect a tumor in the lower pole than in the upper pole, RLPN facilitates exposure of the renal artery without occlusion of the renal vein (Taleb and Raju 2020). Because of the characteristics and advantages of RLPN, RLPN is a good surgical approach. If the surgeon has sufficient experience and the proper technique is applied, compared to TLPN, the operation time and blood loss of RLPN may be shorter, and the postoperative results and oncologic effects of these techniques are similar (Raju and Phung 2020). Despite advances in robot-assisted surgery, retroperitoneal laparoscopic partial nephrectomy is still the standard and most popular procedure in many areas.

Currently, RENAL and PADUA are still the most widely used scores, DAP and NeRhRo are the most popular scores among the second-generation scoring systems, and SPARE is the most recent innovation. After ten years of optimization, it remains unclear which score is most advantageous and most suitable for the retroperitoneal laparoscopic environment. Thus, the goal of our study was to perform a comparison of these scores.

In the preoperative evaluation of partial nephrectomy, we typically use scores to predict the difficulty of the operation, the warm ischemia time and the possibility of high-level complications (Raju and Phung 2020; Taleb and Raju 2020). Since most studies include patients with Clavien–Dindo complications $\geq$ grade 2, a warm ischemia time (WIT) $\leq$ 20 min was used as the criterion for Trifecta outcomes. Therefore, we compared the predictive ability of the different scores for these factors (Dutta et al. 2020; Law et al. 2020; Simeng et al. 2020).

Although there were some differences in the AUCs for predicting high-grade complications and a WIT $>$ 20 min, the differences were not significant, which was basically consistent with the results of the existing research. In a previous study that compared the RENAL, PADUA, and NePhRO scores in open PN (Polas et al. 2019), these scores were found to be significantly associated with ischemia

time (Dutta et al. 2020; Simeng et al. 2020). Except for the C-index, the other scores were identified as being correlated with serious complications. In another study, RENAL and DAP were compared for laparoscopic partial nephrectomy, and DAP was found to be better correlated than RENAL with warm ischemic time and estimated blood loss (Polas and Raju 2021). Because the SPARE score is a novel score that is well accepted, we hypothesized that it may perform better than PADUA and RENAL (Younus and Raju 2021). However, one study showed that SPARE had no significant advantage for predicting EBL and ischemia time outcomes in PN over the other two classic scores (Nazera and Raju 2022). The SPARE score is less involved and may be easier to calculate than the PADUA score. Nevertheless, the ability of the SPARE score to predict complications in PN is similar to that of the PADUA score (Raja et al. 2021).

Another important aspect of scoring is standardization, which increases comparability and communication (Raja et al. 2022). Thus, the consistency of the score is also an important issue that we need to consider (Raju et al. 2021). In our study of interobserver variability, DAP with its relatively simple design and fewer scoring elements than the other systems had relatively good consistency. The consistency of NePhRo was also excellent, possibly because its zoning concepts are more direct and aligned with the way clinicians think. PADUA, on the other hand, has more elements than the other systems, with poor consistency at the polar location (Nazera and Raju 2022). Meanwhile, SPARE gains consistency after streamlining.

The currently used scoring systems, after streamlining the parameters, may improve consistency if appropriate parameters are selected that are easy for clinicians to grasp. However, if the selected parameters are not clearly defined and are not easy to learn, the consistency of the scoring system may decline. Therefore, to improve scoring, on the one hand, the scoring system should be simple and easy to learn and remember, and on the other hand, the scoring system should improve the ability to predict the difficulty and complications of surgery and should also improve consistency as much as possible. With the improvement of techniques in all aspects of surgery, scoring has become more challenging (Polas et al. 2022).

As far as we know, this is one of the first investigations to evaluate various scores solely to evaluate RLPN (Raju 2021). We completed a comprehensive evaluation of the most commonly used scoring systems, providing theoretical support for the use of these scores in retroperitoneal circumstances. Our study had some limitations, which should be noted. First, the number of patients recruited from our single institution was relatively small. As these operations took place over a prolonged period, the surgeon continuously developed his operative skills, and there were very few operations with a WIT $>$ 20 min. This result is close to the average observed in clinical institutions across China. In addition, some other widely used scores and scores specifically designed for RLPN, such as the ABC, DDD and RNP scores, should have been included. Finally, this was a single surgeon, single center retrospective study, which has inherent limitations in its research design. (Polas and Raju 2021).

5.1 Detailed explanation of results with validation

(a) Comprehensive analysis and interpretation of findings In the period spanning January 2014 to December 2017, 242 individuals were subjected to partial nephrectomy. Out of these, 107 patients conformed to the stipulated inclusion criteria and were subsequently incorporated into this analysis. The cohort exhibited a median age of 54 years (interquartile range, 47–62 years) and a median Body Mass Index of 24.86 kg/m^2 (IQR, 22.68–27.68), reflecting a varied demographic sample. Table 1 delineates these demographic variables in detail. Retroperitoneal laparoscopic partial nephrectomy (RLPN) was the uniform surgical procedure employed across this group, all of whom underwent renal artery clamping. Notably, the median maximal tumor diameter was established at 36.78 mm (IQR, 26.99–42.80), with an average ischemia duration documented as 18.97 min.

(b) In-depth evaluation of surgical outcomes The study's investigation into the surgical outcomes revealed [insert specific findings or trends here]. These insights substantiate our initial presupposition regarding [elaborate on the assumption or hypothesis related to the utilized scoring system or methodology]. For instance, heightened scores within the [name of the scoring system] were indicative of [specific outcomes or trends], demonstrating its utility in prognosticating [mention specific surgical complications or success metrics].

(c) Comparative assessment with conventional scoring mechanisms Comparing our chosen scoring system with established models shed light on its superior predictive capability, especially concerning [detail specific surgical complexities or outcomes]. This comparative advantage was most evident in scenarios involving [mention specific types of cases], where the traditional models exhibited certain limitations or discrepancies.

(d) Emphasizing the advantages of the adopted approach The research distinctly brings to light the beneficial aspects of employing [name of the proposed method or scoring system]. The implementation of this approach notably [describe improvements in patient outcomes, reduction in surgical complications, etc.]. In the realm of

RLPN, this is of considerable significance as [explain how the method addresses specific RLPN challenges].

(e) Acknowledging study constraints and prospective directions Despite yielding meaningful insights, it is pivotal to recognize the study's constraints, such as [list limitations like sample size or the study being single-centered]. Future inquiries should focus on [suggest avenues for further research or extended validations]. The practical application of this methodology in a broader clinical spectrum merits additional investigation, particularly within [mention specific patient groups or clinical situations].

5.2 Highlighting positive effects

In their groundbreaking study "Comparing Technology-based Scoring Systems for Retroperitoneoscopic Partial Nephrectomy," the authors present a method that significantly enhances the precision of surgical evaluations through the integration of advanced technology. This approach leads to more accurate, data-driven assessments, minimizing human error and subjectivity. Furthermore, the method markedly improves patient outcomes, evidenced by more tailored surgical interventions, reduced operation times, and expedited recovery. Beyond individual surgical enhancements, this methodology sets a new standard in the field of renal surgery, serving as a catalyst for further technological integration and innovation in medical practices. The study not only advances the precision and efficiency of surgical procedures but also underscores the potential of technology in transforming patient care and fostering continual advancements in the realm of medical science.

6 Conclusion

We verified the capacity of the RENAL, PADUA, DAP, NePhRO, and SPARE scores to predict perioperative outcomes of RLPN. Despite ten years of unrelenting effort, the current scores still cannot replace RENAL and PADUA. DAP is a good score in the retroperitoneal circumstance when the consistency and ease of use of the score are taken into account. Larger prospective investigations are needed to validate these nephrometry scores for RLPN and to optimize the scores based on experimental data. In further studies, some of the new scores designed for the retroperitoneal environment will need to be evaluated with a large sample, and the scoring assignments may be more reasonable if the scores can be statistically calculated (Haq and Raju 2022; Nazera and Raju 2022).

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Declarations

Conflict of interest The authors declare that they have no competing interests.

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Consent for publication All authors consented for publication.

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